Pitch Discrimination and Melodic Memory in Children with Autism

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Degree of Doctor of Philosophy

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Montreal, Quebec, Canada

A Thesis

Submitted to

McGill University

In Partial Fulfillment of the

Requirements for the

Degree of

Doctor of Philosophy

October 1st, 2009

Dedication

I dedicate this work to my four children: Max, Anna, Bailey, and Luke. I am thankful for their presence in my life. It is through my experience living with them that I realized the boundless extent to which one's individuality endlessly shapes one's life.

Acknowledgements

I am grateful to my first supervisor, Dr. Charlene Ryan, Music Education, Berklee School of Music, who encouraged me to pursue a Ph. D. degree. Without her tremendous support, I would not have completed studies beyond the Master's level. Her positive outlook, unassuming nature, and goal oriented approach was a motivating factor in this work. I am equally grateful for my second advisor, Dr. Joel Wapnick, Music Education, Schulich School of Music, McGill University, who in his quiet way has taught me a tremendous amount about the art of expressing one's ideas, however ironic that seems.

I would also like to thank Dr. Jacob Burack, Department of Educational Psychology, McGill University, for giving me crucial opportunities, through workshops, to extend my knowledge of autism. He has been a tremendous source of information and provided me with the support for the administration of the non-verbal IQ tests used in this study.

I'd like to also extend my gratitude to Dr. Isabelle Cossette, Music Education, Schulich School of Music, McGill University, for providing me valuable feedback as a second reader. I am also thankful to Isabelle for providing moral support and a tremendous amount of encouragement with regard to my studies over the years.

I am grateful to Frederico O'Reilly, MA Music Technology, McGill University, for taking the time to explain some key acoustical concepts. He was an invaluable resource in the creating of the music game used in this study.

I sincerely thank all the children and their families who took the time to participate in this study. Without you this research could not have been possible.

I thank my husband for his tremendous support. Without his superior skill as a father, it would not have been possible to complete this work.

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Abstract

Objective: The current research indicates that those with autism have an excellent memory for pitch. Persons with autism have better pitch discrimination and memory for individual notes. The purpose of this study was to extend this research in school aged children, comparing pitch discrimination and melodic memory of children with autism to that of typically developing children.

Method: Twenty-five children with autism between the ages of 8-12 and 25 typically developing children within the same age range participated in the study. Children completed pitch discrimination tasks in two differing contexts. In one context, children were asked to indicate whether two pitches were the same or different when the two pitches were either the same or one note of the pair had been altered so that it was 25, 35, or 45-cents sharp or flat. In the other context, children were asked to discriminate whether two melodies were the same or different when the leading tone of each melody was either the same or had been altered so that it was 25, 35, or 45-cents sharp or flat. In addition, children were also asked to recall melodies one week after they were paired with pictures during a familiarization task. All the tasks in the study were formatted on computer.

Results: Children with autism outperformed typically developing children in both pitch discrimination contexts. Children with autism were superior to typically developing children when remembering melodies one week after they had been paired with animal pictures.

Conclusion: Children with autism demonstrated better pitch discrimination and melodic memory than typically developing children. These abilities may be genetic, as the majority of the participants in the study had limited music training. Alternatively, these abilities could be reflective of a different developmental process in the auditory modality of children with autism whereby developmental differences in auditory perceptions may be adaptive in some musical contexts.

Abrégé

Objectif: Les recherches actuelles démontrent que les personnes autistiques discernent mieux la hauteur des sons et ont une meilleure mémoire des sons individuels. La présente étude vise à étendre la recherche aux enfants d'âge scolaire en comparant, chez les enfants autistiques par rapport aux enfants qui se développent normalement, le discernement de la hauteur des sons et la mémoire mélodique.

Méthodologie: Vingt-cinq enfants autistiques ainsi que 25 enfants ayant un développement normal, tous âgés de 8 à 12 ans, ont participé à l'étude. Placés dans deux contextes différents, les enfants ont effectué des tâches faisant appel à leur capacité de discerner la hauteur des sons. Dans le premier contexte, les enfants devaient indiquer si deux sons étaient semblables ou différents lorsque les deux sons étaient les mêmes ou lorsque l'un d'eux avait été modifié pour être plus aigu ou plus bas de 25, 35, ou 45-cents. Dans l'autre contexte, les enfants devaient dire si deux sons mélodies étaient les memes ou si elles étaient différentes lorsque chacune des melodies étaient la mêmes ou si elles étaient différentes lorsque la sensible de chacune des melodies étaient soit la même, soit qu'elle avait été modifiée pour être plus aigue ou plus basse de 25, 35, ou 45-cents. En outre, les enfants devaient aussi se remémorer des mélodies qui, la semaine précédente, avaient été associées à des images d'animaux au cours d'une tâche de familiarsation. Toutes les tâches accomplies par les enfants au cours de l'étude ont été effectuées sur ordinateur.

Résultats: Les enfants autistiques ont mieux réussis que les enfants ayant un développement normal et, cela, dans les deux contextes de discernment de la hauteur des sons. Ils ont aussi été supérieurs lorsqu'il a fallu se remémorer des melodies une semaine après qu'elles eurent été associés à des images d'animaux.

Conclusions: Les enfants autistiques ont démontré que leur jugement de la hauteur des sons et et leur mémoire mélodique étaient meilleurs que ceux des enfants ayant un développement normal. Ces habiletés pourraient être innées étant donné que la majorité des participants á l'étude avaient une formation musicale limitée. Par ailleurs, ces habiletés pourraient être le signe d'un processus développemental different des attributs auditifs des enfants autistiques, ces différences développementales des perceptions auditives pouvent comporter une capacité d'adaptation à certains contextes musicaux.

Chapter 1 Introduction

The current research suggests that persons with autism not only have better discrimination for differences in pitch than typically developing persons (Bonnel, Mottron, Peretz, Trudel, Gallun, & Bonnel, 2003) but may also have a better long-term memory for individual pitch (Heaton, Hermelin, & Pring, 1998). Superior short term memory used in discriminating differences in pitch (Bonnel et al., 2003), and superior long-term memory used in remembering single tones over the period of a week (Heaton et al., 1998), points to the possibility that some of the musical skills of autistic musical savants may be present to some degree in the general population of persons with autism. Musical savants have excellent long-term memory for individual pitch termed absolute pitch (Miller, 1989,1999) and can also have a superior melodic memory (Sloboda, Hermelin, & O'Connor, 1985). Most musical savants also have autism (Miller 1989, 1999). This research attempts to extend the previous research by examining both memory of melody and pitch discrimination in school-aged children with autism. Pitch discrimination was examined using both paired single tones and tones within the context of a melody. This extended Bonnel's (2003) finding of superior discrimination of paired single tones in adolescence and young adults with autism. In addition, neither pitch discrimination nor melodic memory had been examined in children with autism to date. The objective of the research was to discover how the musical memory and pitch discrimination of school-aged children with autism compared with that of typically developing children within the same age range. In light of some of the deficits in autism with regard to language learning, the current research indicating better short and long-term memory for pitch in autistic populations as compared to typically developing populations is surprising.

Increased awareness of the prevalence of autism (Fombonne, Zakarian, Bennett, Meng, & McLean-Heywood, 2006) is driving the need for further research. Understanding the cognitive profile of children with autism is important to eventually improving their systems of education. This particular research may contribute to the understanding of developmental differences between children with autism and typically developing children within the auditory domain and to the understanding of how those differences may interact with language learning.

Over the last thirty years, autism research has expanded exponentially (Volkmar, Lord, Bailey, Schultz, & Klin, 2004). This phenomenon is a result of the shifting definition of autism from that of a rare developmental disorder to the most prevalent childhood medical condition today (Fombonne et al., 2006).

Although recent research has illuminated many facets of autistic functioning there are many behavioral aspects of autism that remain poorly understood. Many children with autism experience either hypersensitivity or hyposensitivity to sensory stimulation that can cause unpredictable, individualistic reactions (Frith, 2007). In addition, there is currently limited communication in the transfer of existing research information to the grass roots level of the public school systems. Taken together, the gaps in both the knowledge and resource base in both medical and educational systems has created an extremely frustrating environment for children with autism and their parents. Even today, with the increased awareness of autism, there are still many issues unresolved in regard to recognizing, diagnosing, and educating both high functioning and low functioning children with autism.

One of the largest barriers for educators, parents, and medical professionals is that the world of the child with autism is extremely difficult for anyone not living with the condition to decipher. The biggest difficulty with understanding autism is that autistic perceptions of the world can be very different from those of typically developing children. Compounding the problem is the fact that children with autism have limited ability in using language to describe how they feel. In addition, realizing that other's perceptions may be different than one's own is a fairly advanced concept even for typically developing children. It is not a characteristic of autistic thinking. Fortunately, in the last twenty years, published accounts of childhood perceptions by high functioning persons with autism, such as Donna Williams and Temple Grandin, have contributed to our understanding of just how extreme autistic perceptions can be (Grandin, 1986, 1988, 1995; Williams, 1998).

Those with autism not only have unusual sensory perceptions (O' Riordan & Passetti, 2006; Rutter, Le Couteur, & Lord, 2005) but also have a different way of thinking (Baron-Cohen, Tager-Flusberg, & Cohen, 1993; Happé, 1999). For example, the child with autism understands concepts of socialization solely through explicit instruction, while the same concepts are intuitive for the typically developing child. High functioning children with autism must study the rules of social engagement in order to live an adaptive life in society.

Those with autism, especially young children, act in ways that are confounding and seem unexplainable. Those in authority situations may be more apt to misinterpret odd behavior as personal attacks on their control over a situation. This kind of emotional interaction can mask what is at the root of the problem: those with autism tend to have difficulty in inferring what others think (Baron-Cohen, et al., 1993). This deficit has been referred to as mind blindness and creates huge problems in social situations. Therefore, it is important that ongoing autism education is available to those who work with children. As Uta Frith (2007) states:

> This handicap is in its nature more similar to blindness or deafness than to, say, shyness. Imagine trying to bring up a blind child without realizing that he or she is blind. One might get quite impatient with the child bumping into things! A child cannot learn well from an impatient or angry teacher. Therefore, it is important for all teachers, therapists, parents, and friends to have some knowledge of the nature of the handicap. (p. 223)

One area where sensory perception may be different between autistic children and typically developing children is that of the auditory domain. Autistic children are frequently reported to have an aversive reaction to spectrally complex sounds like blenders, vacuum cleaners, and the din of crowds. In fact, of 17,000 responses on a diagnostic questionnaire developed by the Autism Research Institute of San Diego, 40% of parents indicated that their autistic child exhibited some form of sound sensitivity (Rimland & Edelson, 1995). On the other hand, children with autism can seem oblivious to speech as toddlers. For example, many of them are consistently unresponsive when their name is called (Samson, Mottron, Jemel, Belin, & Ciocca, 2005).

Studies that measure electrical reactivity of the brain or regional cerebral blood flow indicate that there are differences in processing strategies between typically developing children and those with autism (Boddaert, et al., 2004; Siegal & Blades, 2003). In a passive listening task, which required children to listen to random deviant (different) tones imbedded in a string of tones with the same pitch, brain reactivity to deviant tones was measured (Gomot, Giard, Adrien, Barthelemy, & Bruneau, 2002). Although children with autism reacted faster than typically developing children to deviant tones, different brain mechanisms were involved, indicated by the pattern of electrical activation. In particular, the electrical conductivity of the left cortex followed an unusual pattern.

In another passive listening task, electrical brain reactivity was measured in response to a series of pure tones of differing frequencies (Gage, Siegel, Callen, & Roberts, 2003). Children with autism reacted faster than typically developing children to pure tones of a wide frequency range as measured by the cortical activity in the right hemisphere. Gage et al. (2002) had previously found that brain reactivity varied with pitch frequency. In that study, typically developing adults had longer reaction times to pitches of lower frequency. Because damage to auditory areas in the right hemisphere had been linked to deficits in processing the prosody of language (Pell, 1999), Gage et al. (2003) concluded that the faster reaction times of the children with autism to pure tones in the right hemisphere reflected a deficit in processing spectrally complex sounds. The tendency in autism research to explain any auditory event in terms of language development may inhibit our understanding of autistic capability. Faster reaction times in most other instances would indicate enhanced cognitive skill. These studies suggest that although children with autism may have an increased sensitivity to pitch, they may be processing the information through different neural pathways than typically developing children.

Children with autism showed enhanced discrimination of pitch in both pure tones and vowel sounds, as indicated by enlarged reactionary electrical amplitudes in the brain (Lepistö et al., 2005). They also exhibited larger electrical amplitude in conditions where either the pitch changed or the phoneme changed (Lepisto et al., 2008). Performance on the task, however, diminished to levels of typical children when both pitch and phonemes changed simultaneously. Here we see that performance diminishes when more than one parameter varies simultaneously. This finding may clarify some of the issues in autism with regard to cognitive style in attending to multiple aspects of a situation (Mottron & Burack, 2001; Mottron, Dawson, Souliéres, Herbert, & Burack, 2006). Other auditory differences in autism can include increased sensitivity to loudness (Khalfa et al., 2004) and problems in segregating speech sounds from noise in certain situations (Alcantára, Weisblatt, Moore, & Bolton, 2004). Alcantára (2004) found that speech reception was significantly worse in these three situations: a) when there was a competing female talker, b) when the competing noise had variations in amplitude, and c) when the competing noise varied in both the amplitude and frequency.

What these studies imply is that there is a physiological basis for the difference in auditory perception in autism. The auditory perceptions of the autistic child may be very different from typically developing children, often provoking unusual and confounding behavior. Oddly enough, most autistic children test in the normal range on audiological tests (Rosenhall, Sandström, Ahlsén, & Gillberg, 1999). This information can be misleading. Consider the situation in which a teacher reads the assessment of normal hearing in an autism spectrum disordered child. Unless the teacher has extensive knowledge of the disorder, s/he is then likely to interpret the behavior of a child, who is not responding to her directives, as non-compliant. In fact, this type of behavior may be more likely a product of some of the auditory complications in autism.

Audiologists assess normal hearing by determining the threshold of hearing at different frequencies with varied intensity levels (Bess & Hall, 1992; Cranford, 2008). One wonders whether such tests, in fact, capture the full nature of differences in auditory perception between typically developing children and those with autism.

The current research suggests that those with autism may perceive pitch differently than typical children. This study builds on the current knowledge of pitch perception in autism, exploring further the possibility that memory for pitch is more salient than in other areas of autistic functioning. This study is developmentally oriented with the focus on the perception and memory for pitch in school-aged children. Further knowledge of the development of pitch discrimination and pitch memory in children might help to identify strengths in autistic perception and explain how those strengths may interact with language and social learning. In addition, the nature of this research may eventually shed light on the adaptability of autistic auditory perception in certain contexts.

Chapter 2 Literature Review

Musical savant syndrome has long been a fascination to researchers in many different fields. Musical savants display precocious musical ability despite gross deficits in language and communication. Because most of them are autistic and also have absolute pitch ability, researchers have inquired whether similar musical abilities could be found in people with autism. Indeed, research suggests that a number of people with autism exhibit isolated skills that seem to go beyond the level of their everyday adaptive function. Musical pitch perception may be one of these skills. The following literature review examines evolving diagnostic concepts in autism in conjunction with research suggesting the possibility that pitch memory could be another example of an isolated skill in autism. These findings are discussed within the context of the developmental course of pitch processing in typical populations, current theories of cognitive function in autism, and deficits in language learning in autistic populations.

Autism: a Concept in Revision

Initially, autism was thought of as a severe impenetrable developmental disorder. In 1943, Kanner recognized a severe form of autism he termed as "early infantile autism" (Frith, 1991; Kanner, 1943). Although these children exhibited severe deficits in language and communication, he did not believe that they fit the profile of the emotionally disturbed. He also felt that their pattern of specialized capabilities demonstrated that they did not fit the pattern of the slow learner either. Asperger (1944) described a group of children with autism who also had normal intelligence and language. Knowledge of Asperger's work wasn't widespread until the eighties when it was translated into English (Frith, 1991).

Asperger Syndrome is a relatively new concept for medical practitioners. It was not until 1994 that it was accepted as a syndrome into the Diagnostic and Statistical Manual of Mental Disorders, American Psychiatric Association (*DSM-IV*) (American

Psychiatric Association Diagnostic and Statistical Manual of Mental Disorders, 1994; Wing & Potter, 2002).

It was also during the eighties that Lorna Wing recommended a much broader definition of autism than that of Kanner (Fitzgerald, 2004; Wing & Gould, 1979; Wing, 1991). She recognized that people with the condition varied widely in intelligence, ability, and adaptive function. Wing & Gould (1979) coined the term Autistic Spectrum Disorder to reflect a further division within the disorder.

Today, Autistic Disorder, previously known as Kanner's infantile autism, is defined as one of five classification subtypes of Pervasive Developmental Disorders (PDDs). Autistic Disorder is considered the prototype of all PDDs (Scahill, 2005). The term pervasive implies that these disorders persist into adulthood. The following are the classification subtypes of PDDs: a) Autistic Disorder, b) Asperger Syndrome, c)Pervasive Developmental Disorder Not Otherwise Specified, d) Rett's Syndrome, and e) Childhood Disintegration Disorder (*DSM-IV*, 1994). The terms Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) and Autism Spectrum Disorder (ASD) are widely considered to be interchangeable to describe the same diagnostic profile (Rutter et al., 2005). The first three PDD classifications are by far the most common (Rutter et al., 2005; Scahill, 2005) with an estimated combined prevalence 64.9 per 10,000 (Fombonne et al. 2006). It is these classifications that will be the focus of this discussion.

Autistic Disorder, Asperger syndrome and PDD-NOS are characterized by a triad of behaviors including: a) qualitative impairments in social interaction, b) qualitative impairments in language and communication, and c) restrictive, repetitive, and stereotyped patterns of behavior, interests, and activities (*DSM-IV*, 1994; Lord, Rutter, DiLavore, & Risi, 2002; Rutter et al., 2005; Scahill, 2005). The diagnosis of Autistic Disorder, PDD-NOS, or Asperger Syndrome depends on the degree to which these impairments are evident. Higher scores on each of the three domains of impairment characterize Autistic Disorder while lower scores characterize PDD-NOS. High scores indicative of a diagnoses of Autistic Disorder indicate severe maladaptive behavior stemming from the core impairments characteristic of autism. Lower scores indicative of a diagnoses of PDD-NOS indicate clinically significant but less severe behavior stemming from the core impairments. Significant social abnormalities and restrictive and repetitive interests without obvious communication dysfunction characterize Asperger Syndrome.

Researchers now recognize wide individual differences in levels of adaptive functioning, IQ, and special abilities (Scahill, 2005; Wing & Gould, 1979). Temple Grandin's highly articulate accounts of her childhood experiences living with autism exemplifies one example of these individual differences (Grandin, 1986, 1995). Originally diagnosed as a child with what would now be considered as severe Autistic Disorder, Temple Grandin eventually developed into a leading architect. Her case exemplifies a puzzling developmental profile of autism.

Although Grandin's case is an extreme example, some children with autism eventually do mature to exhibit great skill in a particular area. The developmental profile of extreme autistic behavior has been shown to improve with maturity (Fecteau, Mottron, Bertiaume, & Burack, 2003). For some children, immaturity may mask an uneven intelligence profile of unusually extreme strengths and weaknesses.

The prevalence of autism has increased since the first epidemiological study in 1966 (Lotter, 1966). What was once considered to be a very rare condition affecting 4.5 children out of 10,000 is now considered to be the most prevalent medical condition in childhood affecting 64.9 children out of 10,000 (Fombonne et al., 2006). This rise is generally regarded as being due to the broader definition of autism and to better systems for diagnoses (Wing & Potter, 2002) but environmental factors have not been ruled out (Steyaert & De La March, 2008). The ratio of boys to girls affected with autism is 4:1. Thirty percent of those with autism have normal to high intelligence, 30% score in the mildly to moderately mentally retarded range, and 30% are in the severe mentally retarded range.

The current thought on the inheritability of autism, taking into account the epidemiological, twin, and family data, suggests that the majority of cases arise on the basis of complex genetic factors (Bailey, Palferman, Heavey, & LeCouteur, 1998; Pickles, Starr, Kazak, Bolton, & Papanikolaou, 2000; Volkmar et al., 2004). In fact, a great deal of interest has been directed towards the broad phenotypical expressions in the family members of those with autism (Happé, Briskman, & Frith, 2001). Not only are siblings at a higher risk for having autism, but it also seems that the cognitive profile characteristic of autism is more likely to be present in extended family members.

Savant Syndromes in Autism

Savant Syndrome is characterized by tremendous cognitive ability in one specific area while general IQ, language, communication, and adaptive functioning remain low (Heaton & Wallace, 2004; Obler & Fein, 1988; Treffert, 1988). However, researchers have recognized that there are ranges of ability in Savant Syndrome (Treffert, 1988). Savant Syndrome in persons with autism is estimated to be higher as compared with other populations. Although the few studies of the prevalence of Savant Syndrome have design flaws, the most often quoted rate is 10% savant ability among autistic children (Rimland & Fein, 1988) and less than 1% in the population of persons with other developmental disabilities (Hill, 1977). Savants can exhibit ability in math, calendar calculating, language, factual memory, visual spatial tasks, and musical ability.

Musical ability in Savant Syndrome has been widely documented (Heaton & Wallace, 2004; Hermelin, 2001; Miller, 1989, 1999; Peretz, 2001; Rimland & Fein, 1988; Sloboda et al., 1985). Musical savants have Absolute Pitch Ability (AP) and are autistic for the most part (Miller, 1989, 1999). Rimland (1988) reports that music and memory ability were by far the most common savant abilities among children with autism. Five percent in that sample were found to have musical savant ability. Therefore, the incidence of AP among autistic persons has been estimated to be as high as 1 in 20 (Brown et al., 2003; Miller, 1989). The memory of musical savants is exceptional (Sloboda et al., 1985). Their skills seem to go beyond that of merely rote learning.

Absolute Pitch Ability

AP has been defined as the ability to generate or identify the pitch class of any isolated tone in the absence of a reference pitch (Parncutt & Levitin, 2001). In typical populations, AP is considered to be a rare ability with an estimated prevalence of 1 in 10,000 (Profita & Bidder, 1988). However, the prevalence rate for AP was found to be as high as 24.6% in the population of music students attending a conservatory-based music program (Gregerson, Kowalsky, Kohn, & Marvin, 1999).

There is a continuing debate as to whether AP can be learned (Brady,1970; Baharloo, Johnston, Service, Gitschier, & Freimer, 1998; Crozier, 1997) or is solely a genetic trait (Baharloo, Service, Risch, Gitschier, & Freimer, 2000; Gregerson, 1998). Baharloo et al. (2000) found that AP aggregates in families even after controlling for early musical training indicative of a genetic trait. Another theory speculates as to whether AP ability is a disinhibitory process (Bossomaier & Snyder, 2004) suggesting the possibility that AP is inherent in everyone but as maturation occurs, the ability is abandoned. Musicians were more likely to have AP if they started music instruction before the age of five (Gregerson, 1998). Perhaps early training prolongs and strengthens a skill that would have been otherwise dropped. Saffran & Griepentrog (2001) found that 8-month old infants favored absolute pitch cues over relative pitch cues for identifying tone words. Adults however, performed the task best using relative pitch cues. This result would seem to support the theory that AP could be a disinhibitory process where the onset of language learning could play a role in the acquisition of relative pitch and diminishing the strength of AP. Perhaps as infants mature and show more interest in people other then the primary caregiver, relative pitch is more useful in discerning language from voices of differing pitch and timbre.

Another aspect of AP is that the term itself can be misleading. The “absoluteness” of AP ability is questionable. AP possessors are typically able to label between 70-100% of randomly selected middle range piano tones to within a semi-tone of the targeted note (Miyazaki, 1989), while non AP possessors are able to label 40% of tones to within a semi-tone of the targeted note (Lockhead & Byrd, 1981). The accuracy rate of non-possessors is well beyond the chance level of 8.3%. Researchers have recognized and labeled varying levels of skill in absolute pitch possessors (Baharloo et al., 1998; Bachem, 1954). Baharloo (1998) established 4 categories of AP. Bachem (1954) considered good relative pitch possessors as having pseudo AP. It seems likely that there are varying degrees of memory for pitch and although true AP ability is rare, there may be other levels of memory for pitch or memory for music that, in a developmental sense, represent a deviation from the norm. Such a deviation could point to a sensory sensitivity in discriminating sounds in line with the observation of an "auditory style" in musicians (Brodsky, Sloboda, & Waterman, 1994).

Apart from the variability of performance of AP possessors and the debate as to whether the skill is influenced by learning, there would seem to be a different aspect to the memory systems of those with AP ability. In studies where the electrical reactivity of brain function was measured, AP possessors did not appear to be accessing working memory when correctly identifying pitches (Klein, Coles, & Donchin, 1984; Zatorre, 2003). As a result of these findings, it is thought that AP possessors have a type of online memory system for pitches analogous to a template. These online memory systems are termed tonotopic maps and enable an instant recognition of pitches where the updating of working memory is not necessary. Also, certain asymmetries of the brain are evident in musicians with AP ability (Schlaug, Jancke, Huang, & Steinmetz, 1995). Musicians with AP ability have a stronger leftward asymmetry of the planum temporale than do musicians without AP ability. In that study, it was observed that the asymmetry is reflective of a structural difference in auditory association areas located on the planum temporale. Taken together these findings suggest that those with AP are accessing different neural pathways than those without AP when processing pitch information.

The higher estimated prevalence of AP among autistic individuals (Brown et al., 2003; Miller, 1989) may indicate a developmental process whereby pitch information is processed differently than in the typical population. For some individuals with autism, such a developmental difference could lead to the favoring of pitch sounds over speech sounds. In one autistic subject with AP, discrimination of the pitch of speech sounds was superior in comparison to typically developing children with AP (Heaton, Davis, & Happé, 2008). A similar pitch discrimination ability has also been found in children with autism (Järvenen-Pasley & Heaton, 2007). In that study, children with Autistic Disorder and Asperger Syndrome were superior in discriminating the pitch frequency of speech sounds as compared to intelligence matched typically developing children. It would, therefore, seem obvious to predict that sensitivity to frequency change in speech sounds would predict receptive and expressive language deficits but this has been shown not to be the case. In fact, autistic children without significant language impairment have also been shown to have superior pitch discriminating ability with tones and speech (Heaton, Hudry, Ludlow, & Hill, 2008).

The finding that memory systems in AP possessors may operate differently than the memory systems of non AP possessors (Klein et al., 1984; Zatorre, 2003) is intriguing when considering the impairments of working memory in autistic individuals. Working memory deficiencies are grouped in a cluster of other cognitive deficits termed “executive dysfunction” (Happé,1999; Happé et al., 2001; Russell, 1997; Volkmar et al., 2004) that have been thought to underlie many of the social and non-social impairments associated with autism. Impulsivity, deficits with regard to holding information in working memory in order to be able to plan and monitor behavior, lack of flexibility in the ability to move from one activity to another, and inability in inhibiting automatic movements, are some attributes that characterize executive dysfunction. The particular style of memory systems in those with AP for processing pitch could have commonalities with the style of memory systems involved in processing pitch in the general population of persons with autism. Although executive dysfunction has been associated with autism, research has indicated that it is by no means universal and it is unlikely to cause autism or deficits in adaptive function (Liss et al., 2001). Memory systems in autism may be more conducive than typically developing populations to remembering pitch information over other information.

A review of what is known about the developmental course of pitch processing in typical populations will provide the context for the discussion on pitch memory in non-savant autistic populations.

Pitch Discrimination in Typical Populations

This section outlines what is known about the developmental course of pitch discrimination ability in typically developing populations drawing, to a large degree, on the musical ability testing literature of the twentieth century. First, a brief explanation of pitch and frequency is needed.

Pitch discrimination, also referred to as pitch acuity, is the degree to which the frequency of a note has to change in order for an observer to detect a change in pitch (Radocy & Boyle, 2003). Frequency is the physical property of sound that occurs when a vibrating object sets air in motion. This movement is characterized by periodic rarefaction and condensation of air molecules referred to as sound waves. Sound waves are measured in cycles per second or Hertz (Hz) (Backus, 1969; Helmholtz, 1954). Although frequency and pitch are closely related, they are not the same. Frequency can be measured objectively using a physical apparatus while pitch is a psychological phenomenon measured subjectively by a human observer (Backus, 1969; Helmholtz, 1954; Joseph, 1967; Radocy & Boyle, 2003). The relationship between frequency and pitch is not exact. A small change in frequency does not necessarily alter the pitch of tone (Radocy & Boyle, 2003). Concepts of pitch vary under certain conditions and between individuals. Judgments of pitch are better for middle range tones and poorer for the tones in both the upper and lower range of hearing. The approximate frequency range of audible sound is 15-15,000 Hz. Concepts of pitch can vary with intensity levels even though frequency remains stable (Sergeant, 1973). For example, pure tones below 1000 Hz and above 3000 Hz can be perceived as getting higher or lower in pitch with increased intensity levels. Complex tones, those that are generated by musical instruments, are generally thought to be more stable and easier to discriminate than pure tones (Backus, 1969; Joseph, 1967; Mursell, 1970; Radocy & Boyle, 2003; Seashore, 1938), although timbre has been shown to affect musician's judgments as to whether a tone is sharp or flat (Wapnick & Freeman, 1980). It would seem that the relationship between frequency and pitch is complicated and at times can seem ambiguous.

The human ear is more sensitive to changes in the frequency than to changes in the duration or the intensity of sound (Backus, 1969; Cranford, 2008). In laboratory conditions, it is generally accepted that the average adult can discriminate as little as 3 Hz difference between pitches (Backus, 1969; Seashore, 1938). At frequencies of up to 1000 Hz, 3 Hz is .3 % of the pitch, which is .05 of a semitone or approximately 20 cents. A cent is one-hundredth of a semitone (Backus, 1969). For example 50 cents is thus a half semitone or, a quartertone. When frequencies are lower, pitch discrimination is poorer. A 3 Hz difference between two tones becomes a much bigger percentage of the pitch at lower frequencies. For example, 3 Hz is 10% of a 30 Hz pitch. There is evidence of some conflicting information with regard to discrimination thresholds. For example, from the audiological literature, Cranford (2008) reports that most healthy young people can distinguish a 1-2 % change in frequency, up to 1000 Hz.

Developmental Course of Pitch Discrimination

It is widely accepted that pitch discrimination can be improved with training. However there has been some debate on this topic. Carl Seashore, a pioneer in the field of musical ability testing, felt that this ability was innate, stable, and could not be improved by training (Seashore, 1938). His "Measures of Musical Talents" was the first published standardized test of musical ability. He felt that any developmental improvement in pitch discrimination was a function of either the child's improved understanding of the nature of the task, improved attention to the task, or a combination of both.

Others believed that pitch discrimination abilities were largely acquired throughout a child's development (Lundin, 1967; Révész, 1954). As the nature - nurture debate raged on, musical ability testing gradually lost favor in music education as fears of musical elitism ensued (Murphy, 1999). Whatever the beliefs of music psychologists and music educators as to the usefulness of tests of music ability, we should recognize that information from the music ability testing of the first half of the twentieth century is useful in understanding the developmental course of sensory capacities such as pitch discrimination in children.

We know that from even before a child is born, hearing is very acute. Newborns whose mothers vocalized to them while in the womb favored familiar melodies and stories over unfamiliar ones (De Casper & Spence, 1986; Panneton, 1985). Infants are capable of extracting contour information from both melody and speech prosody. This suggests that musical processing capacity is present before birth. This ability is substantial considering that the sense of sight is not fully developed until some time after birth (Dworetsky, 1981). In addition, there has been some indication of auditory sensory dominance in infants four, six and ten months old (Rosenblith, 1992). In that study, when auditory and visual stimuli competed for infants' attention, it was the auditory stimulation that dominated.

Research has focused intensively on the importance of music in early language learning in infants. Some researchers argue that musical innateness is important to the evolutionary adaptability of our species (Papoušek, 1996; Trainor, Wu, & Tsang, 2004; Trehub, 2003). Musical competence in toddlers has been assessed by analyzing the manner in which spontaneous musical babbling develops into song (Hargreaves, 1986). Researchers have described a process whereby the spontaneous chants of the infant eventually become "outline songs" of the 2 year old (Moog, 1976; Moorhead & Pond, 1978). Children of this age are able to reproduce the contour of a song but leave out the precise details of pitch and rhythm. By the age of 4 or 5, children are capable of memorizing a significant repertoire of songs from their culture. The outline of the song has been filled in somewhat but in most cases is largely dependant upon the lyrics (Feierabend, Saunders, Holahan, & Getnick, 1998). Some pitches within small groups of notes become more accurately sung but in the majority of children there remains considerable inaccuracy between certain intervals that results in a roaming tonic note (Flowers & Dunne-Sousa, 1990; Hargreaves, 1986). Children of this age are more apt to sing offkey than older children (Cooper, 1995). Cooper found that average vocal pitch deviation was as large as a semitone in both echoing a musical phrase and singing in unison. Her subjects ranged in age from 6-11 years. When 4 and 5-year-old children were required to recognize a different tone in a series of 3 consecutive pitches, the threshold for judging whether the different tone was indeed different was as much as 80 Hz at the level of 440 Hz, approximately 3 semitones, or the size of a minor third (Jensen & Neff, 1993).

It would seem that the last skill to develop in children's singing is the accurate discrimination of pitch within the framework of tonality (Hargreaves, 1986). This could be a consequence of the developing vocal tract of the child (Flohr, 2005; Trollinger, 2003), difficulty in accurately perceiving what is being produced as a product of an immature "feedback" system (Hewitt, 2002), or difficulty with discriminating fine differences in pitch. It may be that all these factors play roles in reproducing what is being heard.

A reliable source of information on the developmental course of pitch discrimination in children between the ages of 7-14 comes from the musical ability testing literature. In order to illustrate pitch discrimination thresholds accurately, I will describe pitch deviations in terms of cents.

Three standardized tests of music ability contain a pitch discrimination task similar to the one employed in the present study. In Seashore's pitch discrimination tasks, participants respond by indicating whether the second of two tones was higher or lower. He used tones with differences as small as 2 cents (Lundin, 1967; Seashore, 1938). The test was originally intended for children in grade 8, approximately 13 and 14 years of age. Although norms were developed for children as young as grade 4, Seashore's test has been criticized for its length and inability to sustain attention in younger children (Bentley, 1966; Lehman, 1968). The Kwalwasser-Dykema Music tests employed a similar pitch discrimination task but the reliability of the battery remains in question (Lehman, 1968; Lundin, 1967; Shuter-Dyson, 1981). A test of musical ability developed especially for children aged 7-14 was Arnold Bentley's "Measures of Musical Ability" (Bentley, 1966, 1968; Lehman, 1968). By 1966, Bentley had administered these tests to 2000 children. The Measures of Musical Ability had a retest reliability of .84 suggesting that when the same test was administered a second time, the results were similar to the first test 84% of the time. Bentley's norms for pitch discrimination provide important and useful information as to the developmental course of pitch discrimination.

In the "Measures of Musical Ability," children are required to judge whether the second of two pitches is higher, lower, or unchanged as compared with the first. Deviations in pitch are as low as 12 cents. Contrary to Seashore's belief that pitch discrimination ability remained relatively stable throughout life, Bentley found that there was an annual 5 percent improvement on scores of pitch discrimination. However, performance in discriminating 12 and 24-cent pitch deviations was poor in children aged 7-12. Children aged 7-9 correctly judged as few as 35% of the 24-cent deviations and 15% of the 12-cent deviations. Performance marginally improved for 10-13 year olds who correctly judged 55% of the 24-cent deviations and 20 % of the 12-cent deviations. In fact, a surprising number of errors were made on semitone judgments. Children between the ages of 7-9 misjudged semitones 20% of the time. Similar findings have been reported. For Example, Taylor (1968) reported poor performance on a less than a semitone pitch discrimination task for children aged 8-9 years old in a pilot study using a sample of 800 children aged 8-11. When tuning an octave using an oscillator, children aged 4 -9 on average made errors of 1-2 semitones (Litke & Olsen, 1979). Similarly, little more than half of 72 ten-year-olds were able to distinguish 50 cent deviations in a same/different pitch comparison task (Geringer, 1983).

Although the Bentley test battery is the only adequately standardized music aptitude test for use in the elementary grades, caution must be exercised in interpreting the norms for the test. Pitch discrimination of pure tones is very difficult in a group testing situation due to the varying intensity levels throughout any given room (Sergeant, 1973). Also, there are claims that Bentley’s pitch discrimination task was recorded inaccurately. Apparently, the preciseness of the frequency deviation from the standard pitch is in doubt (Mills, 1984).

The audiological literature concerning children’s pitch discrimination ability is sparse. Maxon & Hochberg (1982), however, reported average frequency discrimination thresholds of approximately 25 cents for eight 8 year olds and 16 cents for twelve 12 year olds in a same/ different two-tone comparison task where the standard frequency was 500 Hz. The authors concluded that by the age of 12 or 13 pitch discrimination reaches adult levels. The sample size was small, so caution should be taken in interpreting the data.

From the musical ability testing and audiological literature we can see a general trend showing that pitch discrimination improves with age. The magnitude and rate of improvement is less clear. Discrepancies in findings may have to do with specific tasks employed, language required for a correct response, problems with the group testing method, quality of recording, attention capacity in children of differing ages, and small sample sizes. The exact difference in pitch discrimination ability between age groups is not clear.

The research on pitch processing in autism may indicate a much different developmental path.

Pitch Processing in Autism

Pamela Heaton found that the memory for pitches was superior in a group of high functioning school-aged children with autism than was for typically developing school-aged children (Heaton et al. 1998). High functioning children with autism with no previous musical training outperformed typically developing children in remembering tones when paired with animal pictures, for up to one week after the learning condition. The memory for pitch was superior to that of speech sounds paired with pictures. Also, high functioning children with autism had better pitch memory than the controls when identifying individual tones within a chord (Heaton, 2003). These findings may point to the possibility that in non-savant autistic populations a cognitive strategy similar to AP ability was being employed to recall individual pitches.

Bonnel et al. (2003) found that adolescents and young adults with autism had more accurate discrimination for pitches less than a semitone apart in a same/different task. In that study, the group with autism discriminated two tones 18 cents apart more accurately than the typically developing group. Performances such as these where comparisons are made between small pitch differences may be attributed to better short term memory for pitch among persons with autism.

These two studies exemplify, in the auditory domain, the tendency in autism for elevated performance on tasks where discrimination of detail is important. Researchers have viewed the cognitive strategy used in autism as “style” rather than deficit (Happé, 1999).

Cognitive Style in Autism

Many researchers view auditory abilities in autism as analogous to abilities in the visual domain. Those with autism tend to perform very well on visual tasks where the memory for detail is important and non-verbal reasoning skill is employed. An extreme example of the visual memory of a savant draughtsman indicates a visual processing trend in non-savant autistic populations (Mottron & Belleville, 1993). Mottron observed that the drawings of this savant always grew from one unimportant detail. The picture was then composed piece by piece. In contrast, a professional draughtsman would approach the task by making an outline and then filling in the details. Researchers have explained the strategy used by those with autism as one that focuses on detail. It is thought that autistic individuals have a tendency to process details at the expense of understanding details in terms of context (Heaton, 2003; Heaton et al., 1998; Lord et al., 2002; O' Riordan, Plaisted, & Driver, 2001; Rutter et al., 2005; Shah & Frith, 1993). This tendency in cognitive processing has been termed weak central coherence (Happé, 1999) and predicts poor performance in tasks where context is a factor. Psychologists have viewed AP ability in musical savants as a form of weak central coherence (WCC). A superior memory for pitch may interfere with the understanding of specific notes in terms of the context of a scale or a piece of music (Shah & Frith, 1993).

There is some controversy however, with the wholehearted acceptance of a cognitive strategy in autism that excludes contextual understanding. Research has shown that high functioning autistic individuals understand the gestalt of a short melody (Mottron, Peretz, & Ménard, 2000) and visual detail in terms of context (Mottron & Belleville, 1993). Superior performance on visual and auditory tasks may reflect the development of enhanced perceptual functioning in autism (Mottron & Burack, 2001; Mottron et al., 2006). According to this model, those with autism prefer to process detail. This model differs from that of WCC to the degree in which the processing of context and detail interact. The preference for processing detail may not necessarily predict an imbalance between the two.

Evidence for a cognitive strategy employing both detail and context in a task where harmonic expectations are violated (Heaton, Williams, Cummins, & Happé, 2007) and in perceiving melody pairs to be the same or different (Foxton et al., 2003) provides further evidence that where music processing is concerned, autistic individuals may be using strategies which contradict the weak central coherence theory. However, replicating the results of those studies that employ the two cognitive strategies of recognizing both detail and detail in terms of context have been difficult. Heaton (2005) found that superior pitch discrimination in the autism group did not result in superior contextual discrimination of melody pairs containing small pitch changes. Furthermore, Altgassen et al. (2005) failed to replicate both Heaton's findings of superior long term pitch memory (1998) and chord tone labeling ability (2003) in a group of autistic children.

Evidence for Subgrouping

Altgassen (2005) found that when subdividing the autism group into groups with and without Asperger's syndrome that memory for individual pitches reached significance in the group with Asperger's syndrome. The participants with Asperger's syndrome performed more accurately than the typical group and the group with autism when remembering and identifying individual tones within a triad. Heaton et al. (2008) reported similar results. She found that a group of children with autism performed at ceiling levels on a sophisticated interval categorization task. Their performance on both the interval categorization task and long-term memory for pitch was four to five standard deviations above the mean. Perhaps elevated performance on some auditory tasks as compared to typically developing children indicates another developmental difference for a certain subgroup of children with autism.

Cognitive Style in Autism vs. Spatial Temporal Reasoning Ability

As mentioned previously, researchers have found that children with autism perform better than typically developing children on visual tasks where detail and non-verbal reasoning skills are required. Elevated performance of children with autism has been demonstrated on both the visual tasks of block design (Shah & Frith, 1993) and visual search (O' Riordan et al., 2001). In music education research, similar psychological tasks were used in studies where music listening and learning were linked to improvements in spatial temporal reasoning ability (Rauscher, Shaw, Levine, Ky, & Wright, 1994).

The block design task of the Wechsler Intelligence Scale for Children (Weschler, 1992) involves copying a design from a group of blocks with different patterns. One of the difficulties of typically developing children in completing this task is in segregating the picture into its component parts. For example, if they are required to copy a black diamond design, typical children will have more difficulty understanding that the entire design can be composed of four black triangles. Autistic individuals outperformed typically developing children in this task when it was not aided by the pre-segmented condition. These tests have been used to measure weak central coherence in autism.

In music education research, performance on similar perceptual tasks improved after passive music listening. This finding has been coined as the " Mozart effect" (Rauscher et al., 1994). Performance on these tasks improved after music instruction in kindergarten children (Rauscher & Zupanee, 2000). Rauscher (1994) employed four tasks of spatial temporal reasoning from the non-verbal performance subtests of the Wechsler Preschool and Primary Scale of Intelligence-Revised (Wechsler, 1989), one of which was a block design task. These studies suggested that music education might somehow improve performance in other areas of education. The degree to which music learning transfers into other areas of learning is questionable but perhaps an important aspect to these studies was overlooked. It is plausible that the results from the Rauscher studies revealed an interaction between pitch processing and visual tasks. Perhaps strategies in processing visual and pitch information overlap.

Findings from the Mozart effect studies have been very difficult to replicate (Costa-Giomi, Gilmour, Siddell, & Lefeburre, 2001; McKelvie & Low, 2002). Schellenberg (2001) and others (Husain, Thompson, & Schellenberg, 2002) argued that improved performance on tests of spatial ability after listening to Mozart is more a consequence of altered mood and arousal effects rather than it being due to alterations in cognitive performance per se. However, the Mozart effect has been shown in studies measuring the brain waves of epileptics while listening to the Mozart Sonata K 448. Listening to music generated regular brain wave patterns in epileptics (Hughes, Daaboul, Fino, & Shaw, 1998). Epileptiform activity is characterized by sudden bursts of extremely erratic brain wave patterns. During Mozart listening, the frequency and amplitude of epileptiform discharges decreased. The effect of the Mozart K 448 sonata cannot be viewed as a result of a changing awareness, attention, or a reflection of a deep appreciation of music. Some patients were in a coma and others were in status epilepticus without any outward signs of reactivity. In a pilot study employing two children with epilepsy, a similar result was found (Turner, 2004). An overall greater than 25% decrease in epileptiform activity occurred when listening to the Mozart K 448 sonata compared with a control music and a silence condition. These studies are interesting in light of the fact that autism has been genetically linked to epilepsy (Bailey, et al., 1998; Volkmar, et al., 2004). In fact, children who have core autism often develop epilepsy (Jordan, 2005).

Aside from the obvious debate as to whether music learning enhances other types of learning we may want to consider whether pitch processing may be related to visual processing. In terms of understanding pitch processing in autism, perhaps we should be looking to the cognitive origins in processing visual and pitch information. Those with autism consistently perform at average or significantly above average on visual tasks where non-verbal reasoning skills are required. This is significant considering poor performance typical of those with autism on tasks where language and social reasoning skills need to be employed. Visual and pitch processing ability seem to be, to a large degree, preserved in autism. Would ability in one area such as visual processing predict ability in the other and vice versa? Are the two cognitive processes connected and if so why? Is there evolutionary adaptability to this connection common to the human species in general or is this possible connection created from developmental processes specific to autism? Learning more about the cognitive processes in autism where ability is spared in certain areas despite gross deficits in others will contribute to the understanding of cognitive processes in both typical populations and in autistic populations.

Backward Masking

Another aspect of pitch perception in autism and how it may interact with language learning deserves to be mentioned here. Backward masking is an experimental task whereby a pure tone interval is followed by a narrow frequency band of noise. Backward masking interfered with language impaired children's ability to correctly identify a different interval in a three interval, three forced choice task (Marler, Champlin, & Gilliam, 2002). In order to identify whether the intervals were the same or different, the intervals had to be louder for the language-impaired children as opposed to the typically developing children. The measurement of electrical brain reactivity during this task indicated that for language impaired children, there is a deficit in auditory memory for complex non-musical sounds. When these findings are considered in terms of encoding consonant and vowel sounds, difficulty in perceptually segregating the two acoustic events could disturb linguistic processing. The " noise" or irregular frequency of the consonant sound may impede the comprehension of the tone or more regular frequency of the vowel sound. There is some debate about whether aspects of a language disorder overlap with autism (Bishop, 1989) but similar findings suggest that in autism there is a deficit in " auditory scene analysis" (Bregman, 1990). This deficit is characterized as an inability to segregate streams of sound. Individuals with autism have a reduced ability to accurately perceive speech in noise and this deficit has been thought to contribute to social impairments (Alcantára et al., 2004). Autistic individuals were found to visually fixate on mouths during social situations (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). The fixation times on mouths and objects were strong predictors of social incompetence. If an auditory impediment affects the memory for consonant and vowel sounds, an autistic individual may focus on mouths as an effort to decode sound. This type of auditory impediment may affect those with autism in two ways. Difficulty with attending to multiple streams of sound in social situations could predict social impairments while difficulty in processing consonant sounds may predict an overdeveloped pitch processing ability in autism.

Interest in Music

Children with autism have consistently shown sensitivity to music (Kanner, 1971; Thaut, 1988; O'Connell, T. S., 1974; Grandin, 1988). Research has shown that children with autistic symptoms were more likely to activate a speaker that gave them access to sung lyrics than they were to activate a speaker that gave them access to spoken lyrics (Grandin, 1988). Grandin (1988; 1995) reported that as an autistic child the only thing she could memorize were melodies. Many researchers have found that not only do autistic children enjoy music; they also frequently demonstrate a high level of musical ability even in comparison with typically developing children (Applebaum, Egel, & Koegel, 1979; Armstrong & Darrow, 1999; Thaut, 1988). Applebaum et al. (1979) found that children with autism demonstrated high levels of accuracy in imitating a series of tones. Thaut (1998) showed that children with autism exhibited high levels of musical sophistication in their improvised tone sequences. In addition, many children with autism are echolalic (Frith 2007). They mimic speech and the sounds they hear in their environment often with unusual preciseness of inflection. The observation that many children with autism enjoy music, exhibit imitation and improvising ability, and are able to mimic sound, point to the possibility that individuals with autism may have a strong melodic memory.

The following is a review about what is known about the development of melodic memory in typical populations and is an indicator of the norms for this type of memory.

Developmental Course of Melodic Memory

To a large degree, pitch discrimination ability and melodic memory are connected. If discrimination of individual pitch is poor, then memory for melody will suffer. Much of the previous literature on the developmental course of pitch discrimination applies here as well. As children mature and pitch discrimination develops, outline songs gradually become more precise. Memory for melody improves with maturity. Once again we can look to the musical ability testing of the first half of the twentieth century for information on the developmental course of melodic memory.

Tests of short term memory for melody, often referred to as tonal memory, were often employed in the musical ability testing of the first half of the twentieth century (Bentley, 1966; Lehman, 1968; Lundin, 1967; Seashore, 1938; Seashore & Carl, 1917; Shuter-Dyson, 1981; Wing, 1968). In the tonal memory tests devised by Seashore, Bentley, Wing, and Kwalwasser-Dykema, participants identify whether two melodies are the same or different. If the second melody is different, the participants indicate which note is altered. Performance on the subtests of pitch discrimination and tonal memory are often found to have higher correlations than correlations between other subtests (Shuter-Dyson, 1981). An interpretation of this association is that a general perceptual factor for musical material is at work, and that this factor provides information about the concept of musical ability. Another interpretation is that the two tasks require similar skills (Booth, 1978) . Booth (1978) suggests that when discriminating differences between two tones or two melodies where one note has been altered, subjects enlist the same strategy to solve the problem. Despite the problems in determining what underlying skill is being measured, an obvious difference when comparing the two tasks has to do with memory storage. The tonal memory task will make more demands on the retrieval of short-term memory.

The reliabilities for both the tonal memory and pitch discrimination tasks are high for the Seashore Measures (Lundin, 1967). In fact, Farnsworth (1931) felt that the pitch and tonal memory test of Seashore’s Measures of Musical Talent, 1919 version, were the only subtests that had any predictive value for success in musical endeavors.

The Seashore measures, as mentioned previously, have been criticized for their length and inability to sustain attention in younger children. Also, the reliability for the Kwalwasser-Dykema Battery is in question. Although the Wing battery has good reliability for younger children, the normative data for the tonal memory subtest has been included with the data for two other subtests. The information of the norms for tonal memory in isolation is not available. However, Bentley's tests of tonal memory with reliabilities of .84 may be an indicator of the norms for this particular tonal memory test in young children.

In the test of tonal memory, Bentley reported a 26% mean accuracy rate of the 7-year-olds in discriminating whether a melody was the same or different (Bentley, 1966). By comparison, the 12 year old mean accuracy rate was 69%. As with the pitch discrimination task, Bentley found a steady developmental improvement in the tonal memory task. Children from 7-12 years of age exhibited an average 8.6% yearly improvement on their tonal memory score. Fourteen-year-olds performed almost as well as musically untrained adults. Identification of the melodies as same or different was hardest when the first note had been altered and easiest when the last note had been altered. Bentley also found both the pitch discrimination task and the tonal memory task modestly correlated. The norms were derived from the testing of 2000 school children of " normal school classes " (Bentley, 1966). How much music instruction was offered in the school system or what percentage of children had private music instruction, we do not know.

Music psychologists have been interested in aspects of tonal patterns that facilitate melodic memory (Deutsch & Feroe, 1981; Dowling, 1978; Krumhansl, 1990, 1991). Much of the focus in this area deals with the manner in which various populations perceive tonality and how these perceptions might interact with memory capacity. In line with gestalt psychology (Krumhansl, 1990, 1991; Radocy & Boyle, 2003), it is generally accepted that memory for a sequence of tones as a group of connected sounds will be much stronger than the memory for each individual note in succession. In fact, the salience of each individual note pales in its contribution to the reconstructed meaning of the group of notes in context. The context referred to here is tonality. Melodic patterning depends on cultural conventions of scales and harmony. Recognizing and remembering sequences of notes in context requires familiarity with the musical conventions of the culture (Blacking, 1973). In order to perceive a sequence of notes as a melody, a certain amount of learning, whether informal or formal, is necessary (Cooper, 2005; Hebb, 1949). Hebb (1949) referred to all pattern perception as relative phenomena. He felt that the ability to perceive patterns developed only with direct experience from one's environment and culture. In this way, conventions of culture are learned. This seems to be the case with musical pattern perception. Research has shown that in rating the tonality of a sequence of notes, there is close agreement between both highly trained musicians and those with less experience (Cuddy, 1982). In a similar vein, both musically experienced North American children and adults had difficulty remembering a Japanese tune that used the musical conventions of that culture (Oura & Hatano, 1988). Experience plays a role with rating the final note of a sequence using the probe note technique (Lamont, 1998). Lamont (1998) found that both musically experienced adults and children gave higher ratings to final notes that followed the rules of tonality. In that study, age played a factor in children's improved probe note rating scores. Thus, formal and informal experience tends to heighten perception of tonality.

Experience with the musical tonality of a culture would seem to play a role in children's accuracy in vocally reproducing a melody. For young children, contour is favored over accuracy of pitch intervals (Moog, 1976; Moorhead & Pond, 1978). This may be due to a factor of limited experience with tonality. Age seems to be a factor in the ease with which children remember melodies (Jordon-DeCarbo, 1989; Kauffman, 1990).

In adults, research shows that tonality plays an important role in melodic memory (Krumhansl, 1990). When melody is encoded in short-term memory, subjects will remember contour in the context of tonality. Recognition of a different comparison melody is harder when the intervals were altered so that the rules of tonality and contour was preserved (Dowling & Fujitani, 1970). In situations where subjects were required to discriminate whether pairs of melodies were the same or different, performance was better when the altered intervals of the different melody violated rules of tonality (Dowling, 1978). It would seem that memory for melody is more salient for highly structured tonal sequences than it is for unstructured atonal sequences regardless of training (Cuddy, 1982).

Training seems to play a role in melodic memory. Musically experienced subjects tend to make finer distinctions between contour and exact interval sizes at least for melodic groupings of notes stored in short term memory (Bentley, 1966; Lamont, 1998). Participants who have more experience working within the context of tonality may enlist more strategies such as pitch labeling, to remember and to subsequently recognize a melody. There is evidence however, that long-term storage of melody may work differently. Familiar tunes may be stored in memory as a unit where individual components of the tune are remembered in context. Both musically experienced and inexperienced subjects are able to discriminate between familiar tunes and comparison melodies with a high degree of accuracy regardless of whether they can label individual pitch distances (Attneave & Olsen, 1971; Davies & Jennings, 1976). Feedback on the nature of individual pitch differences does not improve melodic memory over silent rehearsal (Davies & Yelland, 1977). Taken together, these studies support the view that long-term melodic memory operates as an internal construct. Accurate performance depends on comparing a melody to the internal construct or template of the familiar and over learned melody regardless of whether the individual pitch intervals can be categorized or labeled.

Summary

In the effort to understand autism in a wider context, an emerging concept of this developmental disorder is that it may be more a product of a different cognitive style than a cognitive deficit (Happé, 1999; Shah & Frith, 1993). Ability in memory for pitch may be part of this cognitive style. The possibility that this ability interacts at some level with the fluid reasoning skills of those with autism in visual tasks could further the concept of cognitive style.

The supposition that some of the facets of musical savant ability could be found in other autistic populations have been supported to some degree (Heaton et al., 1998; Heaton et al., 2003; Heaton et al., 2008). The research suggests that those with autism have a strong memory for pitch information (Bonnel et al., 2003; Heaton et al.,1998;

Heaton, 2003). This is a significant finding, especially considering that memory for other types of information like language, is often severely impaired.

The difficulty, however, with this body of research is that it is not extensive enough to make any clear delineations. Also, some studies have been difficult to replicate. Research is difficult using autistic populations. Not only is finding appropriate subjects extremely difficult, performance on any particular task of a study can be tenuous when problems such as anxiety with novel situations and people become a factor. Autism studies in musical perception to date have been few, likely reflecting the difficulty with recruiting subjects. More research and improved methods of testing in this area are needed in order to answer the question of cognitive style in autism.

An underlying theme in the literature review of pitch processing in autism has to do with enhanced memory for pitch information. Whether the aim of the studies of musical perception in autism was to discriminate two pitches as same or different (Bonnel, et al., 2003), remember individual pitches (Heaton et al., 1998; Heaton, 2003), categorize intervals (Heaton et al., 2008), or recognize an altered note within a melody (Mottron et al., 2000), memory for pitch was employed.

This study extends the previous research in a number of ways. First, pitch discrimination has not been researched in children with autism to date. In fact, information on the developmental course of pitch discrimination in typical populations, from an audiological standpoint, is sparse. Although pitch discrimination was tested in typical populations within the framework of the musical ability movement, Bentley's tests were the only ones designed especially for use in children. Although his measures have good reliability, there were problems with the accuracy both in administration methods and in the actual recording. Thus, more extensive developmental research in this area is needed not only for autistic populations but also for typically developing populations as well. In addition, this study will reveal to what degree children with autism can discriminate mistuned pitches within the framework of a memorized melody. Their performance on such tasks could provide information as to the nature of cognitive processing in autism and its relationship to theories of weak central coherence and enhanced perceptual processing. Understanding the developmental course of pitch discrimination in children with autism and making comparisons with typically developing populations may have implications for language development both in autistic and typical populations.

Second, this study will determine whether autistic children's enhanced memory for individual pitches (Heaton et al., 1998; Heaton 2003) would extend to melodic memory. Such a finding would be significant in light of memory deficits in other areas.

Third, this study will indicate to what degree the various measures of pitch memory are correlated with visual non-verbal reasoning ability in both typically developing children and children with autism.

Fourth, this study will demonstrate whether there is a relationship between sound sensitivity in children with autism, pitch discrimination ability, and melodic memory.

Finally, this study would determine any developmental differences between children with autism and typically developing children in discriminating a flat versus sharp note in both the single tone and melodic context.

The following specific research questions were addressed during the course of this study.

Research Questions

The research questions of this study apply to school-age children between the ages of 8 and 12.

1. How do children with autism perform on pitch discrimination tasks as compared to typically developing children in the following contexts:
   a. Discrimination of isolated tones?
   b. Discrimination of tones embedded in a melody?

2. How do children with autism perform on melodic memory tasks as compared to typically developing children?

3. What are the relationships between performance on the Leiter International Performance Scale Revised (Leiter-R) (See Appendix J), a measure of non-verbal reasoning ability, and the various musical tasks of the study?
   a. Is there a relationship between overall (autistic and typical) performance on the Leiter R and overall performance on pitch discrimination in the single tone task?
   b. Is there a relationship between overall (autistic and typical) performance on the Leiter-R and overall pitch discrimination in the melodic task?
   c. Is there a relationship between overall (autistic and typical) performance on the Leiter-R and overall melodic memory?
   d. Is there a relationship between autistic children's performance on the Leiter- R and their pitch discrimination in the single tone task?
   e. Is there a relationship between autistic children's performance on the Leiter-R and their pitch discrimination in the melodic context?
   f. Is there a relationship between autistic children's performance on the Leiter-R and their melodic memory?

g. Is there a relationship between typically developing children's performance on the Leiter-R and their pitch discrimination in the single tone context?
h. Is there a relationship between typically developing children's performance on the Leiter-R and their pitch discrimination in the melodic context?
i. Is there a relationship between typically developing children's performance on the Leiter-R and their melodic memory.

4. What are the relationships between autistic children's performance on the musical tasks of the study and their developmental sensitivity to sound?
    a. Are parental accounts of developmental sensitivity to sound in children with autism related to their performance on pitch discrimination in the single tone task?
    b. Are parental accounts of developmental sensitivity to sound in children with autism related to their performance on pitch discrimination in the melodic task?
    c. Is there a relationship between parental accounts of developmental sensitivity to sound in children with autism and their melodic memory?

5. What are the performance comparisons between children with autism and typically developing children in the musical tasks of the study when discriminating either a flat or a sharp note?
    a. How do children with autism perform on pitch discrimination tasks as compared to typically developing children when one pitch is sharp in a single tone context?
    b. How do children with autism perform on pitch discrimination tasks as compared to typically developing children when one pitch is flat in a single tone context?

c. How do children with autism perform on pitch discrimination tasks as compared to typically developing children when the leading tone is sharp in a melodic context?
d. How do children with autism performance on pitch discrimination tasks as compared to typically developing children when the leading tone is flat in a melodic context?

Research Hypotheses

All research hypothesis refer to school-age children between the ages of 8 and 12.

1. There will be no difference in performance between children with autism and typically developing children on pitch discrimination tasks.
    a. There will be no difference in performance between children with autism and typically developing children's pitch discrimination in the single tone task.
    b. There will be no difference in performance between children with autism and typically developing children's pitch discrimination in the melodic task.

2. There will be no difference in melodic memory between children with autism and typically developing children.

3. There will be no relationships between non-verbal reasoning ability, as measured by the Leiter-R, and performance on the various musical tasks of the study.
    a. There will be no relationship between overall (autistic and typical) non-verbal reasoning ability, as measured by the Leiter-R, and overall performance on pitch discrimination tasks in a single tone context.
    b. There will be no relationship between overall (autistic and typical) non-verbal reasoning ability, as measured by the Leiter-R, and overall performance on pitch discrimination tasks in a melodic context.
    c. There will be no relationship between overall (autistic and typical) non-verbal reasoning ability, as measured by the Leiter-R, and overall melodic memory.
    d. There will be no relationship between autistic children's non-verbal reasoning ability, as measured by the Leiter-R, and their performance on pitch discrimination tasks in the single tone context.

e. There will be no relationship between autistic children's non-verbal reasoning ability, as measured by the Leiter-R, and their performance on pitch discrimination tasks in the melodic context.

f. There will be no relationship between autistic children's non-verbal reasoning ability, as measured by the Leiter-R, and their melodic memory.

g. There will be no relationship between typically developing children's non-verbal reasoning ability, as measured by the Leiter-R, and their performance on pitch discrimination tasks in the single tone context.

h. There will be no relationship between typically developing children's non-verbal reasoning ability, as measured by the Leiter-R, and performance on pitch discrimination tasks in the melodic context.

i. There will be no relationship between typically developing children's non-verbal reasoning ability, as measured by the Leiter-R, and their melodic memory.

4. There will no relationships between autistic children's developmental sensitivity to sound and performance on the various musical tasks of the study

   a. There will be no relationship between parental accounts of developmental sensitivity to sound in children with autism and their performance on pitch discrimination in a single tone context.

   b. There will be no relationship between parental accounts of developmental sensitivity to sound in children with autism and pitch discrimination in the melodic task.

   c. There will be no relationship between parental accounts of developmental sensitivity to sound in children with autism and their melodic memory.

5. There will be no difference between autistic children and typically developing children in their discrimination of a flat versus a sharp note.

   a. There will be no difference in performance between children with autism and typically developing children's pitch discrimination where one note is sharp in a single tone context.

b. There will be no difference in performance between children with autism and typically developing children's pitch discrimination where one note is flat in a single tone context.

c. There will be no difference in performance between children with autism and typically developing children's pitch discrimination where the leading note is sharp in a melodic context.

d. There will be no difference in performance between children with autism and typically developing children's pitch discrimination in tasks where the leading note note is flat in a melodic context.

Chapter 3 Methodology

Pilot study subjects

Three boys with autism and three typically developing boys participated in the pilot study. Of the group with autism, one boy was diagnosed with Asperger's Syndrome and two had been diagnosed with PDD-NOS. The age range of the autism group was 9 years 11 months - 11 years 8 months. The age range of the typically developing group was 9 years 8 months -11 years 10 months. The participants were recruited through the Ottawa Catholic School Board and through word of mouth. Children who were taking or previously had taken private music instruction were excluded from the study. In addition, children who had a dual diagnosis of attention deficit disorder and autism were excluded. Only children with intelligence quotients (IQ's) above 70 were included in the study. It was ascertained by parental account that all children had normal hearing ability. A letter describing the experiment was sent to parents. They then signed a letter of consent. These documents can be seen in Appendices A, B, C and D.

Main Study Subjects

Twenty-five children with autism participated in the study. Eighteen of them were recruited through a number of autism support groups in the Ottawa area. The researcher made several presentations to parents of children with autism during the meetings of these groups. Flyers concerning the research were circulated to parents at support group meetings in the spring and fall of 2008. In addition, the research was advertised in autism support group newsletters. Five participants with autism were recruited by word of mouth through the researcher's contacts. Once the parent had contacted the researcher and the child's eligibility for the study had been ascertained, a letter describing the experiment was sent to parents, who then signed a letter of consent. These documents can be seen in Appendices C and D.

Two participants with autism were recruited through the Ottawa Catholic School Board. A research liaison officer at the board office was responsible for finding eligible participants and then sending information letters concerning the research to the appropriate principals within the board (See Appendix E). The principal was responsible for identifying appropriate participants. The principal sent a letter describing the experiment to parents, who then signed a letters of consent (See Appendices H and I).

The 25 typically developing children who participated in the main study were recruited through Ottawa Catholic School Board and by word of mouth. Once the child's eligibility for the study had been established, the researcher or the principal sent the parent an information letter and consent form. See Appendices A, B, F and G.

The age range for the children with autism was 7 years 10 months-13 years 2 months, mean age: 10 years 8 months. The age range for the typically developing children was 8 years 3 months-12 years 6 months, mean age: 10 years 5 months. The two groups were matched for chronological age at the group level as determined by an independent t-test ($t = 0.628$, $df = 48$, $p > .05$).

Professional psychologists had diagnosed all the children with autism. Sixteen children were diagnosed at hospitals; fourteen children had been diagnosed at the Children's Hospital of Eastern Ontario in Ottawa; one was diagnosed at Izaak Walton Killam Hospital in Halifax; and one was diagnosed at the Royal Ottawa Hospital. School psychologists diagnosed four of the children and psychologists in private practice diagnosed 5 of the children with autism, all within the Ottawa area. Sixteen children were diagnosed as having PDD-NOS, and 7 were diagnosed with Asperger syndrome. Of the two children who had been diagnosed with autistic disorder, one of them was diagnosed having severe autistic disorder at the age of 4. Table 1 shows the characteristics of the participants with autism.

The children with autism were all high functioning, IQ> 70. Four of the children with autism had tested within the gifted range of intelligence as determined by school psychologists. In order to be deemed gifted, a child must perform in the top 2% in two out of three areas on measurements of IQ. To be considered profoundly gifted, a child must perform in the top .1% in two out of three areas. Of the four gifted children, three had Asperger Syndrome and one had Autistic Disorder.

Eighteen of the children in the autism group had undergone a standard audiometric procedure. All children who underwent the procedure scored within the normal range of hearing. Normal hearing in the remainder of the children with autism and in the typically developing group was ascertained by parental account.

One ten-year-old child with Autistic Disorder and one ten-year-old typically developing child had been taking piano lessons for one year while one 13-year-old child with PDD-NOS and one 12-year-old typically developing child had been involved in a band program at school for a period of one year. All the remaining children in both the typically developing group and autistic group had never taken private music instruction nor were they involved in band programs.

Table 1

Characteristics of Participants with Autism

	Autistic Disorder	Asperger Syndrome	PDD-NOS
Participants	2	6	17
Gifted	1	2	
Profoundly Gifted		1	
Music lessons one yr	1		1
Normal Hearing Audiology	2	3	14
Normal Hearing Parental Account		3	3
Hospital Diagnoses	2	2	12
School Psychologist Diagnoses		3	1
Private Practice Diagnoses		1	4

Apparatus

Power Point 2004 for Macintosh was used to create and present all tasks in the study. All narrations, single tone pairs and both single melody and melody pairs were recorded using a Yamaha keyboard model P 90, in conjunction with Peak Le 5 recording software. All sounds were recorded in stereo using a 44.1 KHz sampling rate and 32 bit resolution. They were saved as Audio Interchange Format Files (AIFF) on an Apple MacBook computer. The AIFF files then were imported into Power Point. Narrations were recorded using a microphone attached to a set of Casonic model EP-790 headphones. The narration files were then modified by the Sound Soap plug-in of Peak in order to eliminate ambient noise recorded during this process. Participants either used a set Nextech headphones, model #3319154, or the internal speakers of the computer to listen to the tasks of the study

Stimuli

The study was conducted in two sessions separated by one week. In the first session, referred to as Music Game # 1, a pitch discrimination task was followed by a melodic memory task. A week later the child returned to complete the second session referred to as Music Game #2. In Music Game #2, a melodic memory task was presented first followed by a pitch discrimination task embedded within a melody.

Measures

Children completed the visualization and reasoning battery brief IQ measures of the Leiter International Performance Scale -Revised (Leiter-R) (Roid & Miller, 1997). See Appendix J. The Leiter-R is a measurement of non-verbal fluid reasoning ability that is uninfluenced by educational, social or family experience. The Leiter-R yields a non-verbal IQ measurement that correlates well with other IQ instruments. The entire measure takes approximately 30 minutes to administer. Participants completed four subsections of this battery yielding a brief IQ screening score. The subsections were: figure ground; a hidden picture task, form completion; a task involving recognizing component parts of objects, sequential order; a pictoral ordering task, and a repeated patterns task. The Leiter-R was administered and scored using procedures taken directly from both the manual and from a training session by a professional experienced in Leiter-R administration. An independent t-test determined that there was not a significant difference between the typically developing children's scores and the autistic children's scores on this measure ($t = 1.37$, $p > .05$).

Revisions to the Main Study Following the Pilot Study

The procedure for the pilot and the main study were identical except for the ordering and difficulty of the pitch discrimination levels. In the pilot study, children had to judge whether two tones were the same or different when one tone was 15, 25, or 35 cents sharp or flat. Children also were asked to judge whether two melodies were the same or different when the leading tone in the second melody was 15, 25, or 35 sharp or flat. Both pitch discrimination tasks using either single tone or melodies were ordered according to degree of difficulty with the easiest levels being the first. Neither the children with autism nor the typically developing children performed above chance levels on these tasks. The researcher noticed a level of frustration with both the difficulty of the tasks and with the ordering. The children tended to give up and stopped attending on the more difficult blocks of the study.

Based on the findings of the pilot study, the researcher revised the music games in two ways. a) All the pitch deviations were increased to 25, 35, and 45 cents and b) the 25, 35, and 45 cent sharp or flat trials for both the pitch discrimination of single tones and pitch discrimination of tones within a melody were completely randomized throughout each block.

For example, in the pitch discrimination trials for single tone pairs, each of the tone pairs, beginning on C, F, A, G, was presented a total of 9 times. Three of the pairs were the same while 2 deviated by 45, 35 and 25 cents. The nine trials for each of the four notes were completely randomized over the entire thirty-six pitch discrimination trials of music game #1.

The same procedure applied to the pitch discrimination trials for melody pairs in Music Game #2. Each song pair was presented a total of 9 times. Three of the song pairs were the same while two deviated by 45, 35 cents and 25 cents. The nine presentations of each of the 4 melodies were completely randomized over the entire 36 pitch discrimination trials of music game #2.

Pilot Retesting

In order to be certain that participants for both groups could perform at above chance levels, both revised versions of Music Games # 1 and # 2 were piloted. Because of the difficulty in locating appropriate autistic participants for the main study, the researcher retested the previous pilot participants. The revised pilot study was administered in the same fashion as before. All participants performed above chance levels. The mean percentage correct for children with autism was as follows: single tone pitch discrimination 73.1%, melodic memory 68.75%, pitch discrimination within a melody 77.7%. The mean percentage correct for typically developing children was as follows: single tone discrimination 81.4%, melodic memory 77.1%, and pitch discrimination within a melody 62.73%.

Procedure Main Study

Prior to commencing the research, the Research and Ethics Board of McGill University approved the study and a certificate of research involving humans was granted. See Appendices K and L. The study was also approved for implementation within the Ottawa Catholic School Board. See Appendix M. For the two children who were recruited from the school board, the researcher was given a quiet room where a laptop could be set up. The two children completed the 2 music games each separated by a week. The researcher went to the homes of these two children to administer the Leiter-R brief IQ measure 2 weeks after the music games were completed.

For all other children, the entire study was administered in the music studio of the researcher's home. During the first session, both Music Game #1 and the Leiter-R were administered. The mother signed the consent form and then the testing began. After the child had finished Music Game #1, the researcher directed the child's attention to a number of toys in an adjacent room. The child was told that s/he could play quietly before beginning another game. This gave an opportunity for the researcher to ask the mother a number of questions concerning the child's diagnoses, hearing, and sensitivity to sound. See Appendix N. After the researcher had finished speaking with the mother, the child was called in and encouraged to begin " a picture game", the Leiter-R, which was set up on a table in the room. The administration time for both Music Game #1 and the Leiter-R was approximately 1hour 15 minutes.

A week later the child returned to complete Music Game #2. The administration time for Music Game #2 was approximately 30 mins. The researcher thanked each child for participating in the study. Each child received a ticket to the movies as compensation for participating in the study.

<u>Music Game # 1: Design</u>

The design of both music games was a modification of the study designs of both Heaton et al. (1998) and Bonnel et al. (2003). The objective was to design a study that would reveal information about a) pitch discrimination of single tones in school-age autistic children, extending Bonnel's (2003) previous finding of superior pitch discrimination ability in adolescence, b) memory for melody, extending Heaton's previous finding of superior memory for individual tones (Heaton et al., 1998), and c) pitch discrimination within the context of a melody. For the pitch discrimination task, two tones were presented consecutively. Participants decided whether the pitch of the tones were the same or different. They were instructed to click the mouse on one of two buttons on the screen of the computer to reflect their choice. The buttons were color-coded, blue for same and grey for different. Buttons were labeled either same or different. The tones were one second in duration separated by one second of silence. Once the participant clicked the mouse on either a same or different button a new slide appeared and the next set of tones were heard one second later. They chose to listen to the sounds either through a set of headphones or through the internal speakers of the computer. Before starting the 36 pitch discrimination trials of the Music Game #1, the researcher determined that for each child, there was a 70% success rate in a series of practice trials.

Four different middle range piano tones were presented randomly throughout the 36 trials of the study. Middle range tones produced by an instrument are generally considered to be more stable and easier to hear than sine tones (Radocy & Boyle, 2003; Backus, 1969). They were as follows: G3 (196.00 Hz), C4 (261.63 Hz), F4 (349.23 Hz), and A4 (440 Hz). Each tone and its pair were presented a total of nine times in a randomized order throughout the 36 trials. In three of the presentations, the pairs of notes were identical. The remaining pairs were altered so that the second note of the pair was 25, 35, or 45-cents sharp or flat. After the child heard both notes on a trial, s/he clicked on either the same or different button. Once the child clicked on a button, a new slide appeared and the next trial was presented.

In the second half of Music Game #1, four two bar songs were created. See Figure 1. Each song was paired with an animal picture of a bird, fish, rabbit, or cat. See Figure 2. All the songs were in 4/4 time. The bird, cat, and rabbit songs were in the major keys of F#, Bb, and Ab respectively, and the fish song was in the key of c# minor. The cat song began on the upbeat (fourth beat of the bar) while the fish, rabbit, and bird songs began on the downbeat (first beat of the bar). Each song was approximately 3.5 seconds in length. Each animal song began after one second of silence.

There were 6 blocks of 4 trials. The four animal songs played randomly within each block. In blocks 1, 3, and 5, the animal songs were presented paired with their respective pictures. In the second block, the animal songs played without the presentation of the pictures. For blocks 4 and 6, an animal song played while all four animal pictures were presented. The child was instructed to click the mouse on the picture of the animal

“ that liked the song best.” After the child made a choice, the computer indicated which animal song had played. In this way, the child received feedback for each choice. Once the child accurately identified three or more correct melodies in one block, Music Game #1 terminated. If a child identified three or more correct melodies by the fourth block, the researcher allowed the child to finish blocks 5 and 6 and then the game was terminated.

Figure 1: Animal Songs

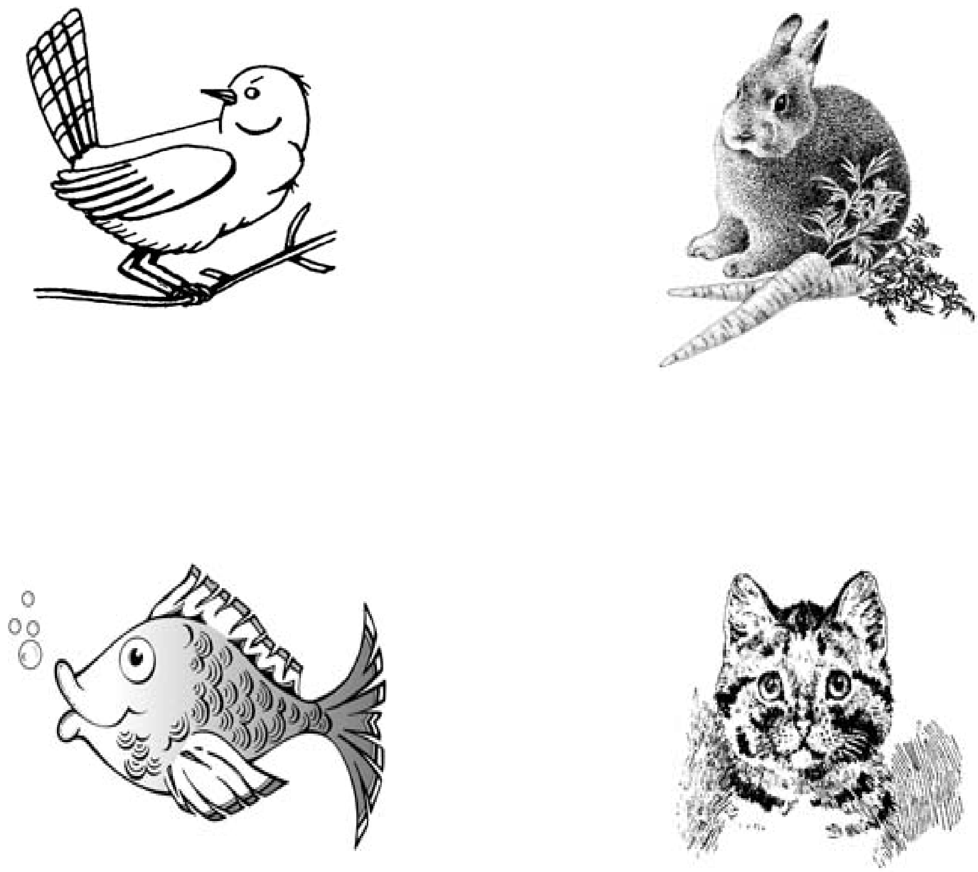
Bird Song

Cat Song

Rabbit Song

Fish song

Figure 2: Animal Pictures



music game #1: description of program.

Each child completed a series of practice trials. Once the child was comfortably seated at the computer and an appropriate volume had been established, the researcher started the game. The researcher sat at a comfortable distance from the child and recorded all responses on an answer sheet. On the first slide entitled "Music Game," two same/different buttons were displayed on the computer screen. Subjects immediately heard the researcher's voice (female) through the headphones:

> "This is a music game. In this game you will listen carefully to two sounds. You will decide if the two sounds sound the same or sound different from each other. If you think they sound different, click the mouse on the grey button. If you think they sound the same, click the mouse on the blue button. Once you have decided whether the sounds are the same or different, a new slide will appear."

The computer program was animated so that when the female voice mentioned a different grey, or a same blue button, an arrow appeared and indicated visually which of the two buttons was being referred to. Each button was programmed to light up at the appropriate time. After the phrase "a new slide will appear" the slide automatically flipped to present the next slide. Again subjects heard the female voice:

> "You will once again listen to the two sounds and decide whether the two sounds are the same or different from each other. Continue like this until the game is finished. Let's practice! In the next slides, an arrow will appear after you decide whether the sounds are the same or different from each other. The arrow will show you the correct answer. Remember, if you need to hear the sounds again, you can click the mouse on the speaker."

Again an animated arrow indicated which button was being referred to. The animated arrow also pointed to a speaker icon. This indicated to the child the option to repeat the sounds. After the phrase " you can click the mouse on the speaker " the slide automatically flipped to present the first pair of tones and the beginning of the practice trails.

There were ten practice trials. The notes of C, F, G and A were chosen randomly throughout. There were 6 different pairs. In each of these pairs the second note was 45, 35 or 25 cents sharp or flat. They were presented in order of difficulty. There were four same tone pairs. They were presented in these positions: #1, #4, #7, and # 10. Once the subject made a same or different comparison by clicking the mouse on the appropriate button, a new trial began. Immediately, an animated arrow pointed to the correct answer. In this way the child received feedback. Following the feedback, the slide automatically flipped to the next trial. When the child had finished the 10 trials of the first practice run, a slide appeared with a yes and no button on the screen. The following instructions were presented:

> "You have now finished a set of practice slides. Ask the teacher beside you if you will be doing more practice slides."

If the participant had responded correctly on at least seven of the trials, the researcher instructed the child to click the mouse on the no button which activated the 36 pitch discrimination trials of the study. If the child responded correctly on fewer than seven correct trials, the researcher instructed the child to press the yes button and another set of 10 practice trails began. Once the child responded correctly on 7 or more trials s/he started the 36 pitch discrimination trials. All children met the criterion within 3 sets of practice trails.

After the child had finished the last pitch discrimination trial, a slide entitled " musical memory " appeared. On this slide, there was a picture of a bird. The following instructions were presented:

> "You have now finished the first part of the music game. In the next part, you will listen to the songs of 4 different animals. After each song has played, click the mouse on the animal picture to take you to the next slide. Listen carefully, later on you will be asked if you can remember the animal songs"

An animated arrow pointed to the bird picture during the phrase "click the mouse on the animal picture." After the female voice stopped, the slide flipped and another picture of a bird appeared. The child heard the following comment:

"This is the song the bird likes best."

The bird song was then presented. After the song ended the subject clicked the mouse on the bird picture to flip the slide. This initiated the next trial.

In three of the six blocks, blocks 1, 3 and 5, four animal pictures: bird, cat, fish and rabbit were individually paired with their songs for a total of 12 trials. All songs were randomized over the four trials in each of the six blocks. In this part of the study the child did not have the option to repeat the song. In block #2, four animal songs were presented without the pictures. Before each song, the child heard the following comment:

"This is the song the __ likes best."

The child simply listened to the songs. The slides were blank, in order to draw the child's attention to the sound of the song. The slides were timed to flip automatically after the song had played.

In blocks 4 and 6, the child was required to remember the melodies. The four animal pictures were presented together on one slide. The child heard the female voice:

> "Now its your turn! Listen carefully to the song and click the mouse on the animal that likes the song best. After you click on a picture a new slide will appear and the arrow will show you the correct answer. Let's begin!"

One of the animal songs played and the child made a choice. Immediately after the child clicked the mouse on an animal picture, a new slide appeared. An animated arrow pointed to the correct answer. In this way, the child received feedback for their choice. After the sixth block was completed, a slide entitled "More Practice Slides?" appeared. The following instructions were presented:

"You have now finished a set of practice slides. Ask the teacher beside you if you will be doing more practice slides."

If the child had responded correctly three or more times on either the fourth or sixth block, the researcher instructed the child to click the "no" button. This button terminated the game. A slide entitled "The end" appeared. The child heard:

"You have now finished the music game. Thank-you"

If the child did not correctly identify three or more melodies by the sixth block, the researcher instructed the child to click the "yes" button. The "yes" button reset the procedure to the beginning of block 5. The child then repeated both blocks 5 and 6.

Music Game #2: Design

Music Game #2 contained one block of 16 melodic memory trials and one block of 36 pitch discrimination trials. The second session was held one week later, the child listened to an animal song and then clicked the mouse on the picture of the animal "that liked the song best". Feedback concerning the child's choice was not given at this time nor was there exposure to the melodies prior to the commencement of the 16 melodic memory trials of Music Game #2.

For the pitch discrimination task of Music Game #2, participants were required to discriminate whether two melodies were the same or different when the leading tone of the second melody was altered. Before starting the 36 pitch discrimination trials of the Music Game #2, the researcher verified that for each child, there was a 70% success rate in a series of practice trials.

The animal melodies were altered and ordered as in the pitch discrimination task in Music Game #1. Animal melodies were paired with either the same or different version of the same song. Paired melody AIFF files were ten seconds in length. Once the participant had clicked the mouse on either the same or different button on the screen of the computer, a new slide appeared and the melody pairs began after one second of silence. Each melody of the pair was separated by 1.5 seconds of silence. Each animal song pair played a total of 9 times. Three of the trials contained identical melody pairs, while in 6 of the pairs the leading tone in the second bar of the second melody was altered. In pairs where the second melody was different, the leading tone in the second bar was altered so that it was 25, 35, or 45-cents sharp or flat. The leading tone preceded the tonic in each animal song, implying a strong dominant – tonic harmony. The leading tone immediately preceded the tonic in the cat, fish, and rabbit songs while in the bird song the leading note preceded the tonic by two notes. All 36 trials were completely randomized as in the paired single tone pitch discrimination task of Music Game #1. The child listened to the melody pairs and clicked on either the same or different button as in the paired single tone pitch discrimination task of Music Game #1. Once the child clicked on a button, a new slide appeared and another trial was presented.

music game #2: description of program.

One week after the completion of Music Game #1, each child returned to complete Music Game #2. Again the child was seated in front of the computer, and once a comfortable volume level was determined, the researcher started the game. A slide appeared with the four animal pictures of Music Game #1. The following instructions were given:

> “This is Music Game #2. On each slide you will hear one of the four animal songs that you heard in the first music game. Decide which animal likes the song best and then click the mouse on its picture. A new slide will appear. Listen to this example.”

The child then heard the cat song. An animated arrow pointed to the cat and then the slide automatically flipped to the next trial. Again, a slide appeared with the four animal pictures. The following instructions were given:

> "You will once again hear an animal song. Decide which animal likes the song best and then click on its picture."

An animated arrow appeared pointing to each picture consecutively. The following instructions were given:

> "You will continue in this way until the game is finished. Let's begin! Which animal likes this song best?"

A song was then presented and the child made a choice by clicking the mouse on an animal picture. This led to the next trial. At this stage no feedback was given nor was there any opportunity to hear the song again. Four blocks of four animal songs were presented consecutively for a total of 16 trials. The four animal songs were randomized within each of the four blocks so that each song played a total of four times over the 16 trials.

After the 16 melodic memory trials, a slide appeared entitled: "The Final Part of the Music Game". On this screen there was a button labeled "same" and one entitled "different". The different button was grey and the same button was brown. Different colors were chosen for the same and different buttons to visually signify to participants that this was a somewhat different task than the pitch discrimination of single tones in Music Game #1. The entire final part of the Music Game #2, the second half of Music Game #2, was modeled and ordered identically to the pitch discrimination of single tones in Music Game #1, the first half of Music Game #1. The procedure also remained identical to the first part of Music Game #1.

Chapter 4 Results

This chapter is divided into five sections. The first section will describe the performance of both the typically developing children and the children with autism on pitch discrimination tasks in two differing contexts: pitch discrimination using paired single tones and pitch discrimination embedded within a melody. The second section will report the performance of the two groups on the melodic memory portion of the study. The third section will document correlations between the Leiter- R brief IQ scores and performance on the pitch discrimination tasks and the melodic memory measures of the study. The fourth section will document correlations between autistic children's developmental sensitivity to sound and their performance on the pitch discrimination tasks and the melodic memory measures of the study. The fifth section reports the performance comparison of the two groups on sharp versus flat pitch discrimination in both the paired single tone context and the paired melodic context.

Pitch Discrimination in Differing Contexts: Descriptive Statistics

Mean pitch discrimination scores and standard deviations for pitch discrimination in the single tone task are shown in Table 2 for both the typically developing children and the children with autism. The mean scores reflect the mean number of correct responses out of 12. Performance means for the children with autism in the single tone task were higher than the typically developing group for the 25, 35 and 45-cent levels.

Mean pitch discrimination scores and standard deviations for pitch discrimination in the melodic task are shown in Table 3. Performance means for the children with autism in the melodic task were higher than the typically developing group in the 25, 35 and 45-cent levels. Performances for both groups were not significantly different when discriminating whether two tones or two melodies were the same. Standard deviations were smaller for the children with autism in the 25, 35, and 45-cent levels for the melodic pitch discrimination task.

Table 2

Pitch Discrimination in the Single Tone Task: Descriptive Statistics

[a]n = 25	Same		25-cent		35-cent		45-cent	
	M	SD	M	SD	M	SD	M	SD
Autistic	10.88	1.62	7.20	2.97	9.30	2.29	10.68	1.58
Typical	10.68	1.60	6.42	2.95	8.28	2.74	9.66	2.25

Note. The means reflect the correct response out of a maximum of 12. *M* = mean, *SD* = standard deviation.
[a]*n* = 25 participants in each group.

Table 3

Pitch Discrimination in the Melodic Task: Descriptive Statistics

[a]*n* = 25	Same		25-cent		35-cent		45-cent	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Autistic	9.80	1.98	9.18	2.38	9.66	2.21	10.44	2.10
Typical	9.92	1.91	6.66	3.60	8.28	2.71	9.42	2.39

Note. The means reflect the correct response out of a maximum of 12. *M* = mean, *SD* = standard deviation.
[a]*n* = 25 participants in each group.

Analysis of Variance: Pitch Discrimination Levels and Contexts by Child

A three-way mixed design analysis of variance was performed to determine differences in performance between children with autism and typically developing children. Within group factors were difficulty levels (25, 35, 45-cents, and same) and context (single note task versus melodic task). See Table 4. A significant main effect was found for levels ($p < .01$) and for child ($p < .025$). Fischer's post hoc test for least significance indicated that all levels were significant $p < .01$ except the third and fourth levels (45 cents and same). In addition, a significant interaction was found between levels and child ($p < .04$) and levels and context ($p < .01$). The performance means of the children with autism and the typically developing children on each level (25, 35, 45-cents and same) and context (single tone task and melodic task) were subjected to a series of paired independent sample t-tests. The t-tests indicated that the performance means for the children with autism were statistically significant at the 25-cent and 35-cent levels in the melodic task $p < .05$. The performance means for the children with autism approached significance at the 45-cent level for the melodic task $p < .06$. The performance means of the children with autism were also significant at the 45-cent level in the single tone task $p < .05$.

Table 4

Analysis of Variance for Pitch Discrimination of Levels and Contexts

Between Subjects

Source	*SS*	*df*	*MS*	*f*	*Sig.*
Child	95.551	1	99.551	5.734	.021*
Error	799.837	48	16.663		

Within Subjects

Source	*SS*	*df*	*MS*	*f*	*Sig.*
Levels	543.797	3	181.266	43.930	.001**
Levels*Child	34.562	3	11.521	2.792	.043*
Error (levels)	594.172	144	4.126		
Context	.106	1	.106	.013	.910
Context*Child	4.951	1	4.951	.608	.439
Error (context)	390.662	48	8.139		
Levels*Context	54.107	3	18.036	6.271	.001**
Levels*Context*Child	15.422	3	5.141	1.787	.152
Error (levels*context)	414.127	144	2.876		

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

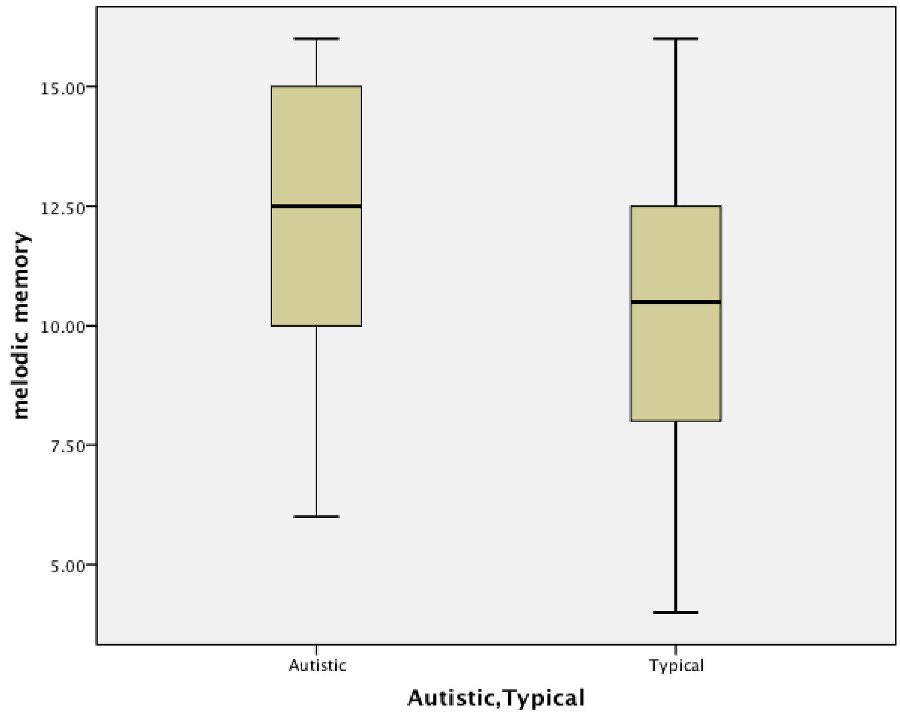
Comparison of Performance Means of Children with Autism and Typically Developing Children in the Melodic Memory Task

Out of 16 possible correct answers, the correct mean scores for each of the groups on the melodic memory task were: children with autism M = 11.84, typically developing children M = 9.88. A t-test was calculated to determine whether the difference in means was statistically significant. The independent t-test indicated that the means approached statistical significance ($t = -1.93$, $p < .059$).

Two outlier scores were removed, one from each group. One score of two was removed from the autism group and one score of three was removed from the typical group. The justification for removing these scores was that the testing procedure was difficult for each of these participants and that their scores remained well below chance. An independent t-test determined that the means when the outliers were removed (children with autism M = 12.25, typically developing children M = 10.17) was statistically significant ($t= -2.26$, $p < .028$).

The box plot compares the spread of scores for each of the groups. See Figure 3. One of the typically developing kids performed at ceiling levels with a score of 16 correct (100%) while 8 of the children with autism performed at ceiling levels, 5 with scores of 16 correct (100%) and 3 with scores of 15 correct (94%). Two of the children with autism who scored 100% were 7 and 8 years of age. The 7 year old was the youngest participant in the study.

Figure 3
Melodic Memory Performance Comparisons



<u>Overall Correlations Between Pitch Discrimination and Melodic Memory and Non-Verbal Fluid Reasoning Ability</u>

Pearson product moment correlations were performed on the scores from the Leiter-R, and the various tasks of the study for both groups of children to reveal any significant relationships between the measures. There was a significant positive correlation between scores on the Leiter-R brief IQ measure and scores on the pitch discrimination tasks in the single tone context ($r = .381$, $p < .01$), but not for the pitch discrimination task in the melodic context. A significant positive correlation was found between scores on the Leiter-R brief IQ measure and scores on the melodic memory task ($r = .317$, $p < .05$). See Table 5.

Table 5

Pearson Correlation between Pitch Discrimination and Melodic Memory of Both Groups of Children and the Leiter-R brief IQ Score.

	Single Tone Discrimination	Melodic Discrimination	Melodic Memory
Leiter-R Pearson Correlation	.381**	.168	.317*
Sig. (2 tailed)	.006	.244	.028
N	50	50	50

Note. Correlation is significant at the 0.01 level (2 tailed) **. Correlation is significant at the 0.05 level (2 tailed)*

<u>Correlations Between Pitch Discrimination and Melodic Memory in Children with Autism and Non-Verbal Fluid Reasoning Ability</u>

Pearson product moment correlations were performed on autistic children's scores from the Leiter-R and the various tasks of the study to reveal any significant relationships between the measures. See Table 6. The results were similar to the overall correlations between the overall Leiter-R brief IQ score of both the typically developing group and the group with autism and the various measures of the study. There was a significant positive correlation between the scores on the Leiter-R brief IQ measure and scores on the pitch discrimination task in the single tone context ($r = .484$, $p < .01$), but not for the pitch discrimination task in the melodic context. A significant positive correlation was found between the scores on the Leiter-R brief IQ measure and scores on the melodic memory task ($r = .404$, $p < .05$). See Table 6.

Table 6

Pearson Correlation between Pitch Discrimination and Melodic Memory of Children with Autism and the Leiter-R Brief IQ score,

	Single Tone Discrimination	Melodic Discrimination	Melodic Memory
Leiter-R Pearson Correlation	.484*	.276	.404*
Sig. (2 tailed)	.014	.181	.050
N	25	25	24

Note. Correlation is significant at the 0.01 level (2 tailed) **. Correlation is significant at the 0.05 level (2 tailed)*

<u>Correlations Between Pitch Discrimination and Melodic Memory in Typically Developing Children and Non-Verbal Fluid Reasoning Ability</u>

Pearson product moment correlations were performed on the typically developing children's scores from the Leiter-R, and the various tasks of the study to reveal any significant relationships between the measures. See Table 7. In line with both the overall and autistic correlations, there was a significant positive correlation between scores on the Leiter-R brief IQ measure and scores on the pitch discrimination tasks in the single tone context ($r = .446$, $p < 026$), but not for the pitch discrimination task in the melodic context. However, unlike the overall and autistic group's statistically significant positive correlations between the Leiter-R score and melodic memory, the correlation between melodic memory and the Leiter-R score for typically developing children was found not to be statistically significant.

Table 7

Pearson Correlation Between Pitch Discrimination and Melodic Memory in Typically Developing Children and the Leiter-R Brief IQ Score.

	Single Tone Discrimination	Melodic Discrimination	Melodic Memory
Leiter-R Pearson Correlation	.446*	.219	.336
Sig. (2 tailed)	.026	.293	.100
N	25	25	25

Note. Correlation is significant at the 0.01 level (2 tailed) **. Correlation is significant at the 0.05 level (2 tailed)*

<u>Correlations Between Pitch Discrimination, Melodic Memory and Developmental Sensitivity to Sound in Children with Autism</u>

Spearman's rank correlations were performed between developmental sensitivity to sound as reported by parental account and both pitch discrimination and melodic memory. See Table 8. No statistically significant relationships were found between developmental sensitivity to sound and pitch discrimination in either a single tone context or a melodic context. No significant relationships were found between developmental sensitivity to sound and to melodic memory.

Table 8

Spearman's Rank Correlations Between Pitch discrimination, Melodic Memory and Sound Sensitivity in Children with Autism

	Single Tone Discrimination	Melodic Discrimination	Melodic Memory
Sound Sensitivity Spearman's rho	- .213	.124	-.012
Sig. (2 tailed)	.306	.556	.954
N	25	25	24

<u>Discrimination of Sharp versus Flat Notes in Single Tone Pairs: Descriptive Statistics</u>

Table 9 shows the means and standard deviations of the children with autism and typically developing children on pitch discrimination of single tone pairs when the second note was either sharp or flat. The mean scores reflect mean correct judgments out of a possible 4 correct. Overall, higher means are reported for the children with autism at every level and direction. Performance means for both groups were larger for sharp pairs than for flat pairs.

Table 9

Discrimination of Sharp versus Flat Notes in Single Tone Pairs: Descriptive Statistics

[a]*n* = 25	25-cent				35-cent				45-cent			
	S		F		S		F		S		F	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Autistic	2.68	1.31	2.12	1.01	3.36	0.81	2.76	1.05	3.68	0.56	3.44	0.82
Typical	2.36	1.32	1.92	1.15	3.32	0.90	2.24	1.23	3.40	0.70	3.00	1.00

Note. The means reflect the correct response out of a maximum of 4. *M* = mean, *SD* = standard deviation. S=sharp, F=flat.
[a]*n* = 25 participants in each group.

Discrimination of Sharp versus Flat Notes in Single Tone Pairs: Analysis of Variance

A three-way mixed design analysis of variance was performed to determine differences in performance between autistic children and typically developing children on their discrimination of flat versus sharp notes in the single tone context. Within group factors were levels (25, 35, and 45-cents) and direction (flat versus sharp). The between group factor was child. See Table 10. Mean scores reflect correct scores out of a possible total of four correct. A significant main effect was found for direction ($p < .01$) where higher means for discrimination of sharp notes were found to be statistically significant. There was a significant main effect for levels $p < .01$. Fischer's post hoc test for least significance indicated that all levels were significant $p < .01$. There was not a significant main effect for child. Both groups of children performed better when discriminating sharp notes than when discriminating flat notes in single tone pairs at every level. There was a significant interaction between levels by direction ($p < .05$). The performance means of the children with autism and the typically developing children on each level (25, 35, 45-

cent) and direction (flat versus sharp) was subjected to a series of paired independent sample t-tests. The paired t-tests indicated that the performance means for both groups of children were significant when discriminating a sharp note at the 35-cent level in the paired single tone context. There were no significant interactions between levels by child, direction by child, or levels by direction by child.

Table 10

Analysis of Variance for Levels and Direction in Single Tone Pairs

Between Subjects

Source	*SS*	*df*	*MS*	*f*	*Sig.*
Child	6.750	1	6.750	2.316	.135
Error	139.920	48	2.915		

Within Subjects

Source	*SS*	*df*	*MS*	*f*	*Sig.*
Levels	62.207	2	31.103	49.501	.001**
Levels*Child	.140	2	.070	.111	.895
Error (levels)	60.320	96	.628		
Direction	22.963	1	22.963	24.328	.001**
Direction*Child	.563	1	.563	.597	.444
Error (context)	45.307	48	.944		
Levels*Direction	3.487	2	1.743	3.215	.045*
Levels*Direction*Child	1.127	2	.563	1.039	.358
Error (levels*direction)	52.053	96	.542		

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

Discrimination of Sharp versus Flat Notes in the Melodic Task: Descriptive Statistics

Table1 shows the means and standard deviations for children with autism and typically developing children on pitch discrimination of melody pairs when the leading tone of the second melody was either sharp or flat. The mean scores reflect mean correct judgments out of a possible 4 correct. Higher means and lower standard deviations were observed for children with autism in every level and direction. Children with autism had higher means than the typically developing children when the leading note of the second melody was either sharp or flat.

Table 11

Discrimination of Sharp versus Flat Notes in the Melodic Task: Descriptive Statistics

[a]*n* = 25	25-cent				35-cent				45-cent			
	S		F		S		F		S		F	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Autistic	2.88	1.24	3.16	0.85	3.16	0.90	3.28	0.79	3.64	0.86	3.32	0.80
Typical	2.08	1.52	2.36	1.15	2.56	1.00	2.96	1.06	3.08	1.04	3.16	1.03

Note. The means reflect the correct response out of a maximum of 4. *M* = mean, *SD* = standard deviation. S=sharp, F=flat. [a]*n* = 25 participants in each group.

Discrimination of Sharp versus Flat Notes in the Melodic Task: Analysis of Variance

A three-way mixed design analysis of variance was performed to determine differences in performance between autistic children and typically developing children on their discrimination of sharp versus flat notes in the melodic task. Within group factors were levels (25, 35, and 45-cents) and direction (flat versus sharp). The between group factor was child. See Table 12. Mean scores reflect correct scores out of a possible total of four correct. A significant main effect was found for child $p < .01$, suggesting that the higher means for the children with autism on the melodic pitch discrimination task were statistically significant There was a significant main effect for levels $p < .01$. There was not a significant main effect for direction. Fischer's post hoc tests for least significance indicated that all levels were significant $p < .01$ suggesting that children with autism were better than typically developing in discriminating whether a note was flat or sharp at every level. There were no significant interactions for levels by child, direction by child, levels by direction or levels by direction by child.

Table 12

Analysis of Variance for Levels and Direction in the Melodic Task

Between Subjects

Source	*SS*	*df*	*MS*	*f*	*Sig.*
Child	21.870	1	21.870	6.951	.011**
Error	151.027	48	3.146		

Within Subjects

Source	*SS*	*df*	*MS*	*f*	*Sig.*
Levels	23.180	2	11.590	15.139	.001*
Levels*Child	2.660	2	1.330	1.737	.181
Error (levels)	73.493	96	.766		
Direction	1.470	1	1.470	2.514	.119
Direction*Child	.963	1	.963	1.648	.205
Error (direction)	28.067	48	.585		
Levels*Direction	2.540	2	1.270	2.069	.132
Levels*Direction*Child	.527	2	.263	.429	.652
Error (levels*direction)	58.933	96	.614		

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

Summary of Findings

The results of this study are reported below in the relation to the null hypothesis.

1. **Null hypothesis 1,** "There will be **no difference** in performance between children with autism and typically developing children **on pitch discrimination tasks," was rejected.**

   a. **Null hypothesis 1a**, **"** There will be **no difference** in performance between children with autism and typically developing children **on pitch discrimination tasks in a paired single tone context," was rejected**. A four-way mixed design ANOVA indicated statistically significant main effects for child and levels. There was an interaction between levels and child and levels and context. Post Hoc Tests revealed that children with autism's means for pitch discrimination in the single tone task at the 45-cent level was significant indicating that children with autism performed better than typically developing children at this level.

   b. Null hypothesis 1b, " There will be **no difference** in performance between children with autism and typically developing children **on pitch discrimination tasks in a melodic context," was rejected**. A four-way mixed design ANOVA indicated statistically significant main effects for child and levels. There was an interaction between levels and child and levels and context. Post Hoc tests revealed that children with autism's means for pitch discrimination in the melodic task at the 25 and 35-cent levels were significant indicating that children with autism performed better than typically developing children at this level.

2. **Null hypothesis 2, "** There will be **no difference in the melodic memory** of children with autism as compared to typically developing children," **was rejected**. An independent t-test indicated statistically significant differences between the means of both groups suggesting that the children with autism had a stronger melodic memory than the typically developing children.

3. **Null hypothesis 3**, "There will be **no relationship between autistic children and typical children's performance on the Leiter-R and their performance on the musical tasks of the study," was rejected.**

a. Null hypothesis 3a, " There will be **no relationship between overall (autistic and typical) non-verbal reasoning ability,** as measured by the Leiter-R, **and overall performance on pitch discrimination tasks in a single tone context," was rejected**. A Pearson Correlation indicated a statistically significant positive correlation between non-verbal reasoning ability and pitch discrimination tasks in a single tone context.

b. Null hypothesis 3b, **"** There will be **no relationship between overall (autistic and typical) non-verbal reasoning ability,** as measured by the Leiter-R, **and overall performance on pitch discrimination tasks in a melodic context,"** was **not rejected**. A Pearson Correlation indicated no significant correlation between non-verbal reasoning ability and pitch discrimination tasks in a melodic context.

c. Null hypothesis 3c, **"** There will be **no relationship between overall (autistic and typical) non-verbal reasoning ability,** as measured by the Leiter-R, **and overall melodic memory**," **was rejected**. A Pearson Correlation indicated a statistically significant positive correlation between non-verbal reasoning ability, as measured by the Leiter-R, and overall melodic memory.

d. Null hypothesis 3d, **"** There will be **no relationship between autistic children's non-verbal reasoning ability,** as measured by the Leiter-R, **and their pitch discrimination in the single tone task," was rejected**. A Pearson Correlation indicated a statistically significant positive correlation between autistic children's non-verbal reasoning ability and pitch discrimination in the single tone task.

e. Null hypothesis 3e, **"**There will be **no relationship between autistic children's non-verbal reasoning ability,** as measured by the Leiter-R, **and their pitch discrimination in the melodic task," was not rejected**. A

Pearson Correlation indicated no significant correlation between autistic children's non-verbal reasoning ability and pitch discrimination in the melodic task.

f. Null hypothesis 3f, "There will be **no relationship between autistic children's non-verbal reasoning ability,** as measured by the Leiter-R, **and their melodic memory," was rejected**. A Pearson Correlation indicated a statistically significant positive correlation between autistic children's non-verbal reasoning ability and their melodic memory.

g. Null hypothesis 3g, "There will be **no relationship between typically developing children's non-verbal reasoning ability,** as measured by the Leiter-R, **and their pitch discrimination in the single tone task," was rejected.** A Pearson Correlation indicated a statistically significant positive correlation between typically developing children's non-verbal reasoning ability and pitch discrimination in the single tone task.

h. Null hypothesis 3h, **"** There will be **no relationship between typically developing children's non-verbal reasoning ability,** as measured by the Leiter-R, **and their pitch discrimination in the melodic task," was not rejected.** A Pearson Correlation indicated no significant correlation between typically developing children's non-verbal reasoning ability and pitch discrimination in the melodic task.

i. Null hypothesis 3i, **"** There will be **no relationship between typically developing children's non-verbal reasoning ability,** as measured by the Leiter-R, **and their melodic memory**," **was not rejected**. A Pearson Correlation indicated no statistically significant relationships between typically developing children's non-verbal reasoning ability and their melodic memory.

4. **Null hypothesis 4**, "There will be **no relationship between autistic children's developmental sensitivity to sound and their performance on the various musical tasks of the study," was not rejected**.

a. Null hypothesis 4a, "There will be **no relationship between parental accounts of developmental sensitivity to sound in children with autism and their performance on pitch discrimination in a single tone context," was not rejected**. A Spearman Correlation indicated no statistically significant relationship between parental accounts of developmental sensitivity to sound in children with autism and their performance on pitch discrimination tasks in a single tone context.

b. Null hypothesis 4b, **"** There will be **no relationship between parental accounts of developmental sensitivity to sound in children with autism and their performance on pitch discrimination tasks in a melodic context," was not rejected.** A Spearman correlation indicated no statistically significant relationship between parental accounts of developmental sensitivity to sound in children with autism and their performance on pitch discrimination tasks in a melodic context.

c. Null hypothesis 4c, " There will be **no relationship between parental accounts of developmental sensitivity to sound in children with autism and their melodic memory," was not rejected**. A Spearman correlation indicated no statistically significant relationship between parental accounts of developmental sensitivity to sound in children with autism and their melodic memory.

5. **Null hypothesis 5**, "There will be **no difference in performance between autistic and typical children's discrimination of a sharp versus flat note," was rejected.**

a. Null hypothesis 5a, " There will be **no difference in performance between children with autism and typically developing children on pitch discrimination tasks where one note is sharp in a paired single tone context," was not rejected**. A three way mixed design ANOVA showed a significant main effect of direction and level but not for child. Post hoc tests revealed that every level was significant. Both groups of children discriminated a sharp note better than a flat note at every level in the paired single tone context

b. Null hypothesis 5b, **“** There will be **no difference in performance between children with autism and typically developing children where one note is flat in a paired single tone context,” was not rejected**. A three-way mixed design ANOVA showed no statistically significant differences in performance between the groups when discriminating a difference when one note was flat versus sharp in a paired single tone context.

c. Null hypothesis 5c, “ There will be **no difference in performance between children with autism and typically developing children in pitch discrimination tasks where the leading note is sharp in a melodic context,” was rejected**. A three-way mixed design ANOVA of pitch discrimination tasks, showed a significant main effect for child and level but not for direction. Post hoc tests indicated that all levels were significant. Children with autism performed better than typically developing children at every level when discriminating both sharp and flat leading tones in a melodic context.

d. Null hypothesis 5d, “ There will be **no difference in performance between children with autism and typically developing children in pitch discrimination tasks where the leading note is flat in a melodic context,” was rejected.** A three-way mixed design ANOVA of pitch discrimination tasks, showed a significant main effect for child and level but not for direction. Post hoc tests indicated that all levels were significant. Children with autism performed better than typically developing children at every level when discriminating both sharp and flat leading tones in a melodic context.

Chapter 5 Discussion

Pitch discrimination ability and melodic memory was examined in school-aged children (7-12 year-olds) with autism and in typically developing children. Two aspects of pitch discrimination ability were examined: a) pitch discrimination of single tones and, b) pitch discrimination of a tone within the context of a melody. Both groups had limited musical training; only two children from each group had been learning to play an instrument for a period of one year. Fifty children in total played two computer music games separated by one week. Each child completed the Leiter-R brief IQ performance scale, which is a measure of non-verbal fluid reasoning ability. The parents of each child answered a series of questions concerning the child's birth date, diagnoses, hearing, and sensitivity to sound.

Interpretation of the Results

In this study, it would appear that children with autism have better pitch discrimination ability than typically developing children as was indicated in pitch discrimination of single tones in Music Game #1. This ability seems to be stronger in a melodic context as was indicated in the pitch discrimination of a leading tone within the context of a melodic in Music Game #2. How does their superior performance on these particular tasks fit in with theories of cognitive functioning in autism? In the case of weak central coherent theory (Gage et al., 2003; Happé, 1999; Shah & Frith, 1993), superior discrimination in the single tone task is predictable. Those with autism, according to this theory, have a tendency to understand their world in terms of details with limited ability to define the details within the context of a situation. In this study, autistic children's superior pitch discriminating performance in the melodic task is therefore somewhat surprising. In the melodic task children with autism were able to discriminate the details of pitch within the larger context of melody. Also interesting was that autistic children's performance diminished to typical levels when discriminating differences between two melodies when they were the same. This is unusual, as this task would seem to be the easiest of the melodic discrimination trials. This may be best explained by the enhanced perceptual theory which suggests that cognitive functioning in autism is driven by an acute detection of small changes to the environment (Mottron & Burack, 2001; Mottron et al., 2006). Perhaps recognizing when the two melodies were exactly the same was more difficult for children with autism because there was no change or difference to be discriminated. Perception in autism may be heightened when small changes occur in the environment.

In the melodic memory task, children with autism were superior to typically developing children in remembering four two bar-melodies when paired with animal pictures. These children remembered the animal “songs” better than typically developing children a week after they had been learned. Performances by a number of the children with autism were striking considering they had heard each of the melodies only four-six times a week earlier. Eight of the 25 children with autism performed at ceiling levels, one of which was a 7-year-old male who was the youngest participant in the study. Another 8-year-old male who also performed 100% on this task appeared to be barely paying attention. He found it difficult to sit still, and his attention seemed to be darting from one aspect of the room to another. It seemed as though he was able to recall the melodies instantly and automatically without effort. The superior melodic memory of these two boys and many of the other participants with autism was surprising in light of problems with general memory systems in autism (Russel, 1997; Volkmar et al., 2004) and the tremendous difficulty with language learning. One wonders whether the memory for music in non-savant autistic individuals has commonalities with the musical memory of savants (Miller 1989, 1999; Sloboda et al., 1985). Superior memory for music may be indicative of developmental differences in individuals with autism that could signify another aspect to their cognitive style (Saffran & Grieppentrog, 2001; Marler et al., 2002; Heaton et al., 2008; Järvenen-Pasley & Heaton, 2007; Happé, 1999) Another aspect to the findings of superior melodic memory in children with autism is that memory systems for music may operate similarly to the type of memory used in AP possessors where recognition is instant and the updating of working memory is not necessary (Klein et al., 1984; Zatorre, 2003). In typical populations the research indicates that familiar over learned melodies are encoded as a whole (Attneave & Olsen, 1977; Davies & Jennings, 1976). It is possible that some children with autism in this study were encoding melody in memory systems in the manner that typical populations encode an over learned melody.

Generally, high functioning autistic persons tend to perform well on measures of non-verbal fluid reasoning ability such as the Leiter-R (O' Riordan et al., 2001; Shah & Frith, 1993). These measures are entirely visual. In order to complete the tasks one must enlist a highly sophisticated sense of patterning ability. It is often surprising how accurately and quickly children with autism complete the tasks. In this study, this patterning ability was positively correlated with the combined overall scores for the single tone pitch discrimination task and the melodic memory task in both typically developing children and the children with autism. After separating the performance scores of the two groups, the patterning ability remained positively correlated in the single tone task for both groups, but was only positively correlated with melodic memory in the children with autism. It is interesting that there was a relationship in this study between visual patterning skills and auditory perception for both melodic memory and pitch discrimination in children with autism. Researchers have observed an effect of music listening on visual patterning ability in college students and in kindergarten children (Rauscher et al., 1994; Rauscher & Zupanee, 2000). Taken together with the findings from this study, one may wonder whether the two skills are either related to each other or affected by each other. Perhaps visual reasoning and auditory reasoning skills are neurologically interconnected and related in a manner that would have been previously hard to imagine.

Developmental sensitivity to sound in children with autism, in this study, was not correlated to performance on pitch discrimination in the single tone or melodic task or to melodic memory. A Spearman rank correlation revealed no relationship between these factors. However, many of the parents of children with autism in this study reported that their child had aversions to certain sounds. In many of the children, it was a persistent problem and with others the acuteness of the sensitivity had diminished somewhat with maturity. A possible hypothesis of the results of the study was that the hearing sensitivities of some children with autism would predict higher scores on the pitch discrimination portion of the study. Some children with autism would be more sensitive to changes in sound because of this sensory sensitivity. This study did not show a relationship between the two factors. However, more research needs to be conducted to specifically target whether there is a relationship between the two phenomena in autism.

There were a number of interesting findings concerning both typical and autistic children's discrimination of sharp versus flat notes the single tone and melodic context. It would appear that in a single tone task both groups of children were better able to discriminate whether a note was sharp rather than flat. The same result was not found when discriminating the difference between two pitches within the context of a melody. Here there is no difference in pitch discrimination between flat notes and sharp notes. Both groups of children are able to discriminate differences when notes are sharp or flat equally, although children with autism discriminated both flat and sharp notes in the context of a melody better than typically developing children. One possible explanation is that when pitches are put into a context of a melody it may be easier to discriminate both flat and sharp notes (Dowling, 1978; Dowling & Fujitani, 1970). The relationship of the notes to one another within a melody creates and tonal center or a key that is the context with which we measure, in audiation, intervals against. Both groups of children may have found the isolated tones harder to discriminate. Alternately, both groups of children may have found it more difficult to sustain attention in the single tone context.

Limitations of the study

One of the biggest challenges in running a study of this nature has to do with the type of participants involved. Finding participants between the ages of 8-12 who have autism is not an easy task. In addition, because of their exceptionality they are a highly protected population. Parents, teachers, principals, school board and psychologists are extremely cautious in allowing interaction between this exceptional population and new people, especially, when the interaction involves testing of any kind. This is a legitimate concern; children with autism need to be advocated for. Their unusual and uneven profile of ability and deficit in cognitive function makes them a prime target for being misunderstood. In addition, children with autism can develop an extreme amount anxiety when faced with new situations, new people, and different routines. Finding participants was one matter, convincing them to participate was another matter. The process was very difficult. Although application was made to conduct the research in two Ottawa School Boards, only one school board approved the research. The researcher was not allowed to make personal contact with any of the principals without the consent of a board liaison. Only one principal from that school board chose to participate in the study. Only two children with autism were recruited through the school board. As a result, children with autism were recruited through presentations to support groups within the Ottawa area and advertisements in support group newsletters. The sample of the autistic population used for this study may have been somewhat biased. Parents may have been more apt to bring their child out to this type of study if they had felt that their child had showed some ability musically.

In addition, there may have been some limitations with regard to the location of the testing. Twenty-three of the autistic participants came to the music studio of the researcher’s home. The environment may have been distracting for many children. The instruments, books and pictures on the walls may have distracted the children with autism and detracted somewhat from their performance on the music games. One of the top instruments for diagnosing a child with autism, the Autism Diagnostic Observation Schedule (ADOS), is conducted in a room purged of objects that are not directly needed for the test itself (Lord et al., 2002). In this study, children with autism may have performed even better had they been in similar surroundings.

Finally, the design of the music game could have been more visually animated for the age of the children. Some children had difficulty in sustaining attention through the tasks. Generally, the game could have had a more playful character with the goal of winning something at the end and there could have been more of a reward system when a correct answer had been achieved. With better mechanisms to sustain attention, it is possible that smaller pitch differences could be discriminated.

Implications and Conclusion

This study revealed that children with autism discriminate differences in pitch better than typically developing children. This ability is present in both single tones and in melodies suggesting that children with autism can discriminate pitches within a context. The fact that children with autism were discriminating sharp and flat tones equally well at every level in the melodic task supports the view that they are adept at discriminating tones within context. This ability may be innate as the majority of the children had limited musical training. In conjunction or alternative to this theory is the idea that enhanced pitch perception is a by-product of cognitive functioning for some children with autism.

Some children with autism may have excellent memory systems for music. There has been some speculation as to whether discriminating the pitch of two single tones or two tones within a melody is actually a similar task (Booth, 1978). Whatever the case, memory systems are employed in order either to compare single tones to each other or melodies to each other. One would suppose that there would be a greater demand on memory systems when two melodies were compared. In this study, children with autism had a better memory for melodies than typically developing children up to one week after the learning condition. Memory for individual pitches taken out of context, referred to as absolute pitch, has been well documented in musical savant syndromes where those savants are usually autistic (Heaton & Wallace, 2004; Miller, 1999). Heaton's study (1998) also suggests that school aged autistic children's memory for individual pitches is reflective of the musical savant phenomenon. The findings from this study taken together from previous research suggests that children with autism have better memory systems for pitch, individually and within the context of a melody than do typically developing children.

Enhanced memory for pitch may be part of a developmental process in autism. Saffran and Greipentrog (2001) demonstrated that infants favored absolute pitch cues over relative ones. The preference for absolute pitch cues dropped with maturity. They concluded that absolute pitch ability could be part of a developmental disinhibitory process whereby absolute pitch ability gets dropped in favor of relative pitch as language acquisition takes place. It is plausible that in autism there is a preference for pitch sounds over language sounds and this leads to the retaining of either some form of absolute pitch or an enhanced memory for pitch. Literature on auditory perception in autism suggests that children with autism have an aversion to spectrally complex sounds like noise (Samson et al., 2005). Speech contains spectrally complex sounds in the formation of consonants. Studies on backward masking suggest that the noise created by consonants may interfere with language comprehension (Marler et al., 2002). It is plausible then that children with autism may be focusing more on the pitch of the vowel sound as a way to compensate for their auditory perception. Alternatively, children with autism may just have a better understanding and memory for pitch sounds over language sounds.

Another idea is that neurologically, pitch discrimination ability and memory for music could be interconnected with visual spatial ability. In this study there was a positive correlation between the non-verbal IQ scores of both groups combined and pitch discrimination in the single tone task and melodic memory. After separating the performance scores of the two groups, the non-verbal IQ scores were positively correlated to pitch discrimination in the single tone task for both groups individually but only to melodic memory in the children with autism. Children with autism performed similarly to typically developing children on the Leiter-R, which measured fluid reasoning ability in a series of visual patterning tasks. This is significant considering deficits in autism in other areas like language acquisition. Children with autism are reported to consistently perform at typical to superior levels on tests of visual reasoning.

Rauscher observed that college student's tests of visual spatial reasoning improved after listening to music (Rauscher et al., 1994). Although the finding was controversial, there may have been an aspect to the finding that revealed an interaction in brain function between visual reasoning and music perception. This study revealed a correlation between visual tasks and memory for music in a population where language acquisition follows a much different developmental path from the norm. More research needs to be done in order to delineate neurological interactions between the two skills both in typically developing populations and in populations with autism.

If enhanced pitch perception and superior melodic memory are characteristic of some children with autism then it is plausible that these attributes may define another subset of the autistic population. According to Bentley (1966, 1968), typically developing school aged children performed well below chance levels on discrimination of two tones 24-cents apart. In addition, twenty percent of these children made errors on semitone judgments. Music psychologists have noted the roaming tonic note of preschool children's singing (Moog, 1976; Moorhead & Pond, 1978). The inability of typically developing young children to stay in key could be reflective of a developmental process in audiation whereby precise pitch perception develops more slowly than previously thought. Children with autism were better able to discriminate differences in pitch within the framework of tonality. In the melodic discrimination tasks, it was the leading tone that was altered to be either flat or sharp. From a harmonic standpoint, the leading tone sets up obvious auditory expectations for the listener immersed in western culture. Children with autism displayed a sophisticated understanding of the harmonic convention of their culture in their ability to identify the mistuning of the leading tone. This seems surprising in light of some of the other deficits in autism.

From an audiological standpoint, the norms on developmental pitch discrimination are sparse. More research needs to be conducted to delineate the developmental course of pitch discrimination. Such research would be necessary in order to determine just how far autistic children's pitch discrimination ability differs from the norm. This kind of research may have implications for language acquisition in both autistic and typical populations.

In addition, more research is necessary to understand the developmental course of melodic memory. There is evidence that familiar melodies are stored in memory differently than novel ones (Attneave & Olsen, 1971; Davies & Jennings, 1976). Attneave & Olsen (1971) found that musically inexperienced adults were able to discriminate between familiar tunes and comparison melodies with a high degree of accuracy. One wonders whether children with autism's enhanced memory for melody was a result of different memory mechanisms as they were also superior in discriminating differences in pitch within these memorized melodies. Studies show that those with absolute pitch enlist a different memory system (Klein & Coles, & Donchin, 1984; Zatorre 2003). This raises the question of whether elevated performance in autism on the melodic memory portion of the study indicates the utilization of different memory systems. More research needs to be done in order to delineate the strategy used in melodic memory systems for both typical and autistic populations. Perhaps memory in autism operates differently for language than it does for music. Perhaps this type of memory shares commonalities with early developmental memory systems in that memory for pitch may be stronger early in a child's development before language and socialization skill are fully developed (Bossomaier & Snyder 2004).

Children with autism seem to have preserved ability in visual tasks that employ non-verbal fluid reasoning ability (Happé, 1999; Shah & Frith, 1993). This is significant in light of deficits with language learning. Pitch processing ability may be another example of preserved ability in autism, contributing to the idea that autism is not a cognitive disorder but a cognitive style (Happé, 1999). More research with regard to whether visual reasoning ability cognitively interacts with pitch processing ability in autistic populations could contribute to understanding the development of cognitive style. In addition, delineating whether visual reasoning ability and pitch processing ability interact in typical populations would broaden our knowledge of cognitive processes involved in perception.This kind of research could have implications for the developmental path of these processes in typical populations and perhaps shed light on the evolutionary role of music.

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Appendix A – Information Letter Typically Developing Children

Dear Parent,

Children with High Functioning Autism and Aspergers syndrome often demonstrate high skill levels in many areas despite their problems with language and social functioning. One such area in which many autistic children excel is in the area of musical pitch processing. I invite you to consider your child's participation in a study on this topic conducted by myself Sandy Stanutz, Ph. D. student McGill University, Schulich School of Music. In particular, I am interested in studying the manner in which autistic children process musical information, their ability with regard to musical memory and pitch discrimination. In order to understand the quality of musical processing in high functioning autistic children, a comparison will be made between the performances of a typically developing group of children and an autistic group of children on experimental tasks. You are being asked to consider your child for participation in the typically developing group of children. By comparing the two groups, we can understand whether high functioning autistic children exhibit ability in the areas of pitch discrimination and musical memory.

Children will individually perform two musical listening activities of approximately 18 minutes each administered on two separate days separated by 1 week. The tests will be administered in a quiet area of my home at a time that will be convenient for you. The child will listen to musical tones and short melodies via headphones and respond using a computer.

In order to determine whether the typically developing and autistic groups of children are similar in terms of developmental level, I am requesting permission to administer a short 15-20 min. assessment of developmental level. Your child will complete the Leiter test following the completion of the computer tasks for the 1st session. The data gathered from this measure and from the other aspects of the study will be used only for the purpose of fulfilling the requirements for my PhD degree. The children's identification will not be required and the results of the experiment will be strictly anonymous and used only for the purposes of research.

While it will be most beneficial for children to complete all the tasks of the study in order for the researcher to obtain a better picture of their musical processing abilities, children will not be required to respond to any task that they are uncomfortable with. Each child will be offered a small gift as a token of appreciation for participating in the study. The data collected from the study will be maintained in a locked cabinet for 5 years and then destroyed. If you are interested in involving your child in this study please discuss this matter with your child. By signing the consent form, you and your child agree to participate in the study. If you have any further questions you can contact me by phone: 613-692-1529 or email: sandy.stanutz@mail.mcgill.ca.

It is my hope that by studying the musical processing of autistic children we will be able to understand more fully the abilities of those children. Educating autistic children within the school system can be a challenge on a number of levels. Many autistic children experience learning difficulties that are compounded by low self-esteem. Self Esteem often diminishes as autistic children struggle with their social and communication deficits in interactions with peers. Understanding the musical abilities of those with autism can lead to educational practices that focus on the strengths of those individuals to teach things like social and communication skills. There is some research as well indicating that musical training helps to reinforce certain aspects of language learning. Perhaps more research into the musical abilities of autistic children will lead to educational practices that incorporate music learning as a tool to access language learning. The participants are invited to contact the researcher for a summary of the findings at the conclusion of the study.

If you agree to have your child involved in this study please sign the form below and mail or give to: Sandy Stanutz 1105 Edward Str., Manotick Ont., K4M 1G8. You will be contacted again once the scheduling arrangements have been made. Thank-you for your interest and attention to this matter.

Sincerely,

Sandy Stanutz
Ph D. Candidate
Schulich School of Music
McGill University

Professor Joel Wapnick
Research Supervisor
Schulich School of Music
McGill University

Appendix B – Consent Letter Typically Developing Children

McGill

Research Consent Form
McGill University

Musical Memory and Pitch Discrimination in Autistic Children

Researcher: Sandy Stanutz Ph.D. Candidate, Music Education
613-692-1529
sandy.stanutz@mail.mcgill.ca

Supervisor: Professor Joel Wapnick, Music Education
jwapnick @music.mcgill.ca

I agree to have my child involved in the study entitled Musical Memory and Pitch Discrimination in Autistic Children conducted by researcher Sandy Stanutz, McGill University, Schulich School of Music. I understand that my child will be involved in a study in which he/she will be involved in two music listening games of approximately 18 minutes each separated by a week. My child will be asked to respond to the listening tasks by pressing the appropriate keys on a computer. During one of these sessions, I understand that my child will complete the Leiter-R test, a short assessment of developmental level.

I understand that the data collected from this study will be kept completely anonymous and confidential and will only be used for the purposes of this study. I understand that the researcher will be gathering information as to the IQ of your child. Although the completion of the experimental tasks are important to the researcher's understanding of the musical abilities of autistic children, my child's participation is entirely voluntary and I can withdraw my child from the study at any time. The data collected from the study will be maintained in a locked cabinet for 5 years and then destroyed

It is my hope that this research will contribute to a broader understanding of the musical abilities of autistic children. The results of this study could lead to research into incorporating music learning as a tool to improve the weaker areas of those with autism such as language and socialization. Finally, by diverting attention away from the deficits to the abilities in autistic functioning we are able to view this disorder in a more positive light. If you have any question please contact Sandy Stanutz 613-692-1529, sandy.stanutz@mail.mcgill.ca.

Name of Parent______________________ Name of Child_________________________

Signature of Parent__________________ Signature of Child_____________________
Signature of Researcher____
Date____

Appendix C – Parents of Children with Autism Information Letter

McGill

Dear Parent,

Children with High Functioning Autism and Aspergers syndrome often demonstrate high skill levels in many areas despite their problems with language and social functioning. One such area in which many autistic children excel is in the area of musical pitch processing. I invite you to consider your child's participation in a study on this topic conducted by me. In particular, I am interested in studying the manner in which autistic children process musical information, their ability with regard to musical memory and pitch discrimination.

Children will perform two musical listening activities of approximately 18 minutes each administered on two separate days. The tests will be administered in a quiet area of my home at a time convenient to you. Your child will listen to musical tones and short melodies via headphones and respond using a computer. Every effort has been taken to make the task as non-verbal, as possible to accommodate the learning style of autistic children.

In order to determine whether the typically developing and autistic groups of children are similar in terms of developmental level, I am requesting permission to administer a short 15-20 min. assessment of developmental level. Your child will complete the Leiter test following the completion of the computer tasks for the first session. The data gathered from this measure and from the other aspects of the study will be used only for the purpose of fulfilling the requirements for my Ph D degree. The children's identification will not be required and the results of the experiment will be strictly anonymous and used only for the purposes of research.

While it will be most beneficial for children to complete all the tasks of the study in order to obtain a better picture of the musical processing abilities of autistic individuals, children will not be required to respond to any task that they are uncomfortable with. Each child will be offered a small gift as a token of appreciation for participating in the study. The data collected from the study will be maintained in a locked cabinet for 5 years and then will be destroyed. If you are interested in involving your child in this study please discuss this matter with your child. By signing the consent form, you and your child agree to participate in the study. If you have any further questions you can contact me by phone: 613-692-1529 or email: sandy.stanutz@mail.mcgill.ca.

It is my hope that by studying the musical processing of autistic children we will be able to understand more fully the abilities of those children. Educating autistic children within the school system can be a challenge on a number of levels. Many autistic children experience learning difficulties that are compounded by low self-esteem. Self-esteem often diminishes as autistic children struggle with their social and communication deficits in interactions with peers. Understanding the musical abilities of those with autism can lead to educational practices that focus on the strengths of those individuals to teach things like social and communication skills. There is some research as well indicating that musical training helps to reinforce certain aspects of language learning. Perhaps more research into the musical abilities of autistic children will lead to educational practices that incorporate music learning as a tool to access language learning. You are invited to contact me for a summary of the findings at the conclusion of the study.

If you agree to have your child involved in this study please sign the form below and mail or give to: Sandy Stanutz 1105 Edward Str., Manotick Ont., K4M 1G8. Thank-you for your interest and attention to this matter.

Sincerely,

Sandy Stanutz
Ph D. Candidate
Schulich School of Music
McGill University

Professor Joel Wapnick
Research Supervisor
Schulich School of Music
McGill University

Appendix D – Parents of Autistic Children Consent Letter

Research Consent Form
McGill University

Musical Memory and Pitch Discrimination in Autistic Children

Researcher: Sandy Stanutz Ph.D. Candidate, Music Education
613-692-1529
sandy.stanutz@mail.mcgill.ca

Supervisor: Professor Joel Wapnick, Music Education
jwapnick @music.mcgill.ca

I agree to have my child involved in the study entitled Pitch Memory and Discrimination in Autistic Children conducted by researcher Sandy Stanutz, McGill University, Schulich School of Music. I understand that my child will be involved in a study in which he/she will be involved in two music listening games of approximately 18 minutes each separated by a week. My child will be asked to respond to the listening tasks by pressing the appropriate keys on a computer. During the first session, I understand that my child will complete the Leiter-R test, a short assessment of developmental level.

I understand that the data collected from this study will be kept completely anonymous and confidential and will only be used for the purposes of this study. I understand that the researcher will be gathering information as to the IQ of your child. Although the completion of the experimental tasks are important to the researcher's understanding of the musical abilities of autistic children, my child's participation is entirely voluntary and that I can withdraw my child from the study at any time. The data collected from the study will be maintained in a locked cabinet for 5 years and then destroyed

It is my hope that this research will contribute to a broader understanding of the musical abilities of autistic children. The results of this study could lead to research into incorporating music learning as a tool to improve the weaker areas of those with autism such as language and socialization. Finally, by diverting attention away from the deficits to the abilities in autistic functioning we are able to view this disorder in a more positive light. If you have any question please contact Sandy Stanutz 613-692-1529, sandy.stanutz@mail.mcgill.ca.

Name of Parent____________________ Name of Child_______________________

Signature of Parent_________________ Signature of Child____________________

Signature of Researcher_____________ Date______________________________

Appendix E – School Principal Recruitment Letter

McGill

Dear School Principal,

Thank-you for your interest in the research project Musical Memory and Pitch Discrimination in Autistic Children. This letter is a follow up to our conversation earlier today; you have agreed to involve your school in above study conducted by Sandy Stanutz PH. D. candidate, McGill University, Schulich School of Music.

Results of research suggest that autistic individuals excel in certain musical tasks. The purpose of this research is to examine musical memory and pitch discriminating ability in high functioning autistic children. The study is designed to expand what we currently know about musical processing in autistic individuals and to develop a broader picture of those strengths.

High functioning autistic children mean age of 10 yrs and IQ > than 70 will be recruited from your school for inclusion in the study. The same number of typically developing children matched for age will also be recruited from your school for inclusion in the study. The children in the typically developing group must be free of any learning disabilities or attention deficit disorders. You will be contacting the parents of the autistic children and the typically developing group to inquire about their willingness to be involved in the study. Once permission is given, I will send out a cover letter and consent form to all the parties involved. Once the consent form has been signed and returned I will be contacting you for scheduling arrangements.

For every classroom where an autistic child will be removed to complete experimental tasks, a typically developing child will do the same. Scheduling the study in this manner will aide in alleviating or bypassing any stigmas that may develop among the children's peer groups as a result of participation in the study.

Thank-you for your attention to this matter. If you have any further questions you can contact me by phone: 613-692-1529 or email: sandy.stanutz@mail.mcgill.ca It is my hope that research into the musical abilities of children with autism will lead to educational practices that foster those skills. In focusing research on the strengths of those with autism, we may be able to gain a broader understanding of the cognitive processes involved in the weaker areas of development. More research is needed to eventually improving the lives of those with autism and their families.

Professor Joel Wapnick
Research Supervisor
Schulich School of Music
Mcgill University
jwapnick@music.mcgill.ca
514-398-4535

Sandy Stanutz
Ph. D. Candidate
Schulich School of Music
McGill University
sandy.stanutz@mcgill.ca
613-692-1529

Signature of Principal_______________________________________

Signature of Researcher_____________________________________

Appendix F – Information Letter, Typically Developing Child, Ottawa - Carleton Catholic School Board

McGill

Dear Parent,

Children with High Functioning Autism and Aspergers syndrome often demonstrate high skill levels in many areas despite their problems with language and social functioning. One such area in which many autistic children excel is in the area of musical pitch processing. I invite you to consider your child's participation in a study on this topic conducted by me. In particular, I am interested in studying the manner in which autistic children process musical information, their ability with regard to musical memory and pitch discrimination. In order to understand the quality of musical processing in high functioning autistic children, a comparison will be made between the performances of a typically developing group of children and an autistic group of children on experimental tasks. You are being asked to consider your child for participation in the typically developing group of children. By comparing the two groups, we can understand whether children with high functioning autism exhibit ability in the areas of pitch discrimination and musical memory.

Children will individually perform two musical listening activities of approximately 18 minutes each administered on two separate days. The tests will be administered during the school day in a quiet area of the school. The child will listen to musical tones and short melodies via headphones and respond using a computer.

In order to determine whether the typically developing and autistic groups of children are similar in terms of developmental level, I am requesting permission to administer a short 15-20 min. assessment of developmental level. Your child will complete the Leiter test following the completion of the computer tasks for either the first or second session. The data gathered from this measure and from the other aspects of the study will be used only for the purpose of fulfilling the requirements for my Ph D degree. The children's identification will not be required and the results of the experiment will be strictly anonymous and used only for the purposes of research.

While it will be most beneficial for children to complete all the tasks of the study in order for the researcher to obtain a better picture of their musical processing abilities, children will not be required to respond to any task that they are uncomfortable with. Each child will be offered a small gift as a token of appreciation for participating in the study. The data collected from the study will be maintained in a locked cabinet for 5 years and then destroyed. If you are interested in involving your child in this study please discuss this matter with your child. By signing the consent form, you and your child agree to participate in the study. If you have any further questions you can contact me by phone: 613-692-1529 or email: sandy.stanutz@mail.mcgill.ca.

It is my hope that by studying the musical processing of autistic children we will be able to understand more fully the abilities of those children. Many autistic children experience learning difficulties that are compounded by low self-esteem. Self-esteem often diminishes as autistic children struggle with their social and communication deficits in interactions with peers. Understanding the musical abilities of those with autism can lead to educational practices that focus on the strengths of those individuals to teach things like social and communication skills. There is some research as well indicating that musical training helps to reinforce certain aspects of language learning. Perhaps more research into the musical abilities of autistic children will lead to educational practices that incorporate music learning as a tool to access language learning. The findings of his study will be made available through your child's school.

If you agree to have your child involved in this study please sign the form below and mail in the enclosed envelope to: Sandy Stanutz 1105 Edward Str., Manotick Ont., K4M 1G8. You will be contacted again once the scheduling arrangements have been made with the school. Thank-you for your interest and attention to this matter.

Sincerely,

Sandy Stanutz
Ph D. Candidate
Schulich School of Music
McGill University

Professor Joel Wapnick
Research Supervisor
Schulich School of Music
McGill University

Appendix G – Consent letter, Typically Developing Child, Ottawa - Carleton Catholic School Board

McGill

Research Consent Form
McGill University

Musical Memory and Pitch Discrimination in Autistic Children

Researcher: Sandy Stanutz Ph.D. Candidate, Music Education
613-692-1529
sandy.stanutz@mail.mcgill.ca

Supervisor: Professor Joel Wapnick, Music Education
jwapnick @music.mcgill.ca

I agree to have my child involved in the study entitled Musical Memory and Pitch Discrimination in Autistic Children conducted by researcher Sandy Stanutz, McGill University, Schulich School of Music. I understand that my child will be excused from class twice for a period of 18 minutes separated by a week. My child will be taken to a quiet area of the school where he/she will be involved in music listening tasks. My child will be asked to respond to the listening tasks by pressing the appropriate keys on the computer. During one of these sessions I understand that my child will be administered the Leiter test, a short assessment of developmental level.

I understand that the data collected from this study will be kept completely anonymous and confidential and will only be used for the purposes of this study. I understand that the researcher will be gathering information as to the IQ of your child. Although the completion of the experimental tasks are important to the researcher's understanding of the musical abilities of autistic children, my child's participation is entirely voluntary and that I can withdraw my child from the study at any time. The data collected from the study will be maintained in a locked cabinet for 5 years and then destroyed

It is my hope that this research will contribute to a broader understanding of the musical abilities of autistic children. The results of this study could lead to research into incorporating music learning as a tool to improve the weaker areas of those with autism such as language and socialization. Finally, by diverting attention away from the deficits to the abilities in autistic functioning we are able to view this disorder in a more positive light. If you have any question please contact Sandy Stanutz 613-692-1529, sandy.stanutz@mail.mcgill.ca.

Name of Parent____________________ Name of Child_______________________

Signature of Parent_________________ Signature of Child____________________

Signature of Researcher_____________ Date______________________________

Appendix H –Information Letter, Children with Autism, Ottawa Catholic School Board

McGill

Dear Parent,

Children with High Functioning Autism and Asbergers syndrome often demonstrate high skill levels in many areas despite their problems with language and social functioning. One such area in which many autistic children excel is in the area of musical pitch processing. I invite you to consider your child's participation in a study on this topic conducted by me. In particular, I am interested in studying the manner in which autistic children process musical information, their ability with regard to musical memory and pitch discrimination.

Children will individually perform two musical listening activities of approximately 18 minutes each administered on two separate days. The tests will be administered during the school day in a quiet area of the school. The child will listen to musical tones and short melodies via headphones and respond using a computer. Every effort has been taken to make the task as non-verbal, as possible to accommodate the learning style of autistic children.

In order to determine whether the typically developing and autistic groups of children are similar in terms of developmental level, I am requesting permission to administer a short 15-20 min. assessment of developmental level. Your child will complete the Leiter test following the completion of the computer tasks for the first session. The data gathered from this measure and from the other aspects of the study will be used only for the purpose of fulfilling the requirements for my Ph D degree. The children's identification will not be required and the results of the experiment will be strictly anonymous and used only for the purposes of research.

While it will be most beneficial for children to complete all the tasks of the study in order to obtain a better picture of the musical processing abilities of autistic individuals, children will not be required to respond to any task that they are uncomfortable with. Each child will be offered a small gift as a token of appreciation for participating in the study. The data collected from the study will be maintained in a locked cabinet for 5 years and then will be destroyed. If you are interested in involving your child in this study please discuss this matter with your child. By signing the consent form, you and your child agree to participate in the study. If you have any further questions you can contact me by phone: 613-692-1529 or email: sandy.stanutz@mail.mcgill.ca.

It is my hope that by studying the musical processing of autistic children we will be able to understand more fully the abilities of those children. Many autistic children experience learning difficulties that are compounded by low self-esteem. Self-esteem often diminishes as autistic children struggle with their social and communication deficits in interactions with peers. Understanding the musical abilities of those with autism can lead to educational practices that focus on the strengths of those individuals to teach things like social and communication skills. There is some research as well indicating that musical training helps to reinforce certain aspects of language learning. Perhaps more research into the musical abilities of autistic children will lead to educational practices that incorporate music learning as a tool to access language learning. The findings of this study will be made available through your child's school.

If you agree to have your child involved in this study please sign the form below and mail or give to: Sandy Stanutz 1105 Edward Str., Manotick Ont., K4M 1G8. Thank-you for your interest and attention to this matter.

Sincerely,

Sandy Stanutz
Ph D. Candidate
Schulich School of Music
McGill University

Professor Joel Wapnick
Research Supervisor
Schulich School of Music
McGill University

Appendix I – Consent Form, Children with Autism, Ottawa Catholic School Board

McGill

Research Consent Form
McGill University

Musical Memory and Pitch Discrimination in Autistic Children

Researcher: Sandy Stanutz Ph.D. Candidate, Music Education
613-692-1529
sandy.stanutz@mail.mcgill.ca

Supervisor: Professor Joel Wapnick, Music Education
jwapnick @music.mcgill.ca

I agree to have my child involved in the study entitled Pitch Memory and Discrimination in Autistic Children conducted by researcher Sandy Stanutz, McGill University, Schulich School of Music. I understand that my child will be involved in a study in which he/she will be involved in two music listening games of approximately 18 minutes each separated by a week. My child will be asked to respond to the listening tasks by pressing the appropriate keys on a computer. During one of these sessions, I understand that my child will be administered the Leiter-R test, a short assessment of developmental level.

I understand that the data collected from this study will be kept completely anonymous and confidential and will only be used for the purposes of this study. I understand that the researcher will be gathering information as to the IQ of your child. Although the completion of the experimental tasks are important to the researcher's understanding of the musical abilities of autistic children, my child's participation is entirely voluntary and that I can withdraw my child from the study at any time. The data collected from the study will be maintained in a locked cabinet for 5 years and then destroyed

It is my hope that this research will contribute to a broader understanding of the musical abilities of autistic children. The results of this study could lead to research into incorporating music learning as a tool to improve the weaker areas of those with autism such as language and socialization. Finally, by diverting attention away from the deficits to the abilities in autistic functioning we are able to view this disorder in a more positive light. If you have any question please contact Sandy Stanutz 613-692-1529, sandy.stanutz@mail.mcgill.ca.

Name of Parent____________________ Name of Child_______________________

Signature of Parent_________________ Signature of Child____________________

Signature of Researcher_____________ Date____________________________

Appendix J – Leiter International Performance Scale Revised

Leiter International Performance Scale-Revised (Leiter-R)

Gale H. Roid, PhD and Lucy J. Miller, PhD

Unlike other IQ tests, the totally nonverbal Leiter-R emphasizes fluid intelligence and is not significantly influenced by the level and quality of the child's educational, social, and family experience.

Purpose: Measure intelligence and cognitive abilities in ages 2-20.11 years

Age Range: Infant
Preschool
Child
Adolescent
Adult

Admin: Individual

Time: Varies depending on battery given

Qualification: B

Sample Reports: N/A

Related Products: Test of Nonverbal Intelligence-3

Reynolds Intellectual Assessment Scales™

Wide Range Assessment of Memory and Learning, Second Edition

The Leiter-R is a totally nonverbal test of intelligence and cognitive abilities. It is easily administered and quickly and objectively scored. Its game-like administration holds a child's interest.

Appendix K – Questions to Parent of Autistic Child Participant

Child's Name____

Age____

Date of Birth____

Has your child ever had formal music training ie: private music lessons?

____

What is your child's diagnosis?

____

Who diagnosed your child?

____

Has your child ever had a standard audiometric test?

____

What were the results?

____

Has your child had a history of excessive ear infections?

____

Do you or husband have a family history of deafness or auditory trauma?

____