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The Effect of Rhythmic Proprioceptive Input on Attention in Children with Autism Spectrum Disorder (ASD): An Exploratory Study

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THE EFFECT OF RHYTHMIC PROPRIOCEPTIVE INPUT ON ATTENTION IN CHILDREN WITH AUTISM SPECTRUM DISORDER (ASD): AN EXPLORATORY STUDY

By

Allison E. Lockhart

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The Effect of Rhythmic Proprioceptive Input
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Children with an Autism Spectrum Disorder (ASD) diagnosis may exhibit sensory dysfunction, particularly related to deficits in processing proprioceptive input. These deficits impact multiple skills related to self-regulation and subsequently, academic performance, especially attention. Current research suggests that listening to music and rhythmic patterns can improve attention in children with ASD, which may be a sign of improved sensory integration, yet this connection has yet to be explored. The purpose of this study was to examine the immediate effects of rhythmic auditory stimuli combined with proprioceptive input on attention in children with Autism Spectrum Disorder (ASD). Fifteen school-aged children with ASD and identified proprioceptive deficits participated in the study. Nine participants received seven minutes of rhythmic proprioceptive input (RPI) while six participants received seven minutes of proprioceptive input (PI) without a rhythmic auditory stimulus. Following the protocol, each participant took a series of sustained and selective visual and auditory attention assessments. A series of independent samples *t*-tests were completed to identify any significant differences in attentional outcomes between conditions. Analysis of covariances (ANCOVAs) were completed to determine whether level of ASD or proprioceptive dysfunction influenced the effect of each protocol on attention.

Results indicated a statistically significant difference between individuals who received RPI and individuals who received PI on commission errors within a visual attention assessment (p = .007). Individuals who received RPI committed significantly fewer commissions. There were no statistically significant differences between groups on all other visual and auditory sustained and selective attention assessments (p > .05); however, the RPI group generally performed better across all measures. Furthermore, results showed no statistically significant main effect of functioning level or level of proprioceptive dysfunction on treatment effectiveness or attentional outcomes (p > .22). The results gathered from this study suggest that the addition of rhythmic auditory stimuli to proprioceptive input enhances sensory integration and attention. This connection is explored, and recommendations are made for future research and the need for more appropriate attention assessments for children with ASD.

Dedication

I am honored to dedicate this paper to my younger cousin, Daniel Rodriguez, who inspired me to become a music therapist and work with individuals on the autism spectrum.

Acknowledgement

First, I would like to thank God for the strength he has given me throughout my life. I would also like to thank him for providing me with a wonderful group of supportive individuals in my life that I can always count on.

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TABLE OF CONTENTS

List of Figures

Pages

List of Tables

Pages

Chapter 1

Introduction

Statement of the Problem

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by deficits in social interaction, social communication, and sensory processing (American Psychiatric Association [APA], 2013). Sensory processing deficits typically manifest as hyper- or hypo-reactivity to sensory input as observed through sensory-seeking and sensory-avoiding behaviors (Baranek, Boyd, Poe, David, & Watson, 2007; Baranek, David, Poe, Stone, & Watson, 2006). Individuals on the spectrum may exhibit dysfunction in sensory integration, also known more generally as sensory dysfunction.

Sensory dysfunction describes an inability to organize sensory input from the environment and one's own body in an adaptive manner that allows one to effectively respond to and navigate within the environment effectively (Ayres, 1972; Lane, Miller, & Hanft, 2000). Research suggests that sensory dysfunction is prevalent in at least 70% of individuals on the spectrum (Adamson, O'Hare, & Graham, 2006; Greenspan & Wieder, 1997; Mayes & Calhoun, 1999; Tomchek & Dunn, 2007). Furthermore, study results indicate that individuals on the spectrum may present with a dysfunction in integrating proprioceptive input specifically (Blanche, Reinoso, Chang, & Bodison, 2012). As such, research is needed to help understand and address sensory dysfunction, particularly proprioceptive input processing, in individuals with ASD.

Proprioceptive input is a form of sensory input that allows one to understand the positioning of one's body in space (Myles, Cook, Miller, Rinner, & Robbins, 2000). This input is received through the muscles, joints, and tendons, and allows for proper motor planning.

Poor proprioceptive processing has been cited by individuals on the spectrum as the cause of behavioral regulation difficulties (Mukhopadhyay, 2003), and it has been reported that engaging in behaviors that provide proprioceptive input eases anxious bodily sensations that impede proper attentional regulation (Mukhopadhyay, 2003). An individual on the spectrum who is hypo-sensitive to proprioceptive input may thus seek such input in order to self regulate (Baranek, Boyd, Poe, David, & Watson, 2007; Baranek, David, Poe, Stone, & Watson, 2006; Mukhopadhyay, 2003). When he or she does not receive enough proprioceptive input, poor self-regulatory behaviors are observed and one's ability to attend to a task is impeded (Anderson, 1998; Blanche, Reinoso, Chang, & Bodison, 2012; Eaves & Ho, 1997; Myles, Cook, Miller, Rinner, & Robbins, 2000).

Further research exploring sensory dysfunction has shown that sensory processing deficits have negative implications on attention, learning and memory, auditory information processing, self-regulation (Ashburner, Ziviani, & Rodger, 2008; Bonnel et al., 2003; Eaves & Ho, 1997; Heaton, 2003), and emotional and behavioral functioning (Baker, Lane, Angley, & Young, 2008). In a study exploring the impact of sensory dysfunction on classroom performance in individuals with ASD, Eaves and Ho (1997) found that atypical sensory processing was associated with an inability to self regulate emotions and behaviors. Thus, the individual's ability to attend to a task was negatively impacted, which resulted in a negative impact on classroom performance. This connection between atypical sensory processing, attention to task, and academic performance has since been demonstrated elsewhere (Ashburner, Ziviani, & Rodger, 2008).

Since the ability to attend to a task is a prerequisite to the development of higher-level cognitive processes (Colombo, 1993; Colombo, 2002; Fagan & McGrath, 1981; Hunnius, 2007), attentional processes impacted by sensory dysfunction may be viewed as a main deficit impacting the ability of individuals with ASD to gain maximum benefits from education and therapy (Ashburner, Ziviani, & Rodger, 2008; Blanche, Reinoso, Chang, & Bodison, 2012; Lee, 2015). The development of attention, in particular sustained and selective attention, allows for better self-regulation of behavior, emotion, and thought (Posner & Rothbart, 2000; Posner, Rothbart, & Rueda, 2014), and it positively correlates with academic achievement and classroom performance (Anobile, Stievano, & Burr, 2013; Franceschini, Gori, Ruffino,Pedrolli, & Facoetti, 2012). Thus, since sensory dysfunction impacts the ability of an individual on the spectrum to attend to a task, and the resulting attentional deficits impact classroom performance, self-regulation, behavioral, and emotional outcomes, research is needed that explores how to improve sensory integration functioning and ultimately attention.

Need for the Study

Most research exploring how to improve sensory integration functioning is within the occupational therapy literature. Findings supports the use of sensory integration techniques (e.g., providing proprioceptive, vestibular, tactile, and auditory input) as a way to assist promote self-regulation in individuals with ASD (Bagatell, Mirigliani, Patterson, Reyes, & Test, 2010; Blairs & Slater, 2007; Wilbarger & Wilbarger, 2002). Forms of proprioceptive input that have been utilized in a therapeutic setting include weighted vests, weighted lap pads, joint compressions, therapy ball chairs, brushing, trampoline jumping, and bouncing on a therapy ball (Bagatell et al., 2010; James, Weaver, Clemens, & Plaster, 1985; Wilbarger & Wilbarger, 1991; Wilbarger & Wilbrager, 2002). Research indicates that such forms of proprioceptive input have displayed positive impacts on attention regulation.

While research exists supporting the use of sensory integration techniques to address sensory dysfunction, there is little research that explores the use of music to address sensory dysfunction. Current research suggests that listening to music and rhythmic patterns improve attention in children with ASD (Clauss, 1994; Mahraun, 2004; Scott, 1970), which may be a sign of improved sensory integration. Furthermore, published research exploring the impact of combining music stimuli with sensory integration techniques to address sensory dysfunction or attention is non-existent. Thus, the current study provided a preliminary examination of the immediate impact of combining musical stimuli with proprioceptive input on attentional deficits related to sensory dysfunction in children with ASD. Though research demonstrates that music can enhance attention (Clauss, 1994; Mahraun, 2004; Scott, 1970), the exploration of music's impact on sensory dysfunction in conjunction with attention has not yet been explored. Furthermore, there is a need for music therapy research addressing sensory dysfunction and attention in individuals with ASD, as no current research specifically looks at these constructs. Thus, this study has both theoretical and practical implications.

Theoretical implications. The effect of rhythmic auditory stimuli on sensory integration has not yet been explored. Neither has the combined effects of rhythmic auditory stimuli and proprioceptive input on sensory integration and attention. Thus, the current study fills a gap in current research literature as it explored the impact of music on sensory integration functioning and attention. Implications regarding how rhythmic auditory stimuli when combined with proprioceptive input enhanced sensory integration and attention are explored. Additionally, suggestions regarding how rhythmic auditory stimuli combined with proprioceptive input can fit within current music therapy practice are also discussed. Furthermore, implications are made for the need of attention assessments designed for individuals with ASD.

Practical implications. The current study may prove useful to music therapists in a clinical setting. Music therapists may learn effective ways to incorporate sensory integration techniques into their practice, which will help clients with sensory dysfunction be better able to pay attention and process new information during therapy sessions (Berger, 2002). In particular, findings may enhance knowledge in the use of the Neurologic Music Therapy technique of Auditory Perception Training. This may allow music therapists to better able address client's treatment goals and objectives by improving attention and self-regulation. It is common for students with ASD to become frustrated and hyperactive when they do not attain needed sensory input. When music therapists are able to understand and accommodate the needs of individuals on the spectrum, fewer therapeutic setting disturbances (e.g., behavioral and emotional outbursts) will occur. Fewer disruptions in these settings will benefit not only the music therapists, but also therapy peers.

Finally, children on the spectrum may be the primary beneficiaries from this study. As their sensory needs are met, they will be better able to self-regulate and attend to environmental information. A better ability to self-regulate will positively impact children on the spectrum throughout their activities of daily living. In particular, self-regulation correlates with improved attentional regulation (Eaves & Ho, 1997), which positively impacts performance in therapeutic and educational settings (Ashburner, Ziviani, & Rodger, 2008). Ultimately, improved self-regulation will assist children with ASD in being able to attend and learn within the classroom and therapy settings.

Purpose of the Study

The purpose of this study was to examine the immediate effects of rhythmic auditory stimuli combined with proprioceptive input on attention in children with Autism Spectrum Disorder (ASD). More specifically, this study examined the following research questions:

1. What is the immediate effect of rhythmic proprioceptive input on attention in children with ASD?
2. What is the immediate effect of proprioceptive input on attention in children with ASD?
3. What differences exist between rhythmic proprioceptive input and proprioceptive input on attention in children with ASD?

4. What is the effect of level of proprioceptive dysfunction on attentional responses to rhythmic proprioceptive input and proprioceptive input in children with ASD?
5. What is the effect of functioning level of ASD on attentional responses to rhythmic proprioceptive input and proprioceptive input in children with ASD?

Chapter 2

Review of Related Literature

This chapter will review research literature pertaining to sensory dysfunction, proprioception, rhythm, and attention in typical and special needs populations. The first section of this chapter will provide an overview of sensory dysfunction in ASD and the neural structures involved in sensory integration and attention. Within the second section, neuroanatomical and behavioral evidence for proprioceptive and rhythmic processing will be provided. The third section of this chapter will provide evidence to support the combination of proprioceptive and rhythmic input to enhance sensory integration and attention.

Sensory processing and integration deficits are present in individuals on the spectrum (American Psychiatric Association [APA], 2013), and manifest as sensory-seeking and sensory-avoiding behaviors (Baranek, et al., 2007; Baranek, et al., 2006). Deficits in sensory integration are more generally referred to as sensory dysfunction (Ayres, 1972). Sensory dysfunction negatively impacts attention, which further impacts classroom performance and functions needed for activities of daily living such as memory and emotional and behavioral regulation (Ashburner, Ziviani, & Rodger, 2008; Baker, Lane, Angley, & Young, 2008; Bonnel et al., 2003; Eaves & Ho, 1997; Heaton, 2003). The impact of sensory dysfunction on attention, in particular, can have profound effects on the ability of individuals to attend to their environment and learn new information as attention is necessary for higher level cognitive processes (Colombo, 1993; Colombo, 2002; Fagan & McGrath, 1981; Hunnius, 2007). Thus attention may be considered a main deficit influenced by sensory dysfunction (Ashburner, Ziviani, & Rodger, 2008; Blanche, Reinoso, Chang, & Bodison, 2012; Lee, 2015).

Sensory dysfunction in individuals with ASD may present as proprioceptive processing difficulties (Blanche, Reinoso, Chang, & Bodison, 2012). Sensory integration techniques that utilize proprioceptive input (Bagatell et al., 2010; Blairs & Slater, 2007) have demonstrated to be beneficial in improving sensory integration and attention. Yet, the effects of music listening interventions on sensory integration in conjunction with attention are less explored. However, initial evidence supports the use of music-based interventions to influence sensory integration and attention (Clauss, 1994; Mahraun, 2004; Scott, 1970). While research alludes to both proprioceptive input and music listening enhancing sensory integration and improving attention, little research has explored the combined effects of a proprioceptive, music-based intervention on sensory integration as a tool to improve attention.

Sensory Dysfunction in Autism Spectrum Disorders

Sensory integration is defined as the "neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment" (Ayres, 1972, p. 11). It involves the blending of two or more of the following sensory inputs: visual, auditory, gustatory, olfactory, tactile, vestibular, and proprioceptive. Atypical sensory integration, or sensory dysfunction, relates to the inability of individuals to self regulate (Eaves & Ho, 1997). Sensory dysfunction is estimated to be prevalent in 70% of individuals with ASD (Adamson, et al., 2006; Greenspan & Wieder, 1997; Mayes & Calhoun, 1999; Tomcheck

& Dunn, 2007). Individuals on the spectrum who experience sensory dysfunction present with a difficulty to organize and modulate responses adaptively to incoming sensory stimuli (Ayres, 1972; Lane, Miller, & Hanft, 2000). While sensory dysfunction can relate to the inability to organize any and all types of sensory input, difficulties with proprioceptive processing have been specifically cited as presenting in a unique way in individuals on the spectrum (Blanche, Reinoso, Chang, & Bodison, 2012).

In individuals with ASD, poor processing of proprioceptive input has correlated to poor postural control, poor motor control and planning, and excessive dependence on proprioceptive input. Individuals on the spectrum have cited poor proprioceptive processing as the cause of attentional regulation difficulties and have reported that engaging in behaviors that provide proprioceptive input counteract anxious bodily feelings that cause difficulties with self regulation (Mukhopadhyay, 2003). Evidence supports that improper sensory and proprioceptive integration manifests as poor self-regulation (Anderson, 1998; Myles, Cook, Miller, Rinner, & Robbins, 2000), in particular the ability to attend to a task (Blanche, Reinoso, Chang, & Bodison, 2012; Eaves & Ho, 1997). Thus, sensory integration interacts with self-regulation, and in particular, attention regulation (Dunn, 1999; Williamson & Anzalone, 2001). Since improper sensory integration is exhibited through poor self-regulatory behaviors (Anderson, 1998; Blanche, Reinoso, Chang, & Bodison, 2012; Dunn, 1999; Eaves & Ho, 1997; Myles, Cook, Miller, Rinner, & Robbins, 2000; Williamson & Anzalone, 2001), and previous studies have used attentional outcomes as a measure of self-regulation and sensory integration (Ashburner, Ziviani, & Rodger, 2008; Eaves & Ho, 1997), behavioral evidence of attention regulation can illustrate the efficacy of sensory integration strategies for individuals with ASD.

Evidence suggests that improper sensory integration has negative behavioral implications for those on the autism spectrum. As discussed previously, sensory dysfunction relates to poor attention, which can result in poor classroom performance, learning and memory, auditory information processing, self-regulation (Ashburner, Ziviani, & Rodger, 2008; Bonnel et al., 2003; Eaves & Ho, 1997; Heaton 2003), and emotional and behavioral functioning (Baker, Lane, Angley, & Young, 2008). Proper processing of sensory information allows an individual to modulate sensory information in order to adjust to the environment and maintain optimal arousal for task completion (Miller & Lane, 2000).

Attention deficits may be caused by sensory dysfunction; that stems from atypical neural processing of sensory information. Neuroanatomical evidence utilizing magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI) suggests that the lateral cerebellum is primarily implicated in sensory acquisition and discrimination in healthy adults (Gao et al., 1996; Liu et al., 2000). The lateral cerebellum plays a role in processing sensory input and modulating motor responses appropriately (Gao et al., 1996). In addition, the cerebellum plays a significant role in sensory hyper- and hyporeactivity (Cummings, 1995), and monitors and adjusts responses to sensory information (Bower, 1997). As part of sensory integration involves neurological processes that properly modulate adaptive responses to sensory input from the environment, abnormalities in the cerebellum relate to symptoms of improper sensory integration, processing, and modulation (Koziol, Budding, & Chidekel 2011). Thus, cerebellar abnormalities that exist in individuals on the spectrum may be the cause of sensory processing deficits (Allen & Courchegne, 2003).

Furthermore, enhanced connectivity in the cerebellum is displayed during attentional processes (Grahn & Manly, 2012; Kellermann et al., 2012). Participants who completed a visual attention-to-motion task during fMRI displayed heightened activity within the cerebellum while completing the task (Kellermann et al., 2012). During two sustained attention tasks (visual and auditory) participants undergoing fMRI displayed activation within the cerebellum as well (Grahn & Manly, 2012). Thus, the cerebellum is implicated in attentional and sensory integration processes, which illustrates a possible neuroanatomical connection between both systems. Therefore, an intervention targeting the cerebellum could enhance sensory integration and potentially effect attention.

Current Sensory Dysfunction Interventions

Current intervention strategies addressing sensory dysfunction involve providing various forms of sensory stimulation. Such stimulation can be provided in the form of proprioceptive, vestibular, tactile, visual, and auditory input (Bagatell et al., 2010; Blairs & Slater, 2007; Wilbarger & Wilbarger, 2002). Proprioceptive input has been provided through weighted vests, weighted lap pads, joint compressions, therapy ball chairs, brushing of the skin, trampoline jumping, and bouncing on a therapy ball (Bagatell et al., 2010; James et al., 1985; Wilbarger & Wilbarger, 2002). Sensory diets that involve providing a prescribed set of sensory stimuli to individuals at specific times throughout the day have also been utilized (Wilbarger & Wilbarger, 2002).

While the extant literature alludes to how sensory stimulation can enhance sensory integration, there is currently no research that explores how music as a sensory stimulus, nor how a multimodal stimulus (e.g. a combined music and proprioceptive stimulus) can facilitate this need. Combining proprioceptive input with rhythmic auditory stimuli has the potential to aid in sensory dysfunction given that both of these stimuli are processed in similar neural regions (Grahn 2009; Grahn & Brett, 2007; Grahn & Watson, 2013; Goble et al., 2012; Kavounoudiaset al., 2008; Thaut, Trimarch, & Parsons, 2014) and result in similar attentional outcomes (Bagatell et al., 2010; Blairs & Slater, 2007; Clauss, 1994; Mahraun, 2004; Scott, 1970; Wilbarger & Wilbarger, 2002).This idea was first proposed by James (1984), who explored how sensory integration strategies might be incorporated into music therapy practice.

James (1984) found that music therapy literature rarely mentions sensory integration and drew upon studies from related professions to propose that combining music therapy techniques with sensory integration strategies such as proprioceptive input could increase client's ability to generalize information learned within the therapeutic setting. James drew upon speculation from other researchers stating that auditory stimulation may improve vestibular function (Weeks, 1979). However, he stated that further research is needed in order to support these claims and to examine, specifically, how musical stimuli can improve sensory integration. Thus, this study is built on the concept that a combined proprioceptive and music-based intervention may facilitate sensory integration.

Influence of Music-Facilitated Proprioceptive Input on Sensory Dysfunction: A Theoretical Rationale

There is a need to explore intervention strategies that can facilitate sensory integration functioning in children on the spectrum. This study proposes an intervention that will provide children on the spectrum with steady, rhythmic proprioceptive input as a way to meet their sensory needs so that they can attend more readily to their environment. Previous research has illustrated the neural mechanisms underlying the processing of proprioceptive input and rhythm. Research illustrating the influence of proprioceptive input on attention, and the effect of music listening on attention also exists. However, to this author's knowledge, no studies exist that explore the combination of these two stimuli to influence sensory integration and attention. Thus, the following discussion will outline the neural and behavioral correlates of proprioceptive input and rhythm separately in an effort to explore a foundational overlap in neural processing and behavioral outcomes between each type of stimuli. The overlap will provide preliminary justification for the combination of rhythm and proprioceptive input as a therapeutic intervention to enhance sensory integration and attention.

Proprioceptive input processing. Proprioceptive input is a form of sensory input related to motor planning that allows one to understand the positioning of one's body in space (Myles, Cook, Miller, Rinner, & Robbins, 2000). Proprioceptive input is received through the muscles, joints, and tendons. Proper integration of this sensory input allows for smooth, coordinated movements. Examples of ways in which proprioceptive input can be received include via muscle and joint compressions, jumping, and leaning against objects or individuals.

Neuroanatomical evidence for proprioceptive input processing. Results from neuroimaging studies have identified multiple cortical and subcortical structures that are activated when processing proprioceptive input. Kavounoudias and colleagues (2008) utilized functional magnetic resonance imaging (fMRI) to examine the neural components involved in processing proprioceptive input (e.g., vibrations) and tactile input (e.g., holding a disc). Similar regions were activated when processing both types of input. These included the primary motor cortex, premotor cortex, supplementary motor area, inferior parietal lobe, and cerebellum. However, proprioceptive input resulted in a greater amplitude of response than tactile input. Furthermore, neural responses within these regions become heightened when proprioceptive input was delivered in conjunction with tactile input. Since processing multisensory input (i.e., the combination of tactile and proprioceptive input) relies on similar neural regions and can heighten neural responses, the combination of other forms of input (auditory, visual, vestibular) may also help to elicit a heightened neural response (Bruce, Desimone, & Gross, 1981; Downar, Crawley, Mikulis, & Davis, 2000; Kavounoudias et al., 2008; Macaluso & Driver 2001).

Goble and colleagues (2012) further explored proprioceptive input by studying the neural correlates of proprioceptive processing in healthy younger adults (i.e., adults aged 19 to 32) and healthy older adults (i.e., adults aged 62 to 81) in an effort to understand how the processing of proprioceptive input may alter throughout the lifespan. Proprioceptive input was provided in the form of foot tendon and bone vibrations during fMRI. The researchers reported similar neural activation patterns in both younger and older adults. Areas activated when processing proprioceptive input included the primary sensorimotor cortices, bilateral inferior parietal cortex, primary somatosensory area, bilateral inferior frontal gyri, bilateral anterior insular cortex, supplementary motor area, pre somatosensory motor area, bilateral basal ganglia, and thalamus. Furthermore, the researchers noted under-activation in the older participants in the right putamen, which the authors concluded may relate to proprioceptive sensitivity in older adults. In conclusion, neural structures activated when processing proprioceptive input include the motor and premotor cortices, supplementary motor area, inferior parietal lobe, cingulate motor areas, cerebellum, primary sensorimotor cortices, bilateral inferior frontal gyrus, and basal ganglia (Goble et al., 2012; Kavounoudias et al., 2008).

Behavioral evidence for proprioceptive input processing. In the past 15 years, research has been published that explores in depth the impact of different forms of sensory input on attention and self regulation. In a book titled *Sensory Integration: Theory and Practice, 2nd. ed.*, Wilbarger and Wilbarger (2002) outlined the theory and practice of the Wilbarger Protocol they developed to treat sensory defensiveness. The authors attest that controlled sensory input can affect one's functional abilities—particularly the ability to maintain an age appropriate level of attention for optimal function—and can reduce sensory defensiveness.

One such approach outlined by Wilbarger and Wilbarger involves providing proprioceptive input in the form on deep pressure joint compressions. Blairs and Slater (2007) tested Wilbarger and Wilbarger's deep pressure approach by examining the effect of proprioceptive input, in the form of firm pressure, on anxiety and challenging behaviors in a man with severe ASD. They reported a drastic decrease in the length of restraint time, from 1,954 minutes in the month prior to the intervention, to 240 minutes in the first month of treatment, to 0 to 2 minutes a month during months two through four of treatment. They concluded that proprioceptive input in the form of firm pressure seemed to be effective in reducing anxiety-related challenging behaviors.

Proprioceptive input provided by movement on a therapy ball chair has also demonstrated positive behavioral effects as measured by appropriate in-seat behaviors in children with ASD (Bagatell et al., 2010). The researchers compared in-seat behaviors (e.g., portion of buttocks in seat, legs of seat or therapy ball in contact with floor, one foot in contact with the floor when sitting on a therapy ball) in six, kindergarten-aged boys with moderate to severe ASD when they sat in typical classroom chairs and when they sat on therapy ball chairs. Researchers also provided an opportunity for the participants to choose whether to sit in a typical or therapy ball chair. The majority of study participants demonstrated increased in-seat time, which correlates to increased attention, when sitting in the therapy ball chair and, when given a choice of which chair to use, they chose the therapy ball chair the majority of the time. Children who displayed more prominent vestibular and proprioceptive-seeking behaviors benefited the most from sitting in the therapy ball chair, illustrating the importance of assessing the sensory needs of each individual on the spectrum before providing them with a form of sensory input. Thus, evidence suggests that providing children on the spectrum with proprioceptive input, particularly if they seek that type of input, may help with improved attention (Bagatell et al., 2010; Blairs & Slater, 2007; Wilbarger & Wilbarger, 2002).

Rhythm processing. Much research has been devoted toward outlining the neuroanatomical structures associated with rhythmic processing. While music-based interventions used to improve attention have been researched, little research exists that details how music listening, in particular listening to rhythm, can improve functional behavioral outcomes (e.g. attention) associated with self-regulation and classroom performance. However, preliminary evidence suggests a positive effect (Clauss, 1994; Mahraun, 2004; Scott, 1970).

Neuroanatomical evidence for rhythmic processing. A plethora of research studies have examined the neural regions involved in processing the various components of rhythm (Grahn, 2009; Grahn & Brett, 2007; Grahn & Watson, 2013; Thaut, Trimarch, & Parsons, 2014). Grahn and Watson (2013) provide a thorough overview of results from neuroimaging studies that examine the neural processing of musical (i.e., beat-based) rhythms and irregular (i.e., non-beat-based) rhythms. They identify the supplementary motor area, premotor cortex, basal ganglia, and cerebellum as being consistently active during the perception of musical and irregular rhythms. Two of these regions have been highlighted as integral to rhythm perception: the basal ganglia and the cerebellum (Grahn, 2009; Grahn & Brett, 2007; Grahn & Watson, 2013).

Additionally, Grahn and Brett (2007) examined neural structures involved in beat perception in healthy adults. While undergoing an fMRI scan, participants listened to short samples of beat-based rhythms and irregular, non-beat-based rhythms. The supplementary motor area, premotor cortex, basal ganglia, and cerebellum were active during all listening conditions. However, activity in the basal ganglia was significantly increased during listening to the beat-based rhythms. Thus, the researchers concluded that the basal ganglia may be more closely connected to the perception of beat-based timing, defined as when rhythm is perceived with an underlying beat.

The cerebellum, while also active during all listening conditions (Grahn & Brett, 2007), may be more closely connected with the perception of duration-based timing, intervals in a rhythm being perceived by the distance between beats. Teki, Grube, Kumar, & Griffiths (2011) utilized fMRI to identify neural regions involved in beat-based and duration-based timing perception in healthy adults. Participants completed a series of timing tasks that relied on either beat or duration perception during fMRI. Results demonstrated that the basal ganglia were most active during the beat perception timing tasks, and the cerebellum was most active during the duration perception timing tasks. Since beat and duration perception are both integral parts of rhythm perception, the basal ganglia and cerebellum are cited as major neural structures involved in rhythm perception.

Furthermore, Thaut, Trimarch, and Parsons (2014) used positron emission tomography (PET) to examine the neural regions involved in the processing of three distinct components of rhythm: meter, tempo, and pattern. Healthy adult participants listened to pairs of monotonic rhythms differing in either pattern, tempo, or meter. Participants were told to focus on a particular element and then indicate if that element was the same or different between the two samples during the PET scan. Neural structures active across all three rhythm conditions included the right posterior cerebellum, right insula, bilateral primary motor cortex, and the bilateral anterior cingulate. However, neural activation patterns varied based on whether pattern, tempo, or meter were emphasized. Neural structures activated when rhythm pattern was emphasized included the superior temporal gyrus, middle temporal gyrus, and transverse temporal gyrus. When meter was emphasized, the right inferior, precentral, and middle frontal gyrus were active. When tempo was emphasized, the right inferior parietal cortex, right insula, right superior temporal gyrus, and right middle/precentral frontal gyrus were active. Thus, it seems there are not only different neural activation patterns based on type of beat perception task, but also based on processing different elements of rhythm.

Behavioral evidence for rhythmic processing. No published research appears to exist that supports the use of music-based intervention to specifically address sensory integration. However, since sensory integration relates to and can be measured by improved behavior and attention regulation (Anderson, 1998; Blanche, Reinoso, Chang, & Bodison, 2012; Dunn, 1999; Eaves & Ho, 1997; Myles, Cook, Miller, Rinner, & Robbins, 2000; Williamson & Anzalone, 2001), research examining the effect of music listening on hyperactive behaviors and attention regulation in children with special needs will be discussed.

Scott (1970) examined the effects of background music listening on hyperactivity on children. While an older study, this study is one of few that provide evidence on how music listening can affect the self-regulation of hyperactive behaviors in children. Study participants completed an arithmetic task during four, 10-minute conditions. Two conditions involved the participants completing the task while listening to background music (e.g., The Beatles albums, "Sgt. Pepper's Lonely Hearts Club Band" and "Magical Mystery Tour") and sitting in either a typical classroom desk or three-sided booth, and two conditions involved participants completing the task without background music while sitting in a typical classroom desk or three-sided booth. The number of correctly completed math problems was used as a measure of productivity. While the sample size was too small to achieve significance, results suggest that the children, overall, completed significantly more math problems accurately during the music listening than the non-music listening conditions. The study offers preliminary evidence that listening to background music may lessen hyperactivity, thus improving attention in an academic setting.

Scott's (1970) efforts were furthered by Clauss (1994) who examined the effect of listening to background music on attention and self-stimulatory behaviors in children with ASD. Five children on the spectrum participated in each of three conditions in which they listened to no music, slow music, then fast music while performing attention tasks. Results indicated that the percentage of correct responses on the attention tasks improved while the participants listened to slow and fast music as opposed to no music. However, results on the impact of music listening on self-stimulatory behavior were inconclusive due to the small sample size and the variability in self-stimulating behaviors between participants.

In a related study, Mahraun (2004) examined the effects of background music listening on sustained attention in children with ASD. Mahraun found that listening to music or rhythmic patterns while completing the tasks improved the participants' performance on sustained attention tasks. No such effect was examined when the participants completed the tasks without music or rhythmic stimuli. The author also noted that the frequency of off-task behaviors decreased during the music and rhythmic stimuli conditions compared to the no stimulus condition.

Overall, these studies indicate that music listening may have a positive effect on self regulatory skills, particularly attention regulation, in children with ASD and on decreasing hyperactive behaviors in children with special needs. However, research is needed that examines the effect of music on sensory integration as a mediator to influence attention.

Synthesis and conclusions. The reviewed literature illustrates that proprioceptive input and rhythmic stimuli are both processed within the cerebellum, basal ganglia, supplementary motor area, premotor cortex, primary motor cortex, and inferior frontal gyrus. In particular, the cerebellum is cited as a primary neural structure involved in proprioception and rhythm processing, thus implying that proprioceptive input and rhythmic stimuli can be utilized to target activation within the cerebellum. Furthermore, improved attention regulation outcomes have been observed when individuals on the spectrum are provided with proprioceptive or with auditory (i.e., music-based) input. The presentation of multi-sensory input (i.e., the combination of tactile and proprioceptive input) that relies on similar neural regions has heightened neural responses (Kavounoudias et al., 2008). Thus, the combination of proprioceptive input with musical, rhythmic stimuli, both processed in similar neural regions, could enhance neural processing of such stimuli and attention regulation outcomes (Bruce, Desimone, & Gross, 1981; Downar et al., 2000; Kavounoudias et al., 2008; Macaluso & Driver 2001). In other words, as evidence suggests that proprioceptive input and musical stimuli improve self-regulation, these stimuli in combination may have positive effects on sensory integration and attention.

Combining Proprioceptive Input and Rhythm: A Sensory Integration Intervention

As described previously, proprioceptive input, rhythmic stimuli, sensory integration processing, and attention regulation all require activation from the cerebellum. This implies that proprioceptive and rhythmic input may effect sensory integration and attention via the cerebellum. In addition, a clear behavioral overlap exists between the outcomes of receiving proprioceptive input, listening to rhythmic auditory stimuli, and proper sensory integration. All of which result in improved self-regulation, in particular attention regulation. Combinations of sensory stimuli processed in similar neural regions have heightened neural processing of such stimuli (Kavounoudias et al., 2008). Thus, a combined rhythmic proprioceptive input may influence the attentional outcomes indicative of proper sensory integration.

Potential effect of combined rhythmic proprioceptive input on sensory integration.

While research has not specifically examined the combined effects of proprioceptive and rhythmic input on sensory integration, research has alluded to the combined effects of such inputs on promoting sensory integration and attention (Allen & Courchegne, 2003; Ayres, 1972; Chemin, Mouraux, & Nozaradan, 2014; James, 1984;

James et al., 1985; Molinari, et al., 2005; Thaut, 1984; Thaut, Kenyon, Schauer, & McIntosh, 1999; Weeks, 1979). As auditory stimuli, proprioceptive input, and other sensory processing faculties are processed in the cerebellum, auditory stimuli may influence how other stimuli are perceived and integrated (Ayres, 1972; James et al., 1985). In fact, cerebellar differences seem to exist in individuals with ASD (Allen & Courchegne, 2003), yet rhythmic synchronization abilities are unaffected in children and adults with cerebellar abnormalities (Molinari et al., 2005).

As rhythm is processed within the cerebellum, and auditory feedback from the environment can be utilized to aid in proprioceptive muscular control (Thaut, Kenyon, Schauer, & McIntosh, 1999), intact rhythm processing functions can have implications on sensory integration. Furthermore, auditory and proprioceptive input may work together to optimize sensory integration. For example, Thaut (1984) designed a music therapy treatment model for individuals on the spectrum and reported that pairing words or phrases with melodic or rhythmic patterns and a body movement helped facilitate language development. Thus, Thaut suggested that combining the melodic or rhythmic patterns with body movement provided feedback to the child in diverse ways, which targeted the child's brain through multiple perceptive channels. In addition, analysis results suggested that movement to music may facilitate sensory integration, particularly through the integration of tactile/kinesthetic and auditory stimuli. Movement to music also resulted in individuals on the spectrum being better able to distinguish self from non-self, which is important for individuals with proprioceptive input hypo-sensitivity, as they may exhibit unawareness of where their body is positioned in space (Myles, et al., 2000).

Chemin, Moureaux, and Nozaraden (2014) provided further evidence in support of Thaut's (1984) model by examining how body movement can influence the neural processing of musical rhythms. Brain responses in healthy adult participants were recorded using electroencephalography (EEG) as they listened to musical rhythms in a particular meter before and after performing body movements to the same musical rhythm. For example, during the body movement condition participants clapped their hands, bobbed their hand, tapped their foot, or swayed their torso to the beat of the rhythmic excerpt. Results indicated that neural responses to the rhythmic listening were enhanced following body movement at a frequency associated to the meter of the music to which the body movement was performed. This study was further supported by study participants, who reported perceiving the music as being "more rhythmic" following the body movement. Thus, as motor movements influence the processing of sensory stimuli, it follows that combining rhythm with body movement through proprioceptive input may enhance the neural processing of rhythm within the sensory processing brain regions, and thus act to promote sensory integration.

This connection between rhythmic proprioceptive input and sensory integration was explored by James, Weaver, Clemens, and Plaster (1985) examining the effect of a combined rhythmic proprioceptive and vestibular input on motor function in children with intellectual and developmental disabilities (IDD). While the focus of the study was primarily on motor skills development, implications can be made through the connection between improved motor skills and improved sensory integration. Vestibular and proprioceptive sensory integration techniques (e.g. spinning, bouncing, swaying) were combined with musical stimuli in a pretest/posttest design to examine the effect of such music-based techniques on motor skill development.

Study participants were assigned to one of two conditions, an experimental group that participated in music therapy, and a control group that received no therapy treatment. Motor skill development was assessed prior to and upon completion of the study. Results indicated that the group who received music therapy showed significantly improved motor skills, while the improvements within the control group were non-significant. Since the auditory systems, sensory systems, and motor systems are close in proximity, auditory stimuli can impact sensory integration, which can impact motor development (Ayres, 1972; Weeks, 1979). The authors thus proposed that improved sensory integration may have influenced motor skill development (James, et al., 1985). Overall, this study provides initial evidence that music combined with other sensory integration techniques may improve sensory integration, and thus improve skills such as motor development.

Furthermore, improved sensory integration correlates to improved attention. Improper sensory and proprioceptive integration impede one's ability to attend to a task (Blanche, Reinoso, Chang, & Bodison, 2012; Eaves & Ho, 1997). Therefore, sensory integration interacts with attentional regulation (Dunn, 1999; Williamson & Anzalone, 2001). As poor attentional-regulation can result from sensory dysfunction (Anderson, 1998; Blanche, Reinoso, Chang, & Bodison, 2012; Dunn, 1999; Eaves & Ho, 1997; Myles, Cook, Miller, Rinner, & Robbins, 2000; Williamson & Anzalone, 2001), and previous studies have used attentional outcomes as a measure of sensory integration (Ashburner, Ziviani, & Rodger, 2008; Eaves & Ho, 1997), evidence of attention regulation can illustrate the effectiveness of sensory integration strategies for individuals with ASD.

Synthesis and Conclusions

Proprioceptive input and rhythmic auditory input are both processed within the cerebellum, and both stimuli have demonstrated a positive influence on self-regulation, particularly attention regulation (Bagatell et al., 2010; Blairs & Slater, 2007; Clauss, 1994; Goble et al., 2012; Grahn, 2009; Grahn & Brett, 2007; Grahn & Watson, 2013; Kavounoudias et al., 2008; Mahraun, 2004; Scott, 1970; Thaut, Trimarch, & Parsons, 2014; Wilbarger & Wilbarger, 2002). In addition, the combination of proprioceptive input and rhythmic auditory input may enhance neural activity in the cerebellum and optimize behavioral outcomes, such as the ability to attend to a task (James, 1984; James et al., 1985; Kavounoudias et al., 2008). Given that sensory integration is also processed in the cerebellum (Gao et al., 1996; Liu et al., 2000), it is possible that proprioceptive and rhythmic input may help enhance sensory integration functioning, which directly impacts attention as it is also processed within the cerebellum (Grahn & Manly, 2012; Kellermann et al., 2012). Previous studies have suggested that combining proprioceptive and rhythmic input promotes and optimizes sensory integration by appealing to multiple perceptual channels (Bruce, Desimone, & Gross, 1981; Downar et al., 2000; Kavounoudias et al., 2008; Macaluso & Driver 2001; Thaut, 1984). However, further research is needed examining the effects of rhythmic proprioceptive input on sensory integration as a means to improve attention in clinical populations. Thus, the purpose of this study was to examine the immediate effects of a rhythmic auditory stimulus combined with proprioceptive input on attention in children with Autism Spectrum Disorder (ASD). The following research questions were examined:

1. What is the immediate effect of rhythmic proprioceptive input on attention in children with ASD?
2. What is the immediate effect of proprioceptive input on attention in children with ASD?
3. What differences exist between rhythmic proprioceptive input and proprioceptive input on attention in children with ASD?
4. What is the effect of level of proprioceptive dysfunction on attentional responses to rhythmic proprioceptive input and proprioceptive input in children with ASD?
5. What is the effect of functioning level of ASD on attentional responses to rhythmic proprioceptive input and proprioceptive input in children with ASD?

Chapter 3

Methodology

Individuals with ASD present with sensory dysfunction and proprioceptive processing difficulties (Adamson, et al., 2006; Blanche, Reinoso, Chang, & Bodison, 2012; Greenspan & Wieder, 1997; Mayes & Calhoun, 1999; Tomcheck & Dunn, 2007). Sensory dysfunction impedes attention, which hinders classroom performance, self-regulation, and emotional and behavioral functioning (Ashburner, Ziviani, & Rodger, 2008; Baker, Lane, Angley, & Young, 2008; Bonnel et al., 2003; Eaves & Ho, 1997; Heaton, 2003). While initial evidence supports the use of proprioceptive input (Bagatell et al., 2010; Blairs & Slater, 2007) and music listening (Clauss, 1994; Mahraun, 2004; Scott, 1970) to enhance sensory integration and attention, little evidence exists exploring the combined effects of proprioceptive input and a music-based intervention on these areas. Therefore, the purpose of this study was to examine the immediate effects of a rhythmic auditory stimulus combined with proprioceptive input on attention in children with Autism Spectrum Disorder (ASD).

The study incorporated a posttest only design with two independent variables: rhythmic proprioceptive input (RPI), and proprioceptive input (PI). The dependent variables of sustained and selective attention were measured as indicators of improved sensory integration (e.g. the combination of proprioceptive and auditory input). Sensory integration is related to self-regulation, and one core construct of self-regulation is attentional regulation (Burack, 1994; Eaves & Ho, 1997; Lee, 2015; Meindl & Canella-Malone, 2011; Posner & Rothbart, 2000; Reed & McCarthy, 2012). Furthermore, attention regulation involves the ability to demonstrate both sustained and selective attention (Razza, Martin, & Brooks-Gunn, 2012; Posner, Rothbart, & Rueda, 2014). Thus, attention regulation was measured through a series of auditory and visual sustained and selective attention tasks to provide a comprehensive overview of treatment condition impacts on attention regulation. Figure 1 outlines the variables of interest within the study.

Participants

Seventeen male and female children aged 5 to 8 years old with a diagnosis of ASD were recruited for participation. However, only 16 children provided assent and 15 children completed the study protocol. Nine children participated in the RPI group (M = 6.67 years) and six children participated in the PI group (M = 6.33 years). This age range is comparable to that used in previous studies that explored sensory processing and self-regulation in children with ASD. In addition, attention development literature has also found that sustained and selective attention assessments have been most successfully used with children who are at least 5 to 6 years of age (Edley & Knopf,1987; Gordon, Thomason, & Cooper, 1990).

Participants had been diagnosed with ASD by their healthcare provider and were recruited from various businesses and therapy centers in the Miami, Florida area, including the Center for Autism and Related Disabilities (CARD), Wholesome Harmonies LLC, Children's Resource Education Center, Crystal Premium Therapy

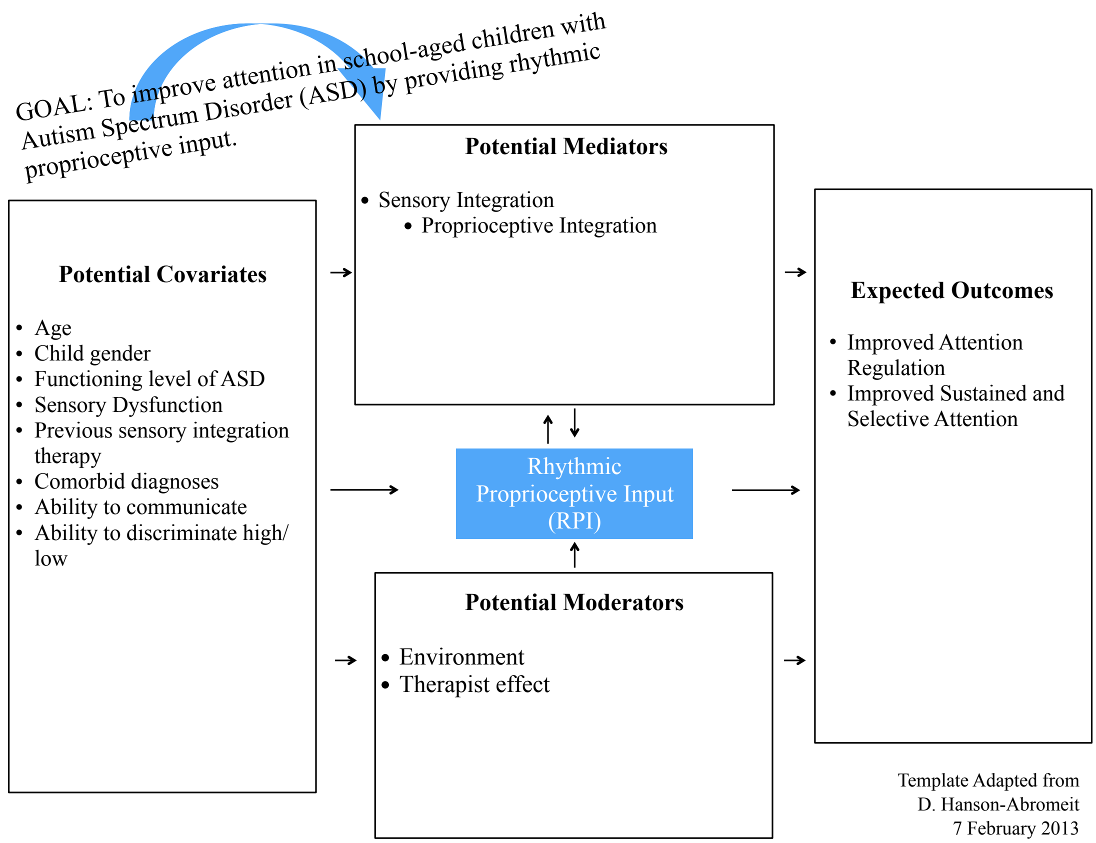

Figure 1. Conceptual framework highlighting the research goal and variables of interest in the present study. Potential covariates include existing participant characteristics implicated in attention and sensory integration. Potential moderators include environmental factors that may have influenced study results. Potential mediators outline the behaviors being measured that are expected to change. Expected outcomes list changes in behavior that may be observed due to the rhythmic proprioceptive input.

Center and School, Whole Steps Creative Arts Center, and Great Heights Academy. In order to meet study inclusion criteria, participants must have been able to communicate through gestures or speech, follow simple one-step directions from an unfamiliar adult, and understand English; these criteria were ascertained through parental report. Eligible participants must also have exhibited dysfunction in integrating proprioceptive input as determined by the Comprehensive Observations of Proprioception (COP; Blanche, Bodison, Chang, & Reinoso, 2012). However, participants could present with any level of functioning across the spectrum, which was assessed using the Social Responsiveness Scale-Second Edition (SRS-2; Constantino & Gruber, 2012).

Participant recruitment. The student investigator submitted the research protocol to the Human Subjects Research Committee at the University of Miami. Upon approval, the student investigator contacted the Center for Autism and Related Disabilities (CARD) and other agencies in Miami that service children on the autism spectrum and their families and requested the agencies disseminate a recruitment flier (Appendix A) to potentially eligible participants. The recruitment flier provided a brief overview of the study and advised families to contact the student investigator via phone call if interested in learning more or having their child be considered for inclusion in the study. Recruitment sites included the flier in their newsletter, emailed it to families, and distributed hard copies as well. The student investigator also coordinated with the recruitment sites several mutually convenient times to come to the site and recruit families in person.

Once parents contacted the student investigator, study details were discussed and parents were provided with an opportunity to ask questions. If parents were interested in their child participating, the student investigator asked the parents to answer four pre-screening questions to determine whether their child may be eligible to participate in the study (Appendix A). Prescreening questions assessed communication abilities, ability to understand English, ability to follow one-step directions from an unfamiliar adult, and whether the parent had observed their child partake in any sensory-seeking behaviors. If it was determined that the child may potentially be eligible, the student investigator and parents scheduled a one-hour appointment to meet and conduct the study at a time mutually convenient for the parents and student investigator. Figure 2 includes an overview of participant recruitment procedures.

Measures

Variables assessed included demographic information (age, gender), communication abilities, functioning level of ASD, degree of proprioceptive sensory dysfunction, and sustained and selective attention abilities. Demographic information and communication abilities were collected using a student investigator-designed questionnaire (Appendix D). Functioning level of ASD was assessed using the Social Responsiveness Scale, second edition (Constantino & Gruber, 2012). Dysfunction in proprioceptive input processing was assessed using the Continuous Observations of Proprioception (Blanche, Bodison, Chang, & Reinoso, 2012). Auditory sustained and selective attention abilities were assessed using the Music-Based Attention Assessment-Revised for Children II (Lee, 2015). Finally, visual sustained attention abilities were assessed using the Preschool Continuous Performance Test (Kerns & McInerney, 2007).

Social Responsiveness Scale, Second Edition (SRS-2). The SRS-2 (Constantino & Gruber, 2012) is a 65-item rating scale completed by the child's caregiver or teacher that rates the severity of symptoms associated with ASD. The SRS-2 generates scores for five treatment sub-scales: social awareness, social cognition, social communication, social motivation, and restricted interests and repetitive behaviors. While the primary

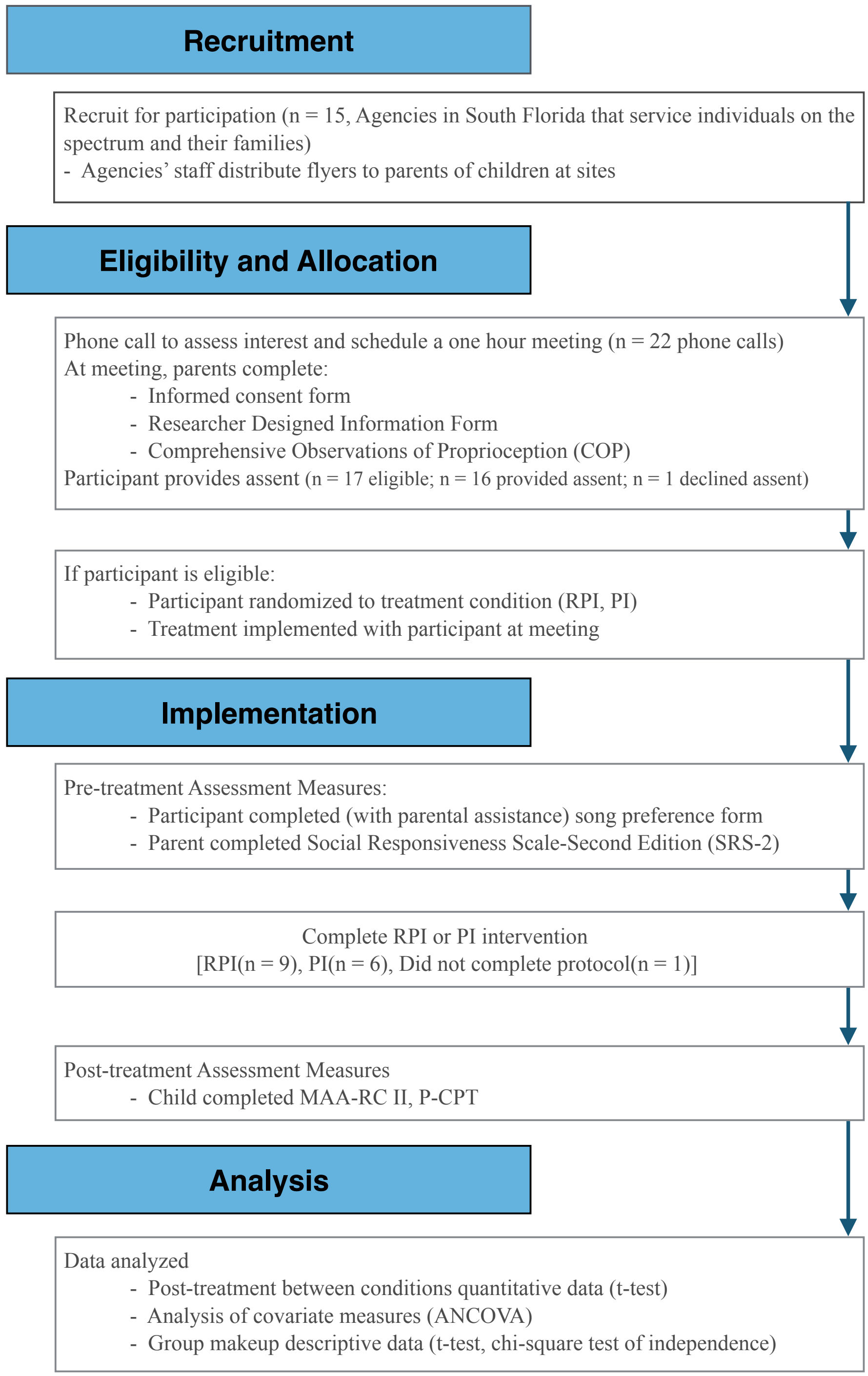

Figure 2. Methodology. Overview of study recruitment, participant eligibility and allocation, implementation procedures, and data analysis.

purpose of the scale is to provide an in-depth analysis of social impairment in individuals on the spectrum, the scale compares to the Diagnostic and Statistical Manual of Mental Disorders, fifth edition ASD diagnostic criteria and can be used to inform diagnosis (Constantino & Gruber, 2012). The SRS-2 includes a form for preschool-aged individuals between the ages of 2.5 to 4.5 years, a form for school-aged individuals between the ages of 4 and 18 years, a form for adults aged 19 and older, and a self-report form for adults aged 19 and older. All forms, except for the adult self-report form, are to be completed by the caregiver or teacher. For the purposes of this study, the school-aged form was utilized and completed by the child's caregiver.

The 65-item rating scale takes about 15 minutes to complete, and those completing the form are prompted to rate on a 4-point Likert-type scale whether or not the child exhibits the identified behavior. The SRS-2 generates a raw score ranging from 0 to 135. Higher scores indicate more severe social impairment (Bruni, 2014; Constantino & Gruber, 2012). Raw scores were converted to *T*-scores in order to control for gender differences between children and differences between the type of rater completing the questionnaire (parent or teacher). *T*-scores also indicate the severity of ASD; scores below 59 indicate the child is high functioning or within normal limits, scores between 60 and 65 indicate mild severity, scores between 66 and 75 indicate moderate severity ,and scores 76 and above indicate severe impairment.

The SRS-2 demonstrates strong test/re-test reliability (r = .88 - .95) and inter-rater reliability between parent reports (r = .91) (Bölte, Poustka, Constantino, 2008; Bruni, 2014; Constantino & Gruber, 2012; Constantino et al., 2009). The scale demonstrates strong predictive validity for accurately identifying individuals on the spectrum, as the scale has a sensitivity value of .92, indicating that the scale will correctly identify 92% of individuals affected. Furthermore, the scale shows strong internal consistency ($r = .91$), and demonstrates moderate correlation ($r = .65 - .77$) with another commonly used parent questionnaire, the Autism Diagnostic Interview-Revised (ADI-R; Constantino et al., 2003; Rutter, Le Couneur, & Lord, 1994). Thus, the SRS-2 has demonstrated to be an effective measure of symptom severity in ASD (Constantino et al., 2003; Duvekot, van der Ende, Verhulst, & Greaves-Lord, 2015).

Continuous Observations of Proprioception (COP). The COP (Blanche, Bodison, Chang, & Reinoso, 2012) is an 18-item rating scale completed by the parent, teacher, or clinician of a child in order to assess dysfunction in the integration of proprioceptive input. The questionnaire is considered short as it takes 15 minutes to complete. The COP was designed to evaluate proprioceptive abilities in children with developmental disabilities. The test produces four factors that can be analyzed separately to provide detail on specific atypical behaviors presented by the child. These include tone and joint alignment, behavioral manifestations, postural motor abilities, and motor planning. Parents rate the level at which a child demonstrates various behaviors associated with sensory dysfunction on a 5-point Likert-type scale. Upon completion of the rating scale, a total score between 16 and 80 is obtained. Scores above 22 are suggestive of dysfunction, and higher scores are indicative of a higher level of dysfunction.

The COP has demonstrated validity and reliability. Face and content validity were established through examination of the measure by a panel of professionals considered experts in sensory integration. Items identified by the panel as strong (index = .7) or adequate (index = .6) were retained within the scale, and items falling below were discarded (Blanche et al., 2012). Construct validity was determined by comparing performance on the COP between individuals with developmental disabilities and typically developing age-matched peers. Results indicated that individuals with developmental disabilities had significantly higher scores ($p < .01$) on the COP than their typically developing counterparts, which indicates the tool differentiated between children with and without proprioceptive processing difficulties (Blanche, Bodison, Chang, & Reinoso, 2012). Criterion validity was assessed by comparing the COP to the proprioception assessment sections of two well-established sensory evaluations of children, the Sensory Processing Measure-Home Form (Parham & Ecker, 2007) and the Sensory Integration and Praxis Test (Ayres, 1989). Moderate to strong correlations ($r = .4 - .9$) were exhibited between each item of the COP and items equivalent within the other two sensory evaluations. The COP demonstrated strong interrater reliability between therapists ($r = .91$) and moderate interrater reliability between a variety of raters (e.g. parents, teachers, therapists) ($r = .62$) (Blanche, Bodison, Chang, & Reinoso, 2012). Thus, while the authors acknowledge that research is needed to examine reliability and validity of the COP more thoroughly, preliminary evidence suggests the COP is an accurate measure of proprioceptive input processing dysfunction.

Music-Based Attention Assessment-Revised for Children II (MAA-RC II). The MAA-RC II (Lee, 2015) is a music-based attention tool developed from the Music-Based Attention Assessment (MAA) (Jeong & Lesiuk, 2011). The MAA was originally developed for adults, and later was revised as the MAA-RC II to be appropriate for children with ASD. Additionally, the number of items were increased to improve test reliability (Lee, 2015).

The MAA-RC II is a 48-item melodic contour identification test that contains two attention subtests, one for sustained attention and the second for selective attention. Each attention subtest consists of 24, three-note melodic contours divided equally into three conditions: ascending, descending, or stationary. Melodic contours are performed in major keys in a 4/4 meter set to 90 beats per minute. During the sustained attention task, children are required to attend to the auditory stimuli and indicate whether the melodic contour is ascending, descending, or remaining stationary. Children complete the same process during the selective attention subtest; however, this subtest includes the addition of distracting sounds (e.g., water running, bird songs, or a wood block playing). Four items within each condition are presented at a low pitch range (220 Hz to 523.55 Hz) and four items within each condition are presented at a high pitch range (1046.5 Hz to 2637 Hz). However, as performance on the lower pitched items was significantly greater than performance on the higher pitched items in children with ASD (Lee, 2015), only the 24 lower pitched items were utilized for assessment in this study. In addition, visuals of directional arrows (Appendix H) were incorporated in order to allow for gestural communication by individuals on the spectrum without verbal communication skills. The number of items on both the sustained and selective attention assessments were shortened to half of the amount (12 per each assessment) in order to improve feasibility for individuals with more severe ASD to complete the assessment. Higher frequency of correct responses indicates more successful sustained or selective attention abilities.

The MAA-RC II is not currently a standardized assessment. However, current attention assessments for children are primarily visual, emphasize numeric information, or have not been designed specifically for children on the spectrum (DeWolfe, Byrne, & Bawden, 1999; Mahone, 2005). The MAA-RC II is designed for individuals on the spectrum and focuses on auditory attention. Thus, the MAA-RC II was deemed appropriate as an auditory attention assessment for individuals with ASD.

Preschool Continuous Performance Test (P-CPT). The P-CPT (Kerns & McInerney, 2007) is a 5-minute computerized assessment of sustained attention. The P-CPT is a modified version on the Children's Continuous Performance Test (C-CPT) (Kerns & Rondeau, 1998); the C-CPT consists of three subtests, while the P-CPT consists of one. While the C-CPT is intended for school-aged children, the P-CPT was incorporated in this study due to findings suggesting the first task of the C-CPT is the only one appropriate for clinical populations (Kerns & Rondeau, 1998). As the P-CPT only includes task one, it was deemed the most appropriate for use in the current study.

During the P-CPT, children are presented with a series of target and non-target stimuli in the form of cartoon pictures of farm animals, and are tasked with pressing the touch sensitive computer screen when the target stimulus appears. The target stimulus is a picture of a sheep. A practice session is conducted before the assessment, and feedback is provided as needed. Performance is measured in terms of reaction time and accuracy (i.e., errors of omission and commission). Omissions occur when an individual does not hit the target stimulus (i.e., does not touch the sheep) and commissions occur when an individual hits stimuli that is not the target (i.e., touches animals other than the sheep). Test-retest reliability was examined in typically developing children aged 3-5 years. Omissions and reaction time demonstrated moderate reliability (r = .63 and r = .77, respectively). Commission errors, while still moderately reliable, displayed less reliability (r = .44) (Muller, Kerns, & Konkin, 2012). With moderate reliability, the P-CPT has demonstrated to be an effective measure of sustained attention.

Study Procedures

Study implementation was conducted at the Center for Autism and Related Diseases (CARD) and the music therapy graduate teaching assistant office in the Frost School of Music at the University of Miami Coral Gables campus.

At the scheduled meeting, the parents signed the informed consent (Appendix B) and the child provided verbal assent (Appendix C). If the parents did not consent or the child did not provide verbal assent, the parents and child were thanked for their time and consideration. If consent and assent were received, parents then completed a student investigator-designed information form (Appendix D) ascertaining communication and direction following abilities and capturing basic demographic information (e.g. age, gender), and filled out the Comprehensive Observations of Proprioception to assess their child's proprioceptive processing abilities (COP; Blanche, Bodison, Chang, & Reinoso, 2012). Upon completion of both questionnaires, the student investigator evaluated the results to determine whether the participant was eligible for the study. If the participant met the eligibility requirements, the student investigator conducted the study with the participant. If the participant did not meet inclusion criteria, parents were thanked for their time and consideration.

Once the child was determined to be eligible for the study, he or she was randomly assigned to one of two treatment conditions: rhythmic proprioceptive input (RPI) or proprioceptive input (PI). If assigned to the RPI condition, prior to beginning the study session, parents were handed a list of 10 pre-selected songs and asked to assist their child in choosing five songs from the list that the child preferred (Appendix E). The student investigator utilized some of the selected songs during the participant's RPI session. Regardless of assigned condition, parents were asked to complete the Social Responsiveness Scale-Second Edition (SRS II; Constantino & Gruber, 2012), which measures functioning level of ASD, while the student investigator conducted the study with their child.

Study sessions were conducted by the student investigator in a one-on-one setting, and lasted no more than thirty minutes. First, participants received their assigned treatment condition—RPI or PI—for seven minutes. Following the treatment, participants completed two attention assessments that measured sustained and selective auditory attention and sustained visual attention: the Music-Based Attention Assessment-Revised for Children II (Lee, 2015) and Preschool Continuous Performance Task (Kerns & McInerney, 2007). Order effects were controlled for by randomizing the order in which participants received the attention assessments during the posttest. Once the posttest assessment was conducted, study participation was complete. Figure 2 provides an outline of study procedures.

Participants in the proprioceptive input (PI) condition were instructed to bounce on a therapy ball at a self-set pace (Appendix F). The therapy ball utilized was a 65-centimeter, Gold's Gym® body ball. This diameter was chosen to be large enough so the participant's feet would not touch the floor. No auditory input was presented, and participants were not required to bounce at a constant, rhythmic pace. The student investigator maintained a light grasp on the participant's waist to ensure safety, but light enough as to not influence how the participants bounced on the therapy ball. In order to control for type of sensory input received, participants were instructed to look at a red dot placed on the wall so that no additional visual stimulation was received. Furthermore, the therapist did not speak to the participants and the participants were instructed not to speak during the intervention so that no auditory stimulation was received.

Participants in the rhythmic proprioceptive input (RPI) condition received the same proprioceptive input as those in the PI condition, but the bouncing was synchronized to a steady rhythmic auditory beat (Appendix G). The songs pre-chosen by the parents and participant were played until the seven-minute protocol was complete. Since five songs had previously been selected, there was more than seven minutes of music available to be played during the protocol. As such, if the participant communicated displeasure for a song (e.g. by stating, "I do not like this song" or "I do not want to listen to this song"), the song was stopped and the therapist moved to the next song in the playlist. The RPI intervention fits within the Neurologic Music Therapy technique of Auditory Perception Training (APT). During the RPI condition, participants were provided with proprioceptive and auditory input through bouncing in rhythm to a rhythmic auditory stimuli— pre-existing recorded music— on the same therapy ball utilized in the PI condition. Rhythmic stimuli was presented over a speaker, as the therapist maintained hands on the waist of the participant. This helped ensure the participant bounced to the beat of the music, and provided postural support so the participant remained safely on the therapy ball. While bouncing participants were instructed to look at a red circle placed on the wall in front of them and to not talk in order to minimize additional visual and auditory stimulation.

Recorded music utilized in the study was selected to meet guidelines based on an analysis of the Therapeutic Function of Music (TFM) (Hanson-Abromeit, 2015). The TFM is defined as “the direct relationship between the treatment goal and the explicit characteristics of the musical elements informed by a theoretical framework and/or philosophical parading in the context of the targeted client(s)” (Hanson-Abromeit, 2013, pp.130-131). For the purposes of the current study, the goal in outlining the TFM was to help determine the type of music to include that was developmentally appropriate and aided in driving the rhythmic bouncing movement. Requirements for music considerations were based on a review and synthesis of music development literature and literature exploring music processing in individuals with ASD. Table 1 presents a detailed outline of the TFM analysis results.

Music utilized had a simple melody (e.g., primarily step-wise motion) and harmonic progression (e.g., primarily consonant harmonies). Rhythmic structure was also simple (e.g., minimal syncopation), repetitive, had a strongly emphasized beat, and each song was in the same meter (4/4) and had a similar tempo of 104 - 114 beats per minute. Vocal pop music was utilized, and the volume was set to a level identified as comfortable by each participant. If the participant did not communicate a preferred volume, the volume was set to 68 decibels. Music incorporated voice and a variety instruments, which facilitated attention maintenance. Finally, since individuals on the spectrum tend to display restricted interests and prefer routine (American Psychiatric Association[APA], 2013), familiar songs (e.g. songs covered by Kidz Bop, Disney songs, songs from children's movies) from pre-existing recordings were utilized in order to provide a level of comfort and build rapport within the short time frame of the intervention. This synthesis is based on the following literature: Bhatara, Babikian, Laugeson, Tachdjiian, & Sininger (2013), Dowling (1988), Gardner (1973), Gembris & Schellberg (2003), Groene (2001), Hardy (2016), Hardy & LaGasse (2013), Kalas (2012), Khalfa et al. (2004), Lee (2015), McDonald & Simmons (1989), Molinari, Leggio, & Thaut (2007), Montgomery (1996), Schellberg (1998), Sims & Cassidy (1997), Stevens & Byron (2009), Thaut, Kenyon, Schauer, & Macintosh (1999), and Zenatti (1993). Appendix E provides a list of songs utilized in the study that meet these guidelines.

Table 1

Therapeutic Functions of Music

Musical Element	Theoretical Framework WHY	Purpose of Element WHAT	Description of Element HOW
Melody	• Simple melodies with step wise motion, no chromatic notes within the diatonic scale, and a small range facilitate attention in individuals with severe ASD, while more complex melodies featuring skips and chromaticism better facilitate attention in individuals with mild to moderate ASD (Kalas, 2012). • Simple, melodic structure can create expectation (Stevens & Byron, 2009).	To provide developmentally appropriate stimulation, to maximally engage the individual, and to create a sense of expectation.	Melody should vary between simple and complex in order to facilitate attention in individuals across all functioning levels of ASD. Thus, some songs should utilize step-wise motion and no chromaticism while other songs should utilize skips and chromatic notes.
Rhythm	• Simple rhythm facilitates attention in all functioning levels of ASD (Kalas, 2012). • Predictable rhythmic structure creates a sense of expectation (Stevens & Byron, 2009) • Predictable rhythmic structure primes mental and physical operations needed for movement (Molinari, Leggio, & Thaut, 2007; Thaut, Kenyon, Schauer, & McIntosh, 1999) • Predictable rhythmic structure assists in facilitating greater motor stability (Hardy & LaGasse, 2013). • Repetitive, predictable, rhythmic structure can promote anticipation of incoming sensory stimuli and assist in stabilization of the sensory system (Hardy, 2016).	To provide developmentally appropriate structure to the music experience and to create a sense of expectation and consistency. To promote sensory integration.	To provide developmentally appropriate structure to the music experience and to create a sense of expectation and consistency. To promote sensory integration.
Dynamic	• Individuals with ASD display an increased sensitivity to and perception of loudness (Khalfa et al., 2004). • Sounds 68 +/- 2 decibels were perceived as too loud for individuals on the spectrum (Khalfa et al., 2004).	To provide developmentally appropriate stimulation while not overstimulating the individual and causing further sensory distress.	Dynamics should be set at a level comfortable to each participant. If the participant does not communicate a volume level that is comfortable, the volume will be set to 68 decibels.

Table 1 Continued

Musical Element	Theoretical Framework WHY	Purpose of Element WHAT	Description of Element HOW
Harmony	• Simple harmonic structure supports simple melody and most consistently facilitates attention in all functioning levels of ASD (Kalas, 2012). • Simple harmony contains minimal chord changes and mostly uses I, IV, and V chords (Groene, 2001). • Children prefer harmonic consonance (Zenatti, 1993)	To provide developmentally appropriate structure to the music experience that will facilitate engagement and create sense of expectation.	Harmony should be simple and primarily consonant, with minimal chord changes, and use mostly I, IV, and V chords.
Form	• In relation to form, children primarily focus on repetitive melodic and rhythmic phrases (McDonald & Simmons, 1989)	To provide developmentally appropriate structure to the music experience and create sense of expectation.	Form should be simple and include melodic and rhythmic repetition.
Pitch	• Children with ASD achieved significantly higher scores on a musical attention assessment when the musical examples utilized lower pitch ranges (220-523.55 Hz.) as compared to higher pitch ranges (Lee, 2015). • Children with ASD display difficulties in discriminating between high pitches and as individuals on the spectrum present more hypersensitivity to auditory stimuli, their threshold to perceive pitch decreases (Bhatara, Babikian, Laugeson, Tachdjiian, Sininger, 2013).	To provide developmentally appropriate stimulation that facilitates attention and does not cause over stimulation.	Pitch range on the musical auditory assessment should be low, between 220 to 523.55 Hz.
Tempo	• Children can distinguish between fast and slow tempi (Dowling, 1988) • Children prefer moderate to fast tempos (bpm = 92-180) (Montgomery, 1996)	To provide developmentally appropriate stimulation and a sense of consistency.	Tempo should be consistent throughout songs and incorporate a moderate to fast tempo.
Timbre	• Children can identify and discriminate between timbres (Schellberg, 1998).	To facilitate attention.	Each musical piece should utilize different timbres.
Style	• Children younger than 11 experience difficulties discriminating between different styles of music (Gardner, 1973) • Children display an overall preference for pop music (Gembris & Schallenberg, 2003)	To provide developmentally appropriate stimulation and a sense of expectation and consistency.	Style should most closely resemble that of pop music.

Table 1 Continued

Musical Element	Theoretical Framework WHY	Purpose of Element WHAT	Description of Element HOW
Medium	• Children display no significant differences in preference for vocal versus instrumental music; however, vocal music seems to be slightly more preferred (Sims & Cassidy, 1997)	To provide developmentally appropriate stimulation and facilitate attention.	Vocal music should be utilized for all song excerpts.
Lyric	• Children best attend to songs to which they find familiar (Gfeller, 2008) • Text that is not too “babyish” or “grown-up” and of a subject matter that may interest children is most developmentally appropriate (Campbell & Scott-Kassner, 1995) • Lyrics for children should not include offensive language (Campbell & Scott-Kassner, 1995)	To provide developmentally appropriate stimulation that will facilitate engagement.	Lyrics should be appropriate for children and familiar. Songs with explicit language or topics should be avoided.

Materials

The MAA-RC II and P-CPT were administered as posttests only. The student-investigator read a script detailing the instructions for both the MAA-RC II (Appendix I) and P-CPT (Appendix J) assessments. The P-CPT was administered via a 2012 Sony Vaio T13 ultrabook touchscreen laptop computer. A Bose bluetooth speaker was utilized for the MAA-RC II assessment and to administer the musical stimuli utilized for the RPI condition. The Music® and Spotify® applications were utilized on an iPhone 5s to transmit all music to the bluetooth speaker. The volume was set at a level comfortable to each participant, as individuals on the spectrum may present with varying degrees of auditory hypersensitivity (Holtzclaw, 2011). Before the student-investigator began the RPI protocol or MAA-RC II assessment, a sample of the music was played and the participant was instructed to tell the student-investigator whether they wanted the volume higher or lower and to state when the volume was at a comfortable level. Results from the MAA-RC II were recorded on a student-investigator designed scoring sheet (Appendix K). A 65-centimeter, Gold's Gym® body ball was utilized to administer proprioceptive input. This diameter was selected to be large enough so the participant's feet would not touch the floor. During the RPI and PI conditions, participants were instructed to look at a red dot taped to the wall. The red dot was made from red construction paper, cut to a diameter of six inches, and laminated.

Data Analyses

Descriptive analyses were conducted through parent questionnaire on the following measures: age, gender, functioning level of ASD, and level of proprioceptive sensory dysfunction. In addition, a series of independent samples *t*-tests were conducted to determine equivalence between groups on age and level of proprioceptive sensory dysfunction, and a series of Chi-square tests of independence were conducted to determine equivalence between groups on gender and functioning level of ASD.

Statistical tests were conducted between conditions on the following posttest measures: the Music-based Attention Assessment-Revised for Children II (MAA-RC II), for assessed sustained and selective attention skills, and the Preschool Continuous Performance Test (P-CPT). A series of independent sample *t*-tests were conducted for each measure to analyze posttest scores between conditions in order to identify any statistically significant differences in attention based on type of condition, RPI or PI. A series of eta-squared (η^2) analysis were also conducted to measure effect size of study variables—functioning level, level of proprioceptive dysfunction, treatment condition, and the interaction between functioning level and treatment condition—on attentional outcomes. In accordance with guidelines outlined by Cohen (1988), a small effect size was set at a magnitude of .01, a medium effect size was set at a magnitude of .06, and a large effect size was set at a magnitude of .14. Calculated effect sizes could be modified due to the number of variables and is likely to drop as more participants are added to the study. Overall, effect size could be an overestimation due to a small sample size (Sterne & Egger, 2001; Zhongheng, Xiao, & Hongying, 2013).

Finally, a series of Analyses of Covariances (ANCOVAs) were conducted on all posttest measures in order to determine and control for the effects of two cofactors (condition and level of functioning with ASD) and one covariate measure (level of proprioceptive dysfunction) on intervention outcomes (attention assessments). As this study contains two factors and one covariate, a series of 2X3 ANCOVA was conducted. The alpha level for significance (p-value) was set at 0.05 for all statistical tests. Figure 2 provides a summary of the data analysis.

Chapter 4

Results

This study provided an initial exploration of the immediate effect of rhythmic auditory stimuli combined with proprioceptive input on attention in children with ASD. The immediate effect of rhythmic proprioceptive input (RPI) and proprioceptive input (PI) on attention were analyzed and the two conditions were compared. Furthermore, the student-investigator analyzed whether level of proprioceptive dysfunction and/or functioning level of ASD influenced the effectiveness of each treatment condition on attention.

Equivalence Between Groups

The study involved two groups of participants: the rhythmic proprioceptive input group (n = 9) and the proprioceptive input group (n = 6). Demographic information was examined via independent samples *t*-tests and chi-square tests of independence to determine whether the RPI and the PI group were equivalent with regard to age, gender, functioning level of autism spectrum disorder (ASD), and level of proprioceptive dysfunction. No significant differences were found between the RPI and the PI group for any demographic factors ($p > .05$). Table 2 outlines demographic information for each group.

Table 2

Demographic Information

Demographic Variable	Frequency		Mean (SD)		
	RPI	PI	RPI	PI	*p*
Age (in years)			6.67 (1.12)	6.33 (1.03)	.73
Gender					.39
Male	4	4			
Female	5	2			
Functioning Level					.52
High	1	2			
Mild	1	0			
Moderate	2	0			
Severe	5	4			
Proprioceptive Dysfunction			36.67 (7.97)	32.00 (12.43)	.15

NOTE: Equivalence between groups for age and proprioceptive dysfunction were measured using independent samples t-tests. Equivalence between groups for gender and functioning level were measured via chi-square tests of independence.

Comparison Between Groups on Attentional Outcomes

A series of independent samples *t*-tests were conducted on the following five measures assessed following the RPI and PI experiences: visual omissions, commissions, and response time on the P-CPT, and correct responses on auditory sustained and selective attention tasks within the MAA-RC II. Results from the visual attention assessment (P-CPT) indicated a statistically significant difference on rate of commissions in the visual sustained attention task compared to the PI group ($t(13) = -1.53$, $p = .007$). The RPI group had significantly fewer commissions than the PI group RPI($M = 5.11$, $SD = 4.65$) PI($M = 12.50$, $SD = 13.59$). However, no statistically significant mean difference emerged for number of omissions ($t(13) = -0.82$, $p = .94$) and response time ($t(13) =

-0.10, $p = .57$) between the RPI and PI group. The RPI group had a lower mean of omissions than the PI group [RPI($M = 11.56$, $SD = 9.63$) PI($M = 15.83$, $SD = 10.30$)] as well as a lower mean response time in milliseconds than the PI group [RPI($M = 828.53$, $SD = 226.42$) PI($M = 840.32$, $SD = 202.67$)].

Results from the music attention assessments indicated no statistically significant differences between groups on the measures of auditory sustained attention ($t(13) = 2.23$, $p = .333$) or auditory selective attention ($t(13) = 1.58$, $p = .756$). Children in the RPI group had a higher mean of correct responses on the auditory sustained attention task than children in the PI group: RPI($M = 5.89$, $SD = 2.57$) PI($M = 3.17$, $SD = 1.84$). Within the auditory selective attention task children in the RPI group also had a higher mean of correct responses than children in the PI group: RPI($M = 5.22$, $SD = 2.64$) PI($M = 3.33$, $SD = 1.51$). Table 3 displays results of independent sample t-tests for each group across each attentional outcome.

Clinical Significance of Study Variables on Attentional Outcomes

Eta-squared (η^2) was utilized as a measure of effect size to determine the percentage of between groups variance in attentional outcomes accounted for by each study variable. Within the visual attention assessment, functioning level explained 16.8% of the variance in omissions, 9.9% of the variance in commissions, and 35.5% of the variance in response time. Level of proprioceptive dysfunction explained 21.7% of the variance in omissions, 1.5% of the variance in commissions, and 7.5% of the variance in response time. Condition explained .7% of the variance in omissions, 5.5% of the variance in commissions, and 6.2% of the variance in response time, and the interaction between functioning level and condition explained 12.8% of the variance in omissions, 0.0% of the variance in commissions, and 1.60% of the variance in response time.

Table 3

Results from Independent Sample T-tests Comparing RPI and PI Attentional Outcomes

Assessment	RPI		PI			
	M	*SD*	*M*	*SD*	*t*(13)	*p*
Visual Sustained Attention: Omissions	11.56	9.63	15.83	10.30	-0.82	.94
Visual Sustained Attention: Commissions	5.11	4.65	12.50	13.59	-1.53	.007*
Visual Sustained Attention: Response Time	828.53	226.42	840.32	202.67	-0.10	.57
Auditory Sustained Attention	5.89	2.57	3.17	1.84	2.23	.333
Auditory Selective Attention	5.22	2.64	3.33	1.51	1.58	.756

* Indicates a statistically significant result

Within auditory sustained attention scores, the percent of the variance accounted for by functioning level was 15.7%, 7.0% by level of proprioceptive dysfunction, 14.6% by condition, and 4.8% by the interaction between functioning level and condition. Functioning level explained 2.4%, level of proprioceptive dysfunction explained 4.1%, condition explained 6.1%, and the interaction between functioning level and condition explained 2.8% of the variance in auditory selective attention scores. Table 4 displays results of eta-squared analysis.

Table 4

Effect Size of Study Variables on Attentional Outcomes

Variables	η^2				
	Visual Sustained Attention: Omissions	Visual Sustained Attention: Commissions	Visual Sustained Attention: Response Time	Auditory Sustained Attention	Auditory Selective Attention
Functioning Level	.168**	.099*	.355**	.157**	.024
Level of Proprioceptive Dysfunction	.217**	.015	.075*	.070*	.041
Condition	.007	.055	.062*	.146**	.061*
Functioning Level*Condition	.128*	.000	.016	.048	.028

* Indicates moderate effect size

** Indicates large effect size

Effects of Proprioceptive Dysfunction and Functioning Level on Attention

The student-investigator conducted a series of ANCOVAs to assess the extent to which the covariate measures of level of proprioceptive dysfunction and functioning level of ASD contributed towards outcomes based on the treatment conditions. The ANCOVA controlling for proprioceptive dysfunction found that the effect of condition was not significant (p = .39). When controlling for functioning level it was also found that the effect of condition was not significant (p = .56). Homogeneity of slopes was tested and found to be not significant across all attentional outcomes (p > .05).

In order to further analyze whether level of proprioceptive dysfunction or functioning level of ASD influenced the effectiveness of the treatment conditions, a series of ANCOVAs were conducted. A 2x4 ANCOVA between subjects factor of condition and functioning level controlling for proprioceptive dysfunction found that the overall model for omissions within the visual sustained attention task was not significant $F(5,9) = 1.02$, $p = .46$. It was also found to be non-significant for commissions $F(5,9) = 0.63$, $p = .68$ and response time $F(5,9) = 1.05$, $p = .45$. The ANCOVA also found that the overall model was not significant for auditory sustained attention $F(5,9) = 1.75$, $p = .22$ and auditory selective attention $F(5,9) = 0.58$, $p = .72$. Table 5 provides results for ANCOVAs across each attentional outcome.

Table 5

Analysis of Covariate Measures on Attentional Outcomes: Corrected Overall Model

Assessment	*df*	*df* error	*F*	*p*
Visual Sustained Attention: Omissions	5	9	1.02	.46
Visual Sustained Attention: Commissions	5	9	0.63	.68
Visual Sustained Attention: Response Time	5	9	1.05	.45
Auditory Sustained Attention	5	9	1.75	.22
Auditory Selective Attention	5	9	0.58	.72

Chapter 5

Discussion

Children with ASD commonly experience deficits in processing proprioceptive input (Blanche et al., 2012). Such deficits result in sensory dysfunction, which impacts attentional regulation (Ashburner, Ziviani, & Rodger, 2008; Bonnel et al., 2003; Eaves & Ho, 1997; Heaton, 2003). Ability to attend to a task is necessary for higher-level cognitive processes and activities of daily living (Colombo, 1993; Colombo, 2002; Fagan & McGrath, 1981; Hunnius, 2007). Thus, strategies to improve attention through facilitating sensory integration are in need of being explored. The purpose of the current study was to examine how a multimodal sensory intervention combining rhythmic auditory stimuli and proprioceptive input could enhance sensory integration and, thus, impact attention.

The research questions within the present study analyzed the immediate effects of rhythmic proprioceptive input and proprioceptive input on attention and explored the differences between the effects of the two conditions. Furthermore, the student-investigator analyzed whether level of proprioceptive dysfunction and/or functioning level of ASD influenced the effectiveness of both conditions on attention.

Results from the current study indicate that children who received the combined rhythmic proprioceptive input (RPI) performed significantly better on one visual attention task (number of commissions) than those in the proprioceptive input (PI) only condition. However, there was no statistically significant differences between groups on measures of omissions, response time, and sustained and selective auditory attention. Nonetheless, analysis of effect size demonstrated moderate to large effects for condition as a predictor of improved response time and auditory sustained and selective attention. Furthermore, there were no significant differences in the effectiveness of either interventions based on the functioning level of ASD or the level of proprioceptive dysfunction. Thus, neither covariate effected the attentional outcomes and the condition resulted in similar effects regardless of the level of proprioceptive dysfunction or functioning level of ASD.

Despite a lack of statistical significance, differences were noted between the RPI and PI groups. The RPI group performed better across all measures — fewer omissions, quicker response time, and a higher number of accurate responses in auditory attention tasks—and did have significantly less commissions during the visual attention task than the PI group. As commissions refer to the number of times the participants touched an animal that was not the target (i.e., the sheep) and children within the RPI group performed significantly fewer commissions, these results demonstrate that participants who received RPI exhibited an improvement in inhibition of responses. Additionally, moderate to large effects sizes for condition on measures of response time and auditory sustained and selective attention indicate that the RPI was a predictor of these attentional outcomes and clinically more effective than the PI condition.

Overall, while most measures did not show statistical significance, results allude to the RPI group performing better across all attention assessments. One potential mechanism underlying this improved performance involves the incorporation of rhythm. Furthermore, study findings highlight the need to develop more appropriate attention assessments for children on the spectrum.

The Influence of Rhythm on Attention

One possible explanation for study findings relates to the influence of rhythm on attention. For example, the incorporation of rhythm in the RPI intervention may have made a difference in the improved mean scores of the RPI compared to the PI group. The rhythm could have provided structure in the form of an organized temporal stimulus to facilitate enhanced cognitive focus and allowed the participants to better attend to and process the proprioceptive input. Research elsewhere has demonstrated that entraining to a rhythm modulates attentional responses (Bolger, Trost, & Schön, 2012). When attentional resources are oriented to a point in time via a steady rhythm, a sense of expectation is created and attention becomes heightened (Bolger, Coull, & Schön, 2014).

Furthermore, moderate to large effect sizes for condition were demonstrated on measures of response time and auditory sustained and selective attention, all measures of which contain a temporal element. In contrast, the other two measures of interest, omissions and commissions, did not contain a temporal component and displayed a small effect size. Thus, the temporal structure provided by the music may have most directly impacted attentional outcomes that contained temporal elements. Overall, the rhythmic auditory stimuli within the RPI intervention could have provided structure and a temporal cue which created a sense of expectation and further oriented the participants' attention to the intervention and attention assessments.

The student-investigator noted that as participants appeared to become less engaged during the visual sustained attention task, they began to touch all of the animals that appeared on the computer screen, thus committing more commissions. However, children who received RPI as opposed to PI performed fewer commissions, which may represent a heightened ability to inhibit responses. Inhibition relates to attention as it refers to the ability to ignore competing stimuli within a situation or task (Howard, Johnson, & Pascual-Leone, 2014). Pascual-Leone (1984) argued that inhibition occurs automatically as a by-product of effortful attention in order to ensure that attention is primarily directed toward the relevant stimuli. Other researchers argue that inhibition is not a distinct process from attention, but rather relates to a heightened ability to control attentional resources toward relevant stimuli (Cohen, Dunbar, & McClelland, 1990; Kimberg & Farah, 1993; Morton & Munakata, 2002). While the precise relationship between attention and inhibition is still being researched, many researchers agree that the two constructs are related.

As inhibition is related to attention, the temporal structure provided by the rhythm during the RPI condition may have not only enhanced cognitive focus during the intervention, but enhanced cognitive focus for a duration of time following the intervention, which may have assisted with inhibition of response during the visual sustained attention task.

Neurally, the addition of rhythm could have enhanced attention by providing an additional layer of sensory stimulation to further engage the cerebellum and enhance sensory integration. Previous research has alluded to the benefits of multimodal sensory presentations that appeal to multiple perceptual channels in order to heighten sensory integration (Bruce, Desimone, & Gross, 1981; Downar et al., 2000; Kavounoudias et al., 2008; Macaluso & Driver 2001; Thaut, 1984). As proprioceptive input, rhythm, sensory integration, and attention are processed in the cerebellum (Ayres, 1972; Gao et al., 1996; James et al., 1985; Liu et al., 2000), the combination of rhythm and proprioceptive input may have enhanced neural activity in the cerebellum, improving sensory integration and, thus, the ability to attend to a task (Grahn & Manly, 2012; James, 1984; James et al., 1985; Kavounoudias et al., 2008; Kellermann et al., 2012).

Behavioral evidence has further corroborated that rhythmic auditory stimuli can enhance attention. Listening to rhythmic patterns has demonstrated positive effects on sustained attention in children with ASD (Mahraun, 2004). Moreover, listening to background music has been shown to reduce hyperactive behaviors and improve attention in an academic setting and during the completion of attention tasks (Clauss, 1994; Mahraun, 2004; Scott, 1970). The tempi of the rhythmic auditory stimuli and music utilized within these studies was not described; however, different tempi may produce different attentional results as some children with ASD may perform better with faster tempi while others may perform better with slower tempi.

Attention Assessments

The current study brought to light the need for attention assessments designed for individuals across all functioning levels of ASD. During the course of study implementation, it was apparent that the attention assessments did not always meet the communication, cognitive, and proprioceptive deficits of participants across all functioning levels of the spectrum.

The first indicator was the P-CPT, an attention assessment designed for typically developing preschool children. The preschool version of this attention assessment was utilized within the current study because it was deemed more developmentally appropriate for school-aged children with ASD. However, certain limitations arose with the use of this assessment with individuals with proprioceptive deficits in ASD. The student-investigator noted that participants with more severe ASD did not always meet the cognitive criteria to complete the assessment. For example, the P-CPT requires participants to be able to discriminate animals and, in particular, be able to identify a sheep. During the practice stage of the assessment, some participants were unable to identify animals and could not discriminate the sheep. Therefore, the assessment was not applicable to individuals across the spectrum, in particular those with more severe cognitive deficits or developmental delays. This limitation was best displayed by the small effect size associated with the treatment condition's ability to predict omission and commission outcomes. As these outcomes were directly measured by correct versus incorrect responses, the level of cognitive difficulty and ability of participants with more severe cognitive deficits to complete the task may have influenced effect size. Thus, assessments that do not require an academic task may allow those with more severe ASD to be eligible for studies that utilize behavioral measures of attention. One alternative is to, for example, measure the amount of time an individual is able to remain seated, a behavioral indicator that has been utilized in other studies (Bagatell et al., 2010).

Furthermore, the P-CPT required participants to tap a computer touch screen with enough force that the screen recognizes the participant's tapping response. As individuals within the present study presented with proprioceptive deficits and proprioceptive deficits are associated with inappropriate grading of force and looseness of muscles and joints, the participants did not always grade force appropriately when touching the screen. Thus, there were times when participants did touch the screen and provide a response, but the response was not recognized by the computer. A more sensitive computer touch screen, or the utilization of buttons instead of a touch screen, may assist with this problem.

The MAA-RC II also presented with challenges. While the assessment was designed for individuals with high functioning ASD and modifications were made in order to make completion of the assessment more feasible for individuals across the spectrum (e.g., addition of visuals, shortened task, etc), individuals with more severe ASD, in particular more severe communication and cognitive deficits, struggled to follow directions and complete the task. When presented with visuals that displayed up, down, and sideways arrows to indicate the direction of the music, participants who presented with more severe communication deficits in ASD tended to fixate on one direction and choose the same response every time or would say or point to all three responses in order when prompted. Verbal prompts from the student investigator instructing the participant to pick one direction were not always successful. Participants also engaged in echolalia throughout the assessment, repeating the “up, down, or same,” prompt from the student investigator. Therefore, correct responses to the task were not always an accurate measure of attention. Providing two choices rather than three may have assisted participants in being able to pick one choice during the assessment. Individuals with ASD can present with executive functioning difficulties (Geurts, Verté, Oosterlaan, Roeyers, & Sergeant, 2004; Pennington & Ozonoff, 1996; Russell, 1997), a skill that encompasses decision making; therefore, fewer choices may have aided in communication and cognitive barriers.

Furthermore, individuals who could communicate adequately in order to complete the task did not always show the ability to discriminate higher, lower, and same pitch. The participants would demonstrate behaviors such as tapping or moving their hand to the music, which indicated attending to the auditory stimulus; however, their responses were inaccurate as they did not appear to understand how to discriminate pitch differences. Thus, accurate responses to pitch cues may not have represented attention. Concepts such as attending to when the music plays and stops or attending to tempo changes may be more developmentally appropriate for individuals on the spectrum than discriminating pitch direction.

The need for more appropriate standardized assessments for this population has been discussed elsewhere. The National Institutes of Health (NIH) identified a need for assessments that meet the unique and wide-ranging needs of individuals on the spectrum, particular individuals with minimal language. Current assessments present with severe limitations when utilized with minimally verbal children with autism and have impeded progress in research, leaving out a segment of the autism population that cannot adequately complete the assessments. Furthermore, current assessments tend not to provide an accurate depiction of the strengths and weaknesses of minimally verbal children with ASD. In 2010, the NIH organized a multidisciplinary workshop to discuss these issues and have cited further challenges in choosing appropriate assessments for individuals with ASD, particularly those with language delay, and have highlighted a need for more standardized assessments for this population (Kasari, Brady, Lord, & Tager-Flusberg, 2013).

Limitations

Study limitations influence the generalizability of study findings. Small sample size was the primary limitation to the study. A total of 15 children participated; however, a statistical power analysis demonstrated that in order to achieve a large effect size, the study needed to have a sample size of approximately 52 participants. Due to time constraints and difficulties presented by scheduling the study meeting around both parents' and participants' schedules, it was not feasible to gather enough participants to meet the large effect size standards. However, as the RPI group performed better overall than the PI group across all attention measures, it is possible that statistical significance may have been reached with a larger sample size. If this study is replicated, a larger sample size is recommended.

Difficulty in the pre-screening process was also a limitation of the study. The pre-screening process required parents to fill out a student-investigator designed questionnaire assessing their child's communication and direction-following abilities. In several instances, parents reported that their child could communicate verbally or gesturally; however, during the intervention protocol, the student investigator noticed that many of the participants either did not display any form of communication or the communication observed was echolalic in nature and not purposeful to the tasks at hand. Parental bias, possibly driven by the desire of parents for their child to be eligible for the study, may have played a role in inaccurate reports on the parent questionnaire. Previous research indicates that parental reports regarding behavioral and developmental concerns for their child are only in moderate agreement with developmental and behavioral assessments of their child (Sheldrick, Neger, & Perrin, 2012). Thus, parental bias has been demonstrated to occur on questionnaires with parents tending to report less concerns regarding their child's behaviors and development than is identified on standardized screenings of their child.

Clinical Implications

While this study was exploratory in nature and further research on the connection between rhythm, proprioception, sensory integration, and attention is recommended, the current findings suggest that when provided with a rhythmic proprioceptive input, children with ASD are better able to attend to visual and auditory stimuli. Thus in a music therapy setting, an RPI intervention could be utilized at the beginning of sessions or throughout, as needed, with children presenting with proprioceptive-seeking behaviors in order to help regulate their sensory systems before addressing other treatment goals and objectives. Music with high pulse clarity (e.g., with a strongly emphasized drum beat) should be selected to assist the child with learning to entrain their bounce to the music. This is especially important so that the child may learn to perform RPI by themselves, when needed, outside of the music therapy setting. Providing such sensory stimulation could assist the child in attending better during the session, thus helping them gain maximum benefits from music therapy.

Conclusions and Future Recommendations

The purpose of this study was to examine the immediate effects of rhythmic auditory stimuli combined with proprioceptive input on attention in children with autism spectrum disorder (ASD). Overall, children with proprioceptive deficits in ASD did perform better in auditory and visual attention tasks after receiving rhythmic proprioceptive input than individuals who received proprioceptive input alone. Since the current study suggests better attentional outcomes when rhythm is combined with proprioceptive input, future research with a larger sample size is needed to further explore these outcomes and how rhythm, in particular, functions to enhance sensory integration and attention.

Future research utilizing attention assessments that are better designed for individuals within all functioning levels of ASD would be more inclusive and provide a more accurate representation of how rhythmic and/or proprioceptive input can enhance attention. For example, measuring attention as a construct of in-seat behavior during class time may provide a more accurate measure of attention and results that are more generalizable to everyday settings. In-seat behavior is also a construct that can be measured in all individuals on the spectrum because it does not require any specific level of cognitive or communicative functioning. Therefore, individuals with more severe ASD could also be included in and potentially benefit from information gained through the study.

Another option is to revise the study design to a repeated measures pre-test post-test design. Such a design would further control for the different functioning levels and cognitive abilities of individuals across the spectrum as each participant would serve as their own control. Utilizing the attention assessments within the present study, differences were noted in outcomes between individuals across the spectrum based on their communicative and cognitive abilities. Some individuals understood the directions of the assessments, while others showed no indication of understanding. Thus, comparing the outcomes of these individuals to each other may have provided inaccurate results. If individuals served as their own control and were administered a pre- and post-test, any improvement on the attentional measures could be more directly related as a result of the intervention itself.

Future research analyzing how rhythm and tempo may effect sensory integration and attentional outcomes is needed. In particular, the student-investigator recommends future studies that examine how different tempi may effect outcomes. As each individual with ASD is unique, they may respond to varying tempi differently from each other — some may perform better on attention tasks after listening to faster music, while others may perform better after listening to slower music.

In conclusion, participants who received a combined rhythmic proprioceptive input performed better, overall, than those who received only proprioceptive input. However, given the small sample size and challenges with the attention assessments, future research is needed to test the efficacy of the intervention and to explore how different types of music may enhance sensory integration and attentional outcomes in children on the autism spectrum.

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Appendix A

Recruitment Materials

Recruitment Flier

Music Therapy Study

1 Hourlong Session at the University of Miami Coral Gables campus

Interested in Participating in a Music Therapy Research Study?

The Effect of Rhythmic Proprioceptive Input on Attention in Children with Proprioceptive Deficits in Autism Spectrum Disorder (ASD): An Exploratory Study

Led by a board certified music therapist

Requirements & Eligibility

1. CHILDREN WITH ASD (AGES 5–8), FLUENT IN ENGLISH
2. DIFFICULTY PROCESSING PROPRIOCEPTIVE INPUT
3. COMMUNICATE VERBALLY AND/OR GESTURALLY AND FOLLOW SIMPLE ONE STEP DIRECTIONS

If interested, contact Allison Lockhart, MT-BC 954-937-7396

Request for Participation in a Research Study - Phone Script

The Effect of Rhythmic Proprioceptive Input on Attention in Children with Proprioceptive Deficits in Autism Spectrum Disorder (ASD): An Exploratory Study

Hello (insert name),

My name is Allison Lockhart. I am a music therapist in the masters of music therapy program in the Frost School of Music at the University of Miami.

Thank you for calling me in regards to the flyer that was sent home with your child that introduced a research study I am doing as part of my education. I am inviting children who are five to eight years old and on the autism spectrum to participate in this research.

I would like to tell you a little bit about the study. The purpose of this study is to help me learn how listening to music while bouncing on a therapy ball can be used to help children with autism improve their attention. I hope to have thirty to sixty children in the study. Your participation is completely voluntary. If you agree, you and your child will meet with me for one hour and during that hour your child will receive one 30 minute session with me that will include bouncing on a ball while either listening or not listening to music. After bouncing on the ball, your child will complete two attention assessments. One is a music game and the other a visual game. For our one hour meeting, we will schedule a time that is mutually convenient.

My purpose in talking with you today is to see if you are interested in learning more about the study and to answer any questions you may have. If you do want to learn more, the next step will be for us to schedule the research session. Again, we will need up to 60 minutes for this session. At the beginning of the research session, I will be asking you to give written information about your child. This information will determine whether or not your child is eligible to participate in this study like you read in the flyer. If your child is not eligible then I will not conduct a 30 minute session with you child. However, your time and willingness to participate is greatly appreciated. If your child is eligible, then we will shift to the last part of the meeting, which is a 30 minute session with me and your child. Please bring a source of entertainment for your child, such as an iPAD or book, to the session, so that they will have something to do while we discuss and fill out paperwork. Do you have any questions?

(Answer questions.)

Before we schedule a meeting, would you mind if I ask you a few quick questions to determine whether your child may be eligible to participate?

If a parent indicates yes, the following questions will be asked:

Does your child communicate verbally, through gestures, or in a different way?
Does your child understand English?
Can your child follow simple one-step directions from an unfamiliar adult?
Does your child ever display any sensory-seeking behaviors?

If the parent asks for clarification regarding sensory-seeking behaviors: Sensory seeking behaviors can include your child flapping his or her hands, jumping excessively, squeezing or requesting squeezes to his or her arms or legs, or wrapping him or herself in blankets or weighted objects in order to feel pressure.

If a parent says that they would prefer not to answer any questions: Thank you (parent name) for your time today and consideration. Have a wonderful day.

(Answer questions. Schedule session, if appropriate.)

If the child meets pre-screening eligibility requirements and a session is scheduled: Thank you (parent name) for your time today. I look forward to meeting you on (insert date) at (insert location). If you have any questions between now and then, please do not hesitate to contact me at 954-937-7396.

If the child does not meet the pre-screening eligibility requirements: Thank you (parent name) for your time today and your consideration. Have a wonderful day.

Appendix B

Informed Consent

University of Miami

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

The Effect of Rhythmic Proprioceptive Input on Attention in Children with Proprioceptive Processing Deficits in Autism Spectrum Disorder (ASD): An Exploratory Study

Allison Lockhart, Graduate Student
Masters of Music Therapy Student, University of Miami

Kimberly Sena Moore, Ph.D.
Assistant Professor of Professional Practice, Music Therapy
Frost School of Music, University of Miami

The following information describes the research study in which your child is being asked to participate. Please read the information carefully. At the end, you will be asked to sign if you agree to allow your child to participate.

REQUEST TO PARTICIPATE

You are being asked to participate in a research study. Staff at the Center for Autism and Related Disabilities (CARD) think that your child may be a good fit for this study.

The student investigator running the study is Allison Lockhart, a board certified music therapist and graduate student in the Masters of Music in Music Therapy program in the Frost School of Music at the University of Miami. The researcher in charge of the study is Dr. Kimberly Sena Moore, Assistant Professor of Professional Practice of Music Therapy at the Frost School of Music, University of Miami.

The student investigator is asking your child to take part in this research study because he or she is 5 to 8 years old and diagnosed with autism spectrum disorder. Research studies only include people who choose to take part. This document is called a consent form. Please read this consent form carefully and take your time making your decision. The student investigator will go over this consent form with you. Ask her to explain anything that you do not understand. Think about it before you decide if you want to take part in this research study. This consent form explains what to expect: the procedures and any risks and benefits if you agree for your child to be in the study.

BACKGROUND

This study is looking at how music and bouncing on a therapy ball can help a child on the autism spectrum improve their attention. Research has already been done to show that music listening and bouncing on a therapy ball can improve attention. The student investigator of this study wants to learn how music listening and bouncing on a ball together can be used to help children have better attention.

PURPOSE OF STUDY:

The purpose of this study is to examine the effect of bouncing on a therapy ball in rhythm to music on attention in children with Autism Spectrum Disorder (ASD).

PROCEDURES:

During our meeting, you will be asked to read an informed consent document and decide if you want to allow your child to participate. If you decide to allow your child to participate, I will explain to your child what he or she will be asked to do, and ask your child if he or she want to participate in the study.

After getting both you and your child's consent, you will be asked to complete two questionnaires to provide general information about your child. One questionnaire will provide information like age, name, and gender. Another questionnaire will provide information about behaviors (such as hand flapping and jumping) that you may or may not see your child do. Based on your answers to these questionnaires, I will determine whether or not your child is eligible to participate in this study. Signing of this consent form does not automatically mean that your child is eligible to participate in this study.

If your child is eligible to participate, you will be asked to help your child choose five songs that he or she likes from a song list made by the student investigator. The student-investigator will then randomly assign your child to one of two treatment groups: bouncing on a therapy ball in rhythm to music or bouncing on a therapy ball without music. Random assignment occurs by chance, like flipping a coin. You will then be asked to complete a survey answering questions about the social skills of your child. While you complete the social skills survey, the student investigator will take your child into a therapy room at the Center for Autism and Related Disabilities (CARD) and provide him or her with the treatment he or she were assigned to.

Depending on the treatment your child was assigned to, he or she will either bounce on a therapy ball in rhythm to popular children's music for 7 minutes or freely bounce on a ball without music for 7 minutes. After bouncing on the ball, your child will participate in two attention assessments given on the computer. The assessments will take no longer than 15 minutes and will teach the student investigator about how well your child is able to focus on activities after being given the treatment. After completing the assessments, your child's participation in the study will be complete and he or she will be free to go home with you. The length of time your child is expected to participate in the study is one day for 30 minutes.

RISKS AND/OR DISCOMFORTS:

This research is considered to be minimal risk. That means that the risks of taking part in this research study are not expected to be more than the risks in your daily life. There are no other known risks to you if you choose to take part in the study.

However, it is unlikely that there are absolutely no risks related with a study. Your child could fall off of the therapy ball during the session. The student investigator will hold the your child's waist or spot your child in order to prevent this from happening. Objects will be removed from the area so they are not near you child while he or she is bouncing. Your child could become frustrated at some points during the session if he or she becomes bored during the bouncing procedure or frustrated during the attention assessments. The student investigator has a lot of experience working with children on the autism spectrum. She will continually monitor your child for signs that indicate he or she is unwilling to continue participating in the session. Participation in the session will be voluntary.

BENEFITS:

Your child may benefit from this study through participating in a music therapy experience. It is possible that your child will benefit from this study by demonstrating improved attention, improved sensory integration, and/or improved mood following the study session. Since your child is only participating in one music therapy experience, any benefits gained will likely last for a short period of time immediately following the study session. However, your involvement in the study may help other children on the autism spectrum who have difficulty with sensory integration and attention. The study will help us learn how music can be used as a way to help children develop better sensory integration and attention skills.

ALTERNATIVES TO STUDY PARTICIPATION:

You have a right to not allow your child to participate in the research study. If you decide to not allow your child to participate, his or her current treatment and future treatment options at the CARD will NOT be impacted.

CONFIDENTIALITY:

The student investigator will do her best to keep the information you share confidential; however, it cannot be absolutely guaranteed. Individuals from the University of Miami Institutional Review Board (a committee that reviews and approves research studies), the U.S. Department of Health and Human Services (DHHS), and regulatory auditors may look at records related to this study to make sure we are doing proper, safe research, and protecting human participants. The results of this research may be published or presented to others. You will not be named in any reports of the results.

To ensure confidentiality, the student investigator will lock all paper document data collected on you (e.g. responses to questions) in a locked filing cabinet. All data collected will be assigned a code number. The master list of participant names and code numbers will be held separate from the raw data by the student investigator in a locked filing cabinet. All electronic data will be stored on the University of Miami's Box cloud storage system (like the google drive and dropbox systems). Access to the data will require a University of Miami userid and password and will only be able to be accessed by the investigator(s).

If you withdraw from the study at any time during the study procedures, your data will not be kept. It will be destroyed once you withdraw.

COMPENSATION:

There will be no compensation for participation in this research study.

RIGHT TO DECLINE OR WITHDRAW:

Your child's participation in this research study is voluntary. Your child is free to refuse to participate in the study or withdraw his/her consent at any time during the study. Your child's withdrawal or lack of participation will not affect the treatment he or she is receiving at the University of Miami or the Center for Autism and Related Disabilities (CARD). The investigator reserves the right to remove your child without your child's consent at such time that they feel it is in the best interest for your child.

CONTACT INFORMATION:

The principal investigator, Kimberly Sena Moore [(305) 284-3943][ksenamoore@miami.edu], or student investigator, Allison Lockhart [(954) 937-7396] [axl486@miami.edu], will gladly answer any questions you may have concerning the purpose, procedures, and outcome of this project. If you have questions about your rights as a research subject you may contact the Human Subjects Research Office at the University of Miami, at (305) 243-3195.

PARTICIPANT AGREEMENT:

I have read the information in this consent form and agree to allow my child to participate in this study. I have had the chance to ask any questions I have about this study, and they have been answered for me. I am entitled to a copy of this form after it has been read and signed.

______________________________ ______________________________

Name of child **Name of Parent/Legal Guardian**

______________________________ ________________

Signature of Parent/Legal Guardian **Date**

____

Name of person obtaining consent

______________________________ ________________

Signature of person obtaining consent **Date**

Appendix C

Child Assent Document

Project Title: The Effect of Rhythmic Proprioceptive Input on Attention in Children with Proprioceptive Deficits in Autism Spectrum Disorder (ASD): An Exploratory Study

Written child assent will not be sought due to the participants having a diagnosis of autism spectrum disorder. Instead, child assent to participate will be obtained verbally (e.g. stating "yes") or nonverbally (e.g. smiling, nodding "yes"), through the child's participation in the session, and through the student investigator's continual monitoring of child behaviors that indicate assent. The following script will be utilized before the treatment session to determine child assent to participate in the study:

My name is Allison, and I am learning about music, bouncing on a ball, and attention. I would like you to help me learn. If you want to help, you will be asked to bounce on a ball for 7 minutes. You may be listening to music while bouncing on the ball, or you may not be. After you bounce on the ball, you will play two games. During one of the games you will use your ears and listen to music, and answer some questions. During the other game you will use your eyes to find sheep on a computer. The games will take 15 minutes. Everything will take about 30 minutes. We will go to [insert location of where session will take place at the site] to bounce on the ball and play. If you don't feel like playing, you don't have to. You can stop at any time and that will be okay. Do you want to join me?

If a child agrees to participate, the student-investigator will begin the session with the child. If the child does not indicate assent, the student investigator will attempt, with the parent's permission, to reschedule the study session for a different day. If the child does not indicate assent at the rescheduled session or if the parent does not agree to reschedule the session, the parent and child will be thanked for their time and consideration.

During the study session, if the student-investigator observes signs that a child no longer wants to participate, the student investigator will initially attempt techniques such as redirection or positive reinforcement to encourage the child to continue to participate. If the participating child continues to exhibit an unwillingness to participate, the child will be asked if he or she would like to try again another day. If the child says or indicates "yes," the session will be rescheduled. If the child says or indicates "no," then it will be determined that the child has indicated a desire to no longer participate and he or she will be removed from the study.

Appendix D

Parent Questionnaire: General Information

Child(s) age: ____

Child(s) gender: ____

Parent Insights:

Is your child able to communicate verbally or gesturally? ☐ yes ☐ no

If yes, which is their preferred method of communication?
☐ verbally ☐ gesturally

Can your child follow simple, one-step, directions from an unfamiliar adult?
☐ yes ☐ no

If no, please explain.

____

____

Can your child understand English?
☐ yes ☐ no

Has your child ever had any previous therapies that addressed sensory integration?
☐ yes ☐ no

If so, what therapies?

____

____

Does your child have any diagnosis other than autism? ☐ yes ☐ no

If so, what diagnosis?

____

____

Anything else you would like to share?

____

____

Thank you for taking the time to help me get to know your child!

Appendix E

Song Selections

Please help your child choose 5 songs from the list that he or she likes.

1. Can't Stop the Feeling — Justin Timberlake (from "Trolls")

Timberlake, J., Martin, M. & Shelback. (2016). Can't stop the feeling [Recorded by J. Timberlake]. On *Trolls: Original motion picture soundtrack* [MP3 File]. New York, NY: RCA Records.

2. Just the Way You Are — Bruno Mars

Mars, B., Lawrence, P., Levine, A., Walton, K., & Cain, K. (2010). Just the way you are [Recorded by B. Mars]. On *Doo-wops & hooligans* [MP3 File]. New York, NY: Elektra Entertainment Group.

3. Life is a Highway — Rascal Flatts (from Disney's "Cars")

Cochrane, T. (2006). Life is a highway [Recorded by Rascal Flatts]. On *Cars: Original motion picture soundtrack* [MP3 File]. Nashville, TN: Lyric Street Records.

4. Uptown Funk — Mark Ronson (Covered by Kidz Bop)

Ronson, M., Bhasker, J., Mars, B., Lawrence, P., Gallaspy, D., & Williams, M. (2015). Uptown funk [Recorded by KIDZ BOP Kids]. On *Kidz bop 28* [MP3 File]. Beverly Hills, CA: Concord Music Group.

5. Yo Ho! A Pirate's Life For Me — Pirates of the Caribbean

Atencio, X., & Bruns, G. (2006). Yo ho (A pirate's life for me) [Recorded by Disney Chorus]. On *Disney's ultimate swashbuckler collection: Pirates of the caribbean* [MP3 File]. Burbank, CA: Walt Disney Records.

6. We Are The Dinosaurs — Laurie Berkner

Berkner, L. (2010). We are the dinosaurs [Recorded by L. Berkner]. On *The best of the Laurie Berner band* [MP3 File]. New York: NY: Two Tomatoes Records.

7. For The First Time in Forever — "Frozen"

Anderson-Lopez, K., & Lopez, R. (2013). For the first time in forever [Recorded by K. Bell & I. Menzel]. On *Frozen: Original motion picture soundtrack* [MP3 File]. Burbank, CA: Walt Disney Records.

8. In Summer — "Frozen"

Anderson-Lopez, K., & Lopez, R. (2013). In summer [Recorded by J. Gad]. On *Frozen: Original motion picture soundtrack* [MP3 File]. Burbank, CA: Walt Disney Records.

9. When Will My Life Begin — "Tangled"

Menken, A., & Slater, G. (2010). When will my life begin [Recorded by M. Moore]. On *Tangled: Soundtrack from the motion picture* [MP3 File]. Burbank, CA: Walt Disney Records.

10. Try Everything — Shakira (from "Zootopia")

Eriksen, M.S., Furler, S., & Hermansen, T.E. (2016). Try everything [Recorded by Shakira]. On *Zootopia: Original motion picture soundtrack* [MP3 File]. Burbank, CA: Walt Disney Records.

Appendix F

Treatment Session Script: Proprioceptive Input (PI) Condition

Instructions: Read the words in bold. Words not in bold provide further instruction.

Proprioceptive Input Condition

Today you get to bounce on a ball! I have my friend Mr. Bouncy (point to ball) **here and you get to sit on him and bounce up and down. You get to bounce on the ball for 7 minutes! I have my timer and when it rings you will be all done. I only have two rules, you will keep your bottom on the ball and look at the red circle on the wall in front of you, like this** (demonstrate bouncing properly on the ball.) **As long as you follow my rules you get to bounce however you want. You can bounce fast, slow, hard, soft, you can bounce any way you want to! We are also going to play the quiet game while we bounce on the ball. That means we are not going to talk. In the quiet game you will not talk until the timer goes off** (point to timer)**. I am going to sit behind you and keep my hand close to you to make sure you do not fall. So now you can go ahead and sit on the ball. I will help you sit on the ball if you need it.** (Allow child time to sit and get situated on the ball,. Assist if necessary.) **Okay, you are all ready. When I say, "Go" you can start bouncing. Remember when my timer rings, you are all done.** Prepare timer for 7 minutes, while pressing start say, **GO.** Place timer in front of the child so they can see it. If child talks to you while bouncing redirect them by saying **Remember we are playing the quiet game when we hear the music, so no talking** (hold up finger to mouth to make quiet sign). If the child begins to not sit with his or her bottom on the ball or stops looking at the red dot you may redirect by saying: **Keep your bottom on the ball** or **Keep looking at the dot.** When the child has one minute left to bounce say **You have one minute left. When the timer goes off you will be all done and we will then play some computer games.** When the timer rings say **All done with bouncing. Now stand up and follow me.** Walk over to a chair you have set up for child. Point to chair and say **Sit in chair.** If child follows direction, reinforce child for sitting by saying **Good sitting.** If child does not sit, continue to prom child until the sit in chair. Begin computer assessments by reading appropriate assessment script.

Appendix G

Treatment Session Script: Rhythmic Proprioceptive Input (RPI) Condition

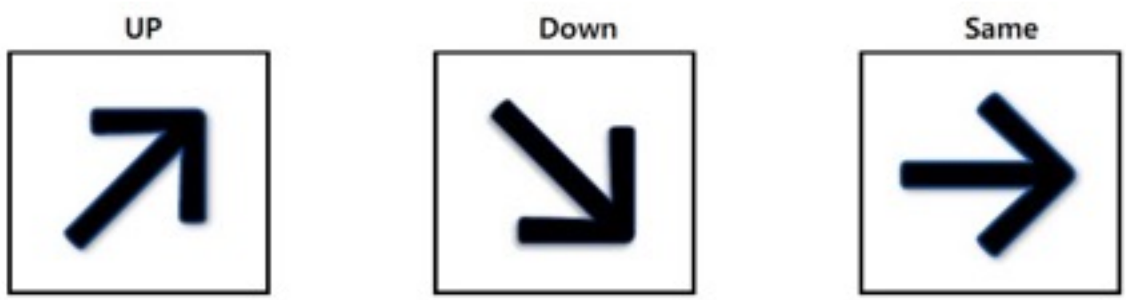
Instructions: Read the words in bold. Words not in bold provide further instruction.

Rhythmic Proprioceptive Input Condition

Today you get to bounce on a ball while listening to music! I have my friend Mr. Bouncy (point to ball) **here and you get to sit on him and bounce up and down. You get to bounce on the ball for 7 minutes! I have my timer and when it rings you will be all done. I only have two rules, you will keep your bottom on the ball and look at the red circle on the wall in front of you, like this** (demonstrate bouncing properly on the ball while being quiet.) **We are also going to play the quiet game while we bounce on the ball. That means we are not going to talk. In the quiet game you will not talk when the music is playing. I am going to sit behind you and put my hands on your hips** (demonstrate putting hands on your hips) **to help you bounce to the music and to make sure you do not fall. So now you can go ahead and sit on the ball. I will help you sit on the ball if you need it.** (Allow child time to sit and get situated on the ball, assist if necessary.) **Okay, you are all ready. When I say, "Go" we will start bouncing. Remember when my timer rings, you are all done.** Prepare timer for 7 minutes, while pressing start say, **GO.** Place timer in front of the child so they can see it. If child talks to you while bouncing, redirect them by saying **Remember we are playing the quiet game when we hear the music, so no talking** (hold up finger to mouth to make quiet sign). If the child begins to not sit with his or her bottom on the ball or stops looking at the red dot you may redirect by saying: **Keep your bottom on the ball** or **Keep looking at the dot.** When the child has one minute left to bounce say **You have one minute left. When the timer goes off you will be all done and we will then play some computer games.** When the timer rings say **All done with bouncing. Now stand up and follow me.** Walk over to a chair you have set up for child. Point to chair and say **Sit in chair.** If child follows direction, reinforce child for sitting by saying **Good sitting.** If child does not sit, continue to prom child until the sit in chair. Begin computer assessments by reading appropriate assessment script.

Appendix H

MAA-RC II Directional Arrows



Appendix I

Music-Based Attention Assessment-Revised for Children II (MAA-RC II) Script

Instructions: Read the words in bold. Words that are not bold provide further instruction.

We are now going to listen to some music. In some songs, you will hear the music go up, in some songs you will hear the music go down, and in some songs you will hear the music go straight. (Use vocal inflection to exaggerate and demonstrate what up, down, and straight sounds like). **Like this:** Open iTunes playlist of demonstration songs, play all three. Directly following each example, state which direction the music in the example went by saying, **The music goes up, the music goes down, the music goes straight.** While stating which direction the music goes, point to the corresponding arrow on the response sheet.

Following the demonstration say **Now it is your turn to practice. I am going to play some music. You will say which way the music goes and point to the arrow for which way the music goes. Remember it can go UP, DOWN, or STRAIGHT.** (Say these words while pointing to the arrows.) Play the first example and ask **Which way does the music go?** Wait for the child to respond. If the child does not respond, as the question again. If he/she still do not respond, provide a prompt for the child by saying **The music goes _______.** If the child does not respond provide a prompt by pointing to the correct arrow on the response sheet. Prompt again by saying **The music goes_____.** If the child still does not respond, say the answer for the child. **The music goes (up/down/straight.)** Repeat these steps until the child has completed all three practice example.

Following practice say **Now that we have practiced, we are going to play the music listening game. Remember, I am going to play some music. After each music clip you hear, you will tell me if the music goes UP, DOWN, or STRAIGHT.** (Say these words while pointing to the arrows.) Open up the sustained attention playlist on iTunes. Select shuffle on your iTunes playlist to play the examples in a random order. Play the first example. After the example ask **Which way does the music go?** Wait for the child to respond. If the child does not respond, ask the question again. If he/she does not respond again, ask the question one more time. You will ask the question 3 times in order to give the child 3 opportunities to answer. If the child does not respond after being asked three times, move on to the next example. If the child still does not respond after being played the second sample, you may terminate this portion of the session. If the child is responding, continue with these steps until the child has listened to all 12 sustained attention examples.

If the child was able to complete the sustained attention portion of the assessment without termination move on to the selective attention assessment portion. Now you will open the selective attention playlist on iTunes. Select shuffle on your iTunes to play the examples in a random order. Say, **Now we are going to listen to some more music. You may hear some different sounds with the music. Keep listening to the music and after each**

music clip you hear, you will tell me if the music goes UP, DOWN, or STRAIGHT. (Say these words while pointing to the arrows.) Play the first example. After the example ask **Which way does the music go?** Wait for the child to respond. If the child does not respond, ask the question again. If he/she does not respond again, ask the question one more time. You will ask the question 3 times in order to give the child 3 opportunities to answer. If the child does not respond after asked three times, move on to the next example. If the child still does not respond after being played the second sample, you may terminate that portion of the session. If the child is responding, continue with these steps until the child has listened to all 12 selective attention examples.

After the have completed the assessment say **Great job, you listened to all the music!**

Appendix J

Pre-school Continuous Performance Test (P-CPT) Script

Instructions: Read the words in bold. Words not in bold provide further instruction.

Now we are going to play a farm animal game! First I'm going to show you the animals we are going to see.

[Select the Animal Visuals menu option]

Here are the animals and you can touch and pet them, like this (demonstrate on the dog). **Do you want to try the other animals?** After the child finishes touching and petting all the animals, say **Now today on the farm, the farmer was feeding all the animals, but he forgot to feed the sheep, so the sheep are REALLY hungry. It's your job to feed the sheep. I'm going to change the screen in a second and every time you see the sheep, I want you to touch his belly, like this** (demonstrate) **and that will put food in his belly! I don't want you to feed the other animals because they already ate their food. You are only going to feed the sheep.** The experimenter practices with the child by saying**, Do we feed the dog? Do we feed the horse? Do we feed the sheep?**

[Close Animal Visuals, then Start a new game with the "Visual" option selected]

Ok, remember you are only going to feed the sheep, so when you see the sheep touch his belly.

[If needed, *occasionally* remind the child to keep feeding/only feed the sheep]

Appendix K

MAA-RC II Scoring Sheet

Participant ID #: ________________________

Date: ____________________________

Sustained Attention	Selective Attention
1.)	1.)
2.)	2.)
3.)	3.)
4.)	4.)
5.)	5.)
6.)	6.)
7.)	7.)
8.)	8.)
9.)	9.)
10.)	10.)
11.)	11.)
12.)	12.)