The Effect of Auditory Pitch Range on Sustained and Selective Attention: A Comparison of Children with Autism Spectrum Disorder and Typically-Developing Children

Hyun-Jung Lee
University of Miami, hexe96@hanmail.net

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THE EFFECT OF AUDITORY PITCH RANGE ON SUSTAINED AND SELECTIVE ATTENTION: A COMPARISON OF CHILDREN WITH AUTISM SPECTRUM DISORDER AND TYPICALLY-DEVELOPING CHILDREN

By

Hyun-Jung Lee

A DISSERTATION

Submitted to the Faculty of the University of Miami in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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the requirements for the degree of
Doctor of Philosophy

THE EFFECT OF AUDITORY PITCH RANGE ON SUSTAINED AND SELECTIVE
ATTENTION: A COMPARISON OF CHILDREN WITH AUTISM SPECTRUM
DISORDER AND TYPICALLY-DEVELOPING CHILDREN

Hyun-Jung Lee

Shannon K. de l’Etoile, Ph.D.
Professor of Music Therapy

Don D. Coffman, Ph.D.
Professor of Music Education

Teresa Lesiuk, Ph.D.
Associate Professor of Music
Therapy

Michael Alessandri, Ph.D.
Clinical Professor of Psychology

Christopher L. Bennett, Ph.D.
Research Assistant Professor of
Music Engineering Technology

M. Brian Blake, Ph.D.
Dean of the Graduate School
The purpose of this study was to examine the effect of pitch range (i.e., high vs low) in a simple, musical context on sustained and selective attention in children with Autism Spectrum Disorder (ASD) and typically-developing (TD) children. This study also explored the effect of different types of distracting sounds on selective attention in both groups. Existing research indicates that music-based interventions or background music during cognitive tasks can promote attention in children with ASD. However, no published study has yet explored the effects of specific musical elements, such as pitch range, on attention in children with and without ASD. Thus, the present study addressed a current void in the research literature.

A total of 70 children with and without ASD completed the Music-Based Attention Assessment-Revised for Children II (MAA-RC II). The MAA-RC II is a melodic-contour identification test, including sustained and selective attention subtests. For each subtest, target melodic contours are presented in three directions: ascending, descending, and stationary. Equal numbers of items are presented either at a low pitch range (i.e., 220 Hz to 523.55 Hz) or at a high pitch range (i.e., 1046.5 Hz to 2637 Hz) in a keyboard timbre. During the selective attention subtest, participants heard a recorded continuous (i.e., water flowing), fluctuating (i.e., bird song), or intermittent sound (i.e., woodblock)
against each target melodic contour as an auditory distraction. In both attention subtests, participants listened to each melodic contour and identified the direction of the melody. The independent variables were pitch range, population, type of attention task, and type of distracting sound. The dependent variable was the frequency of correct responses to the MAA-RC II.

The most prominent finding in the present study was the lack of a significant difference between the two groups regardless of pitch range, type of attention, or distracting sound. These results imply that children with ASD, similar to TD children, can understand and complete a music-based attention task and can maintain attention to simple music stimuli. Results suggest that music is an appropriate sensory stimulus for attention in children with and without ASD.

Results revealed that children with ASD achieved significantly higher scores on the sustained attention subtest when the stimulus consisted of a low pitch range rather than a high pitch range. This finding indicates that children with ASD might attend differently to sound depending on pitch range. Specifically, children with ASD might be more attentive to low-pitched sounds compared to high-pitched sounds. In addition, although the inferential results demonstrated no statistical significance, the descriptive results indicated that both TD children and children with ASD achieved higher MAA-RC II scores in both sustained and selective attention subtests when they heard target melodies at a low pitch range compared to a high pitch range.

Moreover, both TD children and children with ASD successfully completed the MAA-RC II with a fair degree of accuracy for both sustained and selective attention subtests. Additionally, Cronbach’s alpha for internal consistency of the MAA-RC II was
high, indicating that simple music stimuli can be a reliable tool to assess sustained and selective attention in children with and without ASD. Based on these findings, music therapists and other professionals who work with children who have ASD can gain valuable information about the relationship between pitch range and attention for this population. The findings may also contribute to scientific evidence for the therapeutic use of music for improving attention, and may inform the diagnostic use of music for children who have attentional problems.
Acknowledgements

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Chapter One

Introduction

Statement of the Problem

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder associated with social-communication deficits, as well as restricted and repetitive interests and behaviors (American Psychiatric Association, 2013). Among other symptoms, children with ASD frequently show disturbances in different aspects of attention (Burack, 1994; Meindl & Canella-Malone, 2011; Reed & McCarthy, 2012; Yerys et al., 2009; Zwaigenbaum et al., 2005). Attentional processes are prerequisite to the development of higher cognitive functions; therefore, these attentional deficits may prevent children with ASD from obtaining optimal benefits from therapies or educational interventions, and may interfere with the development of social and communication skills.

Observational and empirical evidence shows that children with ASD frequently demonstrate difficulties with different types of attention, including sustained, selective, alternating, and joint attention. In studies of sustained attention, children with ASD appear to remain fixated on a particular stimulus while ignoring other stimuli more so than do typically-developing (TD) peers and peers with other disabilities (Landry & Bryson, 2004; Zwaigenbaum et al., 2005). Liss, Saulnier, Fein, and Kinsbourne (2006) also describe children with ASD as being overfocused due to sensory overarousal, as well as having perseverative behaviors and interests.

Early research found that for adults with ASD, selective attention is more impaired by the presence of distracters than for adults without ASD (Burack, 1994; Ciesielski, Courchesne, & Elmasian, 1990). Recent research also reported that when compared to adults without ASD, adults with ASD show longer reaction times for correct responses and perform less accurately with distracters on visual selective attention tasks.
(Remington, Swettenham, Campbell, & Coleman, 2009). Individuals with ASD also have deficits in shifting attention. For example, children with ASD display poor performance in situations where they are required to switch attention within the same modality, especially the visual modality (Yerys et al., 2009), as well as between different modalities (i.e., visual and auditory stimuli) (Reed & McCarthy, 2012).

In addition, children with ASD experience difficulty with joint attention. Joint attention refers to the ability to coordinate attention with another individual on a specific object or event through the use of verbal or nonverbal behaviors (Morales et al., 2000; Mundy & Acra, 2006). In contrast to children with other disabilities and without disabilities, children with ASD initiate joint attention less often and are less responsive to attempts at engaging them in joint attention (Dawson et al., 2003). Overall, children with ASD commonly demonstrate impairments both in initiating and responding to joint attention (Meindl & Canella-Malone, 2011).

Attentional deficits in children with ASD may interfere with the development of higher cognitive functions and prevent them from receiving the benefits of educational interventions. All types of attention contribute to the developing system of behaviors and responses that allow for greater self-regulation of thought, behavior, and emotion (Posner & Rothbart, 2000). Particularly, attention acts as a filter to select and maintain relevant information, in order to process, memorize, and then acquire that information (Posner & Rothbart, 2005). Furthermore, recent studies have demonstrated a positive relationship between attention and academic achievement, including reading and mathematic acquisition in TD children (Anobile, Stieveno, & Burr, 2013; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012).
In spite of their attentional problems, however, research has demonstrated that children with ASD possess a musical sensitivity and a perceptual preference for music which may facilitate attention to music stimuli (Blackstock, 1978; Frith, 1972; Thaut, 1987). Thaut (1987) found that children with ASD have a significantly longer attention span for music stimuli than TD children. Furthermore, children with ASD maintained attention longer with music stimuli than with visual stimuli. Attention to music can also enhance attention to various cognitive tasks. A study by Clauss (1994) indicated that background music improves attention, problem solving, and working memory in children with ASD. More recently, Mahraun (2004) found that children with ASD perform significantly better on a sustained attention task while listening to music or rhythmic patterns than without such input.

Research also suggests that music effectively elicits joint attention in children with ASD (Kalals, 2012; Kim, Wigram, & Gold, 2008; Reitman, 2006). Kalas (2012) examined the effect of simple versus complex music on joint attention in children with ASD. Results showed that the simple music condition was more effective in eliciting joint attention for children with severe ASD, whereas the complex music condition was more effective for children with mild and moderate ASD. Further research demonstrates the beneficial effects of music therapy interventions on joint attention in children with ASD (Kim, Wigram, & Gold, 2008; Reitman, 2005). Reitman (2005) found that 7 out of 10 participants with ASD in her study demonstrated a significant increase in joint attention behaviors after a music therapy intervention. Kim, Wigram and Gold (2008) also suggest that improvisational music therapy facilitates joint attention behaviors in children with ASD.
Although the findings indicate that music can elicit sustained and joint attention in children with ASD, no published study has yet explored the effects of specific musical elements, such as pitch range, on attention. High-functioning children with ASD demonstrate adequate or superior pitch perception as measured by the ability to detect pitch differences and pitch directions, compared to TD children (Heaton, 2003, 2005; Heaton et al., 2007). These findings indicate that children with ASD can discriminate between sounds by pitch level. Although children with ASD possess pitch discrimination skills, they show decreased pitch discrimination with higher frequency sounds compared to lower frequency sounds (Bhatara, Babikian, Laugeson, Tachdjian, & Sininger, 2013). Similarly, TD adolescents also demonstrate decreased pitch discrimination with higher pitch sounds. This result suggests that children with ASD can discriminate sounds based on pitch level in a way that is comparable to children without ASD.

Another reason to believe that pitch range in music can influence attention stems from brain-imaging studies. Neuroscientific research demonstrates that an overlap exists between brain areas that process pitch and that regulate attention in TD individuals (Angenstein, Scheich, & Brechmann, 2012; Degerman, Rinn, Salmi, Salonen, & Alho, 2006; Hill & Miller, 2009; Satoh, Takeda, Nagata, Hatazawa, & Kuzuhara, 2001; Trainor, McDonald, & Alain, 2002). Findings regarding these shared brain areas suggest that perhaps pitch manipulation may capture a listener’s attention and subsequently facilitate general auditory attention. Activation of overlapping brain areas through music-based attention control training could strengthen attentional skills. However, the effect of pitch range on attention has not yet been explored, specifically in children with or without ASD, and may inform both diagnostic and treatment approaches.
Need for the Study

This study will provide both theoretical and practical implications by exploring the relationship between pitch range in music and attention in children with ASD. Although research indicates that music can elicit sustained and joint attention in children with ASD, there is a need for basic research that investigates the effect of pitch range on attention. This kind of research will offer a foundation for the use of music to assess attention deficits. Furthermore, results will contribute to the development of music-based intervention for facilitating attention in children with ASD.

Theoretical contributions. The effect of pitch range on attention has not yet been explored, thus the present study will fill a current void in the literature. This basic research will provide information on the relationship between pitch range and attention, thus offering initial and preliminary evidence that this musical element can affect attention. Attention is a fundamental cognitive process that helps individuals achieve more advanced cognitive functions. Demonstrating the role of pitch range on attention will offer valuable insights for other professionals in science and the arts, as well as professionals in the fields of neuroscience, neurodevelopment, psychology and audiology.

Additionally, the findings from this study will further the understanding of the relationship between pitch range and attention in clinical populations who have sensory perceptual issues and attention deficits, specifically children with ASD. Along with professionals, this study will also help family members and caregivers of children with ASD understand how pitch range can facilitate a child’s attention.

Practical contributions. The findings from this study will support the use of music as an attention assessment stimulus in children who have atypical sensory
perception, specifically children with ASD. For instance, music therapists as well as other professionals who work with children with ASD can use a music-based assessment to accurately identify the type and severity of attention deficits. Precise assessment is crucial for establishing effective goals and identifying appropriate treatments.

In addition, the results of this study will provide basic evidence necessary for the development of music-based interventions using pitch range to elicit attention. Specifically, music therapists and other professionals could use the findings to create music therapy interventions employing specific pitch ranges to improve attention in children with ASD. For example, music therapists can use stimuli with a certain pitch range during Musical Attention Control Training (MACT) (Thaut, 2005), a neurologic music therapy technique for facilitating attention, to help clients successfully select a target stimulus and stay focused on that stimulus.

Music therapists will also be able to select appropriate auditory distractions according to a client’s severity of attention deficits during attention training. For instance, if clients exhibit severe attentional problems, a therapist might use simple auditory distractors during MACT. In contrast, complex distracting sounds against target sounds might further challenge clients with mild attention deficits. This study will build a scientific foundation for the use of pitch range during music-based interventions, such as MACT, to improve attention.

**Purpose of the Study**

The purpose of this study is to assess the effect of pitch range in a simple, musical context on sustained and selective attention in TD children and children with ASD. This study will also compare the effect of different types of distracting sounds on attention.
during a selective auditory attention task. The distracting sounds include continuous, fluctuating, and intermittent sounds.
Chapter Two

Literature Review

This chapter will review research literature that is pertinent to understanding the effect of pitch range on attention in children with ASD. The first section will focus on research related to auditory attention in a non-musical context, including perceptual and neuroanatomical mechanisms for auditory attention and selective auditory attention in TD populations. The second section will explore attention to music, including research about perception and brain structures for attention to musical stimuli in TD individuals. The second section will also summarize commonalities between attention to pitch in non-musical and musical contexts. The third section will examine the relationship between music and attention in TD, clinical populations and individuals with ASD. Subsequently, the fourth section will explore auditory perception of children with ASD, such as pitch discrimination abilities and different perceptual responses to pitch ranges. This chapter will also present the purpose of the study and list the research questions.

Auditory Attention

Auditory attention is the ability to focus on specific sounds and process them to obtain meaning (Fritz, Elhilali, David, & Shamma, 2007; Kalinli, 2009; Wrigley & Brown, 2004). This ability allows for rapid and precise focus on sounds of interest in the acoustic environment. Auditory attention plays an important role in a broad range of activities including learning, social communication, and problem solving.

Auditory attention can be oriented by bottom-up or top-down mechanisms (Conway, Cowan, & Bunting, 2001; Fritz et al., 2007; Kalinli, 2009; Wood & Cowan, 1995). Bottom-up attention is a rapid, involuntary process which detects objects that perceptually “pop out” of a scene based on their salient features. For example, the sound
of a gunshot in a street will perceptually stand out against traffic noise on the street. Top-down attention is a task-dependent process which uses knowledge and experience to focus attention on the target stimulus in a scene. For instance, top-down attention allows a listener to extract a particular person’s speech in a crowded environment by focusing on acoustic cues such as pitch, timbre, and spatial location. Auditory attention can be captured by a bottom-up process or selectively directed by a top-down process (Fritz et al., 2007; Kalinli, 2009).

**Neuroanatomical evidence of auditory attention.** Most neuroimaging studies, including electroencephalogram (EEG), magnetoencephalogram (MEG), and functional magnetic resonance imaging (fMRI), find that attention to sound generally involves auditory cortex activity. In many cases, auditory attention has shown clear neuronal responses in the primary auditory cortex and secondary auditory cortical regions (Ahveninen et al., 2006; Brechmann & Scheich, 2005; Zatorre, Mondor, & Evans, 1999). Other research has reported greater effects of auditory attention in auditory association areas, including the superior and superior-lateral surfaces of the temporal lobe (Petkov et al., 2004). In addition to auditory cortical areas, imaging data have shown stimulation in the frontal and parietal systems. Auditory attention also activates the left precentral gyrus, the right posterior parietal cortex, and the left superior and the right temporal cortices (Mayer, Harrington, Adair, & Lee, 2006; Shomstein & Yantis, 2004, 2006).

Although task-specificity of processing and attentional demands differentially activate selective areas of the brain, auditory attention involves a distributed network of auditory cortical areas and subcortical structures, such as the basal ganglia and the cerebellum. In addition, attention to sound also integrates with a generalized
multisensory attentional network that includes the frontal, parietal, temporal, and anterior cingulated cortical regions.

**Selective auditory attention.** Selective attention is the ability to maintain a behavioral or cognitive set to task-relevant stimuli while ignoring competing stimuli (Mateer, 2000). In real-world auditory environments, people rely on voluntary selection to focus on meaningful signals from a cluttered background. In other words, selective attention can be achieved through top-down processing (Fritz, et al., 2007; Kalinli, 2009). Selective auditory attention provides a mechanism for determining which sounds will be most thoroughly processed and brought to awareness, to the exclusion of others (Strait & Kraus, 2011). One of the most widely-recognized examples of selective auditory attention is the “cocktail party” effect (Cherry, 1953). This well-known phenomenon occurs when people in a multi-source environment can voluntarily listen to their choice of speakers.

Selective auditory attention is vital in building one’s cognitive, behavioral, and language capabilities. It facilitates the ability to perceive speech in background noise (Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011; Strait & Kraus, 2011), and is central to the efficient use of cognitive functions, such as executive behaviors and working memory (Bialystok & DePape, 2009; Streb, Hille, Schoch, & Sosic-Vasic, 2012). Moreover, selective auditory attention can improve language-related skills, including vocabulary and reading abilities (Forgeard et al., 2008; Forgeard, Winner, Norton, & Schlaug, 2008).

**Neuroanatomical evidence of selective auditory attention.** Auditory attention can be selectively directed to a rich variety of acoustic features, including spatial
location, auditory pitch, frequency, or speech versus nonspeech streams (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999). Given the multiple dimensions of sounds and the closely interconnected auditory processing networks, selective auditory attention is likely to involve multiple neural regions in the brain. Such regions are flexible and depend on the specific demands of the behavioral task being performed (Fritz, et al., 2007). The evidence from functional brain imaging studies has established that selective auditory attention may be guided by both location and frequency cues. However, because of this current study’s purpose, only results relevant to pitch and selective attention will be discussed in this section.

Zatorre, Mondor, and Evans (1999) explored the brain areas involved in attending to the spectral and spatial features of sounds. Participants undergoing positron emission tomography (PET) completed various listening tasks which required detection of tones of a specified frequency. The results demonstrated that attention to pitch activated the bilateral auditory cortex, the right superior parietal region, the right dorsolateral frontal region, and the right premotor region. Furthermore, the pitch-related attention effects showed increased activation in the inferior frontal and parahippocampal areas. The findings of this study indicate that the performance of certain selective auditory tasks engages a specialized network of right-hemisphere regions. In particular, the joint participation of the right parietal, frontal, and temporal cortices contributes to a neural network for the deployment of selective auditory attention.

Later, Degerman, Rinne, Salmi, Salonen, and Alho (2006) also investigated the brain areas activated when attending to the location and pitch of sounds using fMRI. During auditory attention tasks, high and low pitch sounds were delivered randomly to one ear (left or right), and participants attended to the sounds. Regardless of which ear,
attention to pitch produced a stronger activation of the superior temporal gyrus (STG) in the right hemisphere than in the left hemisphere. These results also suggest that the right hemisphere plays a prominent role in selective attention for pitch. In addition, attention to pitch produced bilateral activity in the prefrontal areas, along with activity in the left posterior superior temporal cortex, and the right inferior parietal cortex.

Auditory attention can be selectively directed not only to spatial location and auditory pitch or frequency, but also to speech versus nonspeech streams. Pugh et al. (1996) examined selective auditory attention to both speech and nonspeech auditory perception tasks using fMRI. In one experiment, healthy adults discriminated between various speech stimuli or pitch stimuli under dichotic listening conditions, in which the speech stimulus was simultaneously played to one ear and the tone stimulus to the other ear. In this condition, participants were required to selectively attend to one stimulus while ignoring the other. Participants discriminated between two different phonemes (/ba/ and /da/) when they were instructed to focus on speech stimuli and judged pitch direction (rising and falling pitch) while they selectively attended to pitch stimuli.

When participants performed the tasks with speech or pitch stimuli in the dichotic conditions, the inferior and superior parietal, superior temporal, and inferior frontal regions were activated. These activations were greater in the right hemisphere than in the left hemisphere. Hemispheric differences between speech and nonspeech tasks were also observed, both in Broca’s area within the inferior frontal gyrus and in the middle temporal gyrus. The speech stimuli were associated with greater left hemisphere activation, while the pitch-related task was generally associated with greater right hemisphere activation during the dichotic listening task.

Despite the knowledge of pitch sounds in selective auditory attention and hemispheric differences between speech and nonspeech tasks, only a few studies have
explored the mechanisms of selective auditory attention during real-world, cluttered auditory environments. Hill and Miller (2009) used fMRI to investigate the neural mechanisms of selective auditory attention to natural speech under such high processing-load conditions. Participants experienced “cocktail-party” stimuli consisting of three simultaneous talkers while attending to a single talker, identified by the pitch of the target talker’s voice.

During selection of the target talker, pitch-based effects of selective attention showed bilateral activation of the superior temporal gyrus (STG), the superior temporal sulcus (STS), and frontal and parietal cortices. Additional activation was seen in the basal ganglia and the cerebellum. In particular, the right-dominant superior temporal sulcus (STS) was activated when participants identified the talker by pitch. This study demonstrates that in complex auditory scenes requiring a high processing load, the superior temporal sulcus (STS) regulates the use of selective auditory attention for pitch.

In summary, although task-specificity of processing and attentional demands differentially activate specific areas of the brain, neuroimaging studies demonstrate consistent activity in three distinct functional areas for selective auditory attention to pitch in a non-musical context. First, selective auditory attention for pitch utilizes widespread bilateral regions of the frontal lobe, including the prefrontal, inferior, and dorsolateral frontal areas. (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999). Second, selective auditory attention to pitch also involves the bilateral temporal lobe, especially the superior temporal gyrus (STG) (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999). Third, bilateral activations of the parietal lobe, including superior and inferior regions, occur during selective auditory attention to pitch (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999). Finally, even though selective auditory attention to pitch
activates bilateral regions of the brain, findings indicate stronger activations in the right hemisphere than the left hemisphere. (Degerman et al., 2006; Hill & Miller, 2009; Zatorre et al., 1999).

**Attention to Music**

Researchers have also explored selective attention to pitch, specifically within a musical context. Music is an auditory stimulus that encompasses various pitches, loudness levels, and timbres within a rhythmic framework (Koelsch, 2005; Patel, 2003; Radocy & Boyle, 2003). Because musical stimuli vary greatly in their content and complexity, a listener may choose to focus attention selectively on a target musical sound source (Janata, Tillman, & Bharucha, 2002). For instance, during an orchestral piece, a listener may sometimes focus attention selectively on the percussion, string, or wind instruments.

Although a mixture of musical sounds reaches the ears, a listener can select a particular acoustic source, such as a voice or a musical instrument. To explain this phenomenon, Bregman (1999) proposes a mechanism known as auditory scene analysis (ASA), which takes place in two stages. When listeners hear music, they first analyze the incoming auditory information into distinct musical lines or “streams.” This task is often considered as “pre-attentive” or an involuntary process. After this primitive segregation process, listeners use schema-governed attention to select one or more streams as primary. Wrigley and Brown (2004) point out that Bregman makes a distinction between these two different, but complementary, mechanisms involved in auditory grouping.

The pre-attentive stage of music listening can be achieved through a bottom-up process in which the auditory system groups musical stimuli into streams by salient features, such as timbre, pitch, or temporal proximity. This grouping process is well described by the Gestalt principles of perceptual organization, such as proximity,
similarity, continuity, closure, and common direction (Bregman, 1999; Wrigley & Brown, 2004). For example, timbrally bright pitches can be grouped together on the basis of similarity. These elements then capture attention by standing apart from a less timbrally bright background.

By contrast, during schema-governed attention, listeners can use a top-down process to select an array of stimuli that meet certain criteria (Bregman, 1999). A top-down mechanism employs prior knowledge of commonly-experienced musical stimuli, such as knowledge of tonal music. An example of this process would be recognizing a particular musical pattern that was heard several minutes earlier as a unit. Most researchers agree that attention to music occurs in two stages: first, bottom-up processing allows for stream identification, and, second, top-down processing drives stream selection (Kelly, 2011; Snyder, 2000; Wrigley & Brown, 2004). These two mechanisms theoretically explain how music stimuli facilitate attention. The following section will describe the neural regions activated during different pitch tasks in music in order to provide a neuroanatomical view of attention to musical stimuli.

**Neuroanatomical evidence of music and attention.** Brain imaging studies suggest that music perception involves wide-spread regions in both hemispheres. Listening to music engages distinct neural processes corresponding to the basic components of music. Several brain imaging studies have explored the different sub-components of musical elements, such as rhythm (Bengtsson et al., 2009; Platel et al., 1997; Popescu, Otsuka, & Ioannides, 2003), dynamics (Rinne et al., 2007), form (Koelsch, 2005; Sridharan et al., 2007), pitch (Platel, 1997; Satoh, Takeda, Nagata, Hatazawa, & Kuzuhara, 2001; Trainor et al., 2002), melody (Janata et al., 2002; Sridharan et al., 2007; Trainor, McDonald, & Alain, 2002), harmony (Satoh et al., 2001;
Sridharan et al., 2007), and timbre (Platel et al., 1997). Because of this current study’s purpose, findings relevant to pitch in music will be discussed in detail.

Platel et al. (1997) explored the cerebral structures involved in the appreciation of pitch in music. Participants underwent a positron emission tomography (PET) scan while completing a series of perception tasks in music. Researchers compared brain activation during a pitch change perception task with timbre perception and rhythm perception tasks. These comparisons revealed significant activation during the pitch change task in the left hemisphere, especially in the precuneus and cuneus, temporal gyrus, and superior frontal gyrus. These results indicate that perception of pitch changes relies mainly on the left hemisphere. In a related study, Trainor, McDonald, and Alain (2002) examined the cortical areas that process pitch contour and pitch intervals by measuring event-related potentials (ERPs). The results demonstrated that changes in both pitch contour and pitch intervals produced stronger activations in the right fronto-central regions compared to in the left side regions.

A later brain imaging study also investigated brain areas involved in pitch tasks. Angenstein, Scheich, and Brechmann (2012) explored active brain regions during the processing of pitch intervals and pitch direction using fMRI. During the pitch interval task, participants differentiated between semitone and non-semitone sequences. In the pitch direction task, participants decided whether pitches increased or decreased. Results showed that detection of pitch interval size primarily involved the right frontal and inferior parietal lobes and the right pre-supplementary motor area (pre-SMA). However, a stronger brain activation in the left frontal region was found when participants heard semitone sequences compared to non-semitone sequences during pitch interval tasks.

Regarding the pitch direction task, results demonstrated activations in the right hemisphere, including the anterior superior temporal gyrus (STG), the middle frontal
gyrus, and the parietal lobe. The results suggest that the detection of pitch interval size and pitch direction predominantly activate the right frontal lobe, the right parietal lobe, and the right pre-SMA, except in the case of perception of pitch in semitone intervals.

Few researchers have investigated the brain areas involved in selective attention to different levels of pitch in complex music stimuli. Satoh et al. (2001) measured changes in regional cerebral blood flow (rCBF) while participants concentrated on the alto part’s pitch contour in a four-part choral piece. The task produced increased bilateral activity in the superior parietal lobules, the precunei, the premotor areas, and the orbital frontal cortices.

In summary, pitch perception tasks in music tend to activate both left and right hemispheres of the frontal, temporal, and parietal regions. First, selective attention for pitch in musical context activates bilateral regions of the frontal lobe, including the prefrontal, and premotor areas and left superior frontal gyrus, right pre-SMA, and right middle frontal gyrus (Angenstein et al., 2012; Platel et al., 1997; Satoh et al., 2001; Trainor, et al., 2002). Second, selective auditory attention to pitch in musical stimuli involves the temporal lobe, including the right side of the superior temporal gyrus (STG) and the left temporal gyrus (Angenstein et al., 2012; Platel et al., 1997). Third, bilateral activations of the superior parietal lobe, the right inferior parietal regions, and precuneus/cuneus occur during selective auditory attention to pitch in music (Angenstein et al., 2012; Satoh et al., 2001). In addition, specificity of pitch tasks, such as pitch interval and pitch direction, lead to a stronger activation in one hemisphere than the other. Regarding pitch change tasks, brain activation occurs mainly in the left hemisphere, especially in the precuneus and cuneus areas, the temporal gyrus, and superior frontal gyrus (Platel et al., 1997). By contrast, tasks involving pitch interval size and pitch direction mainly activate the right hemisphere, including the frontal lobe, the parietal
lobe, and the pre-SMA (Trainor et al., 2002). In addition, selective attention to a specific level of pitch in complex music involves bilateral regions of the superior parietal and orbital frontal cortices, the precunei, and the premotor regions (Satoh et al., 2001).

**Selective attention to pitch in non-music and music stimuli.** Selective attention is the ability to maintain a behavioral or cognitive set to task-relevant stimuli while ignoring competing stimuli (Mateer, 2000). With both non-musical auditory stimuli and musical stimuli, selective auditory attention can be oriented by either bottom-up mechanisms or top-down mechanisms (Conway, Cowan, & Bunting, 2001; Fritz et al., 2007; Kalinli, 2009; Wood & Cowan, 1995). Thus, both stimuli appear to be processed via auditory scene analysis (ASA) that takes place in two stages, including the pre-attentive stage and the schema-driven attention stage (Bregman, 1999). In addition to these perceptual and functional commonalities between non-musical auditory stimuli and musical stimuli for attention, neuroanatomical research findings also show the structural commonalities between attention to pitch in non-musical and musical stimuli.

Numerous neural structures are activated during selective attention to pitch in non-musical auditory stimuli, including the bilateral regions of the frontal lobe: the prefrontal, inferior, and right dorsolateral frontal areas (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999). Selective attention to pitch also involves the bilateral temporal regions, especially the superior temporal gyrus (STG) (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999). In addition, the bilateral activations of the parietal lobe, including superior and inferior regions, occur during selective attention to pitch in non-musical stimuli (Degerman et al., 2006; Hill & Miller, 2009; Pugh et al., 1996; Zatorre et al., 1999).

The cortical areas activated during selective attention to pitch in musical stimuli contain the bilateral regions of the frontal lobe, including the prefrontal and premotor
areas, and left superior frontal gyrus, right pre-SMA, and right middle frontal gyrus (Angenstein et al., 2012; Platel et al., 1997; Satoh et al., 2001; Trainor et al., 2002). The temporal lobe, including the right side of superior temporal gyrus (STG) and the left temporal gyrus, is also activated (Angenstein et al., 2012; Platel et al., 1997). Additionally, the bilateral superior parietal regions, the right inferior parietal areas, and precuneus/cuneus are stimulated during selective attention to pitch in musical stimuli (Angenstein et al., 2012; Satoh et al., 2001).

Taken together, selective attention to pitch in either non-musical or musical stimuli involves: (a) the bilateral regions of the frontal lobe and the prefrontal lobe, (b) the right superior temporal gyrus (STG), and (c) the bilateral superior parietal lobe and the right inferior parietal cortex. These findings indicate a noticeable overlap of neural structures used in selective attention to pitch in both non-musical and musical stimuli. Interestingly, selective attention to pitch in complex music is associated with bilateral neural activation, while the right hemisphere plays a prominent role in selective attention to pitch in non-musical contexts (Degerman et al., 2006; Hill & Miller, 2009; Satoh et al., 2001; Zatorre et al., 1999). The brain areas utilized during selective attention to pitch in non-musical and musical contexts are presented in Table 1. Music stimuli may activate these overlapping areas, thus strengthening attention skills.

The common perceptual processes and brain structures used for pitch and attention provide a hypothesized foundation from which the researcher will explore the effect of auditory pitch range on attention. In an effort to examine this relationship, the following section will discuss research studies regarding the relationship between music and attention in TD individuals, clinical populations and children with ASD.
### Table 1

*Brain Areas Active During Selective Attention to Pitch*

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<tr>
<th>Brain Regions</th>
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Music and Attention

The effect of music on attention in typically-developing individuals.

Researchers have studied the effect of music on attention to task and academics in typically-developing (TD) individuals. For example, Shin, Huang and Chiang (2009) examined the effect of background music on the attention performance of college students. One group listened to background music during attention tests, another group received no background music, and one other group had background music prior to attention tests. Findings showed that the group that listened to music before testing obtained significantly higher scores on the attention tests than the group that heard background music during the tests. Both groups that listened to background music either during or before the tests also achieved significantly better scores than the group without background music.

In a later study, Leslie, Donald, and Greg (2010) used a similar process to explore the effect of background music on cognitive tasks with university students. They found that background music during the tasks significantly increased the speed of spatial processing and the accuracy of linguistic processing. Similarly, Champagne (2010) explored the effect of background music on the ability to perform computer-based visual attention tasks in university students. The researcher focused on two likely causes of attention effects in music: familiarity and complexity. Music conditions consisted of experimenter-selected, self-selected, complex, and simple music. The results demonstrated that all participants who listened to music during the tasks showed significantly higher scores on the attention task compared to participants who performed the same task in silence. However, no specific characteristics of the music made a significant difference among the groups.
Music can also promote children’s cognitive performance and enhance their attention skills. In an early study, DeMers (1996) investigated the effect of background classical music on academic achievement in fifth-grade children. Children in the experimental group were exposed to music daily for three weeks in order to become familiar with the playing of background music during reading. After the three weeks, the experimental group listened to classical music while taking a reading comprehension test, while the control group completed the test without music. The results revealed that the group that heard background music achieved significantly higher reading comprehension test scores than the group that heard no music. The researcher concluded that relaxing background music appears to be a stress-reducer in a test-taking situation and thus it helps students remain on task.

In contrast, Dartt (2009) found that in some situations background music could have an adverse effect on sustained attention in preschoolers during a play session. The results revealed that children paid significantly less attention to the play task while listening to background music than they did with no music. This finding suggests that music can work as a distractor, and therefore might decrease children’s sustained attention during play activities. However, Dartt’s key finding was that children with more musical experiences at home exhibited significantly longer periods of sustained attention to play activities with background music than their peers did. This finding indicates that extended musical experience may improve children’s attention to a task.

Another study explored the use of music to enhance children’s attention within academic and musical environments (Wolfe & Noguchi, 2009). Kindergarten students who listened to a story as a song were compared with children who listened to the same story spoken aloud. Both conditions were presented either with or without distracting sounds, and children were asked to identify specific actions and animals during the story.
The results revealed that participants reported a higher number of correct responses during the musical story conditions, with or without distraction, compared to the spoken story conditions, with or without distraction. Additionally, researchers found that participants in the musical story condition with distraction achieved a significantly higher number of correct responses than participants in the spoken story condition with distraction. The researchers suggest that music facilitates attention to tasks and helps students remain focused on tasks despite distractions.

**Music and attention in clinical populations.** Music also has a positive effect on attention in children with attention deficits. Research has shown a positive relationship between music, attention, and academic achievement in children with Attention Deficit/Hyperactivity Disorder (ADHD) (Abikoff, Courtney, Szeibel, & Koplewicz, 1996). Children with and without ADHD completed arithmetic tasks during musical, spoken, and silent conditions. Results showed that children without ADHD performed similarly under all three auditory conditions. In contrast, children with ADHD performed significantly better in the musical condition than in spoken or silent conditions. Researchers suggest that music increases arousal levels and facilitates attention to tasks in children with ADHD.

Another research study examined the effect of music on immediate improvements to on-task performance in three children with attention difficulties (Janbaz, 2009). Participants completed a homework assignment while listening and not listening to music. The findings showed that two of the three children demonstrated significantly better performance on the assignment with background music than they did without background music. The researcher suggests that background music can maximize alertness, allow relaxation, aid in learning, and improve academic performance.
Sussman (2009) compared the effects of musical and nonmusical elements on sustained and alternating attention toward peers in preschoolers with developmental disabilities. Students participated in activities which incorporated object passing and turn-taking in order to target peer awareness. Results indicated that activities utilizing a musical instrument resulted in significantly longer periods of sustained attention toward peers and a significantly higher frequency of alternating attention than activities utilizing a nonmusical object. These findings indicate that a musical instrument may be an effective stimulus to use when addressing sustained attention towards peers and alternating attention from peer to peer.

In addition to exploring the effect of music on attention in children with attention deficits, some researchers have examined music’s influence on attention in individuals with traumatic brain injury (TBI). Knox, Yokota-Adachi, Kershner, and Jutai (2003) evaluated the effect of a Musical Attention Training Program (MATP) on the alternating attention of an adolescent with TBI. Although researchers did not mention statistical significance, results showed that the treatment increased the patient’s ability to shift attention during a task. Researchers propose that the MATP may have stimulated the general arousal mechanism in the right hemisphere and facilitated bilateral hemispheric arousal, consequently improving alternating attention.

Further research has explored the effect of music on attention in adult clinical populations such as patients with schizophrenia and TBI. Khalaf-Baigi, Akbarfahimi, Ashayeri, Dorood and Doostdar (2011) investigated the effect of musical activities on attention to cognitive tasks in adult patients with schizophrenia. The experimental group participated in 24 music therapy sessions over two months, while the control group did not have any intervention. Results demonstrated that participants in the experimental group showed a significant reduction in reaction time during a cognitive task from the
pre- to post-test. However, results revealed no significant differences in reaction time during tasks between the experimental group and the control group.

The experimental group also showed significant increases in correct responses to a cognitive task from pre to post, but did not show significantly higher correct responses than the control group. These findings indicate that music can enhance task speed and accuracy. The researchers propose that musical elements; such as rhythm, tone, melody, and intensity, influence the functions of attention and subsequently improve productivity and correctness during cognitive tasks.

More recently, Jeong and Lesiuk (2011) developed and tested the Music-Based Attention Assessment (MAA) for adult patients with TBI. The MAA is a melodic contour identification test designed to assess three different types of attention, including sustained, selective, and divided attention. The test items of the MAA consist of three different melodic contours: ascending, descending, or stationary. Participants listen to 48 melodic contours, each of which contains nine notes presented in a major key. The sustained attention subtest requires participants to focus on and identify the direction of 16 melodic contours. For the selective attention subtest, participants identify the direction of 16 different melodic contours that they hear against a distracting sound. Using the final 16 contours, the divided attention subtest requires that participants identify the directions of two simultaneously presented contours.

Results showed that participants obtained the highest mean scores on the sustained attention subtest, followed in descending order by the selective and divided attention subtests. The test items in each of the three subtests had an easy to moderate level of item difficulty and an acceptable to high level of item discrimination; therefore, the MAA is appropriate for measuring a wide range of attention in patients with TBI. In addition, the internal consistency of the MAA as computed by Cronbach’s alpha was .95.
Therefore, the MAA has potential to provide diagnostic information in regard to the auditory attention of patients with TBI.

Later, Jeong (2011, 2013) administered the MAA to patients with TBI and typical adults. Results indicated that the MAA was too easy for the typical adult group, as evidenced by a ceiling effect. Therefore, the researcher modified the MAA (MAA-R) to increase item difficulty, and used it to test a larger sample of both healthy adults and adult patients with TBI. For test revision, the researcher varied the length of the test items for each subtest. For example, the test items of the MAA-R consist of a series of 5 tones, 10 tones, and 15 tones, as compared to the 9-tone items in the initial version of MAA. Exploratory factor analysis identified five factor constructs in the MAA-R indicating that attention sub-types involved in music contour identification are grouped primarily into three domains: sustained, selective, and divided attention (Jeong, 2011, 2013). Therefore, the MAA-R test items justify the use of melodic contours to measure the different attention subtypes.

Regarding MAA-R performance, the researcher found significant differences between the healthy adult and TBI groups. The healthy group received significantly higher scores on the long and medium versions of the sustained attention subtests than the TBI group, but not on the short version of the sustained attention subtest. Additionally, the healthy adult group achieved significantly higher scores on all three versions of the selective and divided attention subtests than the TBI patient group (Jeong, 2011). Using the combined scores of healthy adults and patients with TBI on the MAA-R, the researcher again found that participants obtained the highest scores on the sustained attention subtest, followed in descending order by the selective and divided attention subtests. The results provided evidence of high internal consistency (r = .836) and high Cronbach’s alpha (α = .940). The findings suggest that the MAA-R is a valid and reliable
measure to assess different types of auditory attention, including sustained, selective, and divided attention, in both healthy adults and patients with TBI.

**Music and attention in children with ASD.** A number of studies provide evidence that music-based interventions can elicit attentional behaviors as well as promote learning outcomes in children with ASD. Clauss (1994) examined the effect of music on attention and self-stimulation in children with ASD. Participants completed attention tasks while listening to slow tempo music, fast tempo music, and no music. Results indicated that slow and fast background music during the attention tasks significantly reduced self-stimulatory behaviors. In addition, participants made significantly more correct responses to the tasks with background music than without background music. In a related study, Mahraun (2004) found that children with ASD performed significantly better on a sustained attention task while they were listening to music or rhythmic patterns than they did without such stimuli. Additionally, the frequency of inappropriate behaviors during tasks decreased significantly while listening to music.

Similarly, Xu et al. (2010) explored the effect of different types of background music on sustained attention in children with ASD. Researchers presented a set of pictures to participants during different background music conditions: no music, nursery rhyme, percussion sound, and soothing piano music. Results showed that participants demonstrated significantly longer attention to the pictures during all kinds of background music than they did with no background music.

Some researchers have examined the effect of interactive songs during academic tasks in children with ASD. In a study by Simpson and Keen (2010), three young children with ASD learned graphic animal symbols by either spoken words or interactive
songs. Two of the three participants achieved a significantly higher rate of correct responses with the sung condition than with the spoken condition, suggesting that music helps increase attention during tasks. Later, Simpson, Keen, and Lamb (2013) investigated the effect of songs on language learning outcomes for children with ASD. Participants learned words using either sung or spoken recordings. Results indicated that children with ASD demonstrated significantly longer focused attention to the word-learning task in the sung compared to the spoken condition. Moreover, children with ASD achieved a significantly higher number of correct responses during the word-learning task in the sung condition than in the spoken condition, suggesting that music facilitates better learning outcomes.

Although current research demonstrates the positive effect of music on attention and academic learning outcomes in children with ASD, no published research has explored what specific musical elements impact attention in children with ASD. In order to investigate the relationship between auditory pitch range and attention in children with ASD, Lee (in press) revised the MAA (Jeong & Lesiuk, 2011) in a pilot study. Since the MAA was developed for an adult population with TBI, the researcher modified the MAA to be appropriate for children with ASD (MAA-RC). The primary differences between the MAA and the MAA-RC pertain to changes in the total number of items, the number of attention subtests, the length of the melodic contours, and the use of different pitch ranges. The total number of items for the MAA-RC (n=36) is less than in the MAA (n=48). The MAA consists of three different subtests, while the MAA-RC has two subtests, including sustained and selective attention. Regarding length of the melodic contours, each melodic contour in the MAA-RC consists of 3 tones as opposed to the
MAA contours which have 9 tones each. Most distinctively, The MAA does not emphasize pitch range of the contours, while the MAA-RC items are presented either at a low pitch range or at a high pitch range in order to examine the effect of pitch range on attention. For more detailed information on the MAA, see Jeong & Lesiuk (2011).

For each subtest in the MAA-RC, 18 target melodic contours consisting of 3 notes each are presented in three directions: 6 ascending, 6 descending, and 6 stationary. In each set of 6 items, 3 items are presented at a low pitch range (i.e., 220 Hz to 523.55 Hz) and the other 3 items are presented at a high pitch range (i.e., 1046.5 Hz to 2637 Hz) in a keyboard timbre. In both attention subtests, participants listen to each melodic contour and are asked to identify the direction of the melody by verbally answering and/or pointing to the corresponding arrow on the response sheet. During the selective attention subtest, the researcher presents a recorded continuous sound (i.e., water flowing) against each target melodic contour as an auditory distraction.

In Lee’s (in press) study, 20 high-functioning children with ASD ages 7 to 14 years completed the MAA-RC. Results demonstrated that children with ASD achieved significantly higher scores on sustained attention to melodies at a low pitch range than at a high pitch range. This result indicates that children with ASD might demonstrate a different level of sustained attention toward low versus high pitch sounds. However, the researcher found no significant differences between pitch ranges for selective attention. In addition, participants achieved a mean score of 14.8 out of 18 on the sustained attention subtest and 14.95 on the selective attention subtest. These findings demonstrate that high-functioning children with ASD can understand and complete a simple melodic-contour identification test with a fair degree of accuracy. Furthermore, Cronbach’s alpha
for internal consistency of the MAA-RC was .86. This result indicates that simple music stimuli can be reliably used to assess attention in children with ASD. However, this pilot study had some limitations, including a small sample size and lack of a typically-developing control group. Further investigation is needed using a larger sample size and a control group to increase generalizability.

To summarize, music-based interventions have been shown to be effective in establishing and maintaining attention in children with ASD. Although previous research has explored the relationship between pitch level and attention, more research needs to be conducted to determine specifically what kinds of musical components, such as pitch level, are most effective in facilitating and sustaining attention in children with ASD. A large amount of research indicates that high-functioning children with ASD possess adequate or superior pitch perception in comparison to TD children. The next section will explore pitch perception in children with ASD.

**Pitch Perception in Children with ASD**

**Pitch perception.** Pitch is one of the principal auditory sensations and plays a critical role in acoustic environments, such as music and speech (Moore, Fuchs, Rees, Palmer, & Plack, 2010; Oxenham, 2012). According to the American National Standards Institute, pitch is a subjective dimension of sound that orders sound from low to high (Yost, 2009). In music, sequences of pitch create melody and vertical combinations of pitch produce harmony. In speech, rising and falling pitch contours create prosody. In addition, differences in pitch can help listeners to discriminate and understand sound sources (Oxenham, 2012). Perception of pitch is subjective because a human listener will make a perceptual judgment about every pitch they hear (Moore, 2003; Oxenham, 2012; Yost, 2009).
Pitch is closely related to frequency, but the two constructs are not equivalent. Frequency is an objective, scientific concept, whereas pitch is subjective (Howard & Angus, 2008). Sound waves themselves do not have pitch, yet their oscillations can be measured to determine frequency. Pitch is usually quantified as frequency in cycles per second, or hertz, thus different frequencies generate different pitches (Moore, 2003; Moore, Fuchs, Rees, Palmer, & Plack, 2010). The range of pitch perception in humans is commonly given as 20 to 20,000 Hz, though individuals vary considerably depending on developmental level, generic factors, or hearing loss (Moore, 2003; Moore et al., 2010). However, human ability to detect changes within a melodic line depends on the pitch range. If the range is between 30 and 5,000 Hz, the listeners can accurately detect the melodic differences. Outside 30 to 5,000 Hz, pitch changes are perceived, but are not sufficient for recognition of melodic intervals (Attneave & Olson, 1971; Pressnitzer, Patterson, & Krumbholz, 2001).

Pitch perception can be most commonly explained by place theory or temporal theory (Howard & Angus, 2006; Luo, Padilla, & Landsberger, 2012; Mather, 2009; Moore, 2003; Moore et al., 2010; Oxenham, 2012, 2013). Place theory states that the perception of pitch depends on where each frequency produces vibrations along the basilar membrane. According to temporal theory, the perception of pitch is determined by differences in time intervals between neuronal firings of hair cells within the cochlea (Howard & Angus, 2006; Luo et al., 2012; Mather, 2009; Oxenham, 2012, 2013; Yost, 2009). Currently, research suggests that pitches below 1,000 Hz are processed by a temporal mechanism, while pitches between 1,000 Hz and 2,000 Hz are operated by a mixture of both temporal and place mechanisms, and pitches above 2,000 Hz are managed by a place mechanism (Moore, 2003; Palmer & Russell, 1986). In conclusion, each theory alone may not be sufficient to explain all aspects of pitch perception, which
suggests that pitch may be perceived with combined place and temporal mechanisms depending on pitch ranges (Luo et al., 2012; Moore, 2003; Oxenham, 2012, 2013; Palmer & Russell, 1986).

**Pitch discrimination.** This present research requires participants with ASD to discriminate sounds by pitch level. Across several studies, children and adolescents with ASD have demonstrated adequate or enhanced auditory perception as measured by the ability to detect pitch differences and pitch direction, compared to TD children and adolescents. In one study, researchers tested pitch perception using pitch discrimination and pitch categorization tests with high-functioning adolescents with ASD matched to TD children by chronological age and IQ (Bonnel, Mottron, Peretz, Trudel, & Gallum, 2003). Results demonstrated that adolescents with ASD showed significantly better pitch discrimination and pitch categorization than TD adolescents. Results also revealed that participants in the TD group performed significantly better on the categorization task than on the discrimination task. By contrast, the ASD group performed these two tasks equally well. These findings indicate that high-functioning adolescents with ASD can discriminate between sounds based on pitch level.

In a related study, Heaton (2005) examined the ability of 7- to 14-year-old high-functioning children with ASD to identify the direction of pitch intervals and melodic contours. Two TD groups matched by age and intelligence also participated in these experiments. For the pitch interval task, the ASD group performed equally when identifying the direction of medium and large intervals, but were significantly better able to identify the pitch direction of the small intervals compared to the control groups. In addition, within the groups, the ASD group performed equally well on all three intervals while the control groups performed significantly better when identifying the pitch direction of medium and large intervals than small intervals. For the melodic contour
task, results revealed no differences in melodic contour discrimination between the ASD and control groups. The findings from these experiments indicate that high-functioning children with ASD have adequate or superior abilities to detect melodic intervals, directions, and contours.

Recent studies have also revealed adequate or superior pitch discrimination in children and young adults with ASD compared to TD populations. Bonnel et al. (2010) used simple-tone and complex-tone stimuli for pitch discrimination tasks in three groups of adolescents and young adults: those with ASD, those with Asperger syndrome, and those who were TD. Results indicated that both ASD and TD groups displayed significantly enhanced pitch discrimination for simple-tones compared to the Asperger group. For complex-tone discrimination, no significant differences were found between the ASD and TD group. This finding suggests that individuals with ASD can discriminate sounds in simple- and complex-tones in a way that is similar to individuals without ASD.

Further study by Stanutz, Wapnick, and Burack (2012) examined sound discrimination and memory for music in children with ASD and TD children matched by chronological age and IQ. Children completed pitch discrimination and melody discrimination tasks, as well as pitch and melody memory tasks. Results revealed that children with ASD demonstrated significantly better pitch and melody discrimination abilities compared to the control groups. Furthermore, children with ASD presented significantly superior long-term memory for melody than the TD children did. Overall, this body of research provides evidence of sufficient or superior pitch perception in high-functioning children and adolescents with ASD compared to TD populations. In addition, these findings indicate that children with ASD can complete simple pitch discrimination tasks.
**Perception of pitch range.** Although individuals with ASD possess adequate or superior pitch discrimination skills compared to TD adolescents, they also show differences in auditory perception of pitch ranges. Researchers investigated pitch discrimination in adolescents with ASD and age-matched controls (Bhatara et al., 2013). Participants underwent pitch discrimination tests in which auditory stimuli were generated between 500 to 4,000 Hz. Results showed no significant differences between groups, indicating no overall impairment or enhancement in the ASD group relative to the control group. However, the ASD group showed significantly decreased pitch discrimination at 4,000 Hz compared to pitch discrimination at 1000 or 500 Hz. Similarly, TD adolescents also demonstrated decreased pitch discrimination with higher pitched sounds than lower pitched sounds, but this result was not statistically significant. Results indicate that adolescents with and without ASD might demonstrate different auditory sensitivity to sound depending on pitch ranges.

**Types of Auditory Distraction**

This present study used three different types of distracting sounds to assess selective attention in children with and without ASD. Although some research has explored this effect of auditory distractors during cognitive tasks in healthy individuals, the effect of distraction in individuals with ASD is not yet known. Nassiri et al. (2013) examined the effect of industrial noises on occupational performance skills, including speed and accuracy in hand-tool dexterity and two-arm coordination, in healthy university students. The researchers presented a distracting sound in three different ways while participants completed the tasks. One way was a continuous sound which was presented without interruption or variation. The second way was a fluctuating sound
which was a continuous sound that varied in intensity and pitch. The final way was an intermittent sound which was heard with interruptions.

Results revealed no significant effect of any types of distracting sound on task errors. However, participants showed a significant increase in time spent on task completion when they heard intermittent distracting sounds during the tasks compared to when they heard continuous distracting sounds. This study suggests that an intermittent form of distraction is more likely to shift attention away from a task and lead to reduced performance by requiring more time for task completion.

Other researchers have used different types of sounds as a distractor. Wolfe and Noguchi (2009) used three different distracting sounds, including an ambulance siren, people talking, and a telephone ringing, during cognitive tasks in TD children. These distracting sounds appeared to be combinations of continuous, fluctuating, and intermittent sounds. Anecdotal observations revealed that some children who heard distracting sounds during the story seemed to be distracted as evidenced by their behaviors, for example, turning around and looking at the sound source. However, most children continued to focus on the task despite distraction. The researchers note that the ability to focus on music decreases the negative effects of auditory distractors, and may be related developmental stage, previous learning (i.e., listening behaviors), and preference for music.

In her research, Jeong (2011, 2013) used two different types of distracting sounds when developing the MAA for adults with TBI. In the selective attention subtest of the MAA, participants listen to a target melodic contour played on a piano, a flute, or a guitar that is presented simultaneously with a distracting sound. The first type of distracting
sound consists of environmental noises, such as rain, bird song, clapping, or laughing. The second type of distracting sound includes melodic contours played on different musical instruments. All distracting sounds occur as a mixture of continuous, fluctuating, and intermittent sounds. However, the researcher did not analyze data regarding the relationship between types of distracting sounds and attention performance, and therefore no conclusion can be drawn. Current research has not fully examined the effect of distracting sounds on attention in clinical populations. Future studies are needed because different types of distracting sounds might impact attention in both clinical settings and real-world situations. Since people experience various auditory distractions daily, the findings of future research could benefit people with attention deficits.

**Summary of the Literature Review**

The research literature supports an exploration of the effect of auditory pitch range on sustained and selective attention in children with ASD. First, attention to pitch in non-musical and musical stimuli can be oriented by the same perceptual mechanisms, such as bottom-up or top-down processes. In other words, both non-musical and musical stimuli can be processed via auditory scene analysis (ASA), including the pre-attentive stage and the schema-driven attention stage. Additionally, neuroanatomical research identifies brain region commonalities between attention to pitch in non-musical and musical stimuli. The overlapping brain areas involve the bilateral regions of the frontal lobe, and the prefrontal lobe, the right superior temporal gyrus, the bilateral superior parietal lobe and the right inferior parietal cortex. These shared perceptual processes and common brain structures support research investigating the relationship between auditory pitch and attention.
Further research demonstrates the effect of music on attention. Researchers found that music can facilitate attention to tasks and subsequently improve academic learning outcomes in TD children and children with ADHD. Music can also increase productivity and accuracy during cognitive tasks in both TD individuals and adult clinical populations, such as schizophrenia. Additionally, music not only improves attention, but also reliably assesses attention in both typical adults and patients with TBI.

Numerous studies also demonstrate that music can facilitate attention and help children with ASD focus on cognitive tasks, consequently leading to a better learning outcome. High-functioning children with ASD also have adequate or superior pitch perception compared to TD children. In addition, high-functioning children with ASD might have better sustained attention to low pitch sounds than to high pitch sounds. Regarding auditory distractions, some studies used continuous, fluctuating, and intermittent sounds during selective attention tasks. Some studies with TD individuals suggest that intermittent sounds distract more attention from a task than continuous sounds. However, no published research could be found examining the effect of distracting sounds on selective attention in children with ASD.

Future research is needed to explore the relationship between pitch range and attention with a larger sample of children with ASD to increase reliability and generalizability of findings. Since selectively attending to target sounds among other auditory stimuli is fundamentally necessary to achieving learning outcomes, researchers also need to investigate the effect of distracting sounds on selective attention. In addition, future research should include a TD group for comparison. The results will contribute not only to a better understanding of the relationship between auditory pitch range and attention, but also to the development of therapeutic interventions aimed at enhancing attention.
Purpose of the Study and Research Questions

This study will explore whether a specific range of auditory pitch can influence sustained and selective attention in children with and without ASD. This study will also compare the effect of different types of distracting sounds on attention during a selective auditory attention task. The following research questions will be addressed:

1. What is the effect of pitch range, such as high vs. low, on sustained attention in TD children?

2. What is the effect of pitch range, such as high vs. low, on sustained attention in children with ASD?

3. What differences exist between children with ASD and TD children on sustained attention to pitch range, such as high vs. low?

4. What is the effect of pitch range, such as high vs. low, on selective attention in TD children?

5. What is the effect of pitch range, such as high vs. low, on selective attention in children with ASD?

6. What differences exist between children with ASD and TD children on selective attention to pitch range, such as high vs. low?

7. What are the effects of distracting sounds, such as continuous vs. fluctuating vs. intermittent, on selective attention in TD children?

8. What are the effects of distracting sounds, such as continuous vs. fluctuating vs. intermittent, on selective attention in children with ASD?
9. What differences exist between children with ASD and TD children on selective attention during tasks with distracting sounds, such as continuous vs. fluctuating vs. intermittent?
Chapter Three

Method

This chapter presents the participants, recruitment procedures, and the measures for this study. Procedures including data collection and statistical analysis to investigate the research questions are also described.

Participants

Two groups of participants were involved in this study; group one included 35 children with ASD, and group two consisted of 35 age-matched TD children. Group one was recruited from various agencies that provide services for children with ASD in Miami, Florida. In this group, each child had previously been diagnosed with ASD by a health care provider. Each participant with ASD had a documented diagnosis for ASD as noted in diagnostic reports or Individualized Education Plans, per parental report. For group two, TD children were recruited from various facilities that provide educational services for children in Miami, Florida.

All participants in both groups were able to use 3-4 word phrases, understand English, and follow directions to take the Music-Based Attention Assessment Revised for Children (MAA-RC II). Additionally, participants were excluded if they had diagnoses of psychotic or physical conditions (i.e., hearing impairment) that could impact their ability to understand, follow the directions and respond to musical stimuli during the tasks.

Age range. Participants in this study ranged in age from 7 to 14 years. This range was comparable to the range found in previous studies that explored pitch and melodic discrimination in TD children and children with ASD. Most TD children ages 6 to 11 years can reliably discriminate sounds by pitch level (Moore, Cowan, Riley, Edmonson-Jones, & Ferguson, 2011; Sutchliffe & Bishop, 2005). However, children under age 7 demonstrate inconsistent pitch discrimination skills (Thompson, Cranford, & Hoyer,
Moreover, the final step in structural maturation of the auditory cortex occurs between ages 6 to 12 (Moore & Linthicum, 2007). These findings suggest that the sensory and/or cognitive skills required to discriminate pitch should be adequately developed between 7 to 14 years.

Similarly, pitch discrimination is evident in high-functioning children with ASD aged 7 to 14 years. At this age, children with ASD demonstrate adequate or superior ability in the discrimination of pitch differences, pitch directions, and pitch contours, compared to TD children (Bonnel, Mottron, Peretz, Trudel, & Gallum, 2003; Heaton, 2003, 2005; Heaton et al., 2007; Stanutz, Wapnick, & Burack, 2012). These findings indicate that high-functioning children with ASD between 7 and 14 years of age can discriminate between sounds by pitch range.

**Participant recruitment.** The researcher submitted the research protocol to the Human Subjects Research Committee of the University of Miami. After approval, the researcher contacted various agencies in South Florida that provide services for TD children and children with ASD. For TD children, recruiting sites included: the Miami Onnuri Church and the Korean Presbysterian Church of Miami. For children with ASD, recruiting sites included: the Center for Autism and Related Disabilities, The Carrie Brazer Center for Autism, the Children’s Resource Center, and the STARS Autism School.

In order to recruit children with ASD, the researcher asked the agencies to distribute invitation letters (see Appendix A) and informed consent forms (see Appendix B). These documents were given to parents whose child was able to speak in 3-4 word phrases, understand English, and follow directions in order to participate in the music-based attention tasks. For the recruitment of TD children, either the researcher or agencies distributed the same documents to each child’s parents. After parents completed
the informed consent form, a researcher-designed demographic information form (see Appendix C), and the Social Responsiveness Scale (SRS-2; Constantino & Gruber, 2012), the investigator tested each child individually.

Measures

**The Social Responsiveness Scale, Second-Edition (SRS-2).** The SRS-2 (Aldridge, Gibbs, Schmidhofer, & Williams, 2012; Charman et al., 2007; Constantino & Gruber, 2012) is a 65-item rating scale that measures symptoms indicative of autism spectrum disorders. This scale is a parent-report and/or teacher-report measure of children’s social impairments in naturalistic social settings that can be completed in 15 minutes. This assessment generates scale scores for specific symptom domains, such as social awareness, social communication, and social motivation. This rating scale also generates a total score that serves as an index of severity of social impairments on the autism spectrum. The SRS-2 includes a preschool form (2.5 to 4.5 years), a school-age form (4 to 18 years), an adult form (19 years and older), and an adult self-report form (19 years and older).

Each item is scored on a 4-point Likert-scale: 1 = not true, 2 = sometimes true, 3 = often true, and 4 = almost always true (Charman et al., 2007; Constantino & Gruber, 2012; Schanding, Nowell, & Goin-Kochel, 2012). Scores are obtained in five categories including social awareness, social cognition, social communication, social motivation, and restricted interests, and repetitive behavior. The range of raw scores is from 0 to 195. Higher total raw scores on the SRS-2 indicate a greater severity of social impairment. The raw scores are converted to standard T-scores to account for differences between the individual’s gender and raters. In the parent’s report, the range of T-scores is from 37 to 90 for males, and from 38 to 90 for females. For teachers, the range of T-scores is from 38 to 90 for both males and females (Constantino & Gruber, 2012).
A T-score of 76 or higher is considered to indicate severe impairment and is strongly associated with a clinical diagnosis of ASD. Standard scores ranging from 66 to 75 are interpreted as indicating moderate impairment in reciprocal social behavior that is clinically significant and can lead to substantial interference in everyday social interactions. T-scores between 60 and 65 are in the mild range and indicate mild to moderate deficits in social interaction, and scores of 59 and below are considered to be within typical limits and generally not associated with clinically significant ASD (Aldridge et al., 2012; Constantino & Gruber, 2012).

The SRS-2 can quantitatively measure traits and symptoms of ASD across the complete range of severity (Aldridge et al., 2012; Charman et al., 2007; Constantino & Gruber, 2012). This scale demonstrates a strong test/retest reliability ($r=.90$) (Constantino et al., 2009) and an interrater reliability with parent reports ($r=.91$) (Bölte, Poustka, & Constantino, 2008; Constantino et al., 2009). Correlations to the Autism Diagnostic Interview-Revised (ADI-R) (Rutter, LeCounter, & Lord, 1994), which is another reliable assessment tool for diagnosis of ASD, range from .52 to .77. These scores indicate a moderate convergent validity of the SRS-2 (Constantino et al., 2003). Therefore, the SRS-2 can be used confidently in school and clinical contexts as an efficient measure of ASD symptomatology and severity. However, the results from the SRS-2 should not replace clinical assessment and must be integrated with information from additional other assessments in order to make a diagnosis (Aldridge et al., 2012; Charman et al., 2007; Constantino & Gruber, 2012; Schanding et al., 2012).

In this study, the scores of the SRS-2 were used to assess a level of social impairment in participants in the ASD and TD groups. Therefore, TD children who scored 60 or higher on the SRS-2 were excluded from the data analysis since they were suspected of having symptoms of ASD.
Music-Based Attention Assessment-Revised for Children II (MAA-RC II).

Current attention assessments for children with and without special needs mostly consist of visual stimuli and tend to emphasize numeric information (DeWolfe, Byrne, & Bawden, 1999; Mahone, 2005). By contrast, the Music-Based Attention Assessment (MAA) (Jeong & Lesiuk, 2011) is a music-based attention assessment tool for adult patients with TBI. The MAA is a forced-choice, melodic-contour identification test consisting of different attention subtests, including sustained, selective, and divided attention. However, since the MAA was developed for adult populations, the researcher modified the MAA to be appropriate for children with ASD (MAA-RC) in a pilot study (Lee, in press). For more detailed information on the MAA, see Jeong & Lesiuk (2011).

For this present study, the researcher revised the MAA-RC (MAA-RC II) to increase the number of items in both the sustained and selective attention subtests in order to enhance test reliability and increase test-item difficulty. Additionally, the researcher added three different types of distracting sounds to the selective attention subtest. This change was made because the pilot study results demonstrated that the test items in the selective attention subtest were not challenging enough for children with ASD as evidenced by high average scores on the selective attention subtest (Lee, in press).

The MAA-RC II consists of a 48-item melodic-contour identification test, including two attention subtests: sustained and selective attention. In the sustained attention subtest, 24 target melodic contours consisting of three notes each are composed in three directions: eight ascending, eight descending, and eight stationary. In each set of eight items, four items are presented at a low pitch range in a keyboard timbre (i.e., 220 Hz to 523.55 Hz), and the other four items are presented at a high pitch range (i.e., 1046.5 Hz to 2637 Hz). Pitch range utilized two different perceptual mechanisms of pitch
perception: temporal and place mechanisms. Lower frequencies between 220 Hz and 523.55 Hz are processed by the temporal mechanism, whereas higher frequencies between 1,046 Hz and 2,637 Hz are processed by a mixture of both temporal and place mechanisms (Moore, 2003; Palmer & Russell, 1986). After the presentation of each contour, participants are asked to identify the direction of the melody by verbally answering and/or pointing to the corresponding arrow on the response sheet.

In the selective attention subtest, 24 target melodic contours consisting of three notes each are composed in three directions: eight ascending, eight descending, and eight stationary. In each set of eight items, four items are presented at a low pitch range, and the other four items are presented at a high pitch range in a keyboard timbre. The researcher presents each distracting sound against each target melodic contour. The distracting sounds in the MAA-RC II include continuous, fluctuating, and intermittent sounds. For the continuous sounds, a recording of water flowing is presented without interruption or variation. For the fluctuating sounds, a recording of bird songs is heard continuously, varying in intensity and pitch. For the intermittent sounds, a recording is presented of a woodblock being played with unpredictable rhythmic patterns. After participants listen to each melodic contour, they are asked to identify the direction of the target melody heard against the distracting sound by verbally answering and/or pointing to the corresponding arrow on the response sheet.

In both attention subtests, each contour is presented in major keys in 4/4 meter at 90 beats per minute. The MAA-RC II subtests are illustrated in Figure 1. Individual test items can be found in Appendix D. In this study, behavioral responses to the melody direction items are indicators of whether or not the child is attending to the target stimuli. A higher frequency of correct answers on the MAA-RC II reflects attention enhanced by pitch ranges. Jeong (2011, 2013) continues to further revise the MAA,
expanding the applications for various clinical populations, and utilizing current technology for improved data collection.

**Materials.** The researcher provides target melodic contours via a laptop computer amplified with speakers at a 65 dB level for the melodies at a high-pitch range and a 70 dB level for the melodies at a low-pitch range. The use of different dB levels for low and high pitch ranges is because a listener perceives loudness differently depending on sound frequencies (Suzuki & Takeshima, 2004). Sound items of the MAA-RC II are produced and recorded by using a sample library (Kontakt 5) and Cubase MIDI/Audio sequencer (version 5.0). The researcher also provides the response sheet with three arrows pointing in different directions (i.e., up, down, and same) (see Appendix E).

**Procedure**

The research locations included the University of Miami Coral Gables campus, The Carrie Brazer Center for Autism, the STARS Autism School, the Children’s Resource Center, the Miami Onnuri Church, and the Korean Presbyterian Church of Miami. Parents of the children learned about the purpose of the study by reading a prewritten document, and then signed the informed consent form to give permission for their child to be part of this study. Following written permission, parents completed a short demographic questionnaire and the SRS-2 to confirm the diagnosis for their child. After completion of all documents from the parents, each child individually participated in the study. The researcher obtained child assent using an IRB-approved assent form. Each testing session lasted no more than one hour.

The researcher provided three demonstration trials prior to data collection to make sure that the child understands the concept of melody direction. During these trials, the researcher first presented an ascending melody via the laptop computer. Immediately after presentation of the melody, the researcher showed the response sheet and said,
**Figure 1.** The Music-Based Attention Assessment-Revised for Children II (MAA-RC II) (Total 48 items)
“This music goes up” while pointing to the “up” arrow on the response sheet. The researcher used the same procedure to demonstrate a descending melody and a stationary melody. The researcher then presented three practice trial melodies for each direction (i.e., ascending, descending, and stationary) in random order. The participant responded to each melody by verbally answering and/or pointing to the corresponding arrow on the response sheet.

After the demonstration and practice trials, the researcher presented actual test items via a laptop computer with speakers. The researcher first presented the 24 test items for sustained attention in random order. Next, the 24 test items for selective attention were presented in random order. The researcher asked the participants, “Which way did the music go?” After hearing each item, the participants responded by verbally answering and/or pointing to the arrow on the response sheet.

In order to motivate each child’s participation, the researcher provided stickers as a reinforcer after every six items and place them on a picture hung on the wall. Participants took the picture home after completing the test session. Throughout the task, if the child did not respond to a test item, the researcher repeated the question. If the child still did not respond, the researcher asked the question one more time. If the child did not respond again, the researcher presented the next melody. If the child still did not respond, the researcher terminated the session. All children were offered a small inexpensive token (i.e., pencil, yo-yo) after completing the MAA-RC II. Each item was coded as 1 (i.e., correct) or 0 (i.e., incorrect or unanswered). Twenty-four points were allotted to each of the two subtests, for a total possible test score of 48.

Listening to a presented melody and determining its direction was considered a valid assessment of attention (Jeong, 2011, 2013). Factor analysis in Jeong’s studies verified that melodic identification measures different types of attention, such as
sustained and selective attention. In this present study, when children listened to the melody direction, their attention was focused on the target stimulus as supported by Jeong’s research. Therefore, the children who achieved high overall scores on the MAA-RC II were considered to be utilizing a higher level of attention.

**Data analysis.** Statistical analyses were performed with IBM SPSS version 20.0. This study used a mixed factorial design since the independent variables consisted of both between-subjects and within-subjects variables (Tabachnick & Fidell, 2013). The between-subjects factor was population which included TD and ASD status. The within-subjects factors were pitch range which pertained to low and high pitch ranges, and type of attention which included sustained and selective attention. The researcher conducted four paired samples \( t \)-tests and five analyses of variance (ANOVAs) to analyze the data (Tabachnick & Fidell, 2013).

For sustained attention, the researcher first used two paired samples \( t \)-tests to examine the effect of pitch range on sustained attention for each group. The independent variable was pitch range (i.e., low vs. high) and the dependent variable was the frequency of correct responses to the MAA-RC II regarding melody direction. The researcher then conducted a 2x2 ANOVA to compare mean differences on the sustained attention subtest scores between groups for each pitch range. The independent variables included pitch range (i.e., low vs. high) and population (i.e., ASD vs. TD). The dependent variable was the frequency of correct responses on the MAA-RC II.

The significant alpha level was set at 0.017. If the alpha level had been set at 0.05, which is the typical rate for behavioral research studies, when running two \( t \)-tests and one ANOVA using the same data set, the probability of a Type I error would have increased. Therefore, the researcher divided the typical alpha level of 0.05 by three which
was equal to the number of analyses to avoid an increased chance of Type I error (Huck, 2012; Tabachnick & Fidell, 2013).

To analyze the data for selective attention, the researcher first conducted two paired samples \( t \)-tests to examine the effect of pitch range on selective attention for each group. The researcher then conducted a 2x2 ANOVA to compare mean differences on the selective attention subtest between groups for each pitch range. Using the same data set, the researcher conducted two 3x1 ANOVAs to assess the effect of three different distracting sounds on selective attention for each group. The independent variables consisted of type of distracting sounds (i.e., continuous, fluctuating, or intermittent) and the dependent variable included the frequency of correct responses on the MAA-RC II pertaining to melody direction.

Finally, the researcher conducted a 3x2 ANOVA to compare the effect of distracting sounds on selective attention between groups. The independent variables included type of distracting sounds and population, and the dependent variable was the frequency of correct answers to the MAA-RC II. Since the same data in the selective attention subtest were used in six different analyses, the researcher divided the typical alpha level of 0.05 by the number of analyses, which was six. The researcher then used this alpha level of 0.008 instead of 0.05 in order to prevent an inflated overall Type I error (Huck, 2012; Tabachnick & Fidell, 2013).

For effect size, the researcher used Cohen’s \( d \) for the \( t \)-tests and partial eta squared (\( \eta^2 \)) for ANOVAs. For the index of Cohen’s \( d \), the popular criteria for small, medium, and large effect sizes are 0.20, 0.50, and 0.80, respectively (Gravetter & Wallnau, 2011; Huck, 2012). For the index of partial \( \eta^2 \), the typical criteria for small,
medium, and large effect sizes are 0.01, 0.06, and 0.14, respectively (Gravetter & Wallnau, 2011; Huck, 2012). The effect sizes infer practical significance for the effect of pitch range on sustained and selective attention, as well as for the effect of distracting sounds on selective attention in TD children and children with ASD.
Chapter Four

Results

This chapter includes the results obtained from the statistical analysis of the data. Participant demographics will be presented, followed by the inferential and descriptive results according to the nine research questions.

Demographic Results

Two groups of participants were involved in this study. Group one initially included 37 children with ASD. However, two children with ASD did not complete the MAA-RC II; thus, the data for these 2 children was invalid and disregarded. In addition, their scores on the Social Responsiveness Scale-Second Edition (SRS-2) indicated severe deficiencies in reciprocal social behaviors. Consequently, the data from the remaining 35 children with ASD were included in data analysis and reporting. Group two consisted of 35 age-matched TD children.

The ASD group consisted of 30 male and 5 female children, with a mean age of 9.1 years. Since ASD is more common in males than in females, with a male to female ratio of 4.3:1 (Fombonne, 2003), imbalanced gender ratio in the ASD group was not unusual. The ASD group included 2 Asian, 9 Caucasian, 23 Hispanic participants, and 1 child of mixed ethnicity. SRS-2 scores for all participants in the ASD group were associated with clinically significant symptoms of ASD (Aldridge et al., 2012; Constantino & Gruber, 2012). Specifically, SRS-2 scores for 18 participants with ASD indicated severe impairment of social interactions. SRS-2 scores for 13 participants were related to moderate impairment; and 4 other participants had SRS-2 scores linked to mild deficits in social behaviors.

In the TD group, 23 children were male and 12 children were female, with a mean age of 9.1 years. The TD group consisted of 18 Asian, 5 Caucasian, 11 Hispanic
children, and 1 child of mixed ethnicity. Based on SRS-2 scores, the scores for all children in the TD group were not associated with any clinical ASD symptoms related to reciprocal social behaviors (Aldridge et al., 2012; Constantino & Gruber, 2012). Detailed demographic information for all participants is listed in Table 2.

Table 2

*Frequency of Participant Demographics*

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<tr>
<td>11</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>2</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>9</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>23</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Severity of Social impairment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>0</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>4</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>13</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>18</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
With respect to participants’ musical background, most participants with ASD had very little musical experience outside of school, music lessons, music ensemble and music therapy. Meanwhile, more TD children demonstrated more than one year of musical experience, including music class in school and music lessons, and no experience with music therapy. Detailed information for participants’ musical background is listed in Table 3.

Table 3

*Frequency of Participant’s Musical Background*

<table>
<thead>
<tr>
<th>Type of musical activity</th>
<th>Length of participation</th>
<th>ASD</th>
<th>TD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Music class in school</td>
<td>1 - 6 months</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>6 months - 1year</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>More than 1 year</td>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Music class outside of school</td>
<td>1 - 6 months</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>6 months - 1year</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>More than 1 year</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>31</td>
<td>25</td>
</tr>
<tr>
<td>Music lessons (i.e., piano lesson)</td>
<td>1 - 6 months</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>6 months - 1year</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>More than 1 year</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Musical ensemble (i.e., band, choir, orchestra)</td>
<td>1 - 6 months</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>6 months - 1year</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>More than 1 year</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td>Music therapy</td>
<td>1 - 6 months</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>6 months - 1year</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>More than 1 year</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>31</td>
<td>35</td>
</tr>
</tbody>
</table>
Research Question # 1

The first research question investigated the effect of pitch range, such as high vs. low, on sustained attention in TD children. The inferential and descriptive results are presented.

Inferential analysis. A paired samples t-test was conducted to evaluate the effect of pitch range on sustained attention in TD children. Results demonstrated no statistically significant differences in sustained attention scores between low and high pitch ranges ($t_{(34)}=1.932, p=.062$) for TD children. The effect size was small (Cohen’s $d=.32$) (Gravetter & Wallnau, 2011; Huck, 2012).

Descriptive analysis. The descriptive results, shown in Table 4, include the mean ($M$) and standard deviation ($SD$) of the MAA-RC II scores for pitch range (low vs. high) on the sustained attention subtest for both groups. The total possible score on the sustained attention subtest was 24. TD children achieved higher scores with a low pitch range ($M=11.37, SD=0.94$) than with a high pitch range ($M=10.94, SD=1.63$). The means of the MAA-RC II scores for pitch range on the sustained attention subtest with TD children are depicted in the form of a bar graph in Figure 2.

Table 4

Means and Standard Deviations of MAA-RC II Sustained Attention Scores by Pitch Range in the TD and ASD Groups

<table>
<thead>
<tr>
<th></th>
<th>Low Pitch</th>
<th></th>
<th>High Pitch</th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>TD</td>
<td>11.37</td>
<td>0.94</td>
<td>10.94</td>
<td>1.63</td>
<td>22.31</td>
</tr>
<tr>
<td>ASD</td>
<td>11.03</td>
<td>1.20</td>
<td>10.26</td>
<td>1.97</td>
<td>21.29</td>
</tr>
</tbody>
</table>

Note. Total possible MAA-RC II score for each pitch range in sustained attention condition = 12. Total possible MAA-RC II score for both pitch ranges in sustained attention condition = 24.
Research Question # 2

The second research question examined the effect of pitch range, such as high vs. low, on sustained attention in children with ASD. Both inferential and descriptive results are presented.

Inferential analysis. A paired samples $t$-test was conducted to evaluate the effect of pitch range on sustained attention in children with ASD. Results indicated that children with ASD received significantly higher scores on the sustained attention subtest when the
stimulus consisted of a low pitch range rather than a high pitch range ($t_{(34)}=3.01, p=.005$). The effect size was close to a medium level (Cohen’s $d=.48$) (Gravetter & Wallnau, 2011; Huck, 2012), indicating that 48% of the variance in the participants’ sustained attention was explained by pitch range.

**Descriptive analysis.** As shown in Table 4, children with ASD also achieved higher scores on the sustained attention subtest with a low pitch range ($M=11.03, SD=1.20$) than with a high pitch range ($M=10.26, SD=1.97$). The means of the sustained attention scores by pitch range for children with ASD are depicted in the form of a bar graph in Figure 3.

*Figure 3. Average MAA-RC II Sustained Attention Scores by Pitch Range in the ASD Group*
Research Question # 3

The third research question explored the differences between TD and ASD groups on sustained attention to pitch ranges, such as high vs. low. The inferential and descriptive results are presented.

**Inferential analysis.** The researcher checked for three assumptions of the 2x2 mixed design ANOVA before running the model (Gamst, Meyers, & Guarino, 2008; Tabachnick & Fidell, 2013). First, the assumption of sphericity was inherently met because there were only two levels in each condition. The assumption of normality was met to a sufficient degree, as the Q-Q plots showed a normal distribution of errors associated with the dependent variable. Lastly, the researcher examined Levene’s test to check the assumption of homogeneity. The results of Levene’s test for both pitch ranges in the sustained attention subtest indicated that the groups had equal error variance \((F(1,68)=2.939, p=.091)\) \((F(1,68)=2.907, p=.093)\). Thus, the researcher maintained the alpha level of 0.017 to determine statistically significant group differences. Table 5 shows the results of the mixed design ANOVA.

As shown in Table 5, results demonstrated no statistically significant interaction effect between pitch range and group \((F(1,68)=1.02, p=.315, \text{ partial } \eta^2=.015)\). In terms of pitch range, this result indicates no statistically significant difference in sustained attention between the two groups. The effect size was small (partial \(\eta^2=.015\)). Although not directly related to the research question, results from the ANOVA demonstrated no statistically significant difference on the sustained attention scores between groups regardless of pitch ranges \((F(1,68)=2.72, p=.104, \text{ partial } \eta^2=.04)\). However, when the data for both groups were combined, the results indicated a significant main effect of pitch range on sustained attention \((F(1,68)=12.53, p=.001)\). Both groups achieved higher sustained attention scores with a low pitch range \((M=11.37, 11.03)\) in comparison with a
high pitch range \((M=10.94, 10.26)\). The effect size for pitch range on sustained attention was small (partial \(\eta^2=.16\)) (Gravetter & Wallnau, 2011; Huck, 2012).

Table 5

2x2 Mixed Design Analysis of Variance (ANOVA) for the Effect of Pitch Range and Population on Sustained Attention

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>(F)</th>
<th>(p)</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>12.60</td>
<td>1</td>
<td>12.60</td>
<td>12.53</td>
<td>.001</td>
<td>.156</td>
</tr>
<tr>
<td>Error (Pitch)</td>
<td>68.37</td>
<td>68</td>
<td>1.01</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Population</td>
<td>9.26</td>
<td>1</td>
<td>9.26</td>
<td>2.72</td>
<td>.104</td>
<td>.04</td>
</tr>
<tr>
<td>Error (Population)</td>
<td>231.34</td>
<td>68</td>
<td>3.40</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pitch * Population</td>
<td>1.03</td>
<td>1</td>
<td>1.03</td>
<td>1.02</td>
<td>.315</td>
<td>.015</td>
</tr>
<tr>
<td>Total</td>
<td>322.6</td>
<td>139</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Alpha level = .017.

**Descriptive analysis.** As shown in Table 4, TD children achieved higher sustained attention scores \((M=11.37, SD=0.94)\) at the low pitch range in comparison with children with ASD \((M=11.03, SD=1.20)\). The mean difference on the sustained attention scores between the two groups was 0.34 for the low pitch range. At the high pitch range, TD children also achieved higher sustained attention scores \((M=10.94, SD=1.63)\) than children with ASD \((M=10.26, SD=1.97)\). The mean difference for a high pitch range on the sustained attention scores between the two groups was 0.68. See Figure 4.
Research Question # 4

The fourth research question examined the effect of pitch range, such as high vs. low, on selective attention in TD children. Both inferential and descriptive results are presented.

**Inferential analysis.** A paired samples t-test was conducted to evaluate the effect of pitch range on selective attention in TD children. Results demonstrated no statistically significant differences on selective attention scores between low and high pitch ranges for TD children ($t(34)=2.541, p=.016$). The effect size for pitch range on selective attention was small (Cohen’s $d=.35$) (Gravetter & Wallnau, 2011; Huck, 2012).

*Figure 4.* Average MAA-RC II Sustained Attention Scores by Pitch Range in the TD and ASD Groups
**Descriptive analysis.** The descriptive results, shown in Table 6, demonstrated that TD children achieved higher selective attention scores with a low pitch range ($M=11.29$, $SD=1.27$) than with a high pitch range ($M=10.77$, $SD=1.65$). The means of the MAA-RC II scores for pitch range on the selective attention subtest with TD children are depicted in the form of a bar graph in Figure 5.

Table 6

*Means and Standard Deviations of MAA-RC II Selective Attention Scores by Pitch Range in the TD and ASD Groups*

<table>
<thead>
<tr>
<th></th>
<th>Low Pitch</th>
<th>High Pitch</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>TD</td>
<td>11.29</td>
<td>1.27</td>
<td>10.77</td>
</tr>
<tr>
<td>ASD</td>
<td>10.29</td>
<td>2.05</td>
<td>9.83</td>
</tr>
</tbody>
</table>

*Note.* Total possible MAA-RC II score for each pitch range in selective attention condition = 12. Total possible MAA-RC II score for both pitch ranges in selective attention condition = 24.
Figure 5. Average MAA-RC II Selective Attention Scores by Pitch Range in the TD Group

Research Question #5

The fifth research question examined the effect of pitch range, such as high vs. low, on selective attention in children with ASD. The inferential results are presented, followed by the descriptive results.

Inferential analysis. The results from a paired samples t-test demonstrated no statistically significant differences on selective attention scores between low and high pitch ranges for children with ASD ($t_{(34)}=1.51, p=0.140$). The effect size was small (Cohen’s $d=.20$) (Gravetter & Wallnau, 2011; Huck, 2012).
**Descriptive analysis.** As shown in Table 6, children with ASD achieved higher scores on the selective attention subtest with a low pitch range ($M=10.29$, $SD=2.05$) than with a high pitch range ($M=9.83$, $SD=2.50$). The means of the selective attention scores by pitch range for children with ASD are depicted in the form of a bar graph in Figure 6.

![Bar graph showing average MAA-RC II Selective Attention Scores by Pitch Range in the ASD Group](image)

*Figure 6. Average MAA-RC II Selective Attention Scores by Pitch Range in the ASD Group*

**Research Question # 6**

The sixth research question explored the differences between TD and ASD groups on selective attention to pitch range, such as high vs. low. Both inferential and descriptive results are presented.
**Inferential analysis.** The assumption of sphericity was inherently met because there were only two levels in each condition (Gamst, Meyers, & Guarino, 2008; Tabachnick & Fidell, 2013). The assumption of normality was met to a sufficient degree, as the Q-Q plots showed a normal distribution of errors associated with the dependent variable (Gamst et al., 2008; Tabachnick & Fidell, 2013). The results of Levene’s test for both pitch ranges in the selective attention subtest demonstrated that the assumption of homogeneity was not met ($F(1,68)=5.562, p=.021$) ($F(1,68)=5.23, p=.025$). Therefore, it was necessary to divide the alpha level in half to determine statistically significant group differences, thus the alpha level was 0.004 instead of 0.008 (Gamst et al., 2008; Tabachnick & Fidell, 2013). Table 7 shows the results of the 2x2 mixed design ANOVA.

Table 7

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>8.26</td>
<td>1</td>
<td>8.26</td>
<td>7.13</td>
<td>.009</td>
<td>.095</td>
</tr>
<tr>
<td>Error (Pitch)</td>
<td>78.71</td>
<td>68</td>
<td>1.16</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Population</td>
<td>33.03</td>
<td>1</td>
<td>33.03</td>
<td>5.29</td>
<td>.025</td>
<td>.072</td>
</tr>
<tr>
<td>Error (Population)</td>
<td>424.71</td>
<td>68</td>
<td>6.25</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pitch * Population</td>
<td>.029</td>
<td>1</td>
<td>.029</td>
<td>.25</td>
<td>.876</td>
<td>.000</td>
</tr>
<tr>
<td>Total</td>
<td>544.74</td>
<td>139</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Alpha level = 0.004*
As shown in Table 7, results demonstrated no statistically significant interaction between pitch range and group ($F(1,68)=.25, p=.876, \text{partial } \eta^2=.000$). This result indicates no statistically significant difference in selective attention between the two groups in terms of pitch range. The effect size was small (Gravetter & Wallnau, 2011; Huck, 2012). Although not directly related to the research questions, results from the ANOVA demonstrated no statistically significant main effect of pitch range on selective attention for combined groups ($F(1,68)=7.13, p=.009, \text{partial } \eta^2=.095$). Results also showed no statistically significant main effect of group ($F(1,68)=5.29, p=.025, \text{partial } \eta^2=.072$). The effect sizes for pitch and population were medium (partial $\eta^2= 0.095, 0.072$, respectively) (Gravetter & Wallnau, 2011; Huck, 2012).

**Descriptive analysis.** As shown in Table 6, TD children achieved higher selective attention scores ($M=11.29, SD=1.27$) at the low pitch range in comparison with children with ASD ($M=10.29, SD=2.05$). At the low pitch range, the mean difference on the selective attention subtest between the two groups was 1. At the high pitch range, TD children also achieved higher selective attention scores ($M=10.77, SD=1.65$) than children with ASD ($M=9.83, SD=2.50$). For the high pitch range, the mean difference in the selective attention subtest between the two groups was 0.94. See Figure 7.

**Research Question #7**

The seventh research question examined the effect of the distracting sounds, such as continuous, fluctuating, or intermittent, on selective attention in TD children. The inferential results are presented, followed by the descriptive results.

**Inferential analysis.** In order to compare the mean differences across three different distracting sounds, the researcher conducted a 3x1 ANOVA. The results from Mauchly’s test indicated that the assumption of sphericity was met ($W=.912, X^2_{(2)}=3.058, p=.217$). The assumption of normality was met to a sufficient degree, as the Q-Q plots
showed a normal distribution of errors associated with the dependent variable (Gamst et al., 2008; Tabachnick & Fidell, 2013). As shown in Table 8, results showed no statistically significant effect of distracting sound on selective attention for TD children ($F(2,68) = .327$, $p = .722$, partial $\eta^2 = .010$). The effect size was small (Gravetter & Wallnau, 2011; Huck, 2012).

Figure 7. Average MAA-RC II Selective Attention Scores by Pitch Range in the TD and ASD Groups
Table 8

### 3x1 Analysis of Variance (ANOVA) for the Effect of Distracting Sounds on Selective Attention in the TD Group

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distracting sound</td>
<td>.248</td>
<td>2</td>
<td>.124</td>
<td>.327</td>
<td>.722</td>
<td>.010</td>
</tr>
<tr>
<td>Error (distracting sound)</td>
<td>25.752</td>
<td>68</td>
<td>.379</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Alpha level = 0.008*

**Descriptive analysis.** Table 9 shows the mean ($M$) and standard deviation ($SD$) of the MAA-RC II selective attention scores by distracting sound (continuous vs. fluctuating vs. intermittent) for both groups. The total possible score on the selective attention subtest was 24. TD children achieved the highest selective attention scores when they heard target melodies against a continuous sound (i.e., water flowing) ($M=7.4$, $SD=1.06$). Additionally, TD children achieved higher selective attention scores with an intermittent sound (i.e., woodblock) ($M=7.37$, $SD=1.06$), than a fluctuating sound (i.e., bird song) ($M=7.29$, $SD=0.96$). The means of the selective attention scores across all distracting sounds for TD children are depicted in Figure 8.
Table 9

Means and Standard Deviations of MAA-RC II Selective Attention Scores by Distracting Sound in the TD and ASD Groups

<table>
<thead>
<tr>
<th></th>
<th>Continuous</th>
<th>Fluctuating</th>
<th>Intermittent</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>TD</td>
<td>7.4</td>
<td>1.06</td>
<td>7.29</td>
<td>.96</td>
</tr>
<tr>
<td>ASD</td>
<td>6.74</td>
<td>1.07</td>
<td>6.71</td>
<td>1.56</td>
</tr>
</tbody>
</table>

Note. Total possible MAA-RC II score for each distracting sound in selective attention subtest = 8. Total possible MAA-RC II score for selective attention subtest = 24.

Figure 8. Average MAA-RC II Selective Attention Scores by Distracting Sound in the TD Group
Research Question # 8

The eighth research question explored the effect of the distracting sounds, such as continuous, fluctuating, or intermittent, on selective attention in children with ASD. Both inferential and descriptive results are presented.

**Inferential analysis.** The researcher conducted a 3x1 ANOVA to compare mean differences across three different distracting sounds for children with ASD. Since the Mauchly’s test demonstrated the assumption of sphericity was not met (W=.787, $X^2(2)=7.884, p=.019$), the researcher reported the Huynh-Feldt correction. The assumption of normality was met because errors associated with the MAA-RC II scores were normally distributed according to normal Q-Q plots in ANOVA (Gamst et al., 2008; Tabachnick & Fidell, 2013). As shown in Table 10, the results showed no statistically significant effect of distracting sound on selective attention for children with ASD ($F(1.72,58.57)=.086, p=.892$, partial $\eta^2=.003$). The effect size was small (partial $\eta^2=.003$) (Gravetter & Wallnau, 2011; Huck, 2012).

Table 10

*3x1 Analysis of Variance (ANOVA) for the Effect of Distracting Sounds on Selective Attention in the ASD Group*

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distracting sound</td>
<td>.133</td>
<td>1.723</td>
<td>.077</td>
<td>.086</td>
<td>.892</td>
<td>.003</td>
</tr>
<tr>
<td>Error (distracting sound)</td>
<td>52.533</td>
<td>58.573</td>
<td>.897</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Total</td>
<td>52.67</td>
<td>60.296</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. Alpha level = 0.008*
Descriptive analysis. Table 9 shows the mean \((M)\) and standard deviation \((SD)\) of the MAA-RC II selective attention scores by each distracting sound for children with ASD. The total possible score on the selective attention subtest was 24. Children with ASD achieved the highest selective attention scores when they heard target melodies against a continuous sound (i.e., water flowing) \((M=6.74, SD=1.7)\). The selective attention scores against a fluctuating sound (i.e., bird song) were lower \((M=6.71, SD=1.56)\) than those scores with a continuous sound. Finally, children with ASD achieved the lowest selective attention scores with an intermittent sound (i.e., woodblock) \((M=6.66, SD=1.45)\). The mean difference on the selective attention subtest across all distracting sounds for children with ASD are depicted in Figure 9.

![Graph showing average MAA-RC II Selective Attention Scores by Distracting Sound in the ASD Group](image)

*Figure 9. Average MAA-RC II Selective Attention Scores by Distracting Sound in the ASD Group*
Research Question # 9

The last research question investigated the differences between TD children and children with ASD on selective attention during tasks with distracting sounds, such as continuous, fluctuating, or intermittent. The inferential and descriptive results are presented.

**Inferential analysis.** The researcher conducted a 3x2 ANOVA to compare the mean scores on the selective attention subtest between two groups across three different distracting sounds. Since the Mauchly’s test indicated the assumption of sphericity was not met ($W=.902$, $X^2(2)=6.877$, $p=.032$), the researcher reported the Huynh-Feldt correction (Gamst et al., 2008; Tabachnick & Fidell, 2013). The assumption of normality was met because errors associated with the MAA-RC II scores were normally distributed according to normal Q-Q plots in ANOVA (Gamst et al., 2008; Tabachnick & Fidell, 2013). Results of Levene’s test for continuous and fluctuating sounds in the selective attention subtest indicated the assumption of homogeneity was not met ($F(1,68)=6.92$, $p=.011$) ($F(1,68)=11.73$, $p=.001$). Therefore, it was necessary to divide the alpha level in half to determine statistically significant group differences, thus the alpha level was .004 (Gamst et al., 2008; Tabachnick & Fidell, 2013). Table 11 shows the results of the 3x2 mixed design ANOVA.

As shown in Table 11, results did not show a statistically significant interaction effect between distracting sound and population in selective attention ($F(1.88,58.57)=.157$, $p=.844$, partial $\eta^2=.002$). This result indicates no statistically significant difference between groups for selective attention in terms of distracting sounds. The effect size was small ($\eta^2=.002$) (Gravetter & Wallnau, 2011; Huck, 2012). Although not directly related to the research questions, results also demonstrated no statistically significant main effect of distracting sound ($F_{(1.9,129)}=.174$, $p=.841$, partial $\eta^2=.003$) or population ($F_{(1,68)}=5.29$, $p=.026$, partial $\eta^2=.080$).
\(p = .025, \text{ partial } \eta^2 = .973\) on selective attention. The effect size for distracting sound was small (partial \(\eta^2 = .003\)), while the effect size for population was large (partial \(\eta^2 = .973\)) (Gravetter & Wallnau, 2011; Huck, 2012).

Table 11

3x2 Mixed Design Analysis of Variance (ANOVA) for the Effect of Distracting Sounds on the Selective Attention in the TD and ASD Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
<th>(\eta^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distracting Sound</td>
<td>.200</td>
<td>1.897</td>
<td>.105</td>
<td>.174</td>
<td>.841</td>
<td>.003</td>
</tr>
<tr>
<td>Error (Distracting Sound)</td>
<td>78.286</td>
<td>129.015</td>
<td>.607</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Population</td>
<td>22.019</td>
<td>1</td>
<td>22.019</td>
<td>5.288</td>
<td>.025</td>
<td>.973</td>
</tr>
<tr>
<td>Error (Population)</td>
<td>283.143</td>
<td>68</td>
<td>4.164</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Distracting Sound* Population</td>
<td>.181</td>
<td>1.897</td>
<td>.095</td>
<td>.157</td>
<td>.844</td>
<td>.002</td>
</tr>
<tr>
<td>Total</td>
<td>383.829</td>
<td>201.809</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. Alpha level = .004

Descriptive analysis. Table 9 shows that TD children achieved higher selective attention scores than children with ASD when they heard target melodies for any of the three distracting sounds. Specifically, the TD group achieved the higher selective attention scores when they heard target melodies with a continuous sound \((M = 7.4, SD = 1.06)\) than the ASD group \((M = 6.74, SD = 1.7)\). The TD group also attained higher selective attention scores with a fluctuating sound \((M = 7.29, SD = .96)\) than the ASD group \((M = 6.71, SD = 1.56)\). In addition, the TD group achieved higher selective attention
scores with an intermittent sound ($M=7.37, SD=1.06$) when compared to children with ASD ($M=6.66, SD=1.45$). The mean scores of the selective attention subtest across distracting sounds are depicted in Figure 10.

![Figure 10. Average MAA-RC II Selective Attention Scores by Distracting Sound in the TD and ASD Groups](image-url)
Chapter Five

Discussion

The purpose of this study was to examine the effect of pitch range (i.e., high vs. low) in a simple, musical context on sustained and selective attention in TD children and children with ASD. This study also explored the effect of different types of distracting sounds on selective attention in both groups. Existing research indicates that music-based intervention or background music during tasks can promote attention in children with ASD. However, no published study has yet explored the effects of specific musical elements, such as pitch range, on attention in children with and without ASD. Therefore, this study examined whether TD children and children with ASD were affected by pitch range on sustained and selective attention. A total of 70 children with and without ASD completed the Music-Based Attention Assessment-Revised for Children II (MAA-RC II). The independent variables were pitch range, population, type of attention, and type of distracting sounds. The dependent variable was the frequency of correct responses to the MAA-RC II.

In this chapter, the results of the statistical analyses will be interpreted. Findings will be discussed in detail and compared with findings in the previous research literature. This chapter will also address the limitations of the present study, as well as recommendations for future research. Additionally, theoretical and clinical implications will be presented.

Discussion of the Research Questions

The effect of pitch range on sustained attention in TD children. The first research question examined the effect of pitch range, such as high vs. low, on sustained attention in TD children. Results demonstrated no statistically significant differences on sustained attention scores between low and high pitch ranges for TD children. However,
descriptive results showed that TD children achieved higher sustained attention scores with a low pitch range than with a high pitch range.

Findings from the present study are consistent with conclusions from previous research, indicating that TD adolescents demonstrated better pitch discrimination when they heard melodies at a lower pitch range than at a higher pitch range (Bhatara et al., 2013). Pitch discrimination and attention to pitch are different perceptual processes, however, they are related constructs. Additionally, both Bhatara et al.’s study and the current study explored the role of pitch range in these processes. Bhatara et al.’s (2013) findings imply that TD adolescents might demonstrate a different auditory sensitivity to sound depending on pitch range, and might perceive low-pitched sounds better than high-pitched sounds.

These researchers further suggest that difficulties with pitch discrimination at a higher pitch range could be related to auditory filter bandwidth. Auditory filters are the structures on the basilar membrane within the cochlea, which enhances certain frequencies, while attenuating others, depending on pitch range (Moore, 2003). Auditory filter bandwidth becomes wider as frequencies increase, and this bandwidth subsequently causes a reduction in the audibility of sounds. In general, pitch discrimination is typically diminished as frequencies increase with a wider auditory filter. Therefore, improved pitch discrimination at a lower pitch range may reflect typical auditory functioning.

The effect of pitch range on sustained attention in children with ASD. The second research question explored the effect of pitch range, such as high vs. low, on sustained attention in children with ASD. Results showed that children with ASD achieved significantly higher sustained attention scores when they heard target melodies at a low pitch range compared to a high pitch range. Results suggest that children with ASD may be more attentive when they hear melodies at a low pitch range rather than at a
high pitch range. This finding is also consistent with conclusions from a previous study (Bhatara et al., 2013). As mentioned before, pitch discrimination and attention to pitch are different perceptual processes, but they are related constructs. Additionally, both Bhatara et al.’s study and the current study explored the role of pitch range in these both processes. Bhatara and colleagues (2013) found that adolescents with ASD discriminated low-pitched sounds more accurately than high-pitched sounds during pitch discrimination tasks, which may reflect a natural auditory perceptual capacity (Bhatara et al., 2013). Bharata et al.’s findings indicate that adolescents with ASD might have a different auditory sensitivity to sound depending on pitch range.

In a previous study regarding attention to pitch range, Lee (in press) found that children with ASD achieved significantly higher sustained attention scores on the MAA-RC when hearing melodies at a low pitch range than at a high pitch range. This finding indicates that children with ASD might have a different level of sustained attention toward low versus high-pitched sounds. Moreover, results imply that children with ASD might be more attentive to low-pitched sounds rather than high-pitched sounds. Collectively, research by Bhatara et al. (2013) and Lee (in press), along with the current findings, provide reliable evidence that a low pitch range might play an important role of pitch discrimination and attention to pitch. These findings may also reflect a typical auditory perceptual capacity (Bhatara et al., 2013).

**Group differences for sustained attention between high and low pitch ranges.** The third research question examined the differences between TD and ASD groups on sustained attention to low and high pitch ranges. Results showed that both TD and ASD groups achieved high scores on the sustained attention subtest. In addition, the descriptive results demonstrated that TD children achieved slightly higher sustained attention scores at both low and high pitch ranges in comparison with children with ASD.
Specifically, TD children obtained a mean score of 22.31 out of 24, and children with ASD achieved a mean score of 21.29 out of 24. These findings indicate that children with and without ASD completed the MAA-RC II with a fair degree of accuracy. In other words, children in both groups demonstrated sustained attention to simple music stimuli.

The descriptive results indicated that the standard deviation (SD) scores for sustained attention in TD children were slightly lower ($SD=0.94$) than scores for children with ASD ($SD=1.20$) at the low pitch range. At the high pitch range, SD scores for TD children were also slightly lower ($SD=1.63$) than scores for children with ASD ($SD=1.97$). The data for TD children, therefore, were more stable and consistent compared to the data for children with ASD.

Although the descriptive results demonstrated that TD children had higher sustained attention scores at both low and high pitch ranges compared to children with ASD, the inferential results showed no statistically significant difference between the two groups. This result implies that children with ASD, similar to TD children, can understand and complete the MAA-RC II, and can maintain attention to music stimuli. In a previous study, Bhatara and colleagues (2013) also found no significant group differences between TD adolescents and adolescents with ASD for pitch discrimination by pitch range. Their results indicated that compared to TD adolescents, adolescents with ASD demonstrated adequate pitch discrimination within specific pitch ranges (Bhatara et al., 2013). However, this research by Bhatara et al. (2013) and the present study do not support some conclusions from a previous study by Stanutz, Wapnck, and Burack (2012), which illustrated superior pitch and melody discrimination in children with ASD compared to TD children.

**The effect of pitch range on selective attention in TD children.** The fourth research question examined the effect of pitch range, such as high vs. low, on selective
attention in TD children. Results demonstrated no statistically significant difference on selective attention scores between low and high pitch ranges for TD children. However, the descriptive results showed that TD children achieved higher selective attention scores with a low pitch range than with a high pitch range. No previous research has examined the effect of a specific pitch range on selective attention in TD children. Consequently, this present study provides a unique contribution to the research literature regarding the effect of auditory pitch range on selective attention in TD children.

**The effect of pitch range on selective attention in children with ASD.** The fifth research question examined the effect of pitch range, such as high vs. low, on selective attention in children with ASD. While the inferential results demonstrated no statistically significant differences on selective attention scores between low and high pitch ranges for children with ASD, the descriptive results showed that children with ASD achieved higher selective attention scores with a low pitch range than with a high pitch range.

In her earlier study, Lee (in press) found that children with ASD also achieved higher selective attention scores when they heard target melodies at a low pitch range than at a high pitch range, even though results were not statistically significant. Since no published research exists on this topic, research by Lee (in press) in combination with the current findings makes a distinctive contribution to the research literature with respect to the effect of pitch range on selective attention in children with ASD.

**Group differences for selective attention between high and low pitch ranges.** The sixth research question explored differences between TD and ASD groups on selective attention by pitch range, such as high vs. low. Results showed that both TD and ASD groups achieved high scores on the selective attention subtest. In addition, TD children achieved slightly higher selective attention scores at both low and high pitch...
ranges compared to children with ASD. Specifically, TD children obtained a mean score of 22.06 out of 24, and children with ASD achieved a mean score of 20.12 out of 24. These results suggest that children in both groups completed the MAA-RC II with a fair degree of accuracy, indicating that children with and without ASD demonstrated selective attention to simple music stimuli.

The descriptive results further indicated that standard deviation (SD) scores for selective attention in TD children were slightly lower (SD=1.27) than SD scores for children with ASD (SD=1.65) at the low pitch range. At the high pitch range, SD scores for TD children were also slightly lower (SD=2.05) than scores for children with ASD (SD=2.50). The data for TD children, therefore, were more stable and consistent compared with the data for children with ASD.

Although the descriptive results demonstrated that TD children had higher selective attention scores at both low and high pitch ranges than children with ASD, the inferential results showed no statistically significant difference between the two groups. This finding indicates that children with ASD, similar to TD children, can focus selectively on target melodies against distracting sounds. Furthermore, both TD children and children with ASD might be better able to selectively maintain attention to target music stimuli at a low pitch range rather than at a high pitch range. However, no published research has explored the effect of a specific pitch range on selective attention in both children with and without ASD. Therefore, this present study is unique in addressing the effect of pitch range on selective attention in TD children and children with ASD.

**The effect of distracting sounds on selective attention in TD and ASD groups.** For research questions seven to nine, the researcher explored the effect of continuous, fluctuating, and intermittent distracting sounds on selective attention in both TD and
ASD groups. Although not directly related to the research question, the descriptive results demonstrated that children with and without ASD achieved higher sustained attention scores than selective attention scores. In earlier studies, researchers found that participants obtained higher scores on a sustained attention task than on a selective attention task (Jeong & Lesiuk, 2011; Lee, in press). These results are most likely due to the presence of distracting sounds in the selective attention tasks, as competing stimuli might interfere with the ability of participants to focus on target music stimuli. In the real world, children with and without ASD are commonly exposed to distracting sounds when they are in educational settings and home environments. Therefore, the present study offers meaningful contributions to the research literature in relation to the effect of distracting sounds on selective attention.

For the seventh research question, the researcher explored the effect of different distracting sounds on selective attention in TD children. The descriptive results demonstrated that TD children achieved the highest selective attention scores when they heard target melodies against a continuous sound, followed in descending order by an intermittent sound, and a fluctuating sound. However, no statistically significant difference was found among the distracting sounds for TD children. The eighth research question examined the effect of different distracting sounds on selective attention in children with ASD. Similar to TD children, children with ASD obtained the highest selective attention scores with a continuous sound. However, they achieved higher selective attention scores with a fluctuating sound compared to scores with an intermittent sound. Overall, no statistically significant differences existed across the distracting sounds for children with ASD.

Based on these descriptive results, the continuous sound had the least impact on selective attention compared to the other distracting sounds for both groups. Likewise,
Nassiri et al. (2013) found that healthy young adults spent a significantly shorter amount of time completing a task when they heard continuous sounds rather than intermittent sounds. This finding is consistent with the results from the present study which suggests that an intermittent sound is more likely to shift attention away from a task than a continuous sound.

Results in the present study might be due to the variation or interruption of fluctuating and intermittent distracting sounds. The variety of sound intensity and unexpected timing of the distracting sounds might interfere with the ability of participants to maintain attention to target stimuli more so than with a continuous sound. Studies using oddball paradigm have frequently shown that unexpected stimuli are more often able to distract away from a task compared to continuous, predictable stimuli (Parmentier, Elford, Escera, Andrés, & Miguel, 2007).

Finally, the last research question investigated the differences between TD children and children with ASD for selective attention by distracting sounds. TD children achieved higher selective attention scores than children with ASD when they heard target melodies for any of the distracting sounds. However, the inferential results indicated no significant difference between the two groups, or among the distracting sounds. In addition, results demonstrated no interaction effect between distracting sound and population. These findings suggest that children with ASD, similar to TD children, might be able to selectively maintain attention to target stimuli against distracting sounds.

**Discussion of Measurements**

**The MAA-RC II scores.** All 70 participants in both groups successfully completed the MAA-RC II with a high degree of accuracy for both sustained and selective attention subtests. For sustained attention, TD children obtained a mean score of 11.37 out of 12, and children with ASD achieved a mean score of 11.03 out of 12. For
selective attention, TD children achieved a mean score of 11.29 out of 12, and children with ASD attained a mean score of 10.29 out of 12. Consequently, a lack of observed differences between groups may possibly have been the result of test simplicity.

During the MAA-RC II tasks, the researcher observed that many participants in both groups showed positive behaviors, such as remaining seated throughout the task, and showing an interest in both target melodies and distracting sounds by smiling, asking questions, and following directions. This observation further supports the idea that music is an appropriate sensory stimulus for children with and without ASD. Moreover, Cronbach’s alpha for internal consistency of the MAA-RC II was 0.828 for the sustained attention subtest, and 0.845 for the selective attention subtest. For combined subtests, Cronbach’s alpha was 0.829. These numbers suggest that simple music stimuli can be reliable tools to assess sustained and selective attention in both groups.

**The Social Responsiveness Scale, Second-Edition (SRS-2) scores.** The SRS-2 is a parent-report and/or teacher-report measure of children’s social impairments in naturalistic social settings (Aldridge, Gibbs, Schmidhofer, & Williams, 2012; Charman et al., 2007; Constantino & Gruber, 2012). This scale generates a total score which serves as an index of the severity of the child’s social impairments. The researcher used the SRS-2 to confirm that children with ASD were on the ASD spectrum, while TD children were not suspected of having symptoms of ASD. In the present study, over half of the participants with ASD (n=18) had SRS-2 scores related to a severe level of social impairment, while scores for a small number of participants with ASD (n=4) were linked to mild deficits. The data for the SRS-2 scores for most participants with ASD in this study revealed a severe level of social impairment. By contrast, the SRS-2 scores for all children in the TD group were within the normal range, indicating no significant deficits in reciprocal social behaviors.
The relationship between the MAA-RC II and the SRS-2 scores.

Interestingly, results showed that children with ASD who were considered to have severe social impairments, based on their SRS-2 scores, successfully completed the MAA-RC II with a high degree of accuracy. Moreover, among participants with severe social impairment, eight children attained perfect scores on the MAA-RC II. This finding indicates that children with ASD who have severely impaired social skills may still be able to respond to and maintain attention to music stimuli.

Based on the researcher’s observation, all participants with ASD were able to speak in three to four word phrases, as well as to understand and follow directions. This observation indicates that children with ASD who are considered to have severe social impairments still may have other intact cognitive functions, and consequently, they may successfully complete the MAA-RC II with a fair degree of accuracy.

In this present study, the SRS-2 for children with ASD was completed mainly by participants’ mothers (n=31). Two fathers and two teachers finished the SRS-2 for other participants with ASD. Despite parental differences in background, perspective, and personal experiences with a child, mother-reported SRS-2 scores strongly correlate with father-reported scores ($r = .91$) (Bölte et al., 2008; Constantino et al., 2003). Constantino et al. (2003) also reported a strong correlation between parent- and teacher-reported SRS-2 scores, specifically a mother-teacher reports correlation of $r = .82$. However, other researchers found differences between the parent- and teacher-report, suggesting that the teacher-report is more consistent with current, clinical observations (Schanding, Nowell, & Goin-Kochel, 2012). Considering these conflicting perspectives, the SRS-2 scores were used in this study may have lacked objectivity and accuracy.

To summarize, the MAA-RC II can be reliably used to measure sustained and selective attention since both children with and without ASD successfully completed the
MAA-RC II and Cronbach’s alpha for internal consistency of the MAA-RC II was high. Based on the SRS-2 scores, results indicate that children with ASD who have severely impaired social skills may still be able to respond to and maintain attention to music stimuli.

Limitations and Recommendations for Future Research

The findings of the present study suggest that pitch range possibly plays an important role in attention for children with and without ASD. However, more research is necessary to further understand the relationship between pitch range and attention in children. Several limitations of the present study need to be discussed, including sample size, group balance, and validity and reliability for the MAA-RC II.

The first limitation of this study was a small sample size which might not have been adequate to achieve a statistical significance. Results revealed statistical significance only for the main effect of pitch range on sustained attention in children with ASD. Additionally, the inferential results approached statistical significance for the main effect of pitch ($p=.009$) and the main effect of population ($p=.025$) in the selective attention subtest, and showed a large effect size for the main effect of population on distracting sound ($\eta^2=.973$). Future research using a larger sample size may increase power to reveal statistical significance for the main effects of pitch range and population. Furthermore, a larger sample size may also increase generalizability of the results.

The second limitation of this study was the imbalanced group composition, such as uneven ratios of ethnicity and age represented in the groups. In this study, the TD group had more Asian children than any other ethnic representation, while the ASD group included a large number of Hispanic children. Becerra et al. (2014) found that Hispanic and African American children with ASD demonstrate more comorbid intellectual disabilities compared to other ethnic groups. These traits could affect the
MAA-RC II scores. Specifically, participants with ASD in the present study might have achieved lower MAA-RC II scores because most of them were Hispanic children, and they may have been at risk for a lower level of intellectual functioning. Therefore, future research may need a balanced ethnicity for both groups, or may explore the differences among the ethnic groups.

The sample for this present study also included an imbalanced distribution of ages. For both groups, out of 35 children, 28 children were between 7 and 10 years, and 7 children were between 11 and 14 years. Thus, most participants were in a younger age group. Some previous studies reported that older participants with ASD out-performed younger participants on cognitive tasks that emphasized working memory, cognitive flexibility, and planning (Happé, Booth, Charlton, & Hughes, 2006; Ozonoff & Jensen, 1999). Participants in the present study might have achieved lower MAA-RC II scores due to their ages. Therefore, results from the present study may generalize better to younger than older children with ASD. If this study is replicated, the use of balanced age groups is recommended not only for generalizability, but also for comparisons of different age groups.

Furthermore, future research in this area should strive to further establish validity and reliability for the MAA-RC II by increasing the number of test items, and using different sounds for the attention tasks. For convergent validity, the MAA-RC II should be compared to other non music-based auditory attention assessments, such as the Auditory Continuous Performance Test (ACPT) which is designed to assess attention in children (Keith, 1994). Another way to enhance reliability of the MAA-RC II could be to increase the number of test items which would reduce measurement error (Rudner & Schafer, 2002).
In educational settings and home environments, children with and without ASD are likely to hear vocal instruction more than any other sounds. Thus, piano sounds for target melodies used in this study may yield a lack of the ecological validity. As a result, future research should include the use of other sounds, including singing voices, in order to produce more functional outcomes. Using vocal sounds may enhance ecological validity, helping to generalize results to real-life situations (Fraenkel, Wallen, & Hyun, 2012).

Finally, behavioral data collection was a limitation. The researcher utilized the MAA-RC II to measure participants’ attention to simple musical tasks. However, measuring only behaviors may produce inaccurate results, especially while exploring the effect of pitch range on attention in children with and without ASD. Particularly, if participants were “good guessers” or “good test takers”, they might have achieved higher MAA-RC II scores even though they were not attentive to the task. Therefore, for future research, brain-imaging, such as EEG, fMRI, and PET, administered during the MAA-RC II might be useful to explore the neuroanatomical evidence of how children with and without ASD differently respond to pitch range. Neuroimaging data can provide structural and functional information of the brain that processes sounds depending on pitch range.

**Implications of the Findings**

This study provides both theoretical and practical implications regarding the effect of pitch range in music on attention in TD children and children with ASD. Theoretical implications will contribute to the understanding of the relationship between pitch range and attention. Practical implications will focus on contributions to clinical uses.
**Theoretical Implications.** This study offers theoretical implications by exploring the relationship between pitch range and attention in children with and without ASD. Results elucidate the unique role of pitch range on sustained and selective attention in children. The findings suggest that TD children and children with ASD might attend differently to low-pitched sounds versus high-pitched sounds. The special role of the low pitch range appears to reflect a typical auditory perceptual capacity for both TD children and children with ASD. These findings may help professionals, across many fields in neuroscience, psychology, and audiology, understand the role of pitch range in attention.

Furthermore, the present study demonstrates that children with ASD, similar to TD children, can understand and complete simple music attention tasks, and can also respond to and maintain attention to music stimuli. Therefore, this study provides evidence that children with ASD might have intact neurological pathways for sustained and selective attention to music stimuli.

**Practical Implications.** This study also provides clinical implications. In the present study, all participants successfully completed the MAA-RC II which showed high internal consistency via Cronbach’s alpha. Consequently, the findings from this study support the use of music as an attention assessment stimulus in children who have atypical sensory perception, or attention problems. Music therapists as well as other professionals who work with children with ASD, such as neuropsychologists, audiologists, and speech-language pathologists, may use a music-based attention assessment in order to identify type and severity of attention deficits in this population. Precise assessment is crucial for establishing effective goals and identifying appropriate therapeutic interventions. Moreover, the MAA-RC II can be an objective tool for professionals to use when tracking a client’s improvement toward therapeutic goals for attention.
The findings from this study may provide basic evidence necessary for further applied research, such as the development of music-based interventions using pitch range to influence attention. Music therapists first could examine the short-term effect of pitch range on attention in children with ASD, and then could use those findings to create music therapy interventions employing specific pitch ranges to improve attention in children with ASD. For example, music therapists may use music stimuli at a low pitch range during Musical Attention Control Training (MACT; Thaut, 2005); a neurologic music therapy technique used to help clients successfully select a target stimulus and stay focused on that stimulus.

Furthermore, music therapists might be able to select an appropriate type of distracting sound, according to a client’s severity of attention deficits during attention training. For instance, if clients demonstrate severe attentional problems, a therapist might use a continuous sound as a distractor, while a fluctuating or intermittent sound might be appropriate for clients with milder attention deficits during MACT.

**Summary and Conclusions**

The purpose of this study was to examine the effect of pitch range on sustained and selective attention in TD children and children with ASD. This study also explored the effect of different types of distracting sounds on selective attention in both groups. A total of 70 children with and without ASD completed the Music-Based Attention Assessment-Revised for Children II (MAA-RC II).

Results revealed that children with ASD achieved significantly higher scores on the sustained attention subtest when the stimulus consisted of a low pitch range rather than a high pitch range. This finding indicates that children with ASD might attend differently to sound depending on pitch range. Specifically, children with ASD might be more attentive to low-pitched sounds compared to high-pitched sounds. Additionally,
although the inferential results demonstrated no statistical significance, the descriptive results indicated that both TD children and children with ASD achieved higher MAA-RC II scores in both sustained and selective attention subtests when they heard target melodies at a low pitch range compared to a high pitch range.

In addition, TD children and children with ASD achieved higher sustained attention scores than selective attention scores. This finding demonstrates a hierarchy of type of attention, indicating that a selective attention task is more difficult than a sustained attention task, due to the presence of distracting sounds. For both TD children and children with ASD, a continuous sound had the least impact on selective attention compared to other distracting sounds. These results indicate that the fluctuating and intermittent sounds are more likely to distract attention to target stimuli than a continuous sound. The fluctuating and intermittent sounds were presented with variation or interruption, and this variety of sound intensity and unexpected timing of distracting sounds might interfere with the ability of participants to maintain attention to target stimuli more so than a continuous sound.

One of the prominent findings in this study was the lack of a significant difference between the TD and ASD groups with regard to pitch range, type of attention, and type of distracting sound. These results indicate that children with ASD, similar to TD children, can understand and complete music-based attention tasks and maintain attention to simple music stimuli. Moreover, both TD children and children with ASD successfully completed the MAA-RC II with a fair degree of accuracy for both sustained and selective attention subtests. Many participants in both groups showed positive behaviors during testing, suggesting that music is an appropriate stimulus to gain their attention, and
subsequently, promote their active participation during tasks. In addition, Cronbach’s alpha for internal consistency of the MAA-RC II was high, indicating that simple music stimuli can reliably assess sustained and selective attention in TD children and children with ASD.

Based on the findings from the present study, music therapists and other professionals who work with children with ASD can obtain valuable information about the relationship between pitch range and attention. The findings also may contribute to scientific evidence of not only the therapeutic use of music for improving attention, but also the use of music as an attention assessment tool.
References


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Appendix A

Letter to Parents

To general parents:

Dear Parents,

Your child is invited to be part of a research study for children with Autism Spectrum Disorder (ASD) as well as typically-developing (TD) children that is being done at the University of Miami. The study is designed to examine the effect of pitch range (low vs. high) in music on sustained and selective attention in children with ASD and TD children. If you have child between 7 and 14 years old with or without a diagnosis of ASD, your child may be eligible for this study. Your child will need to be able to speak in 3-4 word phrases, as well as understand and follow simple directions in English to be part of this study. If you have more than one child who meets these criteria, then all of your children may be eligible to participate.

As part of this research study, you and your child will make a one-hour appointment that will take place in the Music Annex of the University of Miami which is located at 1552 Brescia, Coral Gables, FL. During this appointment, you will complete an informed consent form, a demographic questionnaire, and Social Responsiveness Scale (SRS) for your child.

Your child will complete a Music-Based Attention Assessment. This assessment consists of listening to 48 brief musical excerpts and identifying the direction of the melody in each excerpt by verbally answering and/or pointing to the corresponding arrow on a response sheet.

The results should help develop therapeutic interventions aimed at enhancing attention, and promoting social or higher cognitive functions for children with ASD.

If you are present at the appointment, you may receive a free consultation regarding your child’s attention skills.

If you would like to participate in this study, please either call me at 970.581.0807, or email me at h.lee13@umiami.edu to make an appointment. Your appointment will last no more than one hour and you will need to bring your child with you. You will need to speak, read and write in English.

Please see the back of this page for driving directions and parking/transportation information.
If you would like to participate in this study, please contact me by phone or by email. Your participation in this study is completely voluntary. I look forward to meeting you and your child!

Sincerely,

Hyun-Jung Lee, MMA, MT-BC
Doctoral Student in Music Therapy, University of Miami
Call me at: 970.581.0807
Email me at: h.lee13@umiami.edu
To School and Clinic:

Dear Parents,

Your child is invited to be part of a research study for children with Autism Spectrum Disorder (ASD) as well as typically-developing (TD) children that is being done at the University of Miami. The study is designed to examine the effect of pitch range (low vs. high) in music on sustained and selective attention in child with ASD and TD children. If you have a child between 7 and 14 years old with or without a diagnosis of ASD, your child may be eligible for this study. Your child will need to be able to speak in 3-4 word phrases, as well as understand and follow simple directions in English to be part of this study. If you have more than one child who meets these criteria, then all of your children may be eligible to participate.

As part of this study, the investigator, Hyun-Jung Lee, will visit the school or clinic that your child currently attends. At your child’s convenience and daily schedule of the school or clinic program, the investigator will arrange to meet your child individually in a room at the school or clinic.

Your child will complete the Music-Based Attention Assessment. This assessment consists of listening to 48 brief musical excerpts and identifying the direction of the melody in each excerpt by verbally answering and/or pointing to the corresponding arrow on a response sheet.

The results should help develop therapeutic interventions aimed at enhancing attention, and promoting social or higher cognitive functions for children with ASD.

If you would like for your child to participate in this research study, please sign the attached consent form, complete a demographic questionnaire and the Social Responsiveness Scale (SRS) and return them to your child’s teacher or music therapist. If you would like more information on this study, or if you would like to discuss it with me in further detail, please do not hesitate to contact me. Also, if you are interested in finding out your child’s results at the completion of the study, please feel free to contact me.

Sincerely,

Hyun-Jung Lee, MMA, MT-BC
Doctoral Student in Music Therapy, University of Miami

Call me at: 970.581.0807
Email me at: h.lee13@umiami.edu
Dear Parents,

Your child is invited to be part of a research study for children with Autism Spectrum Disorder (ASD) as well as typically-developing (TD) children that is being done at the University of Miami. The study is designed to examine the effect of pitch range (low vs. high) in music on sustained and selective attention in child with ASD and TD children. If you have a child between 7 and 14 years old with or without a diagnosis of ASD, your child may be eligible for this study. Your child will need to be able to speak in 3-4 word phrases, as well as understand and follow simple directions in English to be part of this study. If you have more than one child who meets these criteria, then all of your children may be eligible to participate.

As part of this study, the investigator, Hyun-Jung Lee, will visit your church that your child currently attends. At your child’s convenience and schedule of the church, the investigator will arrange to meet your child individually in a room at the church.

Your child will complete a Music-Based Attention Assessment. This assessment consists of listening to 48 brief musical excerpts and identifying the direction of the melody in each excerpt by verbally answering and/or pointing to the corresponding arrow on a response sheet.

The results should help develop therapeutic interventions aimed at enhancing attention, and promoting social or higher cognitive functions for children with ASD.

If you would like for your child to participate in this research study, please sign the attached consent form, complete a demographic questionnaire and the Social Responsiveness Scale (SRS) and return them to your child’s teacher or preacher. If you would like more information on this study, or if you would like to discuss it with me in further detail, please do not hesitate to contact me. Also, if you are interested in finding out your child’s results at the completion of the study, please feel free to contact me.

Sincerely,

Hyun-Jung Lee, MMA, MT-BC
Doctoral Student in Music Therapy, University of Miami
Call me at: 970.581.0807
Email me at: h.lee13@umiami.edu
Appendix B

Informed Parental Consent Form

The effect of pitch range on attention: a comparison of children with Autism Spectrum Disorder (ASD) and Typically-Developing (TD) children

INFORMED CONSENT FORM

PURPOSE: The purpose of this study is to investigate the effect of pitch range on sustained and selective attention in children with ASD and TD children. Ultimately, the results should help inform the development of therapeutic interventions aimed at enhancing attention, and subsequently facilitate social or higher cognitive functions.

PROCEDURES: Your child will complete a one-hour appointment. Appointments can take place at any of the following approved locations:

- The Music Annex which is located at 1552 Brescia, Coral Gables, FL.
- The Carrie Brazer Center for Autism which is located at 8790 SW 94th St., Miami, FL.
- Children’s Resources which is located at 8571 S.W. 112 st., Miami, FL.
- Whole Steps Creative Arts Center which is located at 10725 SW 104th St., Miami, FL.
- Miami Onnuri church which is located at 7410 Sunset Dr., Miami, FL.
- Korean Presbyterian Church of Miami which is located at 9730 Stirling Rd., Cooper City, FL.

After you will complete this informed consent form, a demographic questionnaire and the Social Responsiveness Scale (SRS) for your child, the investigator will test your child individually. The researcher will explain the study to your child. If your child appears to understand the information, your child will sign the assent form if he or she agrees to participate in the study.

Your child will then complete the Music-Based Attention Assessment. This assessment consists of listening to 48 brief musical excerpts and identifying the direction of the melody in each excerpt by verbally answering and/or pointing to the corresponding arrow on a response sheet.

If your child does not respond to a test item, the researcher will repeat the question. If your child does not respond again, the researcher will present the next item. If your child does not respond to the next item, the researcher will decide to end the session. If the researcher feels that it would be best for your child to stop data collection at any point, she will end the procedure. You will also have the option to stop the procedure at any point.

RISKS: No foreseeable risks or discomforts are anticipated for your child by participating in this study.
BENEFITS: There is no direct benefit to your child from participating in this research study. We believe the information will lead to a better understanding of the effect of pitch range on sustained and selective attention in children with Autism Spectrum Disorder (ASD) and typically-developing (TD) children, and further contribute to the development of therapeutic interventions aimed at enhancing attention and facilitating social or higher cognitive functions for children with ASD.

ALTERNATIVES: The alternative is to not participate in this study. During the study, your child may stop participating at any time. Your child has the right to not participate and nothing will happen to your child as a result. Your child’s participation in this study is completely voluntary.

COSTS: There will be no additional costs to participate in this study.

INCENTIVES: Stickers will be offered as a reinforcer during the procedure and a small token item (e.g., pencil, yo-yo, etc.) will be offered after the task. In addition, you and your child will be offered a free consultation regarding your child’s attention skills.

CONFIDENTIALITY: The researcher will consider your and your child’s records confidential to the extent permitted by law. The records will not be identified as pertaining to you or your child in any publication without your expressed permission. The U.S. Department of Health and Human Services (DHHS) may request to review and obtain copies of these records. Your and your child’s records may also be reviewed for audit purposes by authorized University employees or other agents who will be bound by the same provisions of confidentiality.

The collected data will not contain any information that could be used to identify your child. All data will be identified by an assigned code, not by your child’s name. All paper and electronic records will be stored in a locked file cabinet and a password-protected computer to which the investigator, Hyun-Jung Lee, will have the only access. All records will be kept in this locked location for a period of seven years. After that time, all data will be destroyed.

RIGHT TO WITHDRAW: Your child’s participation is voluntary; your child has the right to withdraw from the study at any time. If your child does not want to participate or does not follow the procedures, the researcher can also remove him/her from the study without your consent.

WHOM TO CONTACT: If you have any questions or concerns about this research study, feel free to ask for additional information from the principal investigator, Dr. Shannon de l’Etoile, at (305) 284-2241. You can also contact the co-investigator, Hyun-Jung Lee, at (970) 581-0807. If you have any questions concerning the study or your child’s participation in the study, please do not hesitate to contact Dr. de l’Etoile and Ms. Lee. If you have any questions about your child’s rights as a research participant in this project, you may contact the University of Miami’s Human Subjects Research Office at (305) 243-3195.
PARTICIPANT AGREEMENT:
I have read the information in this consent form and agree to participate, and to allow my child to participate. 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.

______________________________________________________________________
Child’s Name

______________________________________________________________________
Parent’s Name

______________________________________________________________________
Parent’s Signature

______________________________________________________________________
Date

______________________________________________________________________
Signature of Person Obtaining Consent

______________________________________________________________________
Date
Appendix C

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

University of Miami
Frost School of Music
Department of Music Education and Music Therapy
Coral Gables, Florida

This survey is designed to obtain basic information about participants who will take the Music-Based Attention Assessment-Revised for children II. Please answer the following questions. I appreciate your completion of this survey, and your responses will be kept strictly confidential.

1. What is your child’s gender? □ Male □ Female

2. What is your child’s date of birth? _____/_____/_____

   month   day   year

3. What is your child’s ethnicity?

   □ □ □ □ □
   Caucasian African American Hispanic Asian/Pacific Islander Other

4. Has your child ever participated in, or is your child currently involved in any type of musical activity? If yes, please indicate the type of musical activity and the length of participation. (Check all that apply)

   Type of musical activity                     Length of participation
   1. Music class in school                     □1-6 mos □6 mos-1yr □more than 1yr □N/A
   2. Music class outside of school             □1-6 mos □6 mos-1yr □more than 1yr □N/A
   3. Music lessons (i.e., piano lesson)        □1-6 mos □6 mos-1yr □more than 1yr □N/A
   4. Musical ensemble (i.e., band, choir, orchestra) □1-6 mos □6 mos-1yr □more than 1yr □N/A
   5. Music therapy                             □1-6 mos □6 mos-1yr □more than 1yr □N/A
Appendix D
Music-Based Attention Assessment-Revised for Children II
(MAA-RC II) : Demonstration and Practice Melodies

DEMONSTRATION MELODY

1. Ascending

2. Descending

3. Stationary

PRACTICE MELODY

1. Ascending

2. Descending

3. Stationary
Music-Based Attention Assessment-Revised for Children II

(MAA-RC II) : Test Melodies for Sustained Attention

Ascending - Low

1

2

3

4

Ascending - High

5

6

7

8

Descending - Low

9

10

11

12
Music-Based Attention Assessment-Revised for Children II
(MAA-RC II) : Test Melodies and Distraction Sounds for Selective Attention

Ascending - Low
1. Water Flowing
   Piano

2. Bird Song
   Piano

3. Bird Song
   Piano

4. Woodblock
   Piano

Ascending - High
5. Water Flowing
   Piano

6. Water Flowing
   Piano
Appendix E

The Response Sheet

UP

Down

Same