CHINN CANNON, MICHELLE L., Ph.D. The Effects of Instrumental Music Instruction on the Neurophysiological Responses and Adaptive Behaviors of Children with Autism Spectrum Disorder. (2018)
Directed by Dr. Patricia E. Sink. 159 pp.

Autism spectrum disorder, also referred to as autism, is a complex and heterogeneous neurodevelopmental condition characterized by deficits in social communication, delayed or absent language development, and restricted or repetitive behaviors. Finding an appropriate, effective, and affordable intervention that targets these differences may increase access of children with autism to treatment that improves their quality of life, independence, and productivity, while reducing lifetime care costs.

The premise of this exploratory study was that music instruction may serve as an appropriate, effective, and affordable intervention for children with autism. Previous researchers noted that children with autism have both an affinity for and ability in music, while neuroscientists demonstrated increased cortical growth and neural network responses among musicians. At the onset of the current study, no published research studies were found that explicitly examined effects of musical training on both neural activity and adaptive behaviors of children with autism. The purpose of this exploratory research study was to investigate the effects of instrumental music instruction on neurophysiological responses and adaptive behaviors of children with autism.

Fourteen children with autism participated in the current study. During a 20-week period, a control group ($n = 7$) received 30 minutes of non-music intervention per week, and an experimental group ($n = 7$) received 30 minutes of music intervention (i.e., violin

instruction) per week. Before and after the intervention period, neurophysiological and adaptive behavioral data were collected from control and experimental groups.

The 14 participants of the study were assigned randomly to either the control (i.e., non-music intervention group), or the experimental (i.e., music intervention group). Eleven children completed the behavioral segment of this study, five in the control group and six in the experimental group. As compared to the non-music intervention group, experimental participants displayed significant gains in Expressive Communication (p = .018). Increases in Interpersonal Socialization by the music intervention group also approached significance (p = .057). The researcher found a moderately large effect size for Expressive Communication (r = .694), and for Interpersonal Socialization (r = .589), accounting for approximately 40% and 35% of the variances of the two adaptive behaviors before and after music intervention, respectively.

Eight children completed the neurophysiological segment of this study, three in the control group and five in the experimental group. Results revealed several trends in the differences between the control and experimental intervention groups' post-intervention neurophysiological responses. While changes were not observed among the non-music group's pre- and post-intervention cortical activity, changes were observed among the experimental group's cortical activation in areas associated with social and language learning. These findings supported the premise that instrumental music study may serve as an appropriate, effective, and affordable intervention, targeting the hallmark behaviors of autism and potentially associated cortical areas.

THE EFFECTS OF INSTRUMENTAL MUSIC INSTRUCTION ON THE

NEUROPHYSIOLOGICAL RESPONSES AND ADAPTIVE

BEHAVIORS OF CHILDREN WITH

AUTISM SPECTRUM DISORDER

by

Michelle L. Chinn Cannon

A Dissertation Submitted to
the Faculty of The Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Greensboro
2018

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APPROVAL PAGE

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March 1, 2018
Date of Acceptance by Committee

March 1, 2018
Date of Final Oral Examination

ACKNOWLEDGMENTS

Completion of my doctoral degree at the University of North Carolina at Greensboro (UNCG) began several years ago. I am grateful for the opportunity to have completed this journey with my family, friends, students, and their parents, and as a part of the University's School of Music family. Acknowledging everyone who has contributed to my education is not possible, but I am grateful for your help and support.

In part, my dissertation research began some years ago with a grant that I received to provide music instruction to children with autism. Thank you to the Organization for Autism Research and their Graduate Research Grant Program for providing funding for all instruments, books, and Bow Hold Buddies used in my research.

As I acquired the research grant, began my research, and throughout my doctoral degree program, my dissertation and academic advisor was always by my side. Thank you, Dr. Patricia Sink, for serving as a constant advisor throughout my doctoral program, and as Chair of my Doctoral Advisory Committee. This research would never have been possible without your creativity, support, knowledge, and inconceivable amounts of time spent editing and guiding my writing. I cannot express enough gratitude for you!

In addition to Dr. Sink, the contributions of all members of my Doctoral Advisory Committee were indispensable to the completion of my dissertation. Thank you to Dr. Donald Hodges and Dr. Jennifer Walter for serving on my dissertation committee and giving endless amounts of support and inspiration. Thank you to Dr. Aysenil Belger for the use of your neuroimaging lab at the University of North Carolina at Chapel Hill, and for serving on my Doctoral Advisory Committee. Thank you for providing years of guidance and abundant knowledge to my research and education.

As I learned, many individuals supported and encouraged me. Specifically, thank you to my wonderful friend Dr. Kara Reichart for emotional support, encouragement, and inspiration. Thank you for celebrating each step along this journey with me.

Most persons who complete any advanced educational degree know the importance of a supportive family. My family members have encouraged me, and expressed their patience and support throughout my doctoral degree and dissertation research. Thank you to my parents, Ed Chinn, Dixie Harger, and Burton Harger, who taught me to never, ever give up. They showed me that with some creativity, out-of-the-box thinking, and tons of hard work, anything is possible.

Thank you to my children, Dean and Joshua, who spent years eating frozen pizzas and chicken nuggets for dinner. Your patience is appreciated, and Mommy will now have time to cook quinoa, kale, and spinach. Thank you to my husband, Dale Cannon, whose love is so great; he proofread my dissertation on Valentine's Day. Thank you for carrying me when I could not keep going. It is my privilege and my honor to take your hand and run together into our next adventure.

Finally, thank you to my youngest son, Shea, for inspiring this research. Through singing, I first heard your beautiful voice, and the thoughts you wanted to share. Shea, you have demonstrated repeatedly how music can bring an abundance of joy into the life of someone with autism and their family. Never stop singing!

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CHAPTER I

INTRODUCTION

Music instruction may serve as an appropriate, effective, and affordable intervention for autism spectrum disorder. Currently, no research studies have examined the effects of musical training on both neural activity and adaptive behaviors of children with autism. The purpose of this exploratory research study was to investigate the effects of instrumental music study on neurophysiological responses and adaptive behaviors of children with autism. Specifically, the study was designed to comparatively analyze the effects of an instrumental music intervention and a non-music intervention on the neurophysiological responses and adaptive behaviors of children with autism. This chapter provides information about the background of the problem, the neurology of autism, adaptive behavioral measures, music instruction as an intervention, purpose of the study, research questions, and definition of terms.

Background of the Problem

Autism spectrum disorder, also known as autism, is a neurodevelopmental condition characterized by atypical social communication, and repetitive interests, activities, or behaviors (American Psychiatric Association [APA], 2013). Reported incidences of autism have increased dramatically during the last 30 years. Rates of autism have remained fairly stable throughout the 1980s with approximately one in 5,000 American children being diagnosed with autism (Center for Disease Control [CDC], 2009). These rates, however, began to increase for children born in the 1990s. Based on data collection and analyses, approximately one in 150 children were diagnosed with autism in 2000, one in 125 in 2004, one in 110 in 2006, and one in 88 in 2008 (Baio, 2014; CDC, 2009). Between 2010 and 2012 rates seemed to stabilize showing one in 68 children were diagnosed with autism (Christensen et al., 2016). Individuals with autism most often are diagnosed between the ages of two and four years old, with the use of psychometric tools, such as the *Autism Diagnostic Observation Schedule* (Lord & Rutter, 2000), or the *Autism Diagnostic Interview – Revised* (Rutter & LeCouteur, 2003).

While all autism diagnoses share differences in communication, social interaction, and repetitive behaviors or interests, autism is a spectrum disorder. People within the autism community often say, “if you have met one person with autism, you have met one person with autism.” This phrase means each child or adult with autism has unique gifts and abilities, with individual characteristics of autism varying widely from one person to another creating a continuum or spectrum within the disorder. At one end of the spectrum, a person may seem a bit socially awkward or interpret language literally, making cultural idioms difficult to understand. Telling a child with autism, ‘the dog kicked the bucket’ might illicit a confused response and/or produce a stern rebuke from the child for speaking such nonsense. Children and people at this end of the spectrum also may have an intense interest in a specific topic or activity. These interests may lead to high aptitude in a particular field, and to a successful career as an adult. Most often, when people with autism are portrayed in the popular media, this end of the spectrum is the focus or is displayed.

The other end of the autism spectrum often is not the focus of popular media. At this end, children or adults with autism may have very little vocabulary or be completely non-verbal, and unable to communicate their most basic needs and desires. This inability to communicate often leads to frustration or anger, and may manifest in violent outbursts. At this end of the autism spectrum, persons may display characteristics of repetitive behaviors in the form of repetitive loud or soft vocalizations, head banging, or biting of themselves. Children and adults with characteristics on this end of the spectrum often have an intellectual disability, as well as autism. When autism is combined with a severe intellectual disability, the affected person may rely completely on caregivers for their basic everyday needs, including eating, toileting, and bathing. Unable to understand danger, the child or adult at this end of the autism spectrum may wander away from home, or attempt to jump out of a moving car. Such cases of autism often require twenty-four-hour supervision, creating extreme stress within families, and exhausting parents and caregivers. When children with autism and severe intellectual disabilities become adults, finding a safe and appropriate placement outside the parent's home can be both difficult and costly.

Researchers have found that up to 46% of people with autism who have an intelligence quotient (IQ) less than 50, require high levels of assistance from their families, and are not able to lead an independent life (Eaves & Ho, 2008; Farley et al., 2009). Similarly, when IQ is not limited to 50 or less, researchers have found up to 78% of adults with autism also experience unfavorable outcomes based on similar criteria (Billstedt et al., 2005). Researchers have estimated that the lifetime cost of supporting an individual with autism and intellectual disabilities to be approximately $2.4 million (Buescher, Cidav, Knapp & Mandell, 2014). The lifetime cost of supporting an individual with autism and no intellectual disabilities is approximately $1.4 million (Buescher, Cidav, Knapp & Mandell, 2014). Examination of medical expenditures for young people with autism shows that costs exceed typically-developing peers between $4,110 and $6,200 per year (Shimabukuro, Grosse & Rice, 2008).

Although there is no known cure for autism, increased levels of functioning may be achieved through early and consistent intervention services that increase quality of life, independence, and productivity, while reducing lifetime care costs. Finding appropriate, affordable, and effective interventions for autism is the key to getting children and families the help they need. This exploratory study is designed to contribute to finding such an intervention by investigating effects of instrumental music study on neurophysiological responses and adaptive behaviors of children with autism.

Cortical Connectivity in Autism

Understanding how music instruction may influence neurophysiological responses among children with autism requires a basic overview of what is currently known about autism and the brain. While a consistent biomarker has not yet been discovered to explain the pathogenesis of autism, Minshew, Williams, and McFadden (2008) suggest an accumulation of multiple environmental and genetic conditions create molecular, cellular and architectural changes in the brain that evolve over time. Researchers who investigate the etiology of autism theorize that it likely involves many converging pathways (Geschwind & Levitt, 2007; Maximo, Cadena, & Kana, 2014), and intricate interactions between genetic, epigenetic and environmental factors (Loke, Hannan, & Craig, 2015; Mevel et al., 2014). Understanding this complex and multifaceted condition leads the scientific community to extensively explore the neurological underpinnings of autism. A novel theory rose to prominence in the early 2000s as a viable explanation for the unique intelligence and behavioral patterns present in an autism spectrum diagnosis. This theory, formally presented in 2004, states that "autism is a cognitive and neurological disorder marked and caused by under-functioning integrative circuitry that results in a deficit of integration of information at the neural and cognitive levels" (Just, Cherkassky, Keller, Kana & Minshew, 2004, p.1817). This theory is known as *the theory of underconnectivity*.

Measuring Connectivity

Connectivity refers to how the brain is structurally and functionally connected. Structural connectivity describes how individual neurons connect on a micro level, and how differing cortical regions connect on a macro level. Functional connectivity describes how activity in one area of the brain is correlated with another area (Wass, 2011).

Scientists use a variety of neuroimaging techniques to examine connectivity. Electroencephalography (EEG) is used to record the electrical activity of synaptic currents within the brain. This activity, measured in Hz, shows the synchrony of neurons on a macroscopic level (Frohlich, 2016). The EEG provides excellent temporal resolution; however, it provides limited spatial resolution. A second neuroimaging technique includes magnetic resonance imaging (MRI); it is used to examine the structure and size of differing brain regions. Data from the MRI often is analyzed with Voxel Based Morphometry (VBM), a post hoc statistical analysis allowing for the comparison of relative volumes of multiple brain regions (Abell et al., 1999). A third method of measuring connectivity includes functional Magnetic Resonance Imaging (fMRI) that is used to measure change in blood flow to regions of the brain. The fMRI is a noninvasive method to measure neural activity. Finally, connectivity also may be measured with Diffusion Tensor Imaging (DTI). This tractography-based method of neuroimaging traces white matter tracts allowing association fiber pathways to be mapped in a living person. These four neuroimaging techniques (i.e., the EEG, MRI, fMRI, and DTI) are used most frequently in research on cortical connectivity to examine both structural and functional connectivity.

Electroencephalography

Considering the strengths of EEG, specifically the high temporal resolution, this measurement of brain activity was chosen to complete the current study. Electroencephalography is the oldest of all brain-imaging techniques, and measures electrical signals created during postsynaptic activity as ions flow through neuronal dendrites forming transmembrane currents (Rippon, 2006). In 1929, Hans Berger attached a small electrode to the scalp and measured an electrical signal that was 8-13 cycles per second (Hz) (Haas, 2003). He named this signal the alpha rhythm. Since that time, scientists have refined EEG technology to measure many subtle electrical signals occurring within the human brain.

Current EEG systems often use nonmetallic electrodes that are pre-mounted in an elastic cap. Contact between the scalp and the electrodes is maintained through electrolyte-soaked sponges. Electrodes are positioned in the cap according to the international "10/20" system. This system identifies each electrode by one letter that describes their location (F = frontal; P = parietal; T = temporal; O = occipital), and by one number, with odd numbers referencing the left hemisphere electrodes, and even numbers referencing the right hemisphere electrodes (Rippon, 2006).

Electrodes measure the frequencies of electrical activity in the brain. The slowest frequency is the delta wave (i.e., < 4Hz) that is associated with sleep or eye motion. Theta waves (i.e., between 4-7Hz) are associated with limbic structures (da Silva, 1992), memory (Burgess & Gruzelier, 1997; Klimesch et al., 1997), and modulation of limbic and prefrontal activation (Basar, Schurmann, & Sakowitz, 2001). Alpha waves (i.e., between 8-13Hz) are associated with specific cognitive activities, inhibition control, and memory function. Beta waves (i.e., between 13-30Hz) usually occur during a specific task and demonstrate active concentration. These waves seem to be responsible for long-distance (Freeman, 2004a, 2004b) and medium-distance synchronizations (von Stein & Sarnthein, 2000), connecting neighboring cortical areas. Finally, Gamma waves (i.e., between 30-+100 Hz) are associated with cross-modal sensory processing, memory (Herrmann, Munk & Engel, 2004), and with activity in localized areas (von Stein & Sarnthein, 2000). Examining these frequencies enable researchers to analyze how the brain responds to different stimuli. Averaging techniques combine EEG readings from many repetitions of a stimulus to produce an average evoked response or evoked potential. These evoked responses also are called event-related potentials (ERPs). A similar frequency analysis technique, referred to as Event-Related Spectral Perturbation (ERSP), recently has become a favored method for examining EEG data. The ERSP measures the average changes in wave amplitude as a function of time and related to a stimulus event. The ERPs do not fully capture collected data, while ERSP analysis produces more information about brain synchronization than ERPs.

The EEG has several limitations, including poor spatial resolution, and the potential for a signal to become distorted while traveling from the intracortical source to the scalp. A signal also potentially may come from an infinite number of intracranial sources due to several factors including head shape (Michel et al., 2004). A precise description of event-related brain activation, however, offers an opportunity to understand conditions where the brain is structurally intact, yet found to have functional deficits. Electroencephalography also provides information about connections between the cortical and the cognitive/behavioral domains, when exploring and measuring various responses to stimuli.

Mirror Neuron System

Electroencephalography may be used to measure a system of neurons associated with social and communicative learning called mirror neurons. Mirror neurons were first described after studying cortical activation in the ventral premotor areas of macaque monkeys (Di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992), and were later named mirror neurons in a follow-up paper published by the same research team (Gallese, Fadiga, Fogassi & Rizzolatti, 1996). While monkeys observed a movement and performed a movement, Di Pellegrino et al. (1992) found that these unique neurons discharged both. This activation during both conditions distinguishes mirror neurons from motor or sensory neurons. Motor and sensory neurons are activated either while observing or executing an action; whereas, mirror neurons are activated during both conditions. Since the discovery of mirror neurons, several different kinds of mirror neurons have been identified in neuroscientific research on communication (Ferrari, Gallese, Rizzolatti & Fogassi, 2003), audiovisual responses (Keysers et al., 2003), tool responses (i.e., observations of someone using a tool; Ferrari, Rozzi & Fogassi, 2005), and peripersonal and extrapersonal responses (Caggiano, Fogassi, Rizzolatti, Their & Casile, 2009). In humans, the mirror neuron system (MNS) seems to affect understanding and imitating others.

The most prominent theory explaining the purpose of mirror neurons is based on a "direct-matching model," where actions that are observed are "directly mapped" onto the viewer's motor system (Rizzolatti & Sinigaglia, 2010). Rozzolatti & Sigigaalia (2010) emphasized the importance of mirror neurons, because both the execution of an action and the goal of the action are recognized. Because the execution and goal of an action are recognized, mirror neurons and their function have been associated with several high-level cognitive processes, including imitative learning (Rizzolatti & Craighero, 2004), understanding social behavior (Gallese et al., 2004), language (Arbib, 2005), and empathy (Gallese, 2003).

The mirror neuron system (MNS) frequently has been studied through analyses of EEG frequencies between 8 and 13 Hz. These frequencies, referred to as mu rhythms, create large EEG oscillations when at rest, but decrease when individuals execute or observe an action. Because of this decrease in power, mirror neuron activity also is referred to as mu wave suppression (Babiloni et al., 2002). This suppression, or desynchronization of the wave is used as a marker for mirror neuron activation.

Aberrant cortical connectivity affects the MNS of children and adults with autism. Multiple studies have investigated mu frequencies and found frequent impairments in people with autism (Nishitani, Avikainen & Hari, 2004; Oberman & Ramachandran, 2007; Williams, Whiten, Suddendorf & Perrett, 2001). Ramachandran and Altschuler (2009) suggest that mu wave suppression might provide a simple, noninvasive probe for monitoring mirror neuron activity. They further report that children with autism maintain mu wave suppression when moving their own hand yet fail to suppress mu waves when observing other children's hand movements. These irregularities indicate abnormal MNS of children with autism. Considering the importance of the MNS in language processing and interpretation of actions, an intervention targeting the underdeveloped MNS in autism may have great potential for treatment (Overy & Molnar-Szakacs, 2009).

Behavioral Measures in Autism

Currently, scientists are not able to diagnose autism through biological markers, such as cortical connectivity or genetic tests. Psychologists must collect and analyze behavioral data, following parents', physicians' and/or educators' expressions of concerns about delayed development and anti-social behavior. Children with autism are most often diagnosed between the ages of two and four years old with the *Autism Diagnostic Observation Schedule* (ADOS, 1999) or the *Autism Diagnostic Interview–Revised* (ADI-

R, 1989). While these measures are appropriate for the initial determination of an autism diagnosis, the ADOS and ADI-R do not measure functional or adaptive behavior. Adaptive behaviors may be described as daily living skills such as walking, speaking, self-care, going to school or work, cooking, or cleaning. Once a diagnosis has been made, behaviors and age-appropriate development may be measured through one of several adaptive behavior protocols. Examples of these protocols include the *Adaptive Behavior Assessment System* (ABAS), the *Developmental Observation Checklist System* (DOCS) and the *Vineland Adaptive Behavior Scales* (VABS).

Adaptive Behavioral Assessment System

The *Adaptive Behavior Assessment System*–Second Edition (ABAS-II; 2005) is a norm-based assessment of adaptive behaviors of children and adults ranging from ages birth to 89 years. This measure provides scores for Conceptual, Social and Practical domains, as consistent with current American Association of Intellectual and Developmental Disabilities (Harrison & Oakland, 2015). Multiple behavioral components are measured under each domain. The Conceptual domain is used to assess communication, self-direction, and functional academics. The Social domain is used to assess social and leisure skills. The Practical domain is used to assess motor skills, home and school living, self-care, health and safety, community use, and work. The ABAS-III contains a total of 11 sub-domains. For each item in the assessment, respondents are provided a four-point Likert-type scale with the option to mark a question as a guess, and/or to write comments about the question. Acceptable and high reliability for the ABAS III has been established via internal consistency and test-retest reliability estimates, with estimates that are greater than or equal to .90. Face and content validity have been established through reviews and expert suggestions (Harrison & Oakland, 2015). Additionally, criterion-related validity has been deemed acceptable for clinical and research purposes, with correlation coefficients ranging from .70 to .89 when correlated with related measures (Harrison & Oakland, 2015).

Developmental Observation Checklist System

The Developmental Observation Checklist System (DOCS) is another norm-based behavioral assessment for children aged birth through six years old. This measure contains three domains with multiple sub-domains. The first domain measures general development and includes 475 yes/no questions in the sub-domains of Language, Motor, Social, and Cognitive Skills (Hresko, Miguel, Sherbenou & Burton, 1994). The second domain measures Adjustment behavior, and the third domain measures Parent Stress and Support. For these domains, questions are rated using a 4-point Likert-type scale. Reliability estimates are between .81 and .96, when measured via test-retest, internal consistency, and interscorer reliability analyses (Panter, 1996). While authors suggest that a high level of construct validity is maintained, Panter (1996) found only a moderate correlation (.69) between the DOCS adjustment behavior sub-domain and the *Vineland Adaptive Behavior Scales* (1984). A modest correlation of .46 exists between the DOCS Language Scale and the established Standford-Binet-IV Verbal Reasoning Scale (Thorndike, Hagen & Sattler, 1986). The DOCS is used in both clinical practice and research.

Vineland Adaptive Behavior Scales

The *Vineland Adaptive Behavioral Scales* (VABS) were first published as the *Vineland Social Maturity Scale* in 1965 (Oakland & Houchins, 1985). Collectively, the VABS is a norm-based assessment of behavior, and may be used for people with developmental disabilities between the ages of infancy and 90 years. The VABS contains five domains including Communication, Daily Living Skills, Socialization, Motor Skills and a Maladaptive Behavior Index. Each domain is comprised of multiple sub-domains. The Communication domain contains receptive, expressive, and written measures of development. The Daily Living Skills domain contains questions used to measure personal, domestic, and community development. The Socialization domain contains sub-domains used to measure interpersonal relationships, play and leisure time, and coping skills. The Motor Skills domain is used to measure fine and gross motor skills. Finally, the Maladaptive Behavior Index may be used for people between the ages of 3 and 90 years. This domain contains sub-domains to measure internalizing, externalizing, and other behaviors.

To complete the VABS, parents or caregivers rate their children's behaviors using a three-point scale, including 0 (never performed), 1 (sometimes or partly performed), and 2 (usually or habitually performed). Widaman (2010) maintains that the composite internal consistency of the VABS is between .95 and .98, and that the composite test-retest reliability of the VABS is between .88 and .96. Widaman (2010) also indicates that the concurrent-validity coefficients of the VABS range from .29 to .91, and the construct-validity coefficients range from .56 to .88. The *Vineland Adaptive Behavior Scales* is widely used in clinical practice, educational settings, and in research.

The *Vineland Adaptive Behavior Scales II* was used to collect data for the present study for several reasons. First, the VABS has been used extensively to assess populations with autism (Paul et al., 2004; Perry, Flanagan, Geier & Freeman, 2009; Tan et al., 2012; Volkmar et al., 1987). Second, collectively, the *Scales* assess behavioral responses across five domains and fourteen sub-domains, including: (1) Communication domain (subdomains: Receptive, Expressive, Written); (2) Daily Living Skills domain (subdomains: Personal, Domestic, Community); (3) Socialization domain (subdomains: Interpersonal relationships, Play and Leisure, Coping skills); (4) Motor skills domain (subdomains: Fine, Gross); and (5) Maladaptive Behavior domain (subdomains: Internalizing, Externalizing). This level of assessment detail is not acquired through using either the DOCS or ABAS, and is essential when measuring changes in adaptive behavior over time. Third, unlike the DOCS that may be used only with children from birth to the age of six years, the VABS measure adaptive behaviors for all ages. Finally, the VABS produces the Maladaptive Behavior index. When completing the VABS, caregivers rate statements, including "avoids social interaction," "bites nails," "has a hard time paying attention," and "obsessed with objects of activities." Rating these statements is especially important and essential to identify repetitive and/or destructive behaviors sometimes present among children with autism.

Music Instruction as an Intervention

When examining the neurological profiles of musicians and children with autism, many researchers and specialists have speculated about the benefits of music instruction for individuals with autism. Interestingly, cortical areas found to be less developed in a person with autism are often areas of overdevelopment in the brains of musicians. Musicians possess many unique skills that increase brain volume, and augment communication between cortical regions, and between the left and right hemispheres (Schlaug, Jancke, Huang & Steinzetz, 1995). Many researchers also have found that music skills transfer to other social and academic domains. Transfer benefits of music instruction may work with special populations, such as autism, greatly enhancing functionality in academic, social, and communication areas of functioning.

Interestingly, children with autism exhibit both a special affinity and ability for music. When compared to typically developing children, researchers have demonstrated children with autism have musicality, a special interest in music, and a preference for music stimuli more than verbal stimuli (Blackstock, 1978). Additionally, researchers have shown that persons with autism possess superior pitch memory (Heaton, Hermelin, & Pring, 1998), pitch labeling (Heaton, 2003), pitch discrimination, and categorization skills (Bonnel et al., 2003). Individuals with autism also comprehend the affective qualities found in music (Kasari, Sigman, Mundy & Yirmiya, 1990).

Benefits of music instruction may have several substantial implications for practitioners. First, many researchers describe children and adults with autism as having a special affinity for music. Consequently, music may provide motivation to engage in social interaction and communication. Second, children with autism often demonstrate an extraordinary aptitude in music. The existence of high music aptitude may not only foster development of abilities to play musical instruments or sing, but may enhance and motivate learning in individual deficit areas, such as social or communication skills. Third, cortical structures shown to be underdeveloped among individuals with autism often are associated with overdeveloped structures in musicians' brains. Studying music may change the structure of the brain of a person with autism, forming connections between distant areas of the brain and growing underdeveloped networks, such as the mirror neuron system (MNS). These changes in the brain may be measured through neuroimaging techniques like electroencephalography. Finally, as a result of music instruction and experience, increased social interaction and communication coupled with brain growth may lead to higher levels of functioning.

Increases in functioning and possible benefits of studying music may be measured through psychological assessments of adaptive behavior. Through the use of the *Vineland Adaptive Behavior Scales II* such increased functioning and benefits may be measured when parents or care-givers respond to an inventory of questions to extrapolate levels of functioning across multiple domains. Measurement and evaluation of adaptive behaviors, based on norms of age-appropriate development, provides an estimate of developmental age. This assessment of adaptive behavior is designed to provide important information on both regression from and progress toward developmental growth, as related to music instruction among other interventions.

Purpose of the Study

Considering the potential benefits of music instruction for a child who has been diagnosed with autism, the purpose of this study was to examine the effects of instrumental music instruction on the neurophysiological responses and adaptive behaviors of children with autism. Specifically, this study was designed to comparatively investigate the effects of instrumental music instructional interventions and non-music interventions on neurophysiological responses of the mirror neuron system, and on communicative and social behaviors of children with autism. The current research answered the following research questions.

1. Do instrumental music and non-music interventions differentially affect adaptive behaviors of children with autism, as measured on the *Vineland Adaptive Behavior Scales II*?

2. Do instrumental music and non-music interventions differentially affect neurophysiological responses of the mirror neuron system of children with autism, as measured using electroencephalography?

3. Based on findings related to research questions one and two, what observed associations may be implied between adaptive behaviors and neurophysiological responses of the mirror neuron system of children with autism?

Definition of Terms

Essential to answering the research questions of this study was acquiring an understanding of terms associated with autism spectrum disorder, with the neurological foundations of music behaviors, and with adaptive behaviors. This section is devoted to defining these terms. Unless otherwise cited, definitions were adapted from the Oxford American College Dictionary (2002), and the Merriam-Webster Dictionary (2016).

- **agenesis –** lack or failure of development (as of a body part)
- **caudal –** at or near the tail or the posterior part of the body
- **central coherence theory –** states that people with autism display a pattern of cognition inclined toward local rather than global information processing (Happe, 1999; Happe and Frith, 2006)
- **connectivity –** how the brain is structurally and functionally connected
- **corpus callosum (CC) –** the largest white matter commissure connecting the right and left hemispheres of the brain
- **diffusion tensor imaging (DTI) –** a tractography-based method of neuroimaging which traces white matter (WM) tracts allowing association fiber pathways to be mapped in a living person
- **electroencephalography (EEG) –** the measurement of electrical activity in different parts of the brain and the recording of such activity
- **fractional anisotrophy (FA) –** measure often used in DTI; measurement of fiber density, axonal diameter, and myelination in white matter
- **frontal lobe –** largest and anterior (forward-most) lobe including areas concerned with behavior, learning, personality, and voluntary movement of each cerebral hemisphere
- **functional connectivity –** describes how activity in one area of the brain is correlated to another area
- **functional magnetic resonance imaging (fMRI) –** used to measure change in blood flow to regions of the brain resulting from increased neuronal activity
- **gray matter –** the darker tissue of the brain and spinal cord, consisting mainly of nerve cell bodies and branching dendrites
- **gyrus (plural gyri) –** a ridge or fold between two clefts on the cerebral surface in the brain

- **hyperconnectivity –** functional activation within certain brain areas which is unusually correlated with activity within the same region

- **magnetic resonance imaging (MRI) –** a form of medical imaging that measures the response of the atomic nuclei of body tissues to high-frequency radio waves when placed in a strong magnetic field, and that produces images of the internal organs and the brain

- **mean diffusivity (MD) –** measure used in DTI; describes the magnitude of water molecule diffusion regardless of direction

- **occipital lobe –** the rearmost lobe in each cerebral hemisphere of the brain

- **parietal lobe –** either of the paired lobes of the brain at the top of the head, including areas concerned with the reception and correlation of sensory information

- **pathophysiology –** disordered physiological processes associated with disease or injury

- **rostral –** at or near the front end of the body, especially in the region of the nose and mouth

- **splenium --** the thick posterior part of the corpus callosum of the brain

- **structural connectivity –** describes how, on a micro level, individual neurons connect or, on a macro level, how differing cortical regions connect

- **temporal lobe –** each of the paired lobes of the brain lying beneath the temples, including areas concerned with the understanding of speech

- **underconnectivity (hypoconnectivity) –** the underfunctioning of neural circuitry and resulting in cognitive, perceptual and motor impairments

- **underconnectivity theory of autism –** underfunctioning of integrative circuitry that results in a deficit of integration of information at the neural and cognitive levels (Just et al., 2004)

- **white matter –** the paler tissue of the brain and spinal cord, consisting mainly of nerve fibers with their myelin

CHAPTER II

RELATED LITERATURE

This chapter includes a discussion of research that was foundational to the completion of this study. First, research on the neurology of autism is discussed. This discussion focuses on underconnectivity theory, early neurological development, local hyperconnectivity, the corpus callosum, and inter- and intrahemispheric hypoconnectivity. Second, the related literature is focused on areas of the brain involved while processing music, and cortical differences found between musicians and non-musicians. Finally, the related literature provides a discussion of musical affinity and ability found among populations of persons with autism, learning outcomes associated areas of interests among people with autism, and using music instruction to facilitate brain growth and improve adaptive behavior.

Neurology of Autism

Researchers continue to search for a consistent biomarker to explain the pathogenesis of autism. Many scientists agree, however, that an accumulation of multiple environmental and genetic conditions create molecular, cellular, and architectural changes in the brain that evolve over time. Understanding this complex and multifaceted condition has led a broad network of researchers to extensively explore the neurological underpinnings of autism.

Underconnectivity Theory

A novel theory rose to prominence in the early 2000s as a viable explanation for the unique intelligence and behavioral patterns present in an autism spectrum diagnosis. This theory, formally presented in 2004, stated that "autism is a cognitive and neurological disorder marked and caused by under-functioning integrative circuitry that results in a deficit of integration of information at the neural and cognitive levels" (Just, Cherkassky, Keller, Kana & Minshew, 2004, p.1817). This theory became known as "the theory of underconnectivity." In research, underconnectivity was described as the failure to develop connections between neural systems.

Horwitz, Rumsey, Grady and Papoport (1988) were the first scientists to offer evidence of functional hypoconnectivity in autism. These researchers found that people with autism demonstrated fewer correlations between frontal and parietal areas, especially in the left inferior frontal region and its homologue in the right hemisphere. Other under-connected areas found included the thalamus, caudate nucleus, lenticular nucleus, and insula to the parietal and frontal regions (Horwitz et al., 1988). Horwitz et al. concluded that adults with autism had impaired interactions between cortical areas.

Happe (1999), and Happe and Frith (2006) expanded on these findings when proposing the central coherence theory that stated people with autism displayed "a cognitive style biased toward local rather than global information processing" (Happe, 1999, p. 216). Five years later and as related to the pathogenesis of autism, Just, Cherkassky, Keller & Minshew (2004) described the theory of underconnectivity as "the underfunctioning of integrative circuitry and emergent cognitive, perceptual, and motor abilities in autism" (p. 1817). The researchers argued that the central coherence theory proposed a core deficit in central processing while the "underconnectivity theory treats the coherence as an emergent property of the collaboration among brain centers" (Just et al., 2004, p. 1818). They described connections between relevant brain regions and the frontal lobe as underdeveloped resulting in compromised complex or higher-order information processing. Just et al. (2004) also proposed that the most severe and profound cases of autism may be explained as associated with little or no development of functional connectivity between the sensorimotor and association cortex, and therefore meaning could not be connected to information.

Later that same year, Belmonte et al. (2004) suggested that, while some researchers believed autism to be the result of an underconnected brain (e.g., Just et al., 2004) other researchers discussed the possibility of autism being the result of an overconnected brain (e.g., Rubenstein & Merzenich, 2003). Belmonte et al. (2004) merged aspects of the central coherence theory, and the underconnectivity theory maintaining that "high local connectivity may develop in tandem with low long-range connectivity" and "high physical connectivity and low computational connectivity may reinforce each other by failing to differentiate signal from noise" (p. 9228). The theory of underconnectivity, therefore, was broadened and evolved as a theory encompassing the underconnection of long-distance tracts and locally overconnected or hyperconnectivity tracts, now referred to as hypo- and hyperconnectivity.

Early Development

Children on the autism spectrum often display a unique developmental trajectory. Numerous research found that Infants have a normal or slightly smaller head circumference at birth, followed by abnormally accelerated brain growth during the first few years of life (Aylward, Minshew, Field, Sparks & Singh, 2002; Constantino et al., 2010; Courchesne, Carper & Akshoomoff, 2003; Courchesne et al., 2001; Frohlich, 2016; Hazlett et al., 2011; Lainhart et al., 1997; Redcay, 2005; Sparks et al., 2002). Through the examination of head circumference of infants with autism, researchers found two infantile periods of accelerated brain growth. The first period began between one and two months old, and the second period occurred between six and fourteen months old (Courchesne et al., 2003). These findings were consistent with a more recent infant neuroimaging study.

Wolff et al. (2012) longitudinally observed and collected data on 92 infants at high-risk for developing autism. At 24 months of age, 28 of the infants had been diagnosed with autism. Data also were analyzed and infants as early as six months old were found to have aberrant white matter growth. This team of researchers also found that growth of the typically-developing brain catches up to the growth of the brain with autism around 12 months of age (Wolf et al., 2012). This abnormal white matter growth seems to translate into greater total brain volume (TBV). Courchesne et al. (2001) found larger than normal brain volume in two to four-year-old children with autism while Sparks et al. (2003) found larger than normal brain volume in children between the ages of three and four. This growth was seen in approximately 70% of children with autism

(Dawson et al., 2007; Herbert, 2005; Lainhart, 2006; Redcay & Courchesne, 2005). Researchers suggested that by two to three years of age, brain growth in autism appeared to abruptly stop and brain volumes normalized by early adolescences (Redcay & Courchesne, 2005).

Multiple researchers have suggested that when a brain initially grows so quickly, patterns of optimal connectivity may differ from normal (Braitenberg, 2001; Chklovskii, Schikorski & Stevens, 2002; Jancke, Staiger, Schlaug, Huang & Steinmetz, 1997; Ringo, Doty, Demeter & Simard, 1994; Sporns & Zwi, 2004). A bigger brain tends to form more local connections neglecting long-distance connections that require greater resources to build (Courchesne & Pierce, 2005a; Ringo et al., 1994; Zhang & Sejnowski, 2000). Because building a brain is a dynamically interactive process, disruptions large or small, tend to have widespread consequences (Johnson, 2005; Karmiloff-Smith, 1992; Quartz & Sejnowski, 1997).

Neurological patterns of disruption in autism have shown the intact cortical development of early infancy becomes progressively worse throughout the first years of life (Courchesne & Pierce, 2005a; Courchesne & Pierce, 2005b). Typical brain growth tends to follow a general pattern: development from caudal (back) to rostral (front) regions. The primary visual cortex, for example, found in the posterior occipital lobe is 33% of full size upon birth and fully mature by 2 years of age. This contrasts greatly with neurons found in rostral regions. The frontal gyri are 3% of full size upon birth and 48% of full size by the second year of age (Gogtay et al., 2004; Huttenlocher, 2002).

Sacco, Gabriele & Persico (2015) conducted a meta-analysis of the head circumference and total brain volume of 391 records of persons with autism. These researchers found significantly larger head circumference among individuals with autism than without autism (p < 05), and a significant interaction between total brain volume (TBV) and age ($p < .05$). Specifically, children in early childhood with autism showed a larger head circumference and brain size than found in other persons' records included within the meta-analysis (Sacco, Gabriele & Persico, 2015). These differences possibly explained converging evidence that later developing frontal and temporal lobes are most adversely affected in children and adults with autism.

Another examination of two to four-year-old children with autism, researchers used structural MRI to document the frontal and temporal lobes as being areas of peak overgrowth compared to parietal and occipital regions that were less affected (Courchesne et al., 2007). Minshew et al. (2008) suggested a marred rostral-caudal (front-back) gradient where frontal cortical gray and white matter displayed the greatest enlargement, followed by a milder enlargement of parietal gray and white matter, and no enlargement of the occipital gray and white matter. In a similar and earlier study, researchers also found the dorsolateral (back and sides) and mesial (middle) prefrontal cortex within the frontal lobes to be especially enlarged in individuals with autism (Carper & Courchesne, 2005).

The overgrowth or enlargement was believed to be the result of abnormally large white matter (WM) volume (Herbert, 2005; Frohlich, 2016). Some hypothesized that early disruption of cortical development triggered a compensation effect resulting in the over-development of local or short-distance white matter tracts thus drastically increasing volume (Minshew et al., 2008). Williams and Minshew (2007) suggested that limited data point to early gray matter changes leading to the overgrowth of WM. This may be associated with large numbers of interstitial neurons, or neurons within the white matter, caused by limited migration or increased remnants of neurons formed pre- and postnatally in the subplate (Frolich, 2016).

Local Hyperconnectivity

Local hyperconnectivity has been defined as "functional activation within certain brain areas which is more than usually correlated with activity within the same region" (Wass, 2011, p. 21). These fibers were found to be shorter in length and have increased volume and density. Courshesne et al. (2007) suggested that an increasing number of neurons in a given location will lead to a higher number of local or short-distance connections.

Researchers have theorized that increased local circuitry is linked to early disturbances interrupting the development of connectivity between neural systems (Johnson, 2005; Minshew, 2008). Elsabbagh et al. (2009) found evidence of early hyperconnectivity in autism siblings as young as 10 months old. Through collected EEG data, these infants showed increased resting-state gamma activity (20-60 Hz – high energy, short wave length) in the central and right temporal areas (Elsabbagh et al., 2009). Increased resting-state gamma activity (25-70 Hz) was also found in 3-8-year-old children with autism (Orekhova et al., 2007). A later EEG study of 14-month-old infants observed elevated phase-lagged alpha-range activity, an indicator of hyperconnectivity, in frontal and central areas of participants who later went on to receive an autism diagnosis (Orekhova, 2014). Other researchers investigating early development of local hyperconnectivity used DTI imaging to examine white matter tracts. Ben Bashat et al. (2007) reported that 1.3 – 3.3-year-old children with autism showed local hyperconnectivity through increased frontal radial fractional anisotrophy (FA). Increased FA reflects an excess of fiber density, axonal diameter, and/or myelination in white matter (Casanova et. al., 2006). Another research team found slightly different results. They examined 6-11-year-old children with autism and combined DTI with voxel-based morphometry (VBM). These imaging techniques suggested both an increase and decrease in WM densities in differing areas of the brain (Ke et al., 2009).

Another measure believed to express hyperconnectivity is total brain volume (TBV). Several research teams identified the early development of enlarged brain size (Aylward et al., 2002; Piven et al., 1995) with the greatest enlargement found in the frontal cortex (Carper & Courchesne, 2005). Nordahl et al. (2011) examined several groups of children ages two to four: boys with autism, boys with regressive autism, girls with autism, and typically-developing boys and girls. Researchers found abnormal brain enlargement was most common in boys with regressive autism. Young boys without regressive autism did not differ from controls. This large-scale study not only described the presence of hyperconnectivity in young boys with autism but also the possible differences between early distinct neural phenotypes of autism.

Some research has indicated that local hyperconnectivity found in young children continued to be present into adolescence and adulthood. Locally elevated hyperconnectivity was found in the parietal regions of adult participants (Valazquez et al. 2009). Using fMRI, other researchers have suggested local functional hyperconnectivity of varying cortical regions especially the frontal and parietal areas (Belmonte et al., 2004; Belmonte & Yurgelun-Todd, 2003; Rubenstein & Merzenich, 2003; Schmitz et al. 2006). Di Martino et al. (2014) examined resting-state fMRI data from 533 adults with autism and 579 typically-developing controls. Researchers found hyperconnectivity was limited to subcortical regions, specifically the thalamus, globus pallidus, and primary parietal sensorimortor areas (Di Martino, 2014). Interestingly, researchers have also used hyperconnectivity data to explain certain behavioral manifestations found in autism including hyper-specificism and low generalization (Casanova et al. 2006; Cohen, 2007), precocious discrimination on visuaospatial tasks including the embedded figures (Cohen, 2007; Mottron et al. 2006; Plaisted, O'Riordan & Baron-Cohen, 1998; Shah & Frith, 1983) and social deficits (Chen et al. 2015).

Not all researchers have found evidence to support local hyperconnectivity. Using fMRI, Mizuno, Villalobos, Davies, Dahl and Muller (2006) found increased subcortical-cortical connectivity during a visuomotor task in participants with autism. Similarly, Sundaram et al. (2008) found no evidence to support short-range hyperconnectivity in a 2008 DTI study. Several other researchers found local over connection to have hemispheric differences in people with autism. Wilson, Rojas, Reite, Teale and Rogers (2007) examined auditory responses in 7-17-year-old children with autism using magnetoencephalography (MEG) and found greatly reduced left, but not right, hemispheric gamma (40 Hz) power. In a recent DTI study, investigators expressed similar findings. Kumar et al. (2009) found shorter than average fiber lengths in the left hemisphere and longer than average fiber lengths in homologous areas of the right hemisphere. Increased regional connectivity among the posterior cingulate cortex, the right temporal lobe and right parahippocampal gyrus was found by Monk et al. (2009). Supekar et al. (2013) examined children seven to thirteen years old during a task-free fMRI. Data collected pointed to widespread functional hyperconnectivity across both short- and long-range connections. In addition, children with greater hyperconnectivity displayed greater social deficits. More recently Nomi and Uddin (2015) found evidence to suggest hyperconnectivity in autism changes over a participant's lifetime. This research team found hyperconnectivity within large-scale brain networks in children under age 11, but similar within-network connectivity between adolescents with autism and adolescents who were typically-developing (Nomi & Uddin, 2015). Further research concerning hyperconnectivity may shed light on these contrasting findings.

Corpus Callosum

The corpus callosum has been found to be the largest white matter structure connecting the right and left hemispheres of the brain. As verified by research, it has been shown to contain over 250 million nerve fibers crucial for interhemispheric communication and directs signals between homologous and heterotopic cortical areas (Innocenti, 1986; Pandya & Seltzer, 1986; Zaidel & Iacoboni, 2003). Rostral or frontal regions of the corpus callosum, including the genu and rostrum, connect bilateral prefrontal brain regions. The midsections of the corpus callosum, referred to as the body and isthmus, connect central areas of the brain, including premotor, motor, parietal and superior temporal cortices. The most caudal (posterior) region, the splenium, maintains bilateral connections between the occipital, inferior temporal, and parietal regions (Hardan & Minshew, 2000; Witelson, 1989). Typically, the corpus callosum area increases throughout childhood and adolescence, with the largest growth occurring in the posterior regions (Giedd et al. 1999, 1996; Keshavan et al., 2002). Researchers have found that the corpus callosum continues to grow well into the twenties and thirties of a typically-developing person (Pujol, Vendrell, Junque, Marti-Vilalta & Capdevila, 1993).

The development of the corpus callosum of children with autism has presented a different profile than the profile provided previously in this section. Researchers found that young children with autism exhibited abnormally increased measures of fiber density and axonal diameter in their corpus callosum (Ben Bashat et al. 2007; Weinstein et al. 2011; Xiao et al. 2014; Travers et al. 2015; Solso et al. 2016). Interestingly, when Boger-Megiddo et al. (2006) compared the corpus callosums and larger brain volumes of children with autism, they found the corpus callosum to be disproportionately small. As a person with autism developed, older children, adolescents, and adults were found to have reduced fiber density and axonal diameter of their corpus callosums (Barnea-Goraly et al. 2004; Alexander et al. 2007; Jou et al. 2011; Travers et al. 2012; Vogan et al. 2016). Multiple studies have suggested that this transition happens very early in life, somewhere between the ages of two and four years old (Ben Bashat et al. 2007; Weinstein et al. 2011; Travers et al. 2015; Solso et al. 2016; Fingher et al. 2017).

Examining older children, Vidal et al. (2006) found boys between the ages of six and sixteen years had thinning in the genu and splenium; while other researchers showed teens to have regionally and globally reduced corpus callosum volume (Alexander et al., 2007; Keller, Kana & Just, 2007). By adulthood, most scientists have found a marked reduction in corpus callosum area, volume and/or density in people with autism (Brambilla et al., 2003; Chung, Dalton, Alexander & Davidson, 2004; Frazier & Hardan, 2009; Thomas, Humphreys, Jung, Minshew & Behrmann, 2010). A few researchers have noted the greatest reduction in anterior (front) areas of the corpus callosum (Keary et al., 2009; Lewis, Theilmann, Sereno & Townsend, 2009; Waiter et al., 2005). These studies of the corpus callosum have supported findings of early excess cortical neuronal growth and accelerated brain growth, followed by subnormal neuronal growth, axonal and synaptic development (Courchesne et al. 2001; Courchesne, Campbell, et al. 2011; Courchesne, Mouton, et al. 2011; Chow et al. 2012). Corpus callosum reduction was believed to reflect hypoconnectivity between right and left hemispheres.

The reduction of the corpus callosum may be responsible, in part, for many atypical behavioral patterns found in autism. Many children born without a corpus callosum (agenesis) display behavioral characteristics consistent with an autism diagnosis (Lau et al., 2013; Paul, Corsello, Kennedy & Adolphs, 2014). Detailed examinations of the agenesis of the corpus callosum of people without autism or intellectual disability has shown cognitive deficits, such as difficulties in abstract reasoning (Brown & Sainsbury, 2000; David, Wacharasindhu & Lishman, 1993), problem solving (Aalto et al., 2002; Fischer, Ryan & Dobyns, 1992) and generalization (Solursh, Margulies, Ashem & Stasiak, 1965). Social deficits including lack of emotional maturity, introspection, social ability and communication of emotions also have been noted (Badaruddin et. al., 2007;

Brown & Paul, 2000; Stickles, Schilmoeller & Schilmoeller, 2002). These data mirror many of the behavioral deficits found in autism.

Overwhelming evidence has been found that associates deficits of the corpus callosum with the pathophysiology of autism. The largest structure connecting the right and left cortical hemispheres has been shown to be crucial for interhemispheric communication. Significant white matter reductions of the corpus callosum have been one of the most replicated findings in autism, and are considered to be a hallmark of interhemispheric hypoconnectivity.

Interhemispheric and Intrahemispheric Hypoconnectivity

Data presented above suggested that rapid infantile brain growth in young children with autism may form more local connections and neglect long-distance connections requiring greater resources to build. The onset of cortical hypoconnectivity in coordinated brain regions has been thought to parallel the onset of hypoconnectivity of the CC – early in childhood. Very young children with autism rarely displayed cortical hypoconnectivity (Ben Bashat et al., 2007; Fingher et al. 2017; Friedman et al. 2006; Solso et al. 2016; Sundaram et al., 2008; Travers et al. 2015; Weinstein et al. 2011), however, as the child aged, hypoconnectivity emerged as a defining characteristic of autism.

Coben, Clarke, Hudspeth and Barry (2008) measured EEG resting state coherences in children six to 11 years old and found reduced inter- and intrahemispheric coherence. Likewise, Isler, Martien, Grieve, Stark and Herbert (2010) found children with autism to have less interhemispheric synchrony at or below the theta band (six to seven Hz) during visual stimulation. Several recent DTI studies have offered similar findings of childhood hypoconnectivity. Children with autism displayed lower FA, an indication of reduced WM integrity, in the anterior cingulate cortex, left dorsolateral prefrontal cortex, right temporal pole, amygdala, superior longitudinal fasciculus and occipitofrontal fasciculus (Noriuchi et al., 2010). Shukla, Keehn, Lincoln and Muller (2010) reported children with autism experienced an increase in mean diffusivity (MD) or less WM integrity, in the internal capsule and middle cerebellar peduncle. In a second study, Shukla, Keehn and Muller discussed increased MD and reduced FA in multiple regions of the brain (2011). This research team added that no cortical areas in the children with autism were found to have the reverse: an increase in FA and decrease in MD. These findings have since been replicated (Walker et al., 2012) and extensively reviewed (Li, Karnath & Xu, 2017). Overall, researchers have suggested hypoconnectivity develops in children with autism sometime after the age of four.

While a number of researchers have explored hypoconnectivity in children, many more have studied hypoconnectivity in adolescent and adult participants with autism. Most research on this older population has found hypoconnected structures throughout the cortex. Researchers have repeatedly found hypoconnectivity in frontal-parietal regions (Damarla et al. 2009; Ha, Sohn, Kim, Sim & Cheon, 2015; Hernandez, Rudie, Green, Bookheimer & Dapretto, 2015; Horwitz et al. 1988; Just et al., 2007; Kana, Keller, Cherkassky, Minshew & Just, 2006; Lenroot & Yeung, 2013; Mahajan & Mostofsky, 2015; Murias, Webb, Greenson & Dawson, 2007; Ruggeri, Sarkans, Schumann & Persico, 2014; Solomon et al. 2009) supporting theories of early disrupted dynamic brain development. Other regions often cited as having displayed hypoconnectivity include the fusiform face area (Kleinhans et al., 2008; Koshino et al. 2008), the dorsolateral pre-frontal cortex (Damarla et al., 2009; Just et al. 2004; Noriuchi et al., 2010), the amygdala (Kleinhans et al., 2008; Noriuchi et al., 2010) and temporal areas (Brambilla et al., 2003 for review; Wellchew et al., 2005). These regions have been shown to assist in executive planning, facial working memory, emotional recognition and response inhibition (Just et al., 2004; Kana, Keller, Minshew & Just, 2007; Koshino et al., 2008; Welchew et al., 2005). Hypoconnectivity of the adolescence and adult brain may also be demonstrated in reductions of total brain volume (TBV). Multiple researchers have found evidence of decreased TBV in people with autism as compared to controls (Carper, Moses & Tigue, 2002; Nordahl et al., 2011) and reduced volume in the frontal and temporal lobes after adolescence (Courchesne, Campbell & Solso, 2011; Lang et al., 2015).

Summary of Research on Neurology of Autism

Aberrant connectivity within the brain has become the most accepted explanation of the pathophysiology of autism. Patterns of aberrant connectivity have been closely linked to age and development, with some differences found in varying autism phenotypes. These data evolved from findings of impaired interactions between brain regions (Horwitz et al. 1988) to a more specific description of local hyperconnectivity and long-distance hypoconnectivity (Belmonte et al., 2004). These groundbreaking studies have led researchers to identify early hyperconnectivity and later hypoconnectivity of the corpus callosum, and frontal, temporal, and parietal regions. In addition, scientists have examined a lesser studied system called the mirror neuron system (MNS). People with autism demonstrated connectivity abnormalities associated with the MNS. Multiple scholars have come to believe these findings stem from cortical disruption early in life which resulted in an altered developmental trajectory of the brain. These alterations are believed to lead to many of the behavioral characteristics seen in autism.

Cortical Areas Involved in Processing Music

To better understand the intersection of connectivity, music and autism, it is important to describe how humans perceive music. Many diverse areas of the brain have been associated with the perception of music. This perception has been broken down into three main categories: pitch, rhythm and emotion: all of which take place in distinct cortical areas and often work in conjunction during the perception of music.

Pitch

Anatomical research has shown processing pitch requires the sound wave to travel into the auditory canal of the outer ear, through the tympanic membrane or eardrum of the middle ear, and into the inner ear. Sound waves vibrate the cochlea, the basilar membrane, and the organ of Corti transforming the wave into electrical signals, which then pass to the auditory nerves (Schnupp, Nelken & King, 2011). This signal is finally deciphered bilaterally (in both sides of the brain) in the auditory cortex in the superior temporal lobe or Brodmann's areas 41 and 42.

Within the auditory cortex, neurons have demonstrated reactivity to a limited range of frequencies and group together according to pitch sensitivity (Arlinger et al., 1982), allowing lower frequency tones to be processed in the rostrolateral (to the front and side) area of the primary auditory cortex (Brodmann's area 42), and higher tones to be processed in the caudomedial (back and to the middle) auditory regions (Bendor & Wang, 2006). When researchers have compared the relationship between several tones, as in a melody or chord, the brain has been shown to analyze this information in the right secondary auditory cortex in Brodmann's area 22 and 42 (Iusca, 2010).

Rhythm

Rhythm stimuli also activate the auditory cortex. The right hemispheric belt and parabelt areas of the auditory cortex have been shown to discriminate changes in tone duration and spacing, while perception of meter has demonstrated activation of the anterior parabelt bilaterally (Tramo, 2001). In addition, when someone has listened to a rhythm, part of the body such as a finger, hand, or foot may spontaneously move along with the beat. This physical action has been shown to activate additional parts of the brain including motor areas and the frontal cortex. Researchers have demonstrated that tapping metrical rhythms will activate the left frontal cortex, left parietal cortex (Tramo, 2001) supplementary motor areas (Grahn & Brett, 2007; Ibbotson & Morton, 1981), basal ganglion (Grahn, 2009; Grahn & Rowe, 2009; Ivry & Spencer, 2004) and right cerebellum (Chen, Penhune & Zatorre, 2008; Tramo, 2001) while nonmetrical rhythms shift activation away from the left frontal cortex to the right hemisphere and cerebellum (Tramo, 2001).

Researchers also have been fascinated by rhythm perception and cortical activation of participants who stand perfectly still. Several neuromusical researchers have found that the perception of rhythm activates motor areas of the brain even in the absence of any movement (Levitin & Menon, 2003; Levitin & Tirolovas, 2009). This discovery has continued to intrigue neuropsychologists (Chen et al., 2008; Grahn, 2009; Grahn & Rowe, 2009; Ivry & Spencer, 2004; Levitin, 2009; Limb, Kemeny, Ortigoza, Rounani & Braun, 2006; Peretz, Gagnon, Herbert & Macoir, 2004) and has had profound implications for the connection between music and movement.

Emotion

The combined effect of pitch and rhythm has been shown to create exceptionally strong emotions and alter the mood of most human beings. Most people have experienced powerful physiological responses to music such as “shivers”, “goose bumps”, or changes in heart rate. These symptoms have been shown to be the result of activation in limbic (amygdala, nucleus accumbens, orbitofrontal cortex, cingulate gyrus and hippocampus) and paralimbic (orbitofrontal cortex, parahippocampal gyrus, temporal poles) structures responsible for processing emotion, reward, and motivation (Blood & Zatorre, 2001; Koelsch & Siebel, 2005).

One noteworthy structure mentioned above, within the limbic/paralimbic system was the amygdala. The amygdala has been shown to be involved in initiating, creating, detecting, maintaining, and terminating emotions imperative for survival (Langner & Ochse, 2006). Researchers who have utilized neuroimaging (Kaas, Hackett & Tramo, 1999; LeDoux, 2000; Ongur & Price, 2000; Patel & Balaban, 2001; Schowiesner, von Cramon & Rubsamen, 2002; Tramo, Shah & Braida, 2002; Warren, Uppenkamp, Patterson & Griffths, 2003) and have studied lesions (Fishman et al., 2001; Naatanen, Tervaniemi, Sussman, Paavilainen & Winkler, 2001; Pantev, Roberts, Schultz, Almut & Ross, 2001) demonstrated that the amygdala was greatly involved in emotional responses to music. Investigators have found the amygdala activated during both positive and negative musical stimuli (Peretz & Zatorre, 2005; Tramo et al., 2002). Specifically, Koelsch and Siebel (2005) found an increased blood flow or blood-oxygen-level dependence (BOLD) signal in the basolateral (bottom and side) amygdala and a decreased signal in the superior region of the amygdala.

Functionally connected to the amygdala, the ventral striatum has been shown to be involved in processing pleasure. Several researchers have found activation of the ventral striatum during pleasant music listening experiences and intense “chill” experiences of music (Griffiths et al., 1999; Kaas et al., 1999; LeDoux, 2000; Liegeois-Chauvel, Peretz, Bahai, Laguitton & Chauvel, 1998; Patterson, Uppenkamp, Johnsrude & Griffiths, 2002). Liegeois-Chauvel et al. (1998) reported activity of the ventral striatum was connected to activation in the ventral tegmental area (VTA), nucleus accumbens and hypothalamus. These structures form the mesolimbic pathway or reward circuit leading to a release of dopamine and increased dopamine binding in the nucleus accumbens. This neurochemical reaction has been shown to occur both in the anticipation and experience of intense musical pleasure (Tillman, Bharucha & Bigand, 2000). Other areas activated during the perception of pleasurable music include the right orbitofrontal cortex and cingulated gyrus (Iusca, 2010).

Researchers have not only studied music perceived as pleasurable but also have studied displeasing music. Several research teams have found increased activity in the amygdala while listening to fearful or dissonant music (Bidelman & Krishman, 2009; Koelsch & Siebel, 2005; Pallensen et al., 2006; Warren et al., 2003). Blood, Zatorre, Bermudez and Evans (1999) exposed test subjects to a melody accompanied by ever-increasing dissonant chords. As the dissonance increased, blood flow to the right parahippocampal gyrus also increased. Similarly, Koelsch and Siebel (2005) and van Zuijen, Sussman, Winkler, Naatanen and Tervaniemi (2004) found dissonant music evoked increased blood flow to not only the parahippocampal gyrus but also to the amygdala, hippocampus and temporal poles (an area which shows a decrease in blood flow in response to pleasant music). Other investigators (Doeller et al., 2003; Nager, Kohlmetz, Altenmuller, Rodriguez-Fornells & Munte, 2003) have suggested that the mid-portion of the parahippocampal gyrus has the specific role of processing harsh sounds such as those in dissonant musical passages.

While dissonant music has tended to elicit a fear response, music in minor keys has been perceived as being sadder than music written in major keys and more pleasant than the clashing tones of dissonance (Green, Baerensten & Stodkilde-Jorgensen, 2008; Pallensen et al., 2006). A sorrowful emotional response to minor melodies has been shown to activate slightly different structures than consonant (pleasant) or dissonant (unpleasant) music. Passages of minor music activated the left parahippocampal gyrus, bilateral ventral anterior cingulated and left medial prefrontal cortex in study participants (Mizuno & Sugishita, 2007). Interestingly, these areas are broadly associated with memory and personality, inviting questions as to how human emotion may be associated with perception, past experience, and musical memory.

Cortical Differences between Musicians and Non-musicians

Many researchers have examined sensorimotor (Amunts, 1997; Hund-Georgiadis and Von Cramon, 1999), auditory (Altenmuller, 1986; Besson, Faita & Requin, 1994; Keenan, Thangaraj, Halpern & Schlaug, 2001; Ohnishi et al., 2001; Pantev et al., 1998), visual-spatial (Hetland, 2002), auditory-spatial (Munte, Kohlmetz, Nager & Altenmuller, 2001) and memory (Chan, Ho & Cheung, 1998) abilities of musicians. These unique skills were often associated with the functional enlargement of cortical areas representative of the specific ability (Karni et al., 1995; Pascual-Leone et al., 1995; Pascual-Leone, Wassermann & Sadaro, 1995; Schlaug, Knorr & Seitz, 1994; Toni, Krams, Turner & Passingham, 1998) and offered evidence of training-induced differences found between the brains of musicians and non-musicians in motor, auditory and visual areas (Gaeser & Schlaug, 2003; Schlaug et al., 2009; Schlaug, 2015).

Auditory Cortex

As discussed previously, pitch is processed in the auditory cortex located within the superior temporal lobe. Curiosity as to how this area may differ in the brains of musicians has existed for many years. Auerbach, in the early 20th century, completed postmortem analyses on several famous musicians and found the middle and posterior thirds of the superior temporal gyrus to be larger than normal (Annett, 1970). More recently, scientists have described increased gray matter in the primary auditory cortex (PAC) of professional musicians (Schneider et al., 2002).

According to scientists using cytoarchitectonic (Braak, 1978; Galaburda & Sanides 1980; Rademacher, Caviness, Steinmetz & Galaburda, 1993), myeloarchitectonic

(Hackett, Preuss & Kaas, 2001; Rademacher, et al., 1993) and histochemical (Hackett et al., 2001; Rivier & Clarke 1997; Wallace, Johnston & Palmer, 2002) ways to study the brain, the PAC is mostly contained in the medial two-thirds of Heschl's gyrus (HG), specifically in the anteromedial (to the front and middle) area of Heschl's gyrus (amHG) (Hackett et al., 2001; Rivier & Clarke 1997; Wallace et al., 2002). The amHG, responsible in part for the fine discrimination of pitches and their patterns (Kilgard & Merzenich, 1998; Recanzone, Scheiner, & Merzenich, 1993), frequently displayed a positive correlation between gray matter volume and musician status (Gaser & Schlaug, 2003; Schneider et al., 2002). Schneider et al. (2002) found the total volume of the right hemispheric HG to be 14% larger in professional musicians compared to non-musicians. This research team also averaged gray matter volume of the amHG from both hemispheres of professional musicians and non-musicians and found an increase of 130% plus or minus 23% (Schneider et al., 2002). Scientists speculated that the size increase was likely due to microstructural changes concerning the number of synapses per neuron, number of glial cells and capillary density (Schlaug, 2001) – changes induced by extensive training.

Another structure affected by musician status was the planum temporale (PT), a triangular surface of the auditory cortex found within the HG and caudally to the PAC. The PT was shown to serve as an integrative function for auditory stimuli and auditory processing (Habib & Besson, 2009). In a typical population, researchers have shown that the majority of people with right hand dominance have leftward PT asymmetry and people with left hand dominance have PT symmetry or rightward PT asymmetry

(Steimentz & Seitz, 1991; Witelson & Kigar, 1992). Interestingly, increased left asymmetry of the PT has been found in a subgroup of musicians with perfect or absolute pitch (AP) (Chen, Halpern, Bly, Edelman & Schlaug, 2000; Schlaug, 2015; Schlaug, Jancke, Huang & Steinmetz, 1995; Steinmetz, 1996; Zatorre, Belin & Penhune, 2002). This ability was believed to only occur in musicians who began training before the age of seven (Schlaug 2001), the same age at which the HG was believed to reach developmental stability (Leonard, Puranik, Kuldau & Lombardino, 1998; Preis, Jancke, Schmitz-Hillebrecht & Steinmetz, 1999). Only one research team did not replicate the finding of PT leftward asymmetry (Keenan et al., 2001). In addition, Loui et al. (2010) found AP musicians displayed connections between the posterior superior temporal gyrus (where the PT is located) and the middle temporal gyrus, an area associated with categorical perception.

Much discussion has occurred concerning the broad concept of auditory hemispheric specialization within musicians. Several researchers indicated that musical training changes the hemisphere in which people process music. During one passive music listening task, non-musicians demonstrated increased activation in right secondary auditory areas, whereas musicians showed increased activation in left secondary auditory areas (Ohnishi et al., 2001). Bhattacharya and Petsche (2005) used EEG to demonstrate that the left hemisphere of musicians was more dynamically synchronized during music listening than was true in non-musicians who had increased synchrony in the right hemisphere. This finding was consistent during all music compositions aurally presented. Interest in how musical training may influence each hemisphere differently continues to intrigue researchers.

Motor Areas

Intense and lengthy motor activities have been shown to create significant microstructural changes in motor-related cortical regions ($p < .05$). Several researchers, who have studied rats, found evidence that animals exposed to prolonged motor activity and complex tasks of motor learning showed increased synaptic density, high numbers of glial cells and capillaries (Anderson, Li, Alcantara, Isaacs, Black & Greenough, 1994; Black, Isaacs, Anderson, Alcantara & Greenough, 1990; Kleim, Lussnig & Schwarz, 1996). Evidence of similar microstructural changes also was documented in people. After learning a new motor skill, researchers found an increase in the number of synapses per neuron (Kleim et al., 1996) and stimulation of the thalamic afferents to the motor cortex (Keller, Kostadink & Asanuma, 1992). Using functional imaging, several investigators have found reorganization of motor areas based on experience (Karni et al., 1995; Karni et al., 1998; Pascual-Leone et al., 1995; Schlaug et al., 1994). Interestingly, extended physical exercise without learning a new motor skill only formed new blood capillaries and did not increase the number of synapses per neuron (Black et al., 1990; Isaacs, Anderson, Alcantara, Black & Greenough, 1992). Dramatic microstructural changes were only seen when learning was involved.

These microstructural brain changes often manifested through an increase in gray matter. Schlaug, Lee, Thangaraj, Edelman and Warach (1998) found a relative brain volume increase of around 5% in male musicians as compared to non-musicians. Gaser and Schlaug (2003) found this gray matter increase to be in a motor network that included the left and right primary sensorimotor regions, the left basal ganglia, the cerebellum and the left posterior perisylvian region. Scientists have also cited additional areas of increased gray matter including the primary motor areas and premotor areas (Amunts, 1997; Gaser & Schlaug, 2003; Grodd, Hulsmann, Lotze, Wildgruber & Erb, 2001; Hutchinson et al., 2003).

The supplementary motor area was another region activated extensively in musicians. This area has been shown to identify the purpose of movement, initiate a movement program, and create organization for a motor sequence (Iusca, 2010). The supplementary motor area of musicians was also well-connected to the basal nuclei, an area responsible for control over automated and routine movements (Schlaug, 2001). This relationship between the supplementary motor area and basal nuclei is believed to conserve energy used to focus attention by engaging less of the frontal lobe, allowing the instrumental musician to rapidly execute complicated and intricate fingering patterns (Iusca, 2010). Several researchers employing neuroimaging have also demonstrated a smaller supplementary motor area of activation in musicians implying a more efficient network to control movements (Hund-Georgiadis & von Cramon, 1999; Jancke, Shah & Peters, 2000; Krings et al., 2000).

In addition to the motor areas discussed above, researchers also have examined the cerebellum of musicians. The cerebellum, translated from Latin meaning “the little brain,” anatomically appears to be a separate part of the brain. Although it makes up only one-tenth of the whole brain volume, the cerebellum contains more than four times the number of cells found in the cerebral cortex (Anderson, Korbo & Pakkenberg, 1992). Because of the few input and output connections found between the cerebellum and the cerebral cortex coupled with the abundance of cerebellar cells, neuromusical researchers have focused on this area because of its important role in movement coordination and the sequential timing of movements (Schlaug, 2001). More broadly, it has been implicated in motor skill learning (Kim, Ugurbil & Strick, 1994; Parsons, 2001) and processing music (Gaab, Gaser, Zaehle, Jancke & Schlaug, 2003; Griffiths et al., 1999; Parsons, 2001).

In comparison studies, investigators have found several differences between the cerebellum of musicians and that of non-musicians. Schlaug, Lee, Thangaraj, Edelman and Warach (1998) found a positive correlation between the intensity of practice (over the course of a lifetime) and increased cerebellar volume. Several other researchers have found increased gray matter in the cerebellum of musicians as compared to non-musicians (Hutchinson et al., 2003; Sluming et al., 2003). Schlaug et al. (1998) demonstrated a cerebellar volume increase of 5% in musicians – an extraordinary finding indicating the importance of this area in the ability of musicians.

Corpus Callosum

One of the most significant findings in the field of music and neuroscience has been the increased size of musicians' corpora callosa (CC). O'Kusky et al. (1998), Schlaug et al. (1995) and Steele, Bailey, Zatorre and Penhune (2013) found that musicians who started musical training prior to the age of seven years had a larger anterior midsagittal CC than non-musician controls or musicians who began training later in life. In a DTI study, researchers specifically defined the genu of the CC as having greater FA in musicians than in non-musicians (Schmithorst & Wilke, 2002).

While scientists have replicated findings of greater CC size in musicians, the underlying architecture of this structural difference might be due to many factors. The increased size may indicate more fibers crossing through the CC, a greater proportion of thick myelinated fibers allowing rapid interhemispheric transfer of information, and/or more fibers with thicker axons or increased axon collateral (Schlaug, 2001).

An interesting side note to these findings is that some gender differences have been discovered concerning the CC of musicians. Lee, Chen and Schlaug (2003) examined female and male musicians as two separate groups and found no significant CC differences between female musicians and non-musicians. Several explanations were offered. The female brain may be generally more symmetrical, maintaining greater levels of interhemispheric communication whereas dramatic CC increases were found when men engaged in increased interhemispheric activity, creating a more symmetrical brain during prolonged musical engagement. Another explanation offered was the high incidence of female absolute pitch (AP) in the sample. Bilateral communication needed for this skill may have skewed non-musician results toward a larger CC. This previously unexplored topic concerning the CC of female musicians warrants further investigation especially as it may relate to gender differences in child musicians with autism.

Musicians: A Model for Neuroplasticity

Neuroplasticity refers to the adaptation of a sensory or motor system to an environmental stimulus—performance requirement, or to compensate for an injured or impaired cortical structure (Hallett, 1995; Rauschecker, 1995; Zilles, 1992). These adaptations have been created by strengthening existing synapses, forming new synapses, and/or recruiting new and unique cortical areas (Hallett, 1995; Jacobs & Donoghue, 1991; Karni et al., 1995; Merzenich, Recanzone, Jenkins, Allard & Nudo, 1988; Nudo et al., 1992; Nudo, Milliken, Jenkins & Merzenich., 1996; Pascual-Leone et al., 1994; Pascual-Leone et al., 1995; Pascual-Leone, Wassermann & Sadaro, 1995; Rauschecker, 1995; Recanzone et al., 1993). Evidence of neuroplasticity has been observed in many animal paradigms (Anderson et al., 1994; Anderson et al., 2002; Black et al., 1990; Isaacs, Anderson, Alcantara, Black & Greenough, 1992; Jacobs & Donoghue, 1991; Jenkins, Merzenich, Ochs, Allard & Guic-Robles, 1990; Kleim et al., 1996; Merzenich et al., 1988; Nudo, Jenkins, Merzenich, Prejean & Grenda, 1992; Racanzone, 1990; Zheng & Purves, 1995; Zilles, 1992). Evidence of neuroplasticity also has been observed specifically in many human electrophysiological and neuroimaging studies (Charness & Schlaug, 2000; Cohen, Bandinelli, Findeley & Hallett, 1991; Hund-Georgiadis & von Cramon, 1999; Karni et al., 1995; Karni et al., 1998; Pascual-Leone et al., 1994; Pascual-Leone et al., 1995; Pascual-Leone, Wassermann & Sadaro, 1995; Schlaug et al., 1994; Seitz et al., 1998; Seitz et al., 1990). Such research studies provide strong evidence of the ability of the human brain to mold and change itself.

This evidence has been especially relevant to the structural brain differences observed between musicians and non-musicians. Generations have debated whether musical ability was inherent to the individual or created through practice; more recently referred to as the “nature or nurture” paradigm. While innate cortical differences likely lead an individual to make music and have fewer difficulties perfecting the skill, neuroplasticity was just as likely to foster use-dependent regional growth and the adaption of brain structures in response to a demanding environmental task. Karni et al. (1998) found performance gains and changes in the primary motor cortex after participants practiced a sequential finger opposition task a few minutes per day over the course of a few weeks. In another short-term investigation, enlarged cortical areas were found to be associated with finger movement after practicing a five-finger piano exercise for five successive days (Pascual-Leone et al., 1995).

In one long-term study, neuroplasticity was examined in musicians as compared to non-musicians. A research team led by Gottried Schlaug, formed two separate cohorts of young children: one of which took private lessons on either the piano or a stringed instrument, the other did not receive private music lessons (Hyde et al., 2008). Magnetic resonance imaging scans were administered to all children at the beginning of the study. No notable structural brain differences were found between the two groups. After only 15 months, Hyde et al. (2008) reported increased voxel area of frontal, temporal and parieto-occipital brain areas in the children who participated in lessons. A marked increase in the midbody of the corpus callosum was found between the musician and non-musician children (Hyde et al., 2008). During a second MRI scan performed after 29 months of lessons, an even greater increase of the anterior midbody of the corpus callosum was found among children practicing two to five hours per week than among children practicing one to two hours per week, and among children not practicing (Schlaug et al., 2009). Long term studies, such as these, have been used to support the high probability that musical ability and structural brain differences observed in musicians are a result of training-induced neuroplasticity. These differences seem to be especially dramatic and apparent in the young and developing brain.

Music and Autism

Since autism was first identified and described, notable musical affinity and ability among children with autism have been noted by clinicians, researchers, and parents. These narratives have led researchers to speculate about how music or music-based interventions possibly increase functioning among children with autism.

Musical Affinity and Ability of Children with Autism

Kanner first noted a musical affinity in children with autism in his groundbreaking paper, entitled “Autistic Disturbances of Affective Contact” (Kanner, 1943). He described several cases where children used music to sooth themselves and to interact with others. Since that ground-breaking paper, many other researchers have noted musicality in this special population (Applebaum, Egel, Koegel, & Imhoff, 1979; Bonnel et al., 2003; Foxton et al., 2003; Heaton, 2003, 2004; Heaton, Hermelin, & Pring, 1998, 2001; Mottron, Peretz, & Menard, 2000). Heaton (2003) specifically noted that 40% of people with autism showed a special interest in music. Individuals with autism also seemed to demonstrate a spontaneous preference for musical stimuli over verbal stimuli (Blackstock, 1978).

Leo Kanner (1943) also noted specific cases of musical ability; for example, one child taught himself to play the piano, while another child could recognize and label 18 different symphonies. These observations have led to several investigations examining the musical abilities of individuals with autism. Applebaum, Egel, Koegel and Imhoff (1979) compared three musically untrained children with autism and three typically developing children with musical experience on their aptitude to sing back a musical passage. The research team found children with autism performed equal to or above the musically experienced controls (Applebaum et al., 1979). In more recent research, extraordinary pitch abilities in children with autism have been observed. Heaton, Hermelin and Pring (1998) found superior performance on both a pitch memory task and a speech sound memory task when compared to controls. Heaton (2003) observed high-functioning autism (HFA) children to have enhanced pitch memory and labeling. Yet another comparison study found HFA individuals to have enhanced ability on pitch discrimination (Mottron et al., 2000) and discrimination/categorization tasks (Bonnel et al., 2003).

People with autism have not only demonstrated superior abilities in pitch processing but have also demonstrated comprehension of the affective qualities found in music – a skill which baffles researchers, due to the noted challenges in social communication and interpretation of emotion (Kasari, Sigman, Mundy & Yirmiya, 1990; Langdell, 1978). Heaton, Hermelin, and Pring (1999) found their child participants with autism performed equally to typically-developing peers when labeling happy and sad excerpts of music. In a follow up investigation, Heaton concluded that through active listening, children with autism could acquire culturally embedded knowledge concerning musical meaning. Emotional processing of music was then preserved (Heaton, Hurdy, Ludlow & Hill, 2008).

Interest-based Learning

Interest-based learning strategies are based on using personal interests, curiosity, and motivation as means to engage a child or adult in learning. Researchers studying young children with and without disabilities have associated interest-based learning to positive child behavioral outcomes (DeLoache, Simcock & Marcari, 2007; Dunst et al., 2001; Johnson, Alexander, Spencer, Leibham & Neitzel, 2004; Pruden, Hirsh-Pasek, Golinkoff & Hennon, 2006). Several other research teams investigating children with autism found that integrating a child's interest with intervention activities was associated with multiple positive behavioral consequences (Adams, 2000; Boyd, Conroy, Mancil, Nakao & Alter, 2007; Dunst, Raab & Hamby, 2017; Vismara & Lyons, 2007; Warreyn, Roeyers, Van Wetswinkel & De Groote, 2007). Boyd et al. (2007) noted an increase in social interaction with peers when employing the child's interests. Vismara and Lyons (2007) saw an increase in joint attention (two people focused on the same object) when employing the child's interests. Other researchers (Koegel & Koegel, 2006; Reinhartsen, Garfinkle & Wolery, 2002) found that following the interests of children with autism promoted pro-social behavior and development. Similarly, Dunst, Trivette, and Masiello (2011) found that children who participated in high interest-based learning interventions experienced significant developmental progress in cognitive, social and motor skills when compared to children participating in low interest-based learning interventions.

These data have important implications concerning musical interventions for children with autism. As discussed previously, individuals with autism repeatedly display both an affinity and aptitude for music. Investigators have also found that interventions rooted in interest-based learning produced greater increases in behavior and development. Musical instruction may serve children with autism in two ways. First, studying music may build skill on an instrument creating greater connectivity within the brain. Second, instructors may use the child's interest in music as a powerful tool for engagement. Social, behavioral and academic skills may be placed in the context of music instruction and targeted during private and/or group lessons, creating a powerful intervention for learning.

Summary of Related Literature

Autism Spectrum Disorder, or autism, has been defined as a triad of deficits in communication, social interaction and repetitive behaviors/obsessive interests (American Psychiatric Association [APA], 2000; International Classification of Diseases [ICD], 1994). Scientists have been unable to discover a method to diagnose autism through biological markers such as cortical hypoconnectivity or genetic tests. To obtain a diagnosis, psychologists must collect and analyze behavioral data through psychometric tools such as the Autism Diagnostic Observation Schedule (ADOS, 1999) or the Autism Diagnostic Interview – Revised (ADI-R, 1989). While these measures have been used extensively for the initial determination of an autism diagnosis, the ADOS and ADI-R cannot measure functional or adaptive behavior. Once a diagnosis has been made, behaviors and age-appropriate development have been measured through one of several protocols including the *Vineland Adaptive Behavior Scales*. Increased functioning and potential benefits of studying music may be measured through psychological assessments of adaptive behavior.

Problems with adaptive behavior in autism have been associated with functional aberrant connectivity of the brain. Data supporting early hyperconnectivity and later hypoconnectivity of the brain with autism have become the most accepted explanation of the pathophysiology of autism. Many researchers have found reduced volume of the corpus callosum and/or reduced connectivity between frontal, temporal and parietal regions. Multiple scholars have stated these findings imply a cortical disruption early in life resulting in an altered developmental trajectory of the brain. These alterations are believed to lead to many of the characteristics seen in autism.

While the brain of an individual with autism generally displayed long-distance hypoconnectivity, the brain of a musician displayed increased long-distance connectivity. The diverse skills of musicians have presented a unique pattern of increased cortical volume, connectivity, and activation in multiple areas of the brain. These areas included auditory and motor areas, including the cerebellum, and the corpus callosum. Neuromusical researchers have also definitively established that these changes are not inborn, but a result of prolonged training. The brains of musicians have continued to serve as a model of specialized cortical development and human neuroplasticity.

Interestingly, children with autism have often exhibited a special affinity for music. Leo Kanner (1943) described both musical affinity and ability in six of the eleven children he studied. Many other researchers have noted musicality in this population and have found that individuals with autism demonstrate a spontaneous preference for musical stimuli over verbal stimuli. Children with autism have also displayed heightened abilities in music. Researchers have found that musically untrained children with autism perform equal to or above their musically experienced counterparts, demonstrating extraordinary pitch memory, labeling and discrimination. People with autism have not only demonstrated superior abilities in pitch processing but have also demonstrated increased comprehension of the affective qualities found in music.

These data may be used to substantiate several exciting implications for practitioners. First, many researchers have described children and adults with autism as having a special affinity for music. Consequently, music may serve as a bridge into their world, and provide motivation for social interaction and communication. Second, children on the autism spectrum have demonstrated extraordinary aptitude in music. This ability may not only be fostered into skill on an instrument or with the voice, but may also be used to enhance and motivate learning in individual areas of deficit. Third, cortical structures shown to be in deficit in individuals with autism correlate to overdeveloped structures in the musician's brain. Studying music may change the structure of the brain with autism, forming long-distance connections and growing underdeveloped areas. Finally, increased social interaction and communication coupled with brain growth may lead to higher levels of functioning.

This exploratory study was designed to extend the findings of the reviewed research literature in this chapter, and to answer some of the questions that remain unanswered as related to the benefits of music instruction as intervention for children with autism. Specifically, the purpose of the current study was to investigate effects of instrumental music instructional intervention and non-music intervention on the adaptive behaviors and neurophysiological responses of children with autism.

CHAPTER III

PROCEDURES

This chapter outlines the procedures used to investigate the effects of instrumental music interventions and non-music interventions on the adaptive behaviors and neurophysiological responses of children with autism. First, a description of recruitment and criteria used to select participants is provided. Second, the music and non-music interventions are described. Third, the data collection procedures are described, including demographic data, measures of adaptive behaviors using the *Vineland Adaptive Behavior Scales II* (VABS; Sparrow, Cicchetti & Balla, 2005), and measures of neurophysiological responses using electroencephalography (EEG). Finally, procedures used to analyze adaptive behavior and neurophysiological data are described.

Recruitment and Selection of Participants

Children were recruited for this study through multiple announcements placed in county-specific Autism Society of North Carolina listservs. The targeted North Carolina counties included Wake, Durham, Orange, Person, and Chatham. Children were recruited to participate in the study if they met the *Diagnostic and Statistical Manual of Mental Disorders Fourth Edition Revised* (DSM-4R) criteria for autism spectrum disorder or Asperger's syndrome, and were between the ages of six and twelve years (American Psychiatric Association, 2013). During interviews to determine whether each recruited child met the criteria to participate in the study, each child's behaviors were observed, noted, and used to support the reported diagnosis of autism. These diagnostic behaviors included, but were not limited to: (1) awkward use of pragmatics, intonation, and pitch in communication, (2) lack of initiation of social interactions, and (3) obsessive preoccupation with the order and/or specific details of the current study procedures. Pragmatics in communication were considered awkward when a child had difficulty using social language skills, such as talking with others, taking turns in conversation, and using appropriate body language.

Children from all ethnic backgrounds were encouraged to participate if they lived in an English-speaking or bilingual household, in which one of the languages spoken was English. A child was excluded from this study if he or she had instrumental music experience through their school music program or through private music lessons. A child was selected to participate in the study if they: (1) met DSM-4R criteria, as displayed during the initial interview, (2) were between the ages of six and twelve years, and (3) had one parent or guardian who was able to meet the weekly demands of this longitudinal study. These demands included bringing their child to weekly meetings, each lasting 30 minutes. All parents or guardians, whose children served as participants, were referred to as adult participants in the study.

Initial approval to conduct this exploratory study was received from the Institution Review Board at the University of North Carolina at Greensboro in June 2012 (Appendix A), and approval was renewed each year following the initial approval, until the study's completion. Participants of the current study were 14 children and one accompanying parent for each child (N = 28). All participating adults gave informed consent to participate in the study (Appendix B), and informed consent for their children to participate in the study (Appendix C). Participating children in the experimental treatment group and in the control treatment group gave informed assent to participate in the current study (Appendix D and Appendix E, respectively).

Interventions

All child participants with their adult participants were assigned randomly to one of two groups—a control group or an experimental group. Both groups received an intervention during the treatment period of the study. The control group received 30 minutes per week of one-on-one non-music intervention during a 20-week treatment period. The experimental group received 30 minutes of one-on-one violin instruction during a 20-week treatment period.

Activities during the non-musical intervention were self-selected and determined by the control group child and adult participants. The non-musical intervention included constructing items with various materials, catching and throwing balls, reading, writing, cutting shapes, coloring, conversing, using an iPad, completing puzzles, and playing games that required taking turns and following directions. These interactions remained unstructured and stress-free.

The child and adult participants in the experimental group, were taught to play the violin using the Suzuki approach—a pedagogical approach using encouragement, aural learning, repetition, and task analyzing skills. Use of the Suzuki approach created an atmosphere where child participants experienced and achieved success, regardless of their developmental level. In accordance with the Suzuki approach, participants in the experimental group were encouraged to practice daily at home through systemic positive reinforcement. In the current study, positive reinforcement was used, and each child was awarded a small prize for every 100 minutes practiced. Home practice time was charted and recorded by the adult participants and the music intervention teacher.

In addition to the Suzuki approach, the researcher adapted evidence-based practices for use during music instruction. Previously, evidence-based practices were shown to be effective through randomized or quasi-experimental research studies, and through multiple single-subject research studies. The National Professional Development Center for Autism Spectrum Disorders (NPDC) outlined 27 evidence-based practices meeting these stringent criteria (Wong et al., 2015). The NPDC also provided online Autism Focused Intervention Resources and Modules for detailed explanation and training for each practice (NPDC, 2016). The 27 evidence-based practices of the NPDC are presented in Table 1, including affirmation of using identified practices in the music intervention of the current study. Based on a review of the tabulated evidenced-based practices in Table 1, and of the music instruction of the current study, the researcher frequently used 16 of the 27 practices throughout the music intervention, as presented in **bold** print in Table 1, with an affirmation of "**Yes**."

Table 1. Evidence-based Practices of the National Professional Development Center for Autism Spectrum Disorders (2016)

Evidence-based Practice	Purpose of Practice	Used in Current Study
Antecedent-based Intervention (ABI)	**Decrease an unwanted behavior and increase engagement through a change in environment**	**YES**
Cognitive Behavioral Intervention (CBI)	Recognize/identify when negative thoughts & emotions escalate and use strategies to modify thinking & behavior	
Differential Reinforcement (DR)	Use of reinforcement to reduce unwanted behavior	
Discrete Trial Training (DTT)	Teacher directed; new skill broken down into simplified, structured steps	
Exercise (ECE)	**Increase wanted behaviors and decrease unwanted behaviors**	**YES**
Extinction (EXT)	Decrease unwanted behavior by taking away consequences maintaining it	
Functional Behavior Assessment (FBA)	Identify unwanted behavior, its purpose, and what factors maintain behavior	
Functional Communication Training (FCT)	Replace unwanted behavior with appropriate communicative behavior	
Modeling (MD)	**Teacher provides model for new skill or behavior**	**YES**
Naturalistic Interventions (NI)	**Reinforce wanted behaviors within person's interests and everyday activities**	**YES**
Parent-implemented Interventions (PII)	**Training parents to use evidence-based practices with their children at home & in community**	**YES**
Peer-mediated Instruction and Intervention (PMII)	Instructing peers without disabilities to engage in positive social interactions with people with autism	
Picture Exchange Communication System (PECS)	**Allow those with limited language abilities to communicate through pictures**	**YES**

Continued

Table 1. (Continued)

Evidence-based Practice	Purpose of Practice	Used in Current Study
Pivotal Response Training (PRT)	Target areas of development instead of individual skills. Areas include motivation, response to cues, and social skills	
Prompting (PP)	**Use cues to build success & generalize a target skill**	**YES**
Reinforcement (R+)	**Provide a consequence to increase use of a skill or behavior**	**YES**
Response Interruption/Redirection (RIR)	**Interrupt or redirect attention to reduce or eliminate unwanted behavior**	**YES**
Scripting (SC)	Provide verbal or written model for increased communication with others	
Self-management (SM)	Self-evaluation & management of appropriate & inappropriate behaviors	
Social Narratives (SN)	**Describe social situations through descriptions and/or pictures**	**YES**
Social Skills Training (SST)	Teacher directed instruction of targeted social skills	
Structured Play Groups (SPG)	**Small group activities with typically developing peers targeting various skills**	**YES**
Task Analysis	**Teaching a skill through multiple individual steps**	**YES**
Technology-aided Instruction and Intervention (TAII)	**Use of technology in the acquisition of a skill or goal**	**YES**
Time Delay (TD)	**Allowing response time between instruction and prompts**	**YES**
Video Modeling (VM)	**Provide a model of skill or behavior on video**	**YES**
Visual Supports	**Visual cues to increase processing of information**	**YES**

Based on several factors, the affirmed evidenced-based practices in Table 1 were used and adapted to music instruction. First, the National Professional Development Center on Autism Spectrum Disorder previously evaluated each evidence-based practice for efficacy based on age (Wong et al., 2015). Each practice was labeled as effective for one or more of the following age ranges: (a) early intervention (0-2 years), (b) preschoolers (3-5 years), (c) elementary (6-11 years), (d) middle school (12-14 years), and (e) high school (15-21 years). Each of the practices used in the current study was found to be effective for children ages 6-12 years, or for the elementary and middle school age ranges. Second, many of the affirmed practices in Table 1 were especially suitable for teaching and reinforcing techniques and skills associated with learning a music instrument. Video modeling, time delay, task analysis, structured play groups, reinforcement, prompting, parent-implemented interventions, and modeling were the evidence-based practices used for instrumental skill acquisition. Third, many of the practices, used in the current study, provided support for behaviors that otherwise would detract from music learning. These practices included structured play groups, social narratives, response interruption/redirection, reinforcement, prompting, naturalistic interventions, exercise, and antecedent-based intervention. Finally, many of the affirmed practices in Table 1 were used to support communication during the music intervention. These practices included visual supports, technology-aided instruction and intervention, social narratives, prompting, Picture Exchange Communication System (PECS), naturalistic interventions, and modeling.

As previously indicated, 16 of the 27 evidence-based practices in Table 1 were used to support instrumental skills, behaviors, and/or communication in the music intervention. Additionally, the music intervention, and the non-music intervention occurred across 20 consecutive weeks of treatment, including 30 minutes of either one-on-one instrumental music intervention (i.e., experimental intervention), or one-on-one non-music intervention (i.e., control intervention) each week.

Data Collection

Multiple measures were used to collect data from children and adults participating in the study. These measures included a demographic data collection form, *Vineland Adaptive Behavioral Scales II* (VABS; Sparrow, Cicchetti & Balla, 2005), and electrophysiological recordings.

Demographic Data

Upon acceptance into the study, parents completed an intake form to provide demographic information on both the child and parent. Collected information included the child's name, age, grade, birthday, gender, and school. Parents were asked to give their name, address, home phone number, cell phone number and email address. In addition, parents listed their child’s extracurricular activities and hours per week spent in occupational therapy, speech therapy and/or physical therapy (see Table 1). Finally, parents provided detailed information about their child's likes, dislikes, fears, behaviors, and dietary needs. Parents also indicated items acceptable for use as motivators with their children.

Table 2. Demographic Data of Child Participants

Participant	**Gender**	**Age in Years**	**Diagnosis**	**Speech Therapy**	**Occupational Therapy**	**Physical Therapy**
1	Male	11.60	Autism	Yes	No	No
2	Male	12.75	Asperger	No	No	No
3	Male	6.75	Autism	Yes	Yes	No
4	Male	11.80	Autism	Yes	No	No
5	Female	6.20	Autism	Yes	Yes	No
6	Male	7.30	Asperger	No	Yes	No
7	Male	8.58	Autism	Yes	No	No
8	Male	10.42	Autism	Yes	Yes	No
9	Male	12.75	Autism	Yes	No	No
10	Male	9.17	Autism	Yes	No	No
11	Male	7.00	Asperger	No	No	No
12	Male	5.90	Autism	Yes	No	No
13	Male	10.58	Autism	Yes	No	No
14	Male	8.00	Autism	Yes	No	No

Vineland Adaptive Behavior Scales

The *Vineland Adaptive Behavior Scales II* (VABS; Second edition, Sparrow, Cicchetti & Balla, 2005) was designed to measure personal and socialization skills of individuals primarily between the ages of preschool and 18 years. In the current study, participants' ages ranged from 5.90 years to 12.75 years, and the VABS was used to measure their personal and social skills. Using a three-point scale, each participant's parent answered questions across the five domains of the VABS, including the domains of Communication, Daily Living Skills, Socialization, Motor Skills, and Maladaptive Behavior.

Under the Communication domain, skills were divided into the subdomains of Receptive, Expressive, and Written Language. Receptive language questions measured attention, comprehension, and appropriately responding to others. Expressive language questions measured the use of words and sentences to verbally express himself or herself. Written language questions measured reading and writing skills. The Daily Living Skills domain was divided into the subdomains of Personal, Domestic, and Community. The Personal questions measured self-sufficiency while eating, getting dressed, and grooming and caring for oneself. The Domestic questions measured cleaning, cooking, and ability to do chores. The Community questions measured an individual's ability to use money, travel, and function safely away from home. The Socialization domain was divided into the subdomains of Interpersonal Relationships, Play and Leisure, and Coping Skills. The Interpersonal Relationships questions measured friendships, caring, conversational skills, and appropriate social behavior. The Play and Leisure questions measured having fun and playing with others. Coping skills questions measured control over behaviors and emotions while interacting with others. The Motor Skills domain was divided into the subdomains of Fine and Gross motor skills. Fine motor skills questions measured control of hands and fingers to manage objects in everyday life, while Gross motor skills questions measured control of legs and arms for mobility and coordination. Finally, the Maladaptive Behavior domain was divided into the subdomains of Internalizing and Externalizing behaviors. Internalizing behavior questions measured problem behaviors that are emotional. Externalizing behavior questions measured problem behaviors where the person acts out physically.

Prior to and after the music and non-music interventions, each parent completed the VABS. Across the five VABS domains, the parents rated their children's behaviors using the three-point scale of 0 (never performed), 1 (sometimes or partly performed), and 2 (usually or habitually performed). Completing the VABS took approximately 60 minutes during the pre-intervention, and during the post-intervention.

Preparation Procedures for Electroencephalogram (EEG)

The electroencephalogram (EEG) was designed to record the electrical activity of synaptic currents within the brain and is measured in Hz. In the current study, the EEG was used to examine mirror neuron activation, or mu rhythms between 8-13 Hz in the sensory motor cortex. The equipment used in the current study was housed in the University of North Carolina at Chapel Hill's Neurocognition and Imaging Research Lab.

Before the participants came to the Lab to complete their EEG, participants and their parents were given caps to take home, with which to play and wear for several weeks. This preconditioning time was used to acclimate each participant to wearing the cap with electrodes as they completed their EEGs. Following this cap-acclimation time period, participants came to the Lab for their initial EEG.

Each participant was given a total of two hours to complete the EEG, providing ample time to explore the Lab, and play with therapy toys before the elastic cap with electrodes was placed onto their head. After the EEG cap was put on the participant's head, a gel was squeezed into all electrodes creating a connection between the child's scalp and each electrode. Participants were then seated within a dimly lit and sound-attenuated room. Task images to be watched during the recording of EEG data, were shown on a Dell 19-inch flat panel monitor, operating at a 60 Hz refresh rate. The participants sat approximately 100 cm from the stimulus monitor that was adjusted to the child's eye level. Electrophysiological data were collected while participants completed several visual and motor tasks that were created to evaluate mirror neuron activation within the sensory motor cortex.

Mirror Neuron EEG Tasks

Mirror neuron EEG data were collected from participants' responses during three tasks: (1) moving own hand, (2) watching a recorded video of a child's moving hand, and (3) watching a bouncing ball. The first two tasks of moving own hand, and of watching a moving hand created an optimal opportunity during the EEG to activate the mirror neuron system through action and observation, respectively. This open- and close-hand action was done with minimal movement of the head, and therefore, with minimal disruption to the EEG recording. The watching-ball task was a neutral, non-social task by that was used to compare mirror neuron activation to action and observation tasks.

First, participants opened and closed their right hand, fully extending the fingers and thumb to a straight position, followed by closing fingers and thumb to make a fist. This motion occurred at an approximate rate of 1Hz, that is, one open and close cycle per second for a 20 second time period. Participants were signaled to open and close their hand with a green screen, and to stop the motion with a red screen (Figure 1).

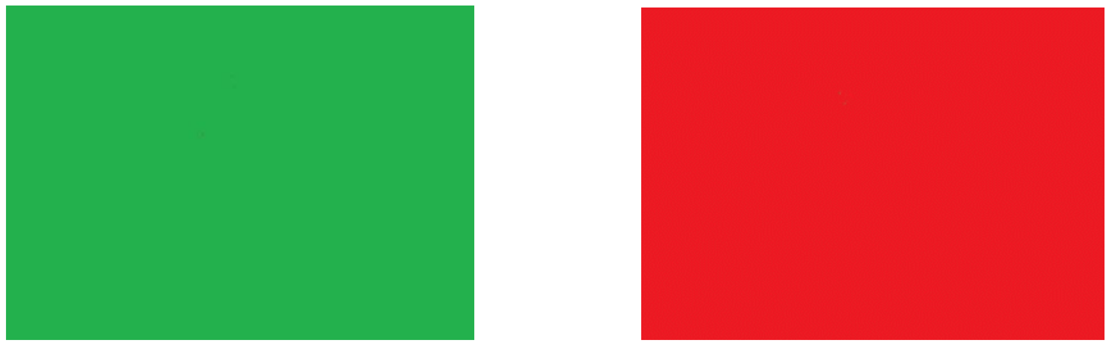

Figure 1. Green Screen Signaling to Open and Close the Hand; Red Screen Signaling to Stop Opening and Closing the Hand.

Second, participants watched a black and white video recording of a 12-year-old child opening and closing his right hand fully extending the fingers and thumb to a straight position, followed by closing fingers and thumb into a fist. This observed motion occurred at an approximate rate of 1 Hz or once per second for a 20 second time period (Figure 2).

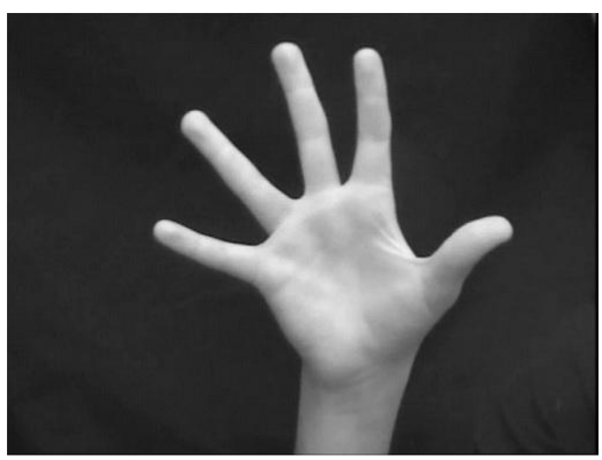

Figure 2. Video Recording of a Child’s Moving Hand.

Third, participants watched a video recording of a ball bouncing at approximately 1 Hz, that is, watching a ball bounce once per second for a 20 second time period (Figure 3).

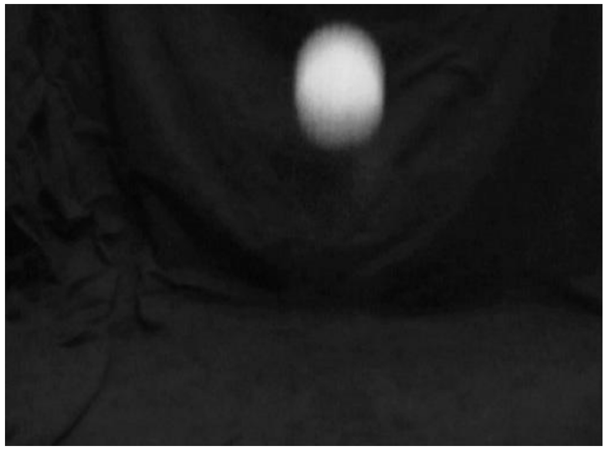

Figure 3. Video Recording of a Ball Bouncing.

All video recordings of tasks were medium gray against a black background, and were presented at a viewing distance of 100 cm. Each video-recording task was presented to the participant for 20 seconds and viewed six times. This repetition increased the likelihood of obtaining a sufficient amount of clean EEG data for a thorough analysis.

Electrophysiological Recording

The EEG recorded data from 18 electrodes, 13 of which were used to collect data: at the frontal (F3, Fz, F4), central (T7, C3, Cz, C4, T8), parietal (P3, Pz, P4), and occipital (O1, O2) scalp locations. These positions were obtained using a 10-5 system elastic cap (Electro-Cap International Inc.). The right mastoid location contained the reference electrode and AFz electrode maintained the ground. Bipolar recordings by the horizontal and vertical electro-oculogram (EOG) were collected by electrodes placed below and above the right eye and at the outer canthus of both right and left eyes. Scalp electrode impedances remained under 25 kΩ for the duration of the EEG. Within the EEG recordings, artifacts were rejected manually and channels with especially abnormal patterns were removed. Source locations were updated for all data components using a database of 385 defined channel labels for the 10-5 system cap. The EEG and electro-oculogram was amplified, bandpass filtered between 0.15 and 70 Hz (notch filter at 60 Hz), and digitized at 500 Hz. The EEG was acquired with a Neuroscan 4.3 system (Neurosoft, Inc., Sterling, VA, USA), and was analyzed with Neuroscan Edit 4.4 and custom MATLAB scripts, built on the open-source EEGLAB toolboxes (Delorme and Makeig, 2004) and FieldTrip (Oostenveld, Fries, Maris & Schoffelen, 2011).

Each stimulus event was identified by type, and labeled as “1” for the watching hand event, “2” for the watching ball bouncing, and “3” for each participant's moving hand event. After the code presentation of 1, 2, or 3, data were examined in 0-20 second epochs, or segments of time. Mu rhythms, that is, EEG oscillations in the 8–13 Hz frequency band, were analyzed through examining recordings from the Cz electrode that measured activity in the sensory motor cortex. EEG analysis compared mean event-related spectral perturbation (ERSP) between each of the three stimulus events.

Summary of Data Collection Procedures

Participants consisted of 14 children and one parent for each child. Data were collected from a total of 28 participants. All parents completed the initial information form, addressing demographic data, and completed the pre- and post-intervention

Vineland Adaptive Behavioral Scales II. Seven children, with a mean age of 9.81 years, were assigned randomly to the control group, and with their parents, they received 30 minutes per week of a one-on-one non-music intervention over a 20-week period. Seven children, with a mean age of 8.54 years, were assigned randomly to an experimental group that received 30 minutes per week of one-on-one instrumental violin instruction during a 20-week period. The participants completed pre-intervention and post-intervention EEG scans at The University of North Carolina at Chapel Hill's Neurocognition and Imaging Research Lab.

Data Analysis

Adaptive Behavioral Data Analysis

The parents of 11 of the 14 originally selected children completed pre- and post-intervention *Vineland Adaptive Behavior Scales II* (VABS) to measure participants' adaptive behaviors. Six of the adult participants were from the music intervention experimental group, and five adult participants were from the non-music intervention control group.

Initially, to analyze participants' pre-intervention or baseline VABS scores from each of the 14 subdomains across the five VABS domains, including Communication, Daily Living Skills, Socialization, Motor Skills, and Maladaptive Behaviors, multiple two-tailed Welch independent *t*-tests were used. Specifically, the Welch *t* tests were used to verify whether there were any significant differences between the experimental and control groups' baseline VABS scores prior to administering the music- and non-music interventions ($p \leq .05$).

To determine the effects of music and non-music interventions on adaptive behaviors (i.e., Research Question 1), a 2 (group—music and non-music interventions) by 2 (time—pre- and post-interventions) mixed factorial analysis of variance (ANOVA) was used. Time and VABS scores across each subdomain of the four domains examined, served as repeated measures within the 2 by 2 mixed factorial ANOVA. The two-way ANOVA was completed using the R Project for Statistical Computing, Version 3.4.3 (2017). When significant main effects or interactions were identified within the ANOVA ($p \leq .05$), a post-hoc two-tailed Welch *t*-test with Holm's sequential Bonferroni multiple comparisons procedure was performed. Data were tested for normality using the Shapiro-Wilk test, and graphically examined for normal distributions of the data using histograms and QQ-plots. No significant non-normality results were found using the Shapiro-Wilk test for normality ($p > .05$).

Electrophysiological Data Analysis

Twelve children were able to participate in electrophysiological data collection in this study, and nine children completed pre- and post-EEGs. Only eight of the participants' EEG scans were clear enough to include in the data analyses. Three pre- and post-intervention EEG scans were analyzed for the non-music intervention group (i.e., control group), and five pre- and post-intervention EEG scans were analyzed for the music intervention group (i.e., experimental group). Mu rhythms, EEG oscillations in the 8–13 Hz frequency, were analyzed through data collected from the Cz electrode that measured activity of the sensory motor cortex. Analysis of mu rhythms from the Cz electrode compared mean event-related perturbation (ERSP) between tasks.

To determine the effects of music and non-music interventions on participants' neurophysiological responses (i.e., Research Question 2), pre-intervention and post-intervention ERSP data were analyzed using a 2x2 mixed factors repeated-measures analysis of variance (ANOVA). Time (i.e., pre- and post-interventions) and task (i.e., move hand, watching hand move, and watching ball bounce) served as the repeated measures in the analysis. The ANOVA was used to compare differences between pre- and post-intervention ERSP data within and between groups (i.e., control and experimental groups) by task (i.e., move hand, watch hand move, watch ball move). These statistical analyses and the resulting graphs were completed and produced using the MATLAB Statistics Toolbox (2012b).

CHAPTER IV

RESULTS

The purpose of this exploratory research was to examine the effects of instrumental music instructional intervention and non-music intervention on the adaptive behaviors and neurophysiological responses of children with autism. Data were collected from a control group (n = 7) and an experimental group (n = 7) receiving 30 minutes per week of one-on-one non-music intervention and music intervention during a 20-week period, respectively.

Adaptive Behavioral Results

To measure participants' adaptive behaviors, parents or guardians of 11 of the 14 originally selected children completed the *Vineland Adaptive Behavior Scales II* (VABS) administered prior to and after the experimental and control interventions. Six of the participants were from the music intervention experiment group, and five participants were from the non-music intervention control group. Only the pre- and post-intervention scores from four domains of the VABS were analyzed, including the Communication, Daily Living, Socialization, and Maladaptive Behaviors Domains. Scores from the VABS Motor Skills domain were not included in the pre- and post-intervention analyses because the VABS measured skills through the developmental age of eight years. Most participants were older than eight years of age (n = 8), and had reached the measured motor benchmarks before starting this study, thus making motor skills analysis irrelevant.

Data were tested for normality using the Shapiro-Wilk test, and graphically were examined for normal distributions, using histograms and QQ-plots. No significant results were found using the Shapiro-Wilk test for normality ($p > .05$). Welch *t*-tests were used to determine whether there were significant differences between experimental and control participants' age and baseline VABS scores prior to administering the music and non-music interventions ($p \leq .05$). Independent *t* tests showed that there were no significant differences between experimental and control participants' age and baseline VABS scores from the four domains analyzed ($p > .05$), except for the Composite Socialization scores ($p = .047$), and Coping Skills scores ($p = .005$) (see Table 2).

Table 3. Independent *t* Tests of Differences between Experimental and Control Groups' Baseline Characteristics[1]

Characteristics[1]	Experimental $\bar{X}$	Experimental SD	Control $\bar{X}$	Control SD	Mean Difference	*p*
Age (Years)	8.54	1.74	9.95	2.88	−1.41	.373
Communication						
Composite	34.17	5.91	27.80	13.39	6.37	.367
Receptive	10.83	1.94	9.60	4.16	1.23	.566
Expressive	10.50	1.87	9.00	5.34	1.50	.577
Written	12.83	2.32	9.20	4.60	3.62	.163
Daily Living						
Composite	37.67	6.59	29.60	10.48	8.07	.182
Personal	12.33	2.94	10.60	3.97	1.73	.445
Domestic	12.33	2.73	10.60	2.61	1.73	.311
Community	13.00	3.46	8.40	4.34	4.60	.093
Socialization						
Composite	**29.67**	**4.84**	**22.40**	**5.37**	**7.27**	**.047***
Interpersonal	9.33	2.66	7.20	3.56	2.13	.304
Play & Leisure	9.50	1.76	7.40	2.97	2.10	.211
Coping Skills	**10.83**	**1.72**	**7.20**	**1.48**	**3.63**	**.005****
Maladaptive Behaviors						
Internalizing	20.17	2.23	20.80	2.28	−.63	.655
Externalizing	18.33	1.21	18.80	2.17	−.47	.683

* $p < .05$ ** $p < .01$

[1] Within the *t*-test analyses, equal variances between groups was not assumed.

The experimental and control groups' pre-intervention and post-intervention scores from the four VABS Domains were analyzed using a two-way mixed factorial analysis of variance (ANOVA). Within the analysis, condition or intervention served as the between effects variable, and session or time served as the within effects variable. The VABS scores served as the repeated measures within the two-way ANOVA. On the preceding page, Table 2 provides the pre-intervention VABS scores, grouped by the experimental and control groups. Table 3 includes the post-intervention VABS scores of the experimental and control groups.

Table 4. Experimental and Control Groups' Post-intervention Scores from the *Vinland Adaptive Behaviors Scales II*

Adaptive Behaviors	**Experimental**		**Control**		**Mean**
	$\bar{X}$	**SD**	**$\bar{X}$**	**SD**	**Difference**
Communication					
Composite	36.83	5.12	26.60	16.35	10.23
Receptive	12.00	2.61	9.40	6.35	2.60
Expressive	11.33	1.63	8.40	5.13	2.93
Written	13.50	2.43	9.00	4.69	10.23
Daily Living					
Composite	38.00	5.44	29.20	12.70	8.80
Personal	12.33	3.27	10.50	5.25	1.83
Domestic	12.50	2.88	9.80	4.44	2.70
Community	13.17	2.40	8.60	4.22	4.57
Socialization					
Composite	32.17	5.95	20.40	6.54	11.77
Interpersonal	10.50	1.76	6.60	2.51	3.90
Play & Leisure	9.17	1.33	6.20	2.78	2.97
Coping Skills	12.50	3.33	7.60	1.67	4.90
Maladaptive Behaviors					
Internalizing	18.33	1.60	19.00	3.39	–.17
Externalizing	18.50	1.76	18.80	2.17	–.30

Table 4 provides results of analyzing the pre- and post-intervention VABS scores across the four analyzed VABS domains, using a 2 (Condition—music- and non-music interventions) by 2 (time—pre- and post-intervention Sessions) mixed factorial ANOVA.

Table 5. Two-way Mixed Factorial Analysis of Variance for Adaptive Behaviors[1]

Adaptive Behaviors	Condition		Session		Condition X Session	
	F	***p***	**F**	***p***	**F**	***p***
Communication						
Composite	1.66	.230	.47	.510	3.27	.104
Receptive	.70	.425	.46	.514	.92	.362
Expressive	.98	.349	.22	.649	**8.36**	**.018***
Written	3.71	.371	.27	.619	.92	.364
Daily Living						
Composite	2.59	.142	.00	.982	.06	.804
Personal	.74	.414	.00	1.000	.00	1.000
Domestic	1.43	.261	.29	.602	.68	.430
Community	**4.72**	**.058**	.10	.761	.00	.978
Socialization						
Composite	**8.10**	**.019***	.10	.763	**7.83**	**.021***
Interpersonal	3.76	.085	.49	.501	**4.78**	**.057**
Play & Leisure	4.48	.063	1.44	.261	.46	.515
Coping Skills	**12.07**	**.007****	3.22	.106	1.21	.300
Maladaptive Behaviors						
Internalizing	.08	.782	14.94	.004**	.33	.579
Externalizing	.12	.732	.14	.716	.14	.716

* $p < .05$ ** $p < .01$

[1] The degrees of freedom used to determine the critical values of F and the associated probability level were 1,9.

The mixed factorial ANOVA demonstrated few significant differences between participants' VABS scores between Conditions, and within participants' pre-intervention and post-intervention scores ($p < .05$). Within the Communication subdomains, there were no significant differences between the control and experimental participants' VABS Composite, Receptive, Expressive, and Written post-intervention scores ($p > .05$). Additionally, there were no significant differences between participants' pre- and post-intervention within the VABS subdomain scores (*p* > 05). There was, however, a significant interaction effect of Condition and Session on participants' Expressive scores (*p* = .018). The experimental participants' (i.e., music intervention) and control participants' (i.e., non-music intervention) pre- and post-intervention Expressive scores were significantly different. After intervention, the experimental and control participants' Expressive behaviors were different, with one group's mean score increasing, and the other group's mean score decreasing. The experimental group's Expressive mean score increased from 10.50 points to 11.33 points; whereas, the control group's Expressive mean score decreased from 9.00 points to 8.40 points. Post-hoc paired *t*-test analyses of the Expressive scores revealed that participants of the music-intervention group significantly improved their post-intervention Expressive scores, as measured by the VABS (*p* = 042). The Expressive scores of participants of the non-intervention group, however, decreased slightly; this decrease was not significant (*p* = .305). Figure 4 illustrates the significant interaction effect of Condition and Session on participants' Expressive scores.

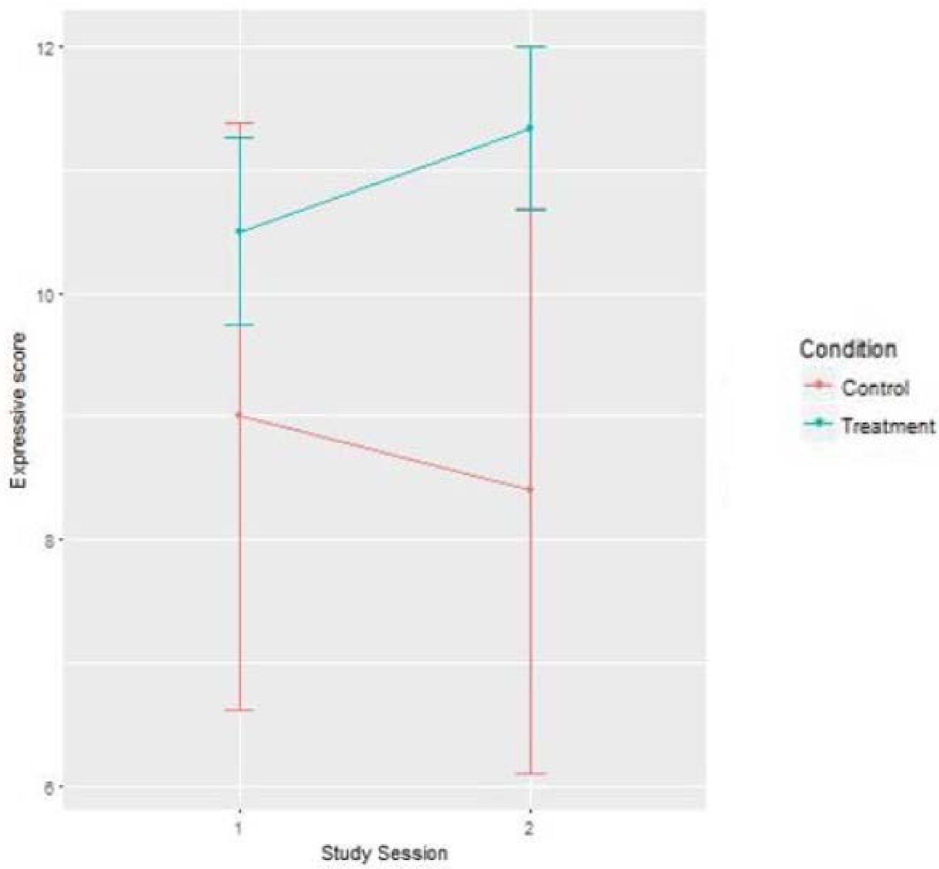

Figure 4. Graph of Significant Interaction Effect of Condition and Session on Participants' Expressive Scores (*p* = .018).

Within the VABS Daily Living Domain, there were no significant differences between the control and experimental participants' Composite, Personal, Domestic, and Community post-intervention scores (*p* > .05). Additionally, there were no significant differences between participants' pre- and post-intervention VABS subdomain mean scores (*p* > 05). Differences between experimental and control participants' Community subdomain scores, however, approached significance (*p* = .058). Experimental participants' post-intervention Community mean scores were notably higher (i.e., $\bar{x}$ = 13.17 points) than control participants' post-intervention mean scores (i.e., $\bar{x}$ = 8.60

points). Both groups' pre-intervention Community mean scores were similar to their post-intervention mean scores, at 13.00 points and 8.40 points, respectively.

Within the VABS Socialization Domain, participants' Interpersonal, and Play and Leisure scores were not significantly different as a result of music and non-music interventions ($p > .05$). Additionally, there were no significant differences between participants' pre- and post-intervention Daily Living subdomain mean scores ($p > 05$). However, there were three subdomain scores that were significantly different ($p < .05$).

The Composite Socialization scores were affected significantly by the music and non-music interventions ($p = .021$). Both groups' post-intervention Socialization Composite score increased, but the experimental participants' mean score was 11.77 points higher than the control group's mean score. Even though the experimental group's pre-intervention Composite mean scores also were significantly higher than the control group's pre-intervention Composite mean scores ($p = .047$), the magnitude of the music-intervention effect appeared to be greater than the non-music intervention effect. The Coping Skills subdomain scores also were affected significantly by the music and non-music interventions ($p = .007$). Both the experimental and control groups' Coping Skills mean scores increased following the music intervention, and the non-music intervention, respectively. The control group's post-intervention mean score increased only by .40 of a point, yet the experimental group's mean Coping Skills score was notably higher than the control group's mean score, increasing from 10.83 points to 12.50 points. This finding supports the premise that the music intervention had a greater effect on participants' Coping Skills than the non-music intervention.

Finally, as related to the VABS Socialization Domain, there was a significant interaction effect of Condition and Session on participants' Composite Socialization mean scores ($p = .021$). The experimental participants' and control participants' pre- and post-intervention Socialization Composite scores were notably different. Following intervention, the experimental group's Socialization Composite mean score increased from 29.67 to 32.17 points; whereas, the control group's Socialization Composite mean score decreased from 22.40 points to 20.40 points, yet, the pre-intervention control and experimental means were significantly different ($p < .047$). Also notable in this interpretation of results was the interaction effect of Condition and Session on Interpersonal means scores, which approached significance ($p = .057$). This result suggested differences between the experimental and control groups' pre- and post-intervention mean Interpersonal scores possibly contributed to the significant interaction effect of Condition and Session on participants' Socialization Composite mean scores, as measured before and after interventions. This finding suggested that music and non-music interventions have different effects on changes in adaptive behaviors of children with autism. Figure 5 illustrates the trending interaction effect of Condition and Session on participants' Interpersonal mean scores.

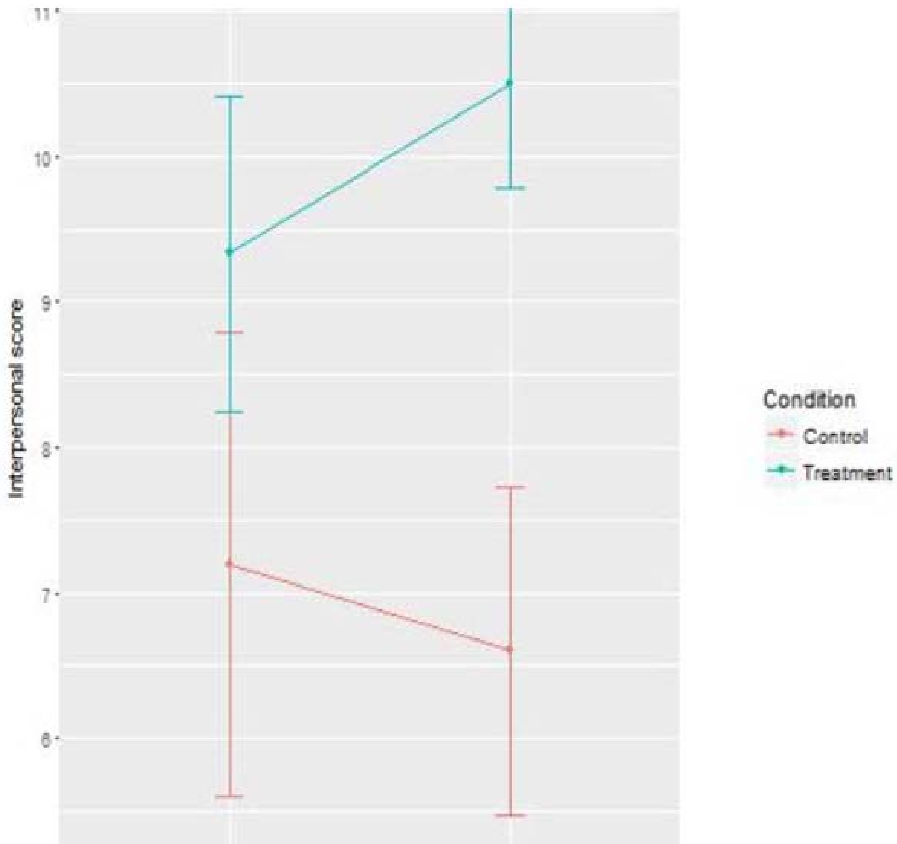

Figure 5. Graph of Interaction Effect of Condition and Session on Participants' Interpersonal Scores of the Socialization Domain that Approaches Significance (p = .057).

Within the Maladaptive subdomains, there were no significant differences between the control and experimental participants' VABS Internalizing and Externalizing post-intervention scores ($p > .05$). Additionally, there were no significant differences between participants' pre- and post-intervention within the VABS subdomain scores ($p >$ 05). Both Internalizing and Externalizing mean scores decreased or basically remained the same for the experimental and control participants following the music and non-music interventions, respectively (See Tables 2 and 3).

Even though the sample size of this study was small, the effect size was relatively large, determined using the Pearson Product Moment Correlation Analysis. For example, for the interaction effect of Condition and Sessions on the Communication Domain's Expressive behaviors, the effect size was $r = .694$, and on the Socialization Domain's Interpersonal behaviors, the effect size was $r = .589$. Both effect sizes exceeded the standard for moderately large effect size ($r = .50$; Cohen, 1988; 1992). The effect size for Expressive behaviors and for Interpersonal behaviors accounted for approximately 48% and 35% of the total variance in participants' adaptive behaviors, as measured by the *Vineland Adaptive Behaviors Scales II*.

Finally, as related to participants adaptive behaviors and characteristics, amount of time that music-intervention participants devoted to practice was examined. Fisher’s exact tests were used to analyze VABS scores dichotomized by high and low violin and music practice time. High practice was defined as greater than 1000 total minutes during the 20-week intervention period; while low practice was defined as less than 1000 total minutes during this intervention period. While generalizable results were not produced by this examination of only three participants, it is interesting that in addition to increases in Interpersonal Socialization scores and Expressive Communication scores, 100% of the high practicing participants also experienced increases in scores associated with Receptive Communication and Socialization Coping Skills. These same high practicing students also displayed reduced Externalizing Maladaptive Behaviors.

Electrophysiological Results

The electroencephalogram (EEG) recorded the electrical activity of synaptic currents within the child participants' brains, measured in Hz. In the current study, the EEG was used specifically to examine mirror neuron activation, or mu rhythms between 8-13 Hz in the sensory motor cortex. Mirror neuron EEG data were collected from participants' responses during three tasks: (1) moving own hand, (2) watching a child's moving hand, and (3) watching a bouncing ball. The first two tasks of moving own hand, and watching a moving hand created optimal opportunities during the EEG to activate the mirror neuron system through action and observation. The open- and close-hand action was completed by each participant with minimal movement of the head, and therefore, produced minimal disruption of the EEG recording. Watching the bouncing ball was a neutral, non-social condition by which to compare mirror neuron activation occurring during action and observing conditions.

An examination of the moving-own-hand task revealed there were no differences between the control group's pre- and post-intervention ERSP responses. Differences were found between the pre- and post-intervention sessions of the experimental group's ERSP responses in the 7000-13000 milliseconds range and in the frequency bands of 11-13 Hz. Differences also were found between the control and experimental groups' pre-intervention ERSP responses in the 8000-millisecond time frame and in the 11-13 Hz frequency bands. Differences were found between the control and experimental groups' post-intervention ERSP responses in the 9000-10,000 millisecond time frame and 8-13 Hz frequency bands. These graphs of participants' ERSP responses indicate a trend of decreased mu suppression in the experimental group's post-intervention move hand task. In Figure 6, differences are illustrated for varying frequencies and times by the red lines in the green plots presented to the right of and below ERSP data boxes. Increased red lines indicated significant differences between ERSP responses ($p < .05$), grouped by Condition (i.e., music and non-music interventions) or Session (i.e., experimental pre- and post-interventions).

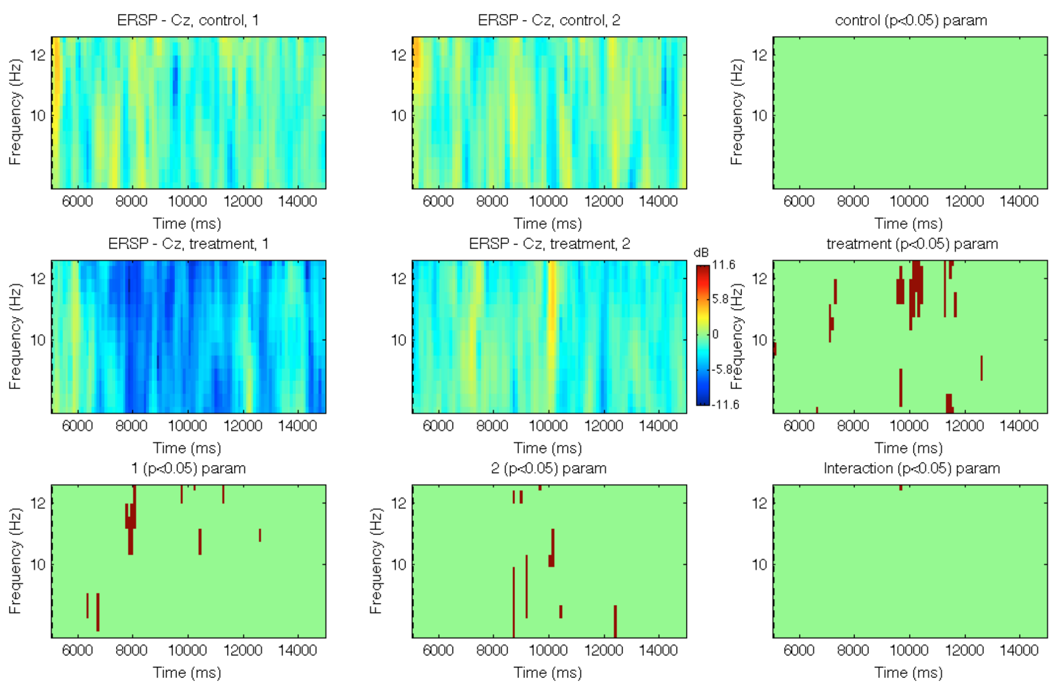

Figure 6. Effects of Condition and Session on ERSP Responses at Cz Location during Moving Hand Task. "Differences [between and within control and experimental groups] are illustrated for varying frequencies and times by the red lines in the green plots presented to the right of and below ERSP data boxes" (i.e., as explained in preceding paragraph).

An examination of the watching hand condition revealed no differences between the control group's pre- and post-intervention ERSP responses. Additionally, there were no differences between the experimental group's pre- and post-intervention ERSP responses, and between the control and experimental groups' pre-intervention ERSP responses. Differences that approached significance, however, were found between the control and experimental groups' post-intervention ERSP responses in 5000-13000 milliseconds range and 8-13 Hz frequency bands. When comparing the control and experimental groups' ERSP data, the graphs of participants' ERSP responses indicate a trend significant increases in mu rhythm suppression among the experimental participants, following music intervention (Figure 7).

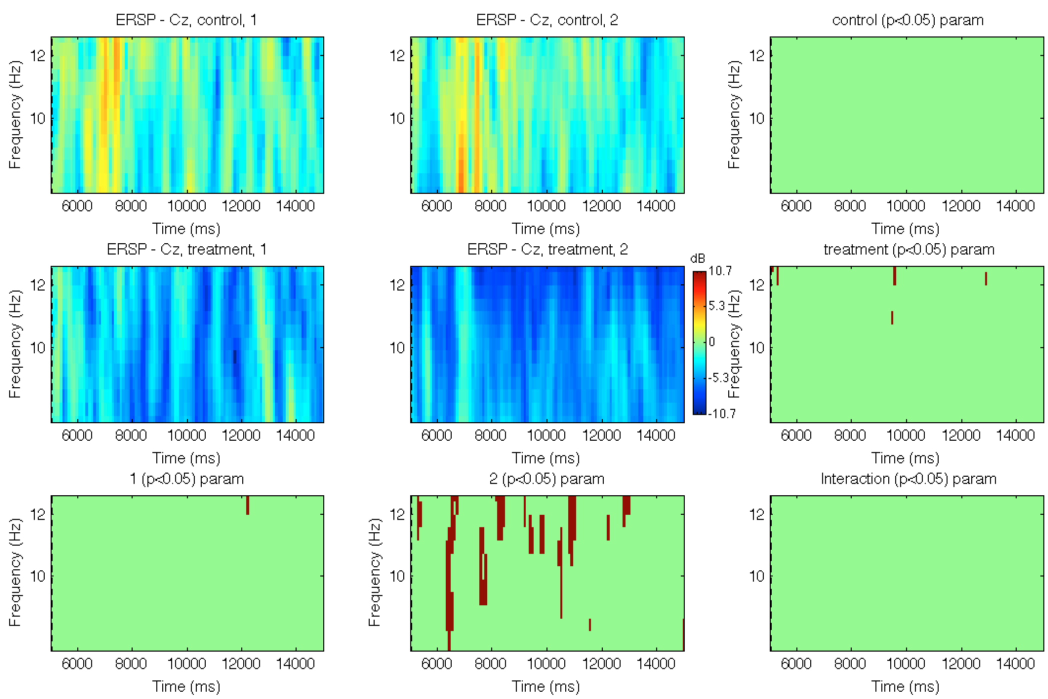

Figure 7. Effects of Condition and Session on ERSP Responses at Cz Location during Watching Hand Task. "Differences [between and within control and experimental groups] are illustrated for varying frequencies and times by the red lines in the green plots presented to the right of and below ERSP data boxes." (as explained on p. 84).

An examination of the neutral, non-social watching ball bouncing task revealed no differences between the control group’s pre- and post-intervention ERSP responses. Notable differences, however, were found between the experimental group’s pre- and post-intervention ERSP responses between the 8000 and 11,000 milliseconds time frame, and 8-13 Hz frequency bands. Marked differences were found between the control and experimental groups’ pre-intervention ERSP responses between 5000 and 14,000 milliseconds and 8-13 Hz frequency bands that approached significance. Notable differences also were found between the experimental group's pre- and post-intervention ERSP responses between 8000 and 11,000 milliseconds, and 8-13 Hz frequency bands that approached significance. The graphs of participants' ERSP response revealed a trend of decreased mu suppression in the experimental group post-intervention for the neutral watching the bouncing ball task (Figure 8).

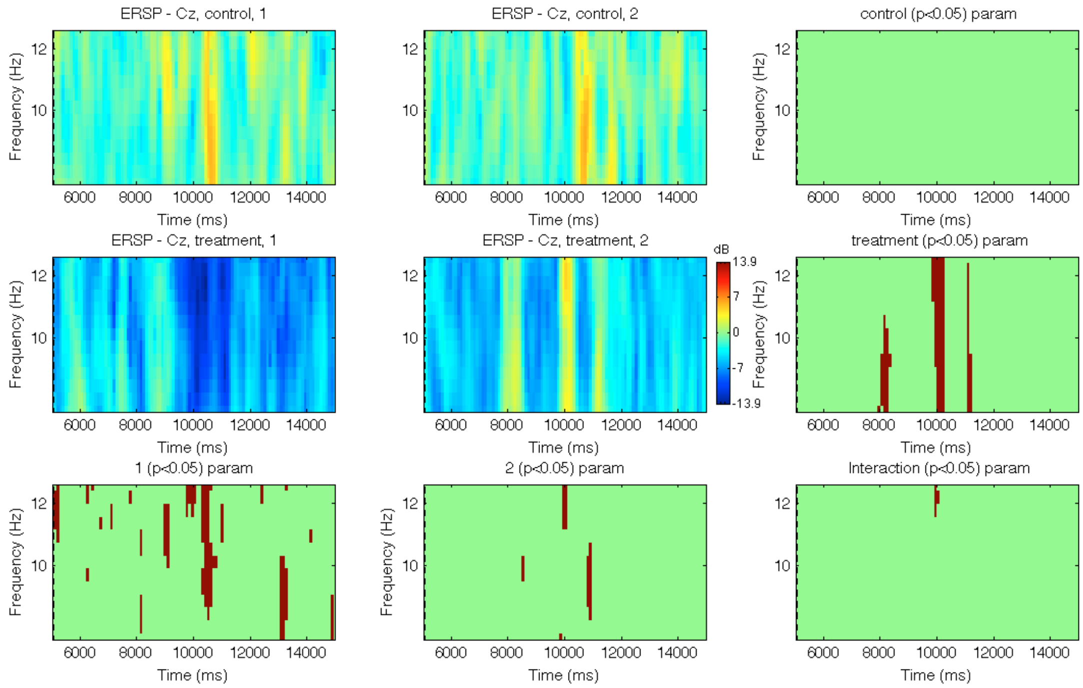

Figure 8. Effects of Condition and Session on ERSP Responses at Cz Location during Watching Ball Bounce Task. "Differences [between and within control and experimental groups] are illustrated for varying frequencies and times by the red lines in the green plots presented to the right of and below ERSP data boxes" (as explained on p. 81).

An examination of the post-intervention ERSP data associated with the moving hand and watching hand tasks revealed differences within each group's post-intervention ERSP responses for each condition. Differences were found between the control group's post-intervention ERSP responses between the 5000 and 7000, and 12000-14000 milliseconds time frame, and in the 10-13 Hz frequency bands during the moving hand and watching hand conditions. Differences also were found between the experimental group's post-intervention ERSP responses between the 6000 and 12000 milliseconds time frame and 8-13 Hz frequency bands during the moving hand and watch hand conditions.

The graphs of ERSP responses showed a trend of significant increases in mu rhythm suppression, while the experimental group watched the moving hand (Figure 9).

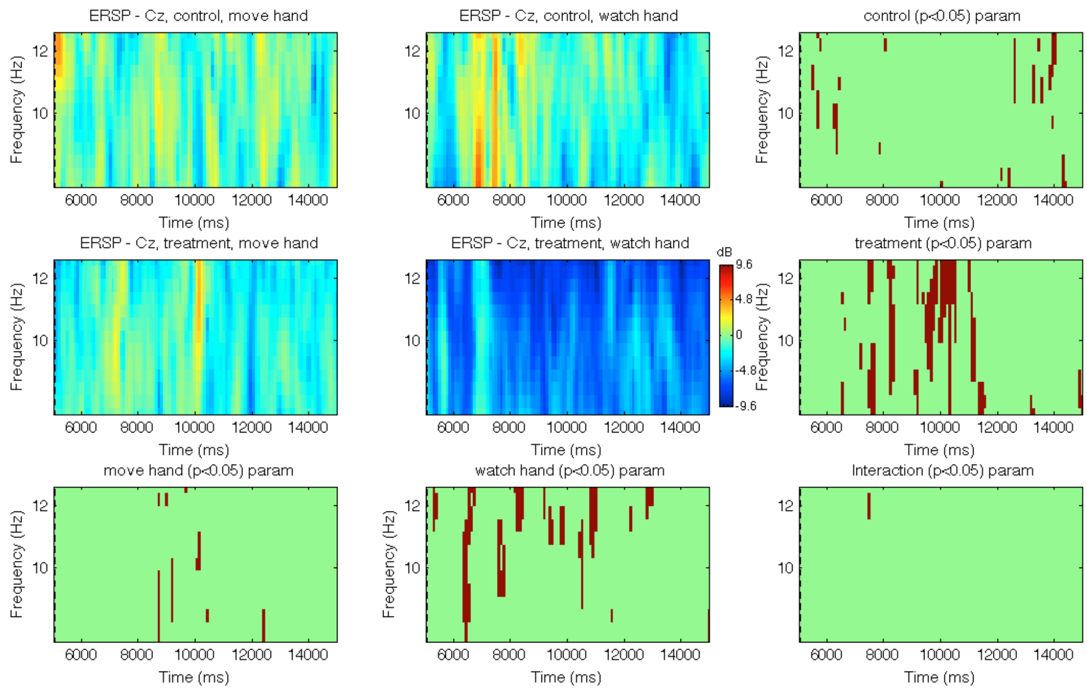

Figure 9. Effects of Condition on Post-intervention ERSP Responses at Cz Location during Moving Hand and Watching Hand Tasks. "Differences [within conditions during tasks] are illustrated for varying frequencies and times by the red lines in the green plots presented to the right of and below ERSP data boxes" (as explained on p. 84).

An examination of the post-intervention ERSP data associated with watching hand move and watching ball bouncing tasks revealed differences between the control group's ERSP responses at the 5,000, 9,000, and 12,000 to 14,000 milliseconds time frame, and in the 8-12 Hz frequency bands. Differences also were found between the experimental group's post-intervention ERSP responses between the 10,000 and 11,000 milliseconds time frame and 8-13 Hz frequency bands during the watch hand and watch ball tasks. The graphs of participants' post-intervention ERSP responses showed a trend of notable increases in mu rhythm suppression in the social watch hand task compared to the non-social ball bouncing task among experimental participants (*p* < .05; Figure 10)

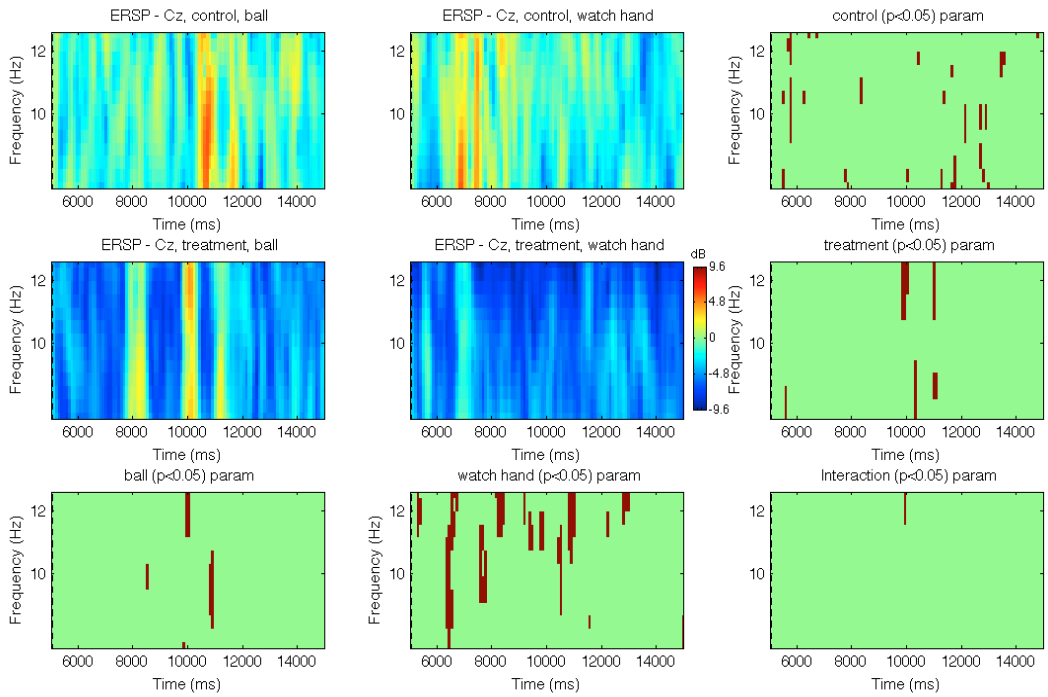

Figure 10. Effects of Condition on Post-intervention ERSP Responses at Cz Location during Watching Hand and Watching Ball Bounce Tasks. "Differences [within conditions during tasks] are illustrated for varying frequencies and times by the red lines in the green plots presented to the right of and below ERSP data boxes" (as explained on p. 84).

Summary of Results

Based on the results of this exploratory study, answers to the research questions are provided. The research was designed to answer three research questions focused on the adaptive behaviors and neurophysiological responses of children with autism spectrum disorders before and after music and non-music interventions.

Research Question 1

Do instrumental music and non-music interventions differentially affect adaptive behaviors of children with autism, as measured on the *Vineland Adaptive Behavior Scales II*? Music and non-music interventions differentially affected adaptive behaviors of children with autism, as measured on the *Vineland Adaptive Behavior Scales II*. Examining VABS scores across the four domains and 11 subdomains, the researcher found that participants randomly assigned to the instrumental music intervention group displayed significant gains in the subdomains of Expressive Communication (p = .018). Additionally, the experimental participants' increases in Interpersonal Socialization behaviors approached significance (p < .057). These increases in expressive communication and interpersonal socialization behaviors were not found within the non-music intervention group (i.e., the control group). Although the sample size of this study was quite small, the researcher found a large effect size accounting for approximately 48% and 35% of the variances among the experimental participants' expressive communication and interpersonal socialization adaptive behaviors, respectively.

In addition, Fisher’s exact tests were used to analyze VABS scores dichotomized by high and low violin and music practice time. High practice was defined as greater than 1000 total minutes of practice during the 20-week treatment period; while low practice was defined as less than 1000 total minutes during the same time period. Though generalizable results were not produced by examining only three participants, it is interesting that in addition to increases in Interpersonal Socialization scores and Expressive Communication scores, 100% of the high practicing participants also experienced increases in scores associated with Receptive Communication and Socialization Coping Skills. These same high practicing students also displayed reduced Externalizing Maladaptive Behaviors.

Research Question 2

Do instrumental music and non-music interventions differentially affect neurophysiological responses of the mirror neuron system of children with autism, as measured using electroencephalography? While statistical analysis was not feasible with this small sample size and noise within the EEG results, the researcher found trends toward significant differences within the pre-intervention and post-intervention data, grouped by control and experimental groups. The exploratory analyses of the data revealed that instrumental music and non-music interventions differentially affected neurophysiological responses of the mirror neuron system of children with autism, as measured using electroencephalography. During the moving hand task, marked differences were found between the control and experimental groups’ post-intervention ERSP responses in the 9000-10,000 millisecond time frame and 8-13 Hz frequency bands. These changes in participants’ ERSP responses implied decreased mu suppression in the experimental group's post-intervention moving hand condition.

During the watching hand task, notable differences were found between the control and experimental groups' post-intervention ERSP responses in 5000-13000 milliseconds range and 8-13 Hz frequency bands. These changes in participants' ERSP responses seemed to reveal increased mu suppression among the experimental participants following the intervention; these changes did not occur among the control participants.

An examination of the ERSP responses during the moving hand and watching hand tasks revealed differences between the experimental group's post-intervention ERSP responses in the 6000 and 12000 milliseconds time frame and 8-13 Hz frequency bands. These changes in experimental participants' ERSP responses revealed increased mu suppression during the moving and watching hand tasks following the music instrument instruction intervention.

Research Question 3

Based on findings related to research questions one and two, what observed associations may be implied between adaptive behaviors and neurophysiological responses of the mirror neuron system of children with autism? Mirror neurons, associated with social and communicative learning, activate while observing and executing an action. Mirror neurons and their function have been associated with several high-level cognitive processes, including imitative learning, understanding social behavior and language. Aberrant cortical connectivity affects the mirror neuron system of children and adults with autism. Previously, researchers have reported that children with autism maintain mu wave suppression when moving their own hand yet fail to suppress mu waves when observing other children’s hand movements (Ramachandran & Altschuler, 2009). These irregularities indicate an abnormal mirror neuron systems among children with autism.

In this exploratory study, participants in the experimental group, during specific tasks, showed trends toward marked increases of mu wave suppression—a measure of increased functioning of the mirror neuron system. Differences observed in the experimental group included decreased mu wave suppression during the moving hand condition, and increased mu suppression during the more social watching hand condition. Additionally, when comparing the experimental group's post-intervention completion of the moving hand and watching hand conditions, the researcher found patterns of increased mu wave suppression during the watching hand condition. Children who participated in the instrumental music intervention showed trends of increased activation of the mirror neuron system, a network associated with social and communicative learning.

Examination of the VABS scores across the four domains and 11 subdomains revealed that participants' in the experimental group displayed significant gains in the subdomains of Expressive Communication (p = .018), and approached significant gains in Interpersonal Socialization (p = .057); whereas the control group did not experience these increased changes in their communicative and socialization behaviors. Instrumental music study improved social and communicative adaptive behaviors, as measured via the VABS.

Considering improvements in the experimental participants social and communicative adaptive behaviors, and observed trends in increased mu suppression of the mirror neuron system—an area associated with social and communicative learning, the researcher concluded that there may be an association between the mirror neuron system responses and adaptive behaviors of the experimental participants with autism. Additionally, this association seemed to be prevalent and occurred after the experimental participants experienced 20 weeks of one-on-one intervention of instrumental music instruction.

CHAPTER V

SUMMARY AND CONCLUSIONS

Introduction

First, this chapter includes a discussion of previous research on using music instruction as a form of intervention for children with autism. Second, the chapter includes a summary of the current research study, including the purpose of the study, description of the procedures, and summary of results. Third, this chapter includes implications and recommendations for future research. Fourth, several limitation of the current study are included in Chapter V. Finally, the content of this chapter offers reflections and feedback from the researcher, and from adult parent participants and children of this exploratory research study.

Discussion of Associated Previous Research

Autism spectrum disorder, or autism, is a neurodevelopmental condition characterized by atypical social interaction and social communication (American Psychiatric Association (APA), 2013). Currently, data from the Center for Disease Control (CDC) suggest one in 68 children have a diagnosis of autism (Christensen et al., 2016). Researchers have found that up to 46% of people with autism, who have an IQ less than 50, require high levels of assistance from their families and are not able to lead an independent life (Eaves & Ho, 2008; Farley et al., 2009). Similarly, when IQ is not limited to 50 or less, Billstedt et al. (2005) claims up to 78% of adults with autism still have unfavorable outcomes based on similar criteria. Researchers estimate the lifetime cost of supporting an individual with autism and intellectual disability to be approximately $2.4 million, while the lifetime cost of supporting an individual with autism and no intellectual disability is approximately $1.4 million (Buescher, Cidav, Knapp & Mandell, 2014). Medical expenditures for young people with autism exceed typically-developing peers by $4,110-$6,200 per year (Shimabukuro, Grosse & Rice, 2008). Individuals with autism, their families and communities financially struggle to provide lifelong support needed for the health and wellbeing of themselves and their loved ones. Many find themselves in a state of crisis, balancing basic household expenses with intense care costs. Finding affordable care while improving quality of life for those with autism has become a desperate need for many families within the autism community.

A first step in creating viable solutions to this care crisis is understanding autism at a biological level. Although a reliable biological marker for autism has yet to be identified, researchers frequently have described common patterns of hyper- and hypoconnectivity within the brain of a person with autism. In addition, scientists have examined a lesser studied system called the mirror neuron system (MNS). People with autism frequently demonstrate connectivity abnormalities associated with the MNS and sensory-motor learning (Nishitani, Avikainen & Hari, 2004; Oberman & Ramachandran, 2007; Williams, Whiten, Suddendorf & Perrett, 2001). Scholars believe these findings stem from cortical disruption early in life, resulting in an altered developmental trajectory of the brain (Courchesne & Pierce, 2005a; Courchesne & Pierce, 2005b). These alterations lead to many of the behavioral characteristics observed in autism.

Although there is no known cure, another step in creating viable solutions to the current care crisis is creating and implementing alternative affordable interventions. Increased levels of functioning may be achieved through early and consistent intervention services that increase quality of life, independence, and productivity while reducing lifetime care costs. Results of this exploratory study suggest music may be one such intervention. When examining the neurological profiles of musicians and children with autism, many scientists speculate about the many benefits of music instruction for persons diagnosed with autism. Cortical areas found to have deficits in the brain of a person with autism are often areas of strength in musicians' brains. Through years of repetitive practice, musicians develop many unique skills that increase brain volume, and also augment communication between distant cortical regions, and between the left and right hemispheres (Schlaug, Jancke, Huang & Steinzetz, 1995). Many researchers find that musical skills transfer to other domains in typically-developing children. Transfer benefits of music instruction also may occur in special populations such as autism, greatly enhancing functionality in academic, social, and communication areas.

Because children with autism exhibit both an affinity for and special ability in music, music may serve as an appropriate, affordable and effective intervention. Kanner (1943) first noted a musical affinity among children with autism in his groundbreaking paper, entitled “Autistic Disturbances of Affective Contact”. In his paper, Kanner described multiple cases where children had uncanny knowledge of music, and used music to sooth themselves and/or to interact with others. Researchers often have noted that children with autism display musicality, a special interest in music, and a preference for musical stimuli over verbal stimuli (Blackstock, 1978). Additionally, investigators find that people with autism possess superior abilities in pitch memory (Heaton, Hermelin, Pring, 1998), labeling (Heaton, 2003), discrimination, and discrimination/categorization tasks (Bonnel et al., 2003). Individuals with autism also demonstrate comprehension of the affective qualities found in music (Kasari, Sigman, Mundy & Yirmiya, 1990).

Summary of Results

In an effort to address the current care crisis and the need for an appropriate, affordable and effective intervention, the purpose of this exploratory research study was to investigate the effects of instrumental music instruction interventions and non-music interventions on neurophysiological responses and adaptive behaviors of children with autism. Individuals were included if they met the Diagnostic and Statistical Manual of Mental Disorders Fourth edition revised (DSM-4R) criteria for autism spectrum disorder or Asperger's syndrome, and had never participated in instrumental music instruction. Participants consisted of 14 children and their parent, with data collected from a total of 28 participants. Seven children, with a mean age of 9.81 years, were assigned randomly to a control group, and with their parents or guardian, received 30 minutes per week of a one-on-one non-music intervention over a 20-week period. Seven children, with a mean age of 8.54 years, were assigned randomly to an experimental group, and with their parents or guardian, they received 30 minutes per week of one-on-one instrumental violin instruction over a 20-week period.

Prior to and after the music and non-music interventions, each parent completed the *Vineland Adaptive Behavior Scales II* (VABS). Across the five VABS domains and 13 subdomains, the parents rated their children's behaviors using the three-point scale of 0 (never performed), 1 (sometimes or partly performed), and 2 (usually or habitually performed). These domains and subdomains included Communication (Receptive, Expressive and Written), Daily Living Skills (Personal, Domestic, and Community), Socialization (Interpersonal Relationships, Play and Leisure, and Coping Skills), Motor Skills (Fine and Gross), and Maladaptive Behavior (Internalizing and Externalizing) domains. Four domains, Communication, Daily Living Skills, Socialization, and Maladaptive Behavior were analyzed to answer the research questions of the current study.

Prior to and after the music and non-music interventions, each child completed an electroencephalogram (EEG). Mirror neuron EEG data were collected from participants' responses during three tasks: (1) moving own hand, (2) watching a recorded video of a child's moving hand, and (3) watching a bouncing ball. Mirror neuron data were observed through mu rhythms, that is, EEG oscillations in the 8–13 Hz frequency. These data were analyzed through examining recordings from the Cz electrode that measured activity in the sensory motor cortex.

The parents or guardians of 11 of the 14 originally selected children completed pre- and post-intervention VABS to measure participants' adaptive behaviors. Six of the participants were from the music intervention group or experimental group, and five participants were from the non-music intervention group or control group. Twelve children were able to participate in electrophysiological data collection in this study, and nine children completed pre- and post-EEGs. Only eight of the participants' EEG scans were clear enough to include in the data analyses. Three pre- and post-intervention EEG scans were analyzed for the non-music control group, and five pre- and post-intervention EEG scans were analyzed for the experimental group.

Adaptive Behavioral Results

The experimental and control groups' pre-intervention and post-intervention VABS scores from the four aforementioned domains were analyzed using a two-way mixed factorial analysis of variance (ANOVA). There was a significant interaction effect of Condition and Session on participants' Expressive scores (p = .018). The data analysis revealed that experimental participants' and control participants' pre- and post-intervention Expressive scores were significantly different. Post-hoc paired t-test analyses of the Expressive scores revealed that participants of the music-intervention group significantly improved their post-intervention Expressive scores, as measured by the VABS (p = .042). The Expressive scores of participants of the non-intervention group, however, decreased slightly; this decrease was not significant (p = .305).

Within the VABS Daily Living Domain, there were no significant differences between the control and experimental participants' Composite, Personal, Domestic, and Community post-intervention scores (p > .05). Additionally, there were no significant differences between participants' pre- and post-intervention Daily Living Domain subdomain mean scores (*p* > 05). Specifically, however, differences between experimental and control participants' post-intervention Community subdomain scores approached significance (*p* = .058).

The Composite Socialization scores were affected significantly by the music and non-music interventions (*p* = .021). Even though the experimental pre-intervention Composite mean scores also were significantly higher than the control group's pre-intervention Composite mean scores (*p* = .047), the magnitude of the music-intervention effect appeared to be greater than the non-music intervention effect. The Coping Skills subdomain scores also were affected significantly by the music and non-music interventions (*p* = .007). Both the experimental and control groups' Coping Skills mean scores increased following the music intervention, and the non-music intervention, respectively. The control group's post-intervention mean score increased only by .40 of a point, yet the experimental group's mean Coping Skills score was notably higher than the control group's mean score, increasing from 10.83 points to 12.50 points. This finding supports the premise that the music intervention had a greater effect on participants' Coping Skills than the non-music intervention.

Also notable in the VABS analysis was the interaction effect of Condition and Session on Interpersonal means scores, which approached significance (*p* = .057). This result suggested differences between the experimental and control groups' pre- and post-intervention mean Interpersonal scores possibly contributed to the significant interaction effect of Condition and Session on participants' Socialization Composite mean scores, as measured before and after interventions. This finding suggested that music and non-music interventions differentially affect changes in adaptive behaviors of children with autism.

Even though the sample size of this study was small, the effect size was relatively large, determined using the Pearson Product Moment Correlation Analysis. For example, for the interaction effect of Condition and Sessions on the Communication Domain's Expressive behaviors, the effect size was $r = .694$, and on the Socialization Domain's Interpersonal behaviors, the effect size was $r = .589$. Both effect sizes exceeded the standard for moderately large effect size ($r = .50$; Cohen, 1988, 1992). The effect size for Expressive behaviors, and for Interpersonal behaviors accounted for approximately 48% and 35% of the total variance in participants' adaptive behaviors, respectively, as measured by the *Vineland Adaptive Behaviors Scales II*.

Finally, as related to adaptive behaviors and characteristics associated with participants, amount of time that music-intervention participants devoted to practice was examined. Fisher’s exact tests were used to analyze VABS scores dichotomized by high and low violin and music practice time. High practice was defined as greater than 1000 total minutes for the 20-week treatment period; while low practice was defined as less than 1000 total minutes during the treatment period. While generalizable results were not produced by this examination of only three participants, it is interesting that in addition to aforementioned increases, 100% of the high-practicing participants also experienced increases in scores associated with receptive communication. These same high practicing students also displayed reduced Externalizing Maladaptive Behaviors.

Electrophysiological Results

The electroencephalogram (EEG) recorded the electrical activity of synaptic currents within each participant's brain, as measured in Hz. In the current study, the EEG was used to examine mirror neuron activation, or mu rhythms between 8-13 Hz in the sensory motor cortex.

Examining the moving hand task, differences were found between the control and experimental groups' post-intervention ERSP responses in the 9000-10,000 millisecond time frame and 8-13 Hz frequency bands. When examining the watching hand task, differences were found between the control and experimental groups' post-intervention ERSP responses in 5000-13000 milliseconds range and 8-13 Hz frequency bands. When comparing control and experimental groups, trends in participants' ERSP responses revealed mu rhythm suppression in the experimental group following the intervention.

Examining the non-social task of watching a ball bouncing, differences were found between the experimental group's pre- and post-intervention ERSP responses between 8000 and 11,000 milliseconds, and 8-13 Hz frequency bands. Participant's ERSP response indicates trends of decreased mu suppression in the experimental group post-intervention for this non-social task.

Analyses of the post-interventions ERSP responses during the moving hand and watching hand tasks revealed differences within each group's ERSP responses. Differences were found between the control group's post-intervention responses during moving hand and watching hand tasks between the 5000 and 7000, and from 12000 to 14000 milliseconds time frame, and in the 10-13 Hz frequency bands. Differences were found between the experimental group's post-intervention moving hand and watching hand tasks between the 6000 and 12000 milliseconds time frame and 8-13 Hz frequency bands. Analyses of experimental participant's post-intervention ERSP responses revealed trends of increased mu suppression during the watching hand condition.

Finally, examination of the post-intervention ERSP responses during the watching hand and watching bouncing ball tasks revealed differences within the control group's ERSP responses at the 5,000 and 9,000 millisecond time frames, and between the 12,000 to 14,000 millisecond time frame, and in the 8-12 Hz frequency bands. Differences also were found between the experimental group's post-intervention ERSP responses during watch hand and watch ball tasks between the 10,000 and 11,000 milliseconds time frame and 8-13 Hz frequency bands. Analyses of the post-intervention experimental participants' ERSP responses indicated a trend in increased mu suppression in the social watching hand tasks compared to the non-social task of watching a ball bouncing.

Applications of Research Results

This exploratory study finds instrumental music instruction improves social and communicative adaptive behaviors as measured by the *Vineland Adaptive Behavior Scales II*. This exploratory study also finds trends of increased response within the mirror neuron system, an area associated with social and communicative learning. Results of the present study seem to provide a promising development for the beneficial uses of music interventions with children with autism to increase selected adaptive behaviors, and to activate desirable mirror neuron systems of the children's brains.

Participants in the experimental group showed patterns of increases in mu wave suppression, a measure of increased functioning of the mirror neuron system. Patterns found in the experimental group included decreased mu wave suppression during the non-social move hand condition, and increased mu wave suppression during the social watch hand condition. Additionally, when comparing the experimental group's post-intervention moving hand and watching hand conditions, the researcher found patterns of increased mu suppression during the watch hand condition.

According to these exploratory findings, instrumental music study may increase the activation of the mirror neuron system, a network associated with social and communicative learning. Instrumental music study also improves social and communicative adaptive behaviors, as measured by the VABS. Considering the improvements in social and communicative adaptive behaviors and trends of increased mu suppression of the mirror neuron system, the researcher believes there may be an association between the mirror neuron system responses and adaptive behaviors of children with autism. In this exploratory study, instrumental music instruction seems to have targeted the hallmark traits of autism, not only on a behavioral level, but potentially at an associated neurophysiological level.

The researcher offers several ideas as to why these hallmark traits of autism were targeted. First, children in the experimental music group engaged in, and repetitively practiced social and communication skills through an activity that held their interest and excited them. This interest-based learning motivated students to use and build upon their current social and communication abilities. Using and building skills in the context of an interest-based activity was not work, but fun for the children.

Second, the researcher carefully adapted multiple evidence-based practices for use during the musical instruction of the experimental group. These evidence-based practices, as outlined by The National Professional Development Center on Autism Spectrum Disorder, have been extensively researched and shown to be effective intervention methods that increase learning and retention of skills. Combining an interest-based activity with evidence-based practices amplifies growth and development of skills targeted during instruction, including social and communicative learning.

Finally, the researcher believes the noted musical affinity and ability found in populations with autism, increased feelings of confidence, and success. Enjoying a new and special musical skill encouraged students to persevere through difficult moments. Multiple experiences of success seemed to reduce the fear of failure and encouraged children to keep trying and to keep taking risks through attempting new skills. Repeated success seemed to build confidence.

Implications for Future Research

While the results of this exploratory study support and highlight the potential of music instruction to become an affordable, appropriate, and effective intervention for children with autism, several observations about this exploratory study need to be addressed in future research. The first observation concerns **sample size**. The adaptive behaviors segment of the current study was completed with 11 participants who completed the pre- and post-intervention measure of the VABS. This sample size is quite small making statistical analyses less accurate, generalizable, and limited. Increasing sample sizes to include at least 15 participants per group would improve the validity, reliability, and generalizability of the collected data. The neurophysiological focus of this study was completed with only eight participants who completed the pre- and post-intervention electroencephalogram recordings—three participants in the control group, and five participants in the experimental group. This sample size prevented the execution of accurate statistical analysis of the neurophysiological data. Executing another behavioral and neurophysiological study, with at least 60 participants (i.e., 30 child participants and 30 parent participants), is needed in future research.

The second observation needing to be addressed involves **replicating findings** in a variety of settings. This study was designed to examine behavioral and neurophysiological outcomes of instrumental music instruction with children on the autism spectrum in a one-on-one setting, supported by at-home parental involvement. While the present study demonstrated significant increases in social and communicative adaptive behaviors ($p < .05$), and patterns of change in neurophysiological responses, future researchers may find alternative outcomes when children with autism study music in a group setting. Eliminating the one-on-one instruction and dividing teacher attention among many students fundamentally would shift social and communication interactions found in the current study. A group setting, however, would increase interactions with peers. Shifting social and communication interactions from the instructor to fellow students may lead to new and interesting results. Adaptive behaviors and neurophysiological responses might differ in an inclusive music class, where children with autism are integrated with typically-developing peers, as compared to a self-contained class where children are placed alongside other peers with autism. A study evaluating changes in adaptive behavior and neurophysiological responses before and after participation in various group instrumental instruction is needed in future research.

Examining **affordability** is another observation that needs to be considered in future studies. While the cost of private instrumental instruction is far below other traditional autism therapies (e.g., speech therapy, occupational therapy, and Applied Behavior Analysis (ABA)), the cost may still be prohibitive to many middle- and low-income families. If increased adaptive behaviors and neurophysiological responses, as found in the current study, could be replicated in group instructional settings, music intervention may provide families with an appropriate and effective intervention at an affordable cost. Assessing and comparing the affordability and outcome of music instruction for children with autism in group and one-on-one settings is needed in future research.

The fourth observation that needs to be addressed in future research focuses on **availability of music instruction** for children with autism. Community music participation may still be prohibitive to many families due to cost, transportation, and/or scheduling. Offering instrumental music instruction to all children with autism within the public-school system would be one solution to increasing access. The infrastructures of band and orchestra programs exist in many public schools, and are legally available to children with special needs. Identifying the needs of schools and music teachers (e.g., training, equipment, and support staff) when recruiting and including children with autism in their programs is needed in future research.

Limitations of the Study

Considering the findings of the current study, it is important to examine several limitations of the exploratory study. First, as discussed previously, the number of participants produced a small sample size. With only 14 children participating in the study, results of the study are less generalizable to the population than with an increased sample size. Additionally, of the 14 children participating in the study initially, several children were unable to complete the study. Others children were unable to complete the neurophysiological portion of the study further reducing the sample size. Including more participants would increase the generalizability of research results.

Second, participants included in the study formed a heterogeneous sample of children with autism. Levels of functioning differed greatly between participants. Some children had been diagnosed with Asperger's syndrome, a high-functioning form of autism and were quite verbal. Other children had been diagnosed with autism and had limited use of language. One child enrolled in the study was non-verbal. These differences contributed to high variability among participants. Using a more discriminating inclusion criteria for participants than used in the current study would increase homogeneity among participants and reduce undesirable variability.

Third, some of the study participants dealt with sensory sensitivities throughout the EEG recordings, resulting in participants' physically moving, and thus, producing noise or artifacts in some of the EEG recordings. While some children were able to quietly completed the EEG tasks, others fidgeted, moved, and found it difficult not to touch or disturb the cap they wore during the EEG recording sessions. Electrodes attached to the face seemed to irritate participants with sensory sensitivities the most. These extra movements created some noisy channel recordings and less accurate readings. These data were then more difficult to analyze accurately. Including participants who are less sensitive to the stimulation of the EEG recording process would increase the accuracy of collected neurophysiological data. Additionally, to accurately analyze all participants' EEG data in the future, these noisy recording artifacts may be cleaned or deleted from the recordings.

Study Reflections

Beyond the quantitative nature of this exploratory study, researcher observations and comments from child and adult participants deserve attention and reflection. Overall, both children and parents, who participated in the study, expressed their thoughts about their experiences during the study. The researcher also observed some interesting trends.

When reflecting on the study, it is important to note the differences and similarities between the experimental (music) and control (non-music) interventions. Both groups were taught by the same person, maintained one-on-one interactions with the instructor, and met for equal amounts of time. The process, however, of learning an instrument in the experimental group and the pedagogical approach of the instructor involved several additional factors, including: (1) structured teacher/student interactions using evidence-based practices, (2) employing music as a tool for interest-based learning, (3) joint attention focused on a common interest (the instrument), (4) repetition, (5) frequent praise, and (6) rewards for skills accomplished. None of these techniques were used in the control intervention group. Additionally, children who practiced more than 1000 minutes across 20 weeks outside of weekly instruction, experienced additional communicative gains and reductions of maladaptive behaviors. Identifying and reflecting on the differences between the experimental and control groups provides additional insight as to why an instrumental music intervention may increase social and communicative behaviors, and increase desirable responses within the children's brains.

Reflections on Child Participants

Throughout the study, the child participants made numerous comments about the study and their experiences in the study. Reflections on these observations and comments by the children throughout the study definitely are worth discussing. Just like typically developing children, the newness and excitement of a new and different activity subsided with time for one of the children in the experimental group. Practicing the instrument at home became a struggle; thus, the child's parent created laminated trading cards of her son’s favorite video game, which he earned only through violin practice. Because of this creative motivator, the child who did not like to practice became one of the three high practicing students logging more than 1000 minutes over the 20-week intervention period. This student showed gains in receptive language and coping skills, and reduced externalizing maladaptive behaviors.

Another interesting observation included the children’s care and respect for instruments. Having worked with children with autism for many years prior to this study, the researcher was prepared for the child participants' frustration, anxiety, and outbursts when experiencing the violin and instruction associated with the violin. Inexpensive violins were provided to the children with the anticipation that some instruments would get damaged during periods of frustration, anxiety, or outbursts. At the completion of the study, all children had shown great respect and gentle care of their instrument. No instruments were broken during the completion of this study.

One particular observation of the child participants warrants additional research. Most children of both the control and experimental music group displayed absolute or perfect pitch abilities. Absolute pitch is the ability to recognize the pitch of any given pitch or reproduce a pitch by name. While children in this study did not have the training to identify pitches by their letter names, other subtle clues indicated absolute pitch ability among most of the participants. Multiple times during music and non-music interventions, children sang their favorite songs or pieces of music. When comparing the original key from the recording and the key sung by the child, these almost always matched. In addition, the teacher, who does not have absolute pitch, would sing violin compositions, or segments of songs to be learned during the music interventions. The experimental children often corrected the teacher by restarting and singing the piece in its correct key. The ability of absolute pitch seemed particularly prevalent among the experimental children with autism. Studying this phenomenon further would be worthwhile by comparing incidences of absolute pitch among typically-developing children as compared to children with autism.

One last observation concerning the children in the experimental group involves self-image and confidence. One child repeatedly said, “I am smart because I can play the violin." Another child repeatedly said, "This is easy for me!" The process of learning to play the instrument seemed to boost some children's self-confidence. Another child stated with self-satisfaction, "I am the only one in my family who can play an instrument." The skill of instrument playing seemed to make this child feel special and unique.

Throughout the research study, the researcher noticed expressions of joy and happiness when each child achieved music skills. Often when working with children with autism, parents, teachers, and therapists focus on what the child cannot do, and on how skill levels compare to typically-developing peers. While attending violin lessons, there was no template for when skills should be achieved, or for how many repetitions of a skill to achieve mastery. Each musical skill was acquired in the child's own time and celebrated as a great accomplishment. Children would smile, high-five, and sometimes flap their arms with joy. Frequently, the children's faces "lit up "and their eyes "sparkled." Musical study seemed to help the children feel accomplished, smart, and capable, thereby, help develop their self-confidence.

Reflections on Adult Participants

One parent stated, "If my child can play the violin, what can't he do?" This sums up a general feeling expressed by parents—hope. Playing a violin is perceived as very difficult in our society. When children, labeled as having disabilities, successfully execute a song on their violins, parents experience hope. Along with feelings of hope, two parents described increased positive attention expressed toward their children from extended family members, or from the church community following public performances.

One parent said her child did something special and the family admired it. Another parent told a story about how members of the family's church now treated her son as a child, not as “the child with autism.”

Three parents of children in the experimental group relayed messages from school teachers near the end of the study. The school teachers described increased attention and focus at school. These three parents conveyed to the researcher that nothing had changed at home, no new medicines had been added, and no new therapies started, other than music and music practice. All three parents attributed this change to music lessons.

Finally, at the completion of this study, three families with four students chose to continue with violin lessons. As of the writing of this document, three of the continuing students remain in violin lessons with one of the children completing a successful audition and playing in his community youth orchestra.

In summary, instrumental music instruction in this study increased desirable adaptive behaviors, and seemed to produce trends of increased neurophysiological responses in children with autism spectrum disorder. Additionally, the researcher established a possible association between the mirror neuron system responses and adaptive behaviors of child participants with autism. Improving levels of functioning through an appropriate, affordable, and effective intervention can increase quality of life, independence, and productivity of people with autism, while also reducing lifetime care costs. The findings of this study support the premise that music instruction may be one such intervention.

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APPENDIX A

NOTICE OF IRB APPROVAL BY EXPEDITED REVIEW, UNDER 45 CFR 46.110: STUDY # 12-0128

THE UNIVERSITY of NORTH CAROLINA
GREENSBORO

OFFICE OF RESEARCH COMPLIANCE
2718 Beverly Cooper Moore and Irene Mitchell Moore
Humanities and Research Administration Bldg.
PO Box 26170
Greensboro, NC 27402-6170
336.256.1482
Web site: www.uncg.edu/orc
Federalwide Assurance (FWA) #216

To: Patricia Sink
Music
250 Music Building

From: UNCG IRB

Authorized signature on behalf of IRB

Approval Date: 6/28/2012
Expiration Date of Approval: 6/27/2013

RE: Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)
Submission Type: Initial
Expedited Category: 7.Surveys/interviews/focus groups,4.Noninvasive clinical data
Study #: 12-0128

Study Title: Music Speaks Autism

This submission has been approved by the IRB for the period indicated. It has been determined that the risk involved in this research is no more than minimal.

Study Description:

The purpose of this study is to document changes in cortical activation and behavior in children with autism who engage in prolonged instrumental musical study as compared to children with autism who do not study an instrument.

Investigator's Responsibilities

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

Signed letters, along with stamped copies of consent forms and other recruitment materials will be scanned to you in a separate email. These consent forms must be used unless the IRB hasgiven you approval to waive this requirement.

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented (use the modification application available at http://www.uncg.edu/orc/irb.htm). Should any adverse event or unanticipated problem involving risks to subjects or others occur it must be reported immediately to the IRB using the "Unanticipated Problem/Event" form at the same website.

CC: Michelle Chinn Cannon

APPENDIX B

PARENT PARTICIPANT CONSENT FORM

Study #: 12-0128

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

CONSENT TO ACT AS A HUMAN PARTICIPANT

Project Title: Music Speaks Autism

Project Director: Dr. Patricia Sink, UNC Greensboro School of Music

Participant's Name: ___________________________________

What is the study about?
This is a research project. The purpose of this study is to research possible benefits of instrumental music study on children with autism.

Why are you asking me?
You have been selected to participate in this study because your child has been diagnosed with autism or Asperger's syndrome, is between the ages of 6 and 12 and has never participated in instrumental music lessons.

What will you ask me to do if I agree to be in the study?
First, we will ask you to complete a Vineland Adaptive Behavioral Scales questionnaire about your son or daughter participating in thpe study (20-60 minutes). If you feel unable or uncomfortable answering any Vineland questions you may elect to skip to the next question. Next, we ask you to accompany your child to the EEG lab during their first brain scan. An EEG is a neuroimaging procedure which measures electrical activity in the brain. During the EEG, you will sit with your child while an elastic cap containing electrodes is placed on your child's head. This cap will make contact with the skin of the scalp, forehead, chin, and earlobes. The electrodes are made of small metal disks and do not penetrate the skin. The skin will be rubbed vigorously with electrode paste. The electrode paste is mildly abrasive, so your child might experience a slight reddening of the skin. This is normal and will disappear shortly after the electrodes are removed. Placing the electrodes usually takes about 20 minutes. All electrodes passively measure electrical activity and do not deliver any electrical impulses. Once the electrodes are connected, you will accompany your child while he or she is asked to listen to sounds delivered through headphones, as instructed by the experimenter and while their brain electrical activity is recorded. This session takes place at the UNC Department of

Psychiatry and is estimated to take 2 hours. If your child is participating in the control group, you will be asked to take part in a non-musical intervention with your child. This includes accompanying your child to weekly (30 minutes) one-on-one, child guided sessions. Twenty weeks later you will be asked to complete a second Vineland questionnaire (20-60 minutes) and a second EEG scan (2 hours). The study will then conclude.

If your child is participating in the experimental group, you will also be asked to take part in violin lessons with your child. This includes accompanying your child to weekly lessons (30 minutes) and facilitating regular practice at home (time will vary according to your child's attention span: 5-30 minutes per day). You will be asked to keep a record of time spent practicing and give the total number of minutes practiced to your instructor each week. This information will later be correlated with changes in adaptive behavior and brain activation. Parents will also be asked to play audio or video recordings daily of pieces to be played. Although not required for participation in the study, parents and children will have the opportunity to attend group lessons and performances throughout the study. You will be asked to attend 20 weeks of lessons. After completing 20 weeks of lessons, parents will accompany their child during the second EEG and complete a second Vineland questionnaire. The study will then conclude.

Is there any audio/video recording?
No.

What are the dangers to me?
The Institutional Review Board at the University of North Carolina at Greensboro has determined that participation in this study poses minimal risk to participants.

If you have any concerns about your rights, how you are being treated or if you have questions, want more information or have suggestions, please contact Eric Allen in the Office of Research Compliance at UNCG toll-free at (855)-251-2351.

Questions, concerns or complaints about this project or benefits or risks associated with being in this study can be answered by Dr. Patricia Sink who may be contacted at (336) 665-2760 or psink@triad.rr.com.

Are there any benefits to society as a result of me taking part in this research?
Understanding changes in brain activation and behavioral modifications associated with musical study may provide practitioners in our society new and effective intervention strategies to improve the functional level of children and young adults on the autism spectrum.

Are there any benefits to *me* for taking part in this research study?
There are no direct benefits to parent participants in this study.

Will I get paid for being in the study? Will it cost me anything?
There are no costs to you or payments to you as a result of participation in this study.

How will you keep my information confidential?
All information obtained in this study is strictly confidential unless disclosure is required by law. Your child's information will be stored in a locked file cabinet and will be destroyed upon completion of the study. Participants will not be identified by name when data are disseminated.

What if I want to leave the study?
You have the right to refuse to participate or to withdraw at any time, without penalty. If you do withdraw, it will not affect you in any way. If you choose to withdraw, you may request that any of your data which has been collected be destroyed unless it is in a de-identifiable state.

What about new information/changes in the study?
If significant new information relating to the study becomes available which may relate to your willingness to continue to participate, this information will be provided to you.

What about future studies?
Over the course of this study it is possible that we may want to contact you for continued participation or offer other members of your family the opportunity to participate in the study.

Voluntary Consent by Participant:
By signing this consent form you are agreeing that you read, or it has been read to you, and you fully understand the contents of this document and are openly willing consent to take part in this study. All of your questions concerning this study have been answered. By signing this form, you are agreeing that you are 18 years of age or older and are agreeing to participate, or have the individual specified above as a participant participate, in this study described to you by Michelle Chinn Cannon.

Signature: ________________________ Date: ________________

APPENDIX C

CONSENT FOR MINOR TO ACT AS A HUMAN PARTICIPANT

Study #: 12-0128

UNIVERSITY OF NORTH CAROLINA AT GREENSBORO

CONSENT FOR A MINOR TO ACT AS A HUMAN PARTICIPANT

Project Title: Music Speaks Autism

Project Director: Dr. Patricia Sink, UNC Greensboro School of Music

Participant's Name: ____

What is the study about?

The purpose of this study is to research possible benefits of instrumental music study on children with autism.

Why are you asking my child?

Your child has been selected because she/he has been diagnosed with autism or Asperger's syndrome and is between the ages of 6 and 12. Your child has also been selected because they have not previously participated in instrumental music lessons.

What will you ask my child to do if I agree to let him or her be in the study?

Children will be asked to undergo an initial EEG: a neuroimaging procedure which measures electrical activity in the brain. During the EEG participants will wear an elastic cap that contains electrodes that will make contact with the skin of the scalp, forehead, chin, and earlobes. The electrodes are made of small metal disks and do not penetrate the skin. The skin will be rubbed vigorously with electrode paste. The electrode paste is mildly abrasive, so participants might experience a slight reddening of the skin. This is normal and will disappear shortly after the electrodes are removed. Placing the electrodes usually takes about 20 minutes. All electrodes passively measure electrical activity and do not deliver any electrical impulses. Once the electrodes are connected, participants will be asked to listen to sounds delivered through headphones, as instructed by the experimenter, while their brain electrical activity is recorded. Multiple rest breaks are provided to prevent fatigue. This session takes place at the UNC Department of Psychiatry and is estimated to take 2 hours.

Children will be randomly placed in either a control group or intervention group. The intervention group will be asked to participate in 20 weeks of private violin lessons (30 minutes each), practice skills learned during lessons at home with a parent/guardian and listen to future pieces to be played. Lesson format and instruction will be adapted to meet the developmental needs of each child. The control group will be asked to participate in 20 weeks of non-musical interventions (30 minutes each), and avoid enrollment in private instrumental music instruction. Before completion of the study, a follow-up EEG will be performed and parents will complete a second Vineland Adaptive Behavior Scales. The study will then conclude.

What are the dangers to my child?

Participating in this study poses minimal risks to your child. While every effort will be made to create a joyful and peaceful environment for participants, children may experience some anxiety during the EEG and limited frustration associated with learning a new and complex skill such as playing an instrument.

If you have any concerns about your child's rights, how they are being treated or if you have questions, want more information or have suggestions, please contact Eric Allen in the Office of Research Compliance at UNCG at (336) 256-1482. Questions about this project or benefits or risks associated with being in this study can be answered by Dr. Patricia Sink who may be contacted at (336) 665-2760 or emailed at psink@triad.rr.com.

Are there any benefits to my child as a result of participation in this research study?

Parents of children participating in the control group will be provided information about changes in their child's adaptive behavior and brain activation. Children participating in the experimental group may experience an increase in gross and fine motor skills, auditory discrimination and memory, increased brain activation and increased social awareness.

Are there any benefits to society as a result of my child taking part in this research?

Understanding changes in brain activation and behavioral modifications associated with musical study may provide practitioners in our society new and effective intervention strategies to improve the functional level of children and young adults on the autism spectrum.

Will my child get paid for being in the study? Will it cost me anything for my kid to be in this study?

There are no costs to you or payments to you or your child as a result of participation in this study.

How will my child's information be kept confidential?

All information obtained in this study is strictly confidential unless disclosure is required by law. Your child's information will be stored in a locked file cabinet and will be destroyed upon completion of the study. Participants will not be identified by name when data are disseminated.

What if my child wants to leave the study or I want him/her to leave the study?

You have the right to refuse to allow your child to participate or to withdraw him or her at any time, without penalty. If your child does withdraw, it will not affect you or your child in any way. If you or your child chooses to withdraw, you may request that any data which has been collected be destroyed unless it is in a de-identifiable state.

What about new information/changes in the study?

If significant new information relating to the study becomes available which may relate to your willingness allow your child to continue to participate, this information will be provided to you.

Voluntary Consent by Participant:

By signing this consent form, you are agreeing that you have read it or it has been read to you, you fully understand the contents of this document and consent to your child taking part in this study. All of your questions concerning this study have been answered. By signing this form, you are agreeing that you are the legal parent or guardian of the child who wishes to participate in this study described to you by Michelle Chinn Cannon.

______________________________________ Date: _________________

Participant's Parent/Legal Guardian's Signature

APPENDIX D

CHILD EXPERIMENTAL TREATMENT PARTICIPANT ASSENT FORM

Study #: 12-0128

Music Speaks Autism

Picture Narrative

My name is Miss Michelle

If you say it is o.k., we will:

Take a picture of your brain!

Go to a violin house

Go inside the violin house...

And learn to play the violin!

Finally, we will take another picture of your brain.

Do you want to join this study? You can say

YES

or

NO

You may say YES now and say NO later.

No one will be sad if you say no.

Do you have questions? Ask Michelle!

Her phone number is (919) 357-1359.

Yes I want to join this study ____________________________________

APPENDIX E

CHILD CONTROL TREATMENT PARTICIPANT ASSENT FORM

Study #: 12-0128

Music Speaks Autism

Picture Narrative

My name is Miss Michelle

If you say it is o.k., we will:

Take a picture of your brain!

Go to a house

Go inside the house...

And play games!

Finally, we will take another picture of your brain.

Do you want to join this study? You can say

YES

or

NO

You may say YES now and say NO later.

No one will be sad if you say no.

Do you have questions? Ask Michelle!

Her phone number is (919) 357-1359.

Yes I want to join this study ___________________________________