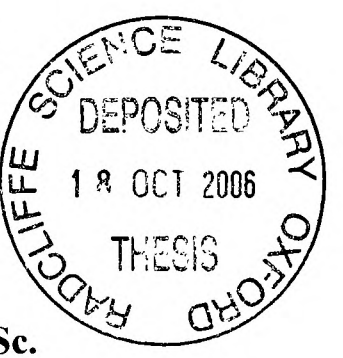
Explorations of Musical Processing in Individuals with Autism



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"Autism as a subject touches on the deepest questions of ontology, for it involves a radical deviation in the development of brain and mind. Our insight is advancing, but tantalizingly slowly. The ultimate understanding of autism may demand both technical advances and conceptual ones beyond anything we can now even dream of."
Oliver Sacks, *An Anthropologist on Mars*, 1995

For my family with love—

Mom, Ronnie Accordino

Dad, Anthony Accordino

Grandma, Mildred Kadish

Brother, Michael Accordino

I have missed you all very much during my two years in England and Australia and thank you for always being a phone call away.

Table of Contents

Table of Contents iv

List of Figures vii

List of Tables ix

Preface and Acknowledgements xi

Abstract xiv

CHAPTER ONE **AUDITORY PROCESSING ACROSS DOMAINS IN THOSE WITH AUTISM: ADVANTAGEOUS IN THE MUSICAL DOMAIN, DISADVANTAGEOUS IN THE LANGUAGE DOMAIN?** 1

1.1 PRE-AMBLE: ASSESSMENT AND PRESENCE OF MUSICAL ABILITY 1

1.2 ENHANCED AUDITORY PROCESSING AND THE PRESENCE OF MUSICALITY IN THOSE WITH AUTISM 3

1.2.1 PITCH MEMORY AND DISCRIMINATION, INTERVAL RECOGNITION, AND CHORDAL PROCESSING 5

1.2.2 MELODIC CONTOUR ASSESSMENT 10

1.2.3 PERCEPTION OF AFFECT 18

1.2.4 MUSICAL PROCESSING 19

1.3 DEFICIENT AUDITORY PROCESSING AND THE PRESENCE OF LANGUAGE PROBLEMS IN THOSE WITH AUTISM 20

1.4 QUESTIONS FROM THE SCIENTIFIC LITERATURE 29

1.5 THESIS OVERVIEW 30

CHAPTER TWO **STUDY 1: EXPLORATIONS OF MUSIC AND LANGUAGE PROCESSING IN HIGH FUNCTIONING INDIVIDUALS WITH AUTISM** 31

2.1 METHOD 35
2.1.1 PARTICIPANTS 35
2.1.2 MATERIALS 37
2.1.3 DESIGN AND PROCEDURE 48
2.2 RESULTS 50
2.2.1 MUSIC TASKS 50
2.2.2 NWR TASK 54
2.2.3 FREQUENCY DISCRIMINATION TASK 55
2.2.4 BPVS II 56
2.2.5 RELATIONSHIPS OF MUSIC AND LANGUAGE PERFORMANCE 57
2.2.6 QUALITATIVE OBSERVATIONS
2.3 DISCUSSION 58
2.3.1 MUSICAL PROCESSING 58
2.3.2 FREQUENCY DISCRIMINATION 60
2.3.3 RELATIONSHIP OF MUSICAL ABILTIES TO LANGUAGE ABILITIES 62
2.3.4 FURTHER CLARIFICATION NEEDED ON THE NATURE AND EXTENT OF MUSICAL ABILITIES 63

CHAPTER THREE STUDY 2: A COMPUTERISED REPLICATION OF HEATON (2003) 64

3.1 METHOD 65
3.1.1 PARTICIPANTS 65
3.1.2 MATERIALS 65
3.2 RESULTS 67
3.2.1 MUSIC TASKS 68
3.2.2 RELATIONSHIPS OF SCORES 70
3.3 DISCUSSION 70

CHAPTER FOUR SEARCHING FOR MUSIC'S POTENTIAL: A CRITICAL EXAMINATION OF RESEARCH ON MUSIC THERAPY WITH INDIVIDUALS WITH AUTISM 73

4.1 METHOD 73
4.2 MUSIC THERAPY 75
4.3 MT IN THE TREATMENT OF AUTISM: CURRENT RESEARCH 76
4.3.1 MT IN THE TREATMENT OF THE SOCIAL ABNORMALITIES OF

AUTISM 76
4.3.2 MT IN THE TREATMENT OF THE BEHAVIOURAL ABNORMALITIES OF AUTISM 78
4.3.3 MT IN THE TREATMENT OF THE COMMUNICATIVE ABNORMALITIES OF AUTISM 80
4.3.4 MT IN THE TREATMENT OF THE SOCIAL AND COMMUNICATIVE ABNORMALITIES OF AUTISM 82
4.3.5 MT IN THE TREATMENT OF THE SOCIAL, BEHAVIOURAL, AND COMMUNICATIVE ABNORMALITIES OF AUTISM 84
4.4 DISCUSSION 91

CHAPTER FIVE STUDY 3: AN EXPLORATORY, OBSERVATIONAL STUDY OF THE SOCIALISATIONS AND MUSICAL GESTURES OF YOUNG CHILDREN WITH SEVERE AUTISM IN RESPONSE TO MUSIC 95

5.1 METHOD 96
5.1.1 PARTICIPANTS WITH AUTISM 96
5.1.2 MATERIALS 96
5.2 RESULTS 100
5.2.1 INTER-RATER RELIABILITY 100
5.2.2 SOCIALISATIONS 101
5.2.3 MUSICAL GESTURES 102
5.2.4 LEVEL OF ACTIVITY 103
5.3 DISCUSSION 104
5.3.1 LIMITATIONS OF STUDY 104

CHAPTER SIX GENERAL DISCUSSION AND FUTURE INVESTIGATIONS 106

6.1 OVERVIEW OF STUDIES 1 AND 2 106
6.2 LIMITATIONS OF STUDIES 1 AND 2 AND SUGGESTIONS FOR FUTURE RESEARCH 111
6.3 STRENGTHS OF STUDIES 1 AND 2 114
6.4 OVERVIEW OF STUDY 3 115
6.5 ON THE IMPORTANCE OF FUTURE INVESTIGATIONS ON THE MUSICAL PROCESSING OF INDIVIDUALS WITH AUTISM 117

REFERENCES 119

APPENDIX ONE SOCIAL AND COMMUNICATION DISORDERS CHECKLIST 132

APPENDIX TWO MUSICAL EXPOSURE AND TRAINING QUESTIONNAIRE 133

APPENDIX THREE MUSICAL EXPSURE AND TRAINING QUESTIONNAIRE-REVISED 135

APPENDIX FOUR CORRELATIONS OF STUDIES 1 AND 2 137

List of Figures

Figure 1	Example of Basic melody (A), its Transposed Version (B), its Contour-Violated (C) and its Contour-Preserved (D) Transformations (Mottron et al., 2000)	11
Figure 2	Auditory Sequence Tests (Foxton et al., 2003)	14
Figure 3	The Horse's Favourite Tune (a), its Melodic Embedding (b), and its Harmonic Embedding (c)	43
Figure 4	Dinosaurs Frequency Discrimination Computer Game	46
Figure 5	Boxplots Showing Distribution of Scores on Music Tasks by Group	52
Figure 6a	Scatter Plot of Identification Check and Melodic Disembedding Score	53
Figure 6b	Scatter Plot of Identification Check and Harmonic Disembedding Score	54
Figure 7	Boxplots Showing Distribution of Nonword Repetition Standardised Scores by Group	55
Figure 8	Estimated Marginal Means of Performance by Music Task by Each Group	69
Figure 9	Boxplots Showing Duration of Socialisations by Music Condition as Scored by Both Raters	102
Figure 10	Boxplots Showing Duration of Musical Gestures by Music Condition as Scored by Both Raters	103

List of Tables

Table 1	Demographic Data for Children with Autism and Typically Developing Children	36
Table 2	Order of Presentation of Tasks	49
Table 3	Results for the Children with Autism and Typically Developing Children on Music and Language Tasks	51
Table 4	Number of Children with Autism and Typically Developing Children who Scored Above Chance (7 or More Correct) on Music Tasks	52
Table 5	Back-to-Back Stem-and-Leaf Plots Showing Distribution of Scores (in Hz) on Frequency Discrimination Task for Typically Developing Children Control Group and Group with Autism	56
Table 6	Demographic Data for Children with Autism and Typically Developing Children	65
Table 7	Results for the Children with Autism and the Typically Developing Children on the Note Identification and Disembeding Tasks	68
Table 8	Number of Children with Autism and Typically Developing Children (of 11 in Each Group) who Scored Above Chance on Note Identification and Disembedding Tasks	68
Table 9	Characteristics of Studies on Music Therapy with Individuals with Autism	77
Table 10	Psychometric Data of Children with Autism	97
Table 11	Socialisations and Musical Gestures in Response to Music	100
Table 12	Inter-Rate Reliability Correlations of Scores of Scores of Two Raters	101
Table 13	Duration Scores (in ms) of Both Raters During Different Music Conditions	101

Table 14 **Level of Activity Scores of Both Raters During Different Music Conditions** **104**

Preface and Acknowledgements

For several years, I have been deeply drawn to research on individuals with autism. I have become enormously interested in learning more about this complex condition and helping to support individuals with autism and their families. My specific research interest, musical processing in individuals with autism, has grown out of my two complementary passions: psychology and music. This research journey began at Princeton University under the extraordinary mentorship of Professor Ronald Comer of the Psychology Department and Professor Wendy Heller of the Music Department. Over the past two years, in the United Kingdom and Australia, I have been able to continue to attempt to answer some of the research questions that interested me greatly as an undergraduate. I have also been able to gain an international perspective of the level of support in different countries to individuals with special needs. As this thesis marks the completion of my work as a graduate student at the University of Oxford, I think it only appropriate to thank the many individuals who have supported me and my research during these two wonderful years.

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Abstract

This thesis consists of three studies that explore the musical processing of children with autism. These studies were based on prior research that has argued that those with autism exhibit enhanced processing of musical stimuli. In study 1, 11 children with high functioning autism, matched to 11 control children on chronological age, nonverbal IQ, gender, and musical training and exposure, were tested on tasks assessing melodic memory and disembedding, frequency discrimination, receptive language, and phonological short term memory to compare the children's processing of language and music. The children with autism's language profiles were deficient. Their musical and frequency discrimination performance, however, were similar to that of the typically developing children. Since these findings were unexpected as there was no evidence of enhanced musical performance, study 2 was a replication of the note identification and disembedding task by Heaton (2003) and was carried out with the same group of participants as study 1. Heaton's results were not replicated with the children with autism performing less well than the typically developing controls on the note identification task and as well as controls on the disembedding task. The third study was an exploratory, observational experiment of musical responsiveness in a group of 16 young children with severe autism whose levels of activity, musical gestures, and socialisations were assessed over a condition of silence and music with and without many changes (in dynamics, tempo, key, meter, etc.). Although statistically significant results were not found, the observational paradigm,

with high inter-rater reliability, served as a starting point for future investigations with this under-researched population.

Chapter One

Auditory Processing Across Domains in Those with Autism: Advantageous in the Musical Domain, Disadvantageous in the Language Domain?

1.1 Pre-Amble: Assessment and Presence of Musical Ability

Before exploring children with autism's auditory processing in the musical and language domains, it is important to discuss the concept of musical ability. Musical ability has been defined as the ability to "make sense" of music. Sloboda (1993) cited several examples of how humans carry out this process. People should, for example, be able to remember music that conforms to the conventions of their culture's musical language better than music that does not. Furthermore, individuals should be able to judge if a musical segment correctly follows their culture's musical rules. Much like the syntax and grammar of language, these musical conventions include the proper completion of cadences and the rejection of discords. A third criterion of musical ability is the ability to identify the mood or emotion of a musical piece. Lastly, when asked to remember a passage of music, individuals should be able to make plausible substitutions of parts of the passage if they are unable to recall it exactly. Although the sophistication of these abilities vary based on the individual's interests, abilities, and training in music, the vast majority of the typically developing population develops these receptive musical skills at some level by age 10. Many research groups (Dowling, 1978, 1994; Edworthy, 1985; Tillmann, Bigand, &

Madurell, 1998) have used various auditory paradigms to test individuals' abilities to hear the various components of music, such as contour, timbre, rhythm, intensity, interval, and tempo.

The assessment of these domains of musical processing through a standardised psychometric test of musical skill has been particularly problematic. The Seashore Measurements of Musical Talents (Seashore, Lewis, & Saetveit, 1939) was the first of its kind to receive world-wide usage when it was published in 1939 and then re-published in 1960. Both versions contained six domains to evaluate the client's tonal memory and sense of pitch, loudness, rhythm, time and timbre. According to the test, an exceptional musician would perform well above norms in all six domains. Although the normative data for the test were obtained by testing high school and college students, representative of the population, Seashore et al. made the claim that professional musicians would perform at ceiling levels on all six domains. This supposition, however, had never been tested until 21 professional musicians sat for the battery, and their results were surprising (Henson & Wyke, 1982). The musicians performed at ceiling in tonal memory only. They performed significantly below average in the timbre domain and better than norms, albeit not at ceiling, at pitch discrimination and rhythm. Their scores were average in the loudness and time domains. Although all these areas are clearly needed to perform as a professional musician, Henson and Wyke revealed the difficulty inherent in attempting to evaluate musical skill and shed serious doubt on the Seashore battery by carrying out an analysis to which many had assumed they knew the outcome. This once popular test of musical skill is no longer widely used, is likely not valid, and does not seem to have been replaced by any other musical ability assessment.

1.2 Enhanced Auditory Processing and the Presence of Musicality in Those with Autism

The notion of musical ability as a correlate of autism has been around for as long as the first scientific papers on autistic disorder. In Kanner's (1943) classic series of 11 case studies, 6 children exhibited exceptional musical abilities. There was Donald T. who "could hum and sing many tunes accurately" at the age of 1 1/2 (p. 217). And Kanner reported that while Paul G. knew the words to almost 40 songs at age 3, Frederick W. started singing at 2 1/2 years of age and could recite 20 to 30 songs. Charles N. could even discriminate between 18 different symphonies at 1 1/2 years of age. Virginia S. often hummed to herself, and her parents heard her humming a Christmas hymn perfectly. And John correctly identified his father's whistling as "Mendelssohn's violin concerto" (p. 239). In another classic of the autism literature, *Infantile Autism*, Rimland commented that "astonishing musical ability is found in these children quite frequently" (1964). Some have even suggested that musical ability is a fundamental component of autism (Hoelzley, 1992).

Based on these observations of Kanner and Rimland, the first attempt at a systematic account of these musical abilities appeared several years later by Applebaum, Egel, Koegel, and Imhoff (1979). Researchers compared 3 teenagers with autism (ranging in age from 14; 3-18 years) to 3 typically developing, musically skilled, age-matched controls on a series of imitations, with one to four pitches and tonal and atonal configurations, to test "musical echolalia." Researchers presented the pitches using the human voice, piano, and synthesiser, and the imitations of the tones were scored on timbre, duration, pitch order, and changes in pitch. Results showed that the individuals with autism performed these tasks as well or better then the controls, who were reported to be highly musically skilled. Although limited by a

very small number of participants, these findings are highly suggestive. Having been carried out during a time in autism research when the narrow focus of the field was to characterise the deficits of those with autism, the prospect of a potential benefit of the autistic cognitive profile must have been unexpected.

The next empirical investigation of the musical ability of those with autism evaluated the musical improvisational abilities of children with autism, chronological age matched controls, developmental age matched controls, and mentally retarded children (Thaut, 1988). Experimenters evaluated the children's first 16 tones produced on the xylophone after the children were shown a demonstration of playing and then asked to play spontaneously. Evaluations of the rhythm, susceptibility to restrictions of tones and intervals, complexity, rule adherence, and originality of those improvisations revealed that the children with autism resembled typically developing children in the rhythmic, restriction susceptibility, and originality domains. In the complexity and rule adherence domains, the participants with autism resembled those who were mentally retarded. Overall, however, total scores of the quality of the improvisations revealed that chronological-age-matched controls performed the best followed by developmental-age-matched and then children with autism followed by children who were mentally retarded. Since the highest scorer was a child with autism, researchers cited this finding as evidence that some children with autism had musical savant capabilties.

Researchers since then have searched to see if these extraordinary musical processing abilities may not be limited to the profiles of savants, but instead may be a component of the cognitive profile of musically naïve individuals with autism (Bonnel et al., 2003; Foxton, Stewart et al., 2003; Heaton, 2003, 2004, 2005; Heaton, Hermelin, & Pring, 1998, 1999, 2001; Mottron, Peretz, & Menard, 2000). Heaton,

Hermelin, and Pring (1998) argued that these abilities may represent a predisposition in the population with autism to a savant condition in music, defined by the combination of a development disability and absolute pitch (AP), an intrinsic understanding of the workings of key relationships during musical improvisations, and remarkable musical memory.[1] Researchers have thus aimed to test the individual's processing of various musical elements, made salient by various paradigms, such as pitch memory and discrimination, interval recognition, chordal disembedding, melodic contour assessment, and affect.

1.2.1 Pitch Memory and Discrimination, Interval Recognition, and Chordal Processing

Heaton (2003) and Heaton et al. (1998, 2001) carried out a series of investigations to assess pitch, interval, and chordal processing in those with autism to see if they processed tones similarly to those with AP, a characteristic of all musical savants. AP is exceptionally rare and is only present in 1 in 10,000 individuals (Takeuchi & Hulse, 1993). Heaton et al. (1998) set up a paradigm to mimic the abilities of AP. The researchers compared 10 7- to 13-year-olds with autism and 10 typically developing 5- to 11.6-year-old children. Neither group exhibited special musical talents nor experienced special musical training, but they were not matched on musical exposure or training that they may have received. Children were trained to associate various pitches and speech sounds with animal pictures. When asked to identify the correct animal picture after a speech sound or pitch was played, the children with autism performed better than controls on identifying pitches, while both groups identified

[1] Savants are exceedingly rare. The savant condition and autism have been shown to be inextricably linked, with estimates of around 10% of those with autism exhibiting some form of a splinter skill, a particular area of enhanced performance in the context of many deficits. (Heaton & Wallace, 2003). (For excellent case studies on savants with autism, see Heaton, Pring & Hermelin (1999) and Mottron, Peretz, Belleville, & Rouleau (1999).) It is important to note that in common parlance, we call typically developing individuals who exhibit savant-levels of performance "prodigies."

speech sounds equally well. Performance at pitch identification was also shown to correlate with the Block Design and Object Assembly sub-tests of the Wechsler Intelligence Scales. In another investigation, Heaton et al. (2001) asked children with autism and typically developing controls to identify the direction (ascending or descending) of a series of two tone intervals of three size categories, small (1-4 semitones), medium (5-8 semitones), and large (9-12). While the children with autism performed equally well on identifying the direction of all three types of intervals, the typically developing controls did better on the medium and large intervals than on the small.

In a final set of experiments involving chordal processing, Heaton (2003) worked with an expanded sample from her 1998 study, comprised of musically naïve 7- to 15-year olds with autism, verbal IQ matched controls and non-verbal matched controls. The participants were once again not matched on musical exposure and training. Once again, Heaton used a paired associate learning paradigm to pair animal pictures to pitches, which the children were told was the animal's favourite. After several trials of pre-exposure, the participants engaged in a conversation with the researcher for 2 ½ minutes. This conversation was put in place to occupy working memory since research had shown that those with AP do not access working memory to judge interval changes (Zatorre, Perry, Beckett, Westbury, & Evans, 1998). After the conversation, the participants were tested on their ability to identify the correct animal picture after hearing one of the four pitches. Results revealed that the children with autism performed significantly better than the children in the verbal and non-verbal matched control groups, who performed at similar levels. Immediately after this experiment, the children were told that they would be hearing groups of three animal notes with one left out and would have to identify that animal whose favourite

note was missing. Once again, the children with autism performed better than both control groups at mentally segmenting chords by identifying the missing note in a chord disembedding task. Both groups performed better at the identification task than the disembedding task. The next experiment explored the children's abilities to identify a missing note in a chord with lessened pre-exposure to those notes. After training the children with pieces of an elephant picture and the entire elephant picture, the children were told they would have to say if a note were part of chord just as they had been asked to identify if the piece of the elephant picture were present in the picture of the entire elephant picture. Heaton exposed the children to the chordal disembeddings without pre-exposure in two ways, with the chord presented followed by the note in question, which was present or absent from the chord, or with the notes of the chord first spelled out in ascending order followed by the playing of the chord and then the playing of the note in question. Regardless of the type of exposure, the children in all three groups performed equally well on the chordal disembedding tasks. Thus, the enhanced chordal disembedding in children with autism was present only when Heaton pre-exposed (to cue the local stimulus of a pitch in the context of a gestalt, in this case a chord) the children over several trials of the pitches matched to animal pictures.

These pitch and interval processing and chordal disembedding tasks were motivated by similar work in the visual domain that assessed the theory of weak central coherence with children with autism. This theory states that those with autism have a tendency to focus on the details of a stimulus at the expense of processing the whole of the stimulus. In other words, they pay close attention to detail by processing the parts better than they process the whole or gestalt (Happé, 1999). The embedded figures task, an altered form of which was used in the Heaton (2003) experiment with

the broken up elephant picture presented to participants, is a classic example of the abilities of those with autism to process fine detail particularly well. In this task, participants must locate a small part of a whole picture. The salience of the global shape makes the task difficult, and children with autism, naturally better at processing the fine details, tend to perform better at this task and block design tasks than they do on other tasks (Happé, 1999; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1993). An intriguing and important feature of this theory is that it was presented during a time when autism researchers focused on searching for the core deficits of the syndrome and did not account for any potential benefits of the autistic cognitive profile. Uniquely, the weak central coherence theory was the first theoretical account of autism that attempted to explain both the potentially positive (although the outcomes of weak central coherence traits are not always positive) and negative features of this cognitive style. The research by Heaton (2003) and Heaton et al. (1998, 2001) was reported to provide support of the theory of weak central coherence in the auditory domain. More recent investigations though have shown that although those with autism may indeed show an enhanced ability to process stimuli at the local level, their global processing may remain intact (Mottron & Burack, 2001; Mottron, Burack, Iarocci, Belleville, & Enns, 2003; Plaisted, Saksida, Alcántara, & Weisblatt, 2003).

An alternative theoretical framework to weak central coherence is the enhanced perceptual functioning model, which proposes that low-level perceptual processing is overdeveloped in those with autism (Mottron & Burack, 2001). This theory was used to explain the pitch processing abilities in those with autism during a signal detection analysis by Bonnel, Mottron, Peretz, Trudel, Gallun, and Bonnel (2003). The researchers worked with 12 musically naïve participants with autism (mean age = 17.91) and 12 musically naïve typically developing controls (mean age =

16.58), group-matched on age, laterality, and overall IQ score. After an audiometric assessment, each participant took part in one of two experiments, counterbalanced across participants, involving pitch discrimination and categorization. The tasks utilised a signal detection analysis to isolate perceptual sensitivity from the response bias inherent in same-different tasks. During the pitch discrimination task, participants listened to pairs of successive tones that were either the same or different, with the second tone either the same as the first or higher than the first by 3%, 2%, or 1%. The standard tone, the one the participant heard first, had a frequency of 500, 750, 1000, or 1500 Hz. One second of silence was presented between each pair, and 40 trials were presented. The participants were given six buttons to choose from to indicate if they thought the tones were the same or different (three buttons each) and the level of confidence of their decision. Results revealed that the teenagers with autism performed better than typically developing controls on the 2% and 3% conditions but not on the 1% condition. The nonsignificant difference in the 1% scenario may have been due to floor effects. In the pitch categorization task, participants heard a low 1000-Hz reference tone and high tones, 3%, 2%, or 1% above the standard. Over 40 trials, the participants heard each tone for 100 milliseconds with 1.5 seconds between each single tone, which the participant then had to classify as either high or low. Researchers asked the participants to express their confidence in their subjective choice of high or low over six response keys similar to the first study. The group with autism performed better than the typically developing group in all three conditions of higher tones (3%, 2%, or 1%). The overall findings of both experiments were that the group with autism performed equally well on both tasks while the typically developing group performed significantly better on the discrimination task. The researchers commented on how these enhanced pitch processing abilities were

evidence for the overdevelopment of low-level operations, as explained by the enhanced perceptual functioning framework.

1.2.2 Melodic Contour Assessment

With the existence of increasing evidence of exceptional pitch memory and discrimination in those with autism, researchers investigated the abilities of individuals with autism to process melodic contours, the direction of the musical line. Mottron, Peretz, and Ménard (2000) argued that the paradigm used by Heaton et al. (1998) to assess weak central coherence in the auditory domain was limited because it only created a binary local/global distinction and did not contain a gradient of local and global auditory stimuli in music. Mottron et al. aimed to assess musical processing hierarchically by evaluating performance on their proposed musical hierarchy of pitch, then interval, then melodic contour. These tasks, Mottron et al. argued, would enable them to assess local and global processing in varying musical contexts. For example, absolute pitch processing was considered local processing in the context of an interval, which would require more local processing in the context of a contour. They compared the performance of a group of high functioning individuals with autism (mean age = 16.73) to age, laterality, and nonverbal IQ group-matched typically developing controls (mean age = 15.33) to determine if pairs of melodies were the same or different. In the first round of testing, half of the melodies were paired to the same melody and the other half were paired to melodies with a single note changed that either preserved (contour-preserved) or changed (contour-violated) the contour of the melody. The researchers argued that if participants exhibited better task performance with contour-preserved melodies than with contour-violated melodies, the participants were exhibiting local processing. Conversely, if participants exhibited better task performance of contour-violated melodies than contour-

preserved melodies, the participants were exhibiting global processing. In the second round of testing, the task also presented contour-preserved and contour-violated comparison melodies (the one presented second), but the target melody (the one presented first) was transposed so that its notes were higher or lower in pitch than those of the comparison melody as shown in Figure 1. In this round, in addition to

Figure 1
Example of Basic Melody (A), its Transposed Version (B), its Contour-Violated (C) and its Contour-Preserved (D) Transformations (Mottron et al., 2000)



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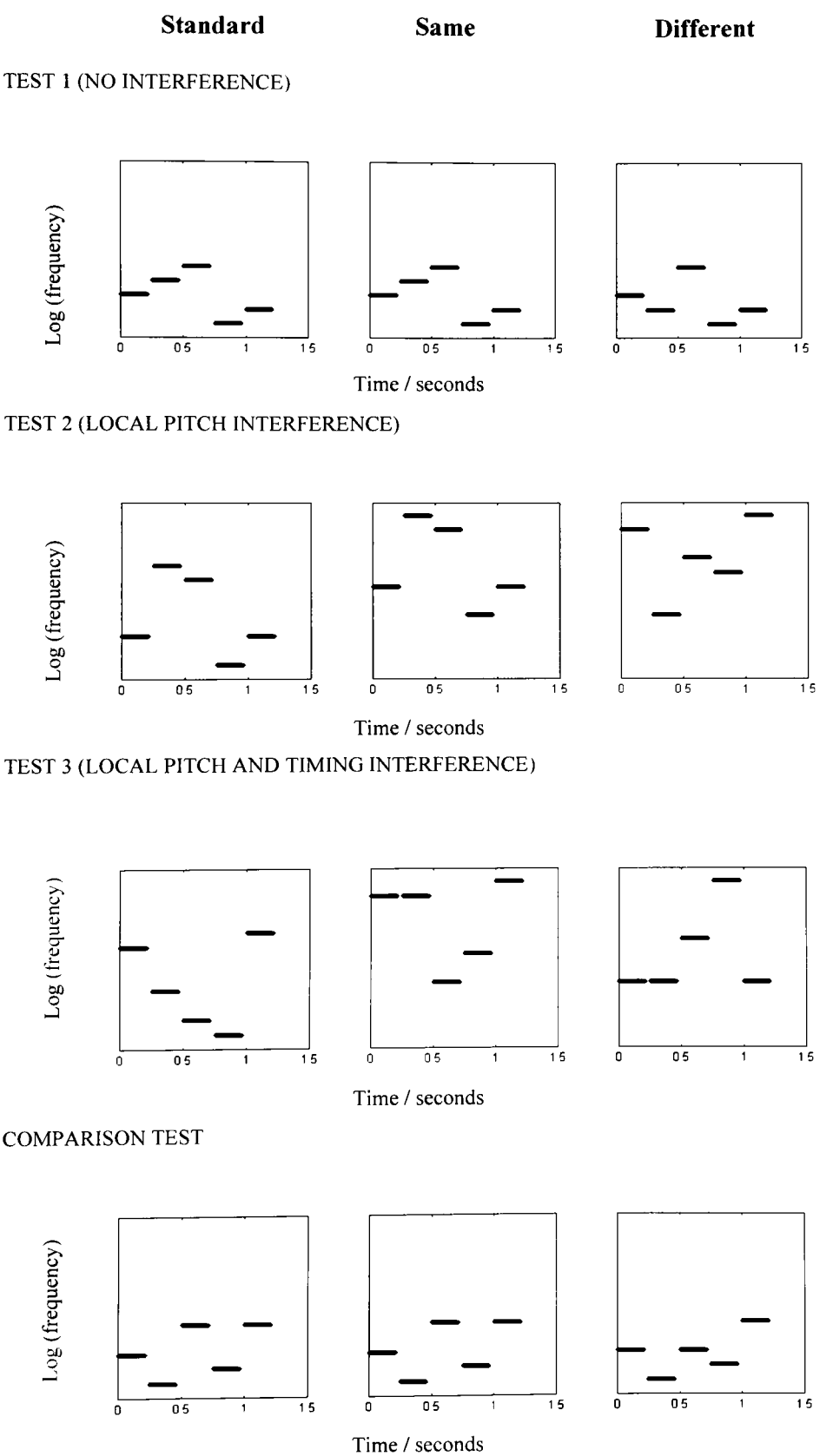
being told to choose if the melodies were the same or different, participants were told to disregard the fact that the melodies were pitched differently "as if they were to judge whether a melody sung by a man was the same as or different from a subsequent melody sung by a woman" (Mottron et al., p. 1061). The researchers

hypothesised that participants exhibited local processing when their task performance was negatively affected by transposition of the target melody, and global processing when their task performance was not negatively affected by transposition of the target melody. The results revealed a similar pattern of performance by both groups. They both performed better when the melodies were in the nontransposed condition. Irrespective of transposition, they both showed an advantage for contour-violating over contour-preserved melodies. An ANOVA failed to find a significant group effect. Thus, both groups seemed to use AP clues, interval distance, and pitch direction to perform the tasks. In contrast to the weak central coherence theory, this experiment showed intact global processing in those with autism. An analysis of simple effects on the contour-preserved melodies was carried out even though there were no interaction effects between group, transposition, and melodic factors. The authors argued that these analyses were appropriate because of previous research showing enhanced pitch memory in those with autism and the claim of enhanced local processing in those with autism based on weak central coherence. This analysis did reveal better performance by those with autism for discrimination of contour-preserved nontransposed melodies compared to typically developing individuals. The two groups, however, performed similarly on tasks utilising transposed melodies. This finding may indicate more effective use of AP in those with autism because AP relies on memory of exact pitches and would thus be ineffective in assessing the contour of a transposed melody. This finding supports the theoretical framework of enhanced perceptual functioning model of autism. It is, however, worthy of further investigation given that it was a comparison that was carried out on the basis of theoretical and not statistical grounds. The overall findings of the study do, however, provide a

convincing argument for intact global processing, as evidenced by similar patterns of performance by the both groups.

Foxton et al. (2003) continued the work on contour processing by claiming that the global and local features of musical stimuli were incorrectly assigned and that the contour, absolute pitch values, and time points of changes in pitch, should each be considered "local" auditory features while the combination of all of these factors should be considered the "gestalt." They examined the performance of a group with autism spectrum disorders, 11 with Asperger's Syndrome and 2 with high functioning autism (mean age = 18.1), and 15 typically developing individuals (mean age = 17.7), group-matched on age, amount of musical training, hearing level, and Full Scale, Verbal, and Performance IQ. The researchers utilised a same-different paradigm with pairs of five-note sequences of pitches separated by gaps of 1 second. After practice, the participants experienced 40 trials of each of four testing conditions, always presented in the same order. The goal of each task was for participants to analyse if the contours, or rises and falls, of the auditory sequence pairs were the same or different. Examples of all auditory sequence types are shown in Figure 2. In the first testing round of "no interference," the standard was presented with the "same" choice identical to the standard, and the "different" choice with one changed note, with its position randomised. The "different" auditory sequence was also contour-violating when compared to the standard. In the second testing round of "local pitch interference," both of the comparison auditory sequences were transposed to bring about what the authors described as "local pitch interference." The "same" condition was an exact transposition of the standard pitch sequence, and the "different"

Figure 2
Auditory Sequence Tests (Foxton et al., 2003)



(Reproduced with permission from the authors.)

condition featured a different pattern of rises and falls in the notes.[2] In the third test, participants had to decide if the contour of the pitches were the same or different when the pitch sequences underwent "local pitch and timing interference." Researchers told the participants that they would hear one of two patterns: up and then down or down and then up, and that they would have to recognise the sameness or difference of these from the standard. In the "same" condition, these pitch changes formed the same contour pattern as the standard, such as a rise and fall in pitch, but the timing of the rise and fall was different. For example, as the standard, the participants could hear the intervals that went "up-up-down-down," and then hear the intervals that went "up-down-down-down" as the "same" sequence. They were the same in contour, which participants were asked to analyse. In the "different" condition, these pitch changes caused differences in contour from the standard. The argument of the authors, according to their definitions of local and global processing, was that as the tests went on from the first to the third, the level of global interference increased. Thus, the authors conceptualised weak central coherence as a cognitive style of those with autism that caused them to ignore global auditory interferences more easily. Lastly, the participants experienced the comparison test, which was the same as the first test, but with the note change not altering the contour pattern of rises and falls so to mimic the task of contour-preserved different sequences from Mottron et al. (2000).[3] The participants pressed one of two buttons, representing, "same" and "different." Overall, participants performed best at the first test, then the second test, and finally the third test. Only the control group, however, exhibited a significant difference in performance based on task type. The groups did not perform differently

[2] In a paper by the same research group that assessed reading skills (Foxton, Talcott et al., 2003), this test was considered a "global sequence task." Here lies an apparent contradiction in what this research group considers local and global.

[3] In Foxton, Talcott et al. (2003), this test was considered a "local sequence task." Yet again, here lies an inconsistency as to what this research group considers local and global in the auditory domain.

on any of the tasks, although results of the third test, which evaluated the effects of global interference and were evaluated after a significant task x group interaction was found, revealed a trend of better performance by those with autism. The authors argued that this trend and the difference in task performance by the control group provided support for the theory of weak central coherence in the auditory domain as it is defined in this paper because those with autism were not affected by global interference, which was maximised in the third test. The authors, however, did not find a main effect of group, and the analysis of simple effects after the interaction of group and task only indicated a trend of enhanced performance by the group with autism. The researchers' argument would have been more convincing if the participants with autism exhibited enhanced processing as global interference increased. Results of the comparison test were compared to those of Test 1 to have analogous data to Mottron et al. (2000) who argued that those with autism showed enhanced abilities to differentiate contour-preserved sequences. The researchers did not find enhanced processing of the contour-preserved melodies as argued by Mottron et al. Foxton et al. went on to argue that their findings supported the theory of weak central coherence, with the newly defined components of "local" and "global," because the perception of contour (categorised as one facet of "local" auditory stimulus) by participants with autism appeared not as affected by the global interference of local pitch and timing alterations.

A recent investigation by Heaton (2005) evaluated interval and contour processing in those with autism. Heaton had 13 children with autism (mean age = 10) and two control groups, individually matched on age, gender, and performance on either a receptive vocabulary test (Peabody Picture Vocabulary Test) or a pattern recognition test (Raven's Matrices). In the first test of interval processing, Heaton

exposed participants to 48 pairs of tones, ranging in interval from a semitone to an octave in ascending and descending fashions. To ensure the children understood the concepts of rising and falling, Heaton showed them pictures of a man descending a staircase, and a woman ascending a staircase to sort into "up" and "down" categories. They were then told to listen to the pairs of tones and say as quickly as possible whether they went up or down. After training with feedback, the participants underwent the round of testing. As previously reported in Heaton et al. (2001), the children with autism correctly identified the small intervals better than typically developing controls, who performed better as the interval widened. No significant group differences emerged for the medium or large sized intervals. Next, Heaton evaluated contour processing by using 30 pairs of 6-note melodies, presented with the same simple harmonic structure and in the same moderate tempo. The participants had to identify the melodic pairs as the same or different. The different melodies had a one note change, with the position of this note varied across trials. The note change caused the contour of the melody to change or remain the same. All participants showed the same pattern of performance on this task by performing best when asked to identify the same melodies, next best when the different melodies were contour violating, and worst when the different melodies were contour preserved. This pattern of results was similar to that of Foxton et al. (2003), but contrasted with the work of Mottron et al. (2000) because the children with autism did not show enhanced performance on detection of contour-preserved melodies. For both groups, interval and contour processing abilities (i.e., performance on the two tasks) did not correlate. Performance of the children with autism on the contour discrimination task correlated with age. Since Mottron et al. worked with older individuals, it is possible that contour detection improves during development. Foxton et al., however, worked with

those similar in age to the sample in Mottron et al.'s study and did not find these abilities.

1.2.3 Perception of Affect

Perhaps one of the most exciting investigations on musical processing in individuals with autism focused on the ability of those with autism to perceive affect in music (Heaton, Hermelin et al., 1999). Therapists could perhaps capitalise on these abilities to help those with autism increase socialisation skills. Anecdotally, individuals with autism have reported the use of music to experience emotions otherwise totally foreign to them. For example, Harold Stone, a 52-year-old with Asperger's Syndrome, commented that he could "better tell people how [he was] by playing a song in [his] mind," and that this "music br[ought] a landscape in [his] mind." Thus, music for this individual, uniquely articulate in describing his cognitive tendencies, provided a means of accessing emotions and communication where language failed him. Thus, he was able "to feel emotions [he]'d never fe[lt] at all." Stone also described childhood tendencies of a remarkable musical memory similar to those in Kanner's report. At age 4, Stone could remember songs, like John Phillip Sousa marches that he heard on newsreels and would instantly memorise (H. Stone, personal communication, October 3, 2004).

Heaton, Hermelin, and Pring (1999) carried out a study to assess the ability of children with autism to comprehend musical affect with 14 high functioning children with autism, individually matched to two control groups based on age, gender, and either verbal or nonverbal reasoning abilities. To minimise the confounding features of rhythm, tempo, and dynamics, 24 original compositions of four bar melodies were used. They were all similarly structured with a tonic-dominant-tonic chordal progression, which was used to create four versions of the tune with either harmonies

of the major mode or harmonies of the minor mode or as a major tune or a minor tune (with melodies only). There were then a total of 96 segments, which were randomised across keys, presented at the same tempo, and kept to a similar dynamic range and pitch height. A random portion of these tunes were then played for each participant. After the children showed that they understood what pictures with drawings of sad and happy faces meant, the children were played the tunes and asked to indicate if the tunes were sad or happy, by saying the word or pointing to the picture. Overall, participants performed better at tasks using harmonic rather than melodic musical selections while the mode of the selection did not affect performance. The children with autism performed very similarly to the two groups of typically developing children. This finding provides some hope of the possibility that children with autism might be able to access emotions in music that they could not access through other means.

1.2.4 Musical Processing

Taken together, research on musical processing in children with autism has shown the potential for "splinter skills," preserved or enhanced areas of the autistic cognitive profile (Heaton et al., 1999). These individuals tend to exhibit better pitch memory and disembedding as well as interval recognition than typically developing children and preserved abilities to process the contour of melodies. These abilities, however, may be task specific, may change with development, and may only occur in a sub-set of those with autism.

One study turned this question on its head by asking whether individuals with AP have autistic tendencies. Brown, Cammuso, Sachs, Winklosky, Mullane, Bernie et al. (2003) compared the language, socialisation, and cognitive features of musicians with AP to musicians without AP. Researchers used several assessment tools (the

Modified Personality Assessment Scale, the Friendship Interview, a screen for childhood language and/or reading problems, and the Pragmatic Rating Scale) to analyse autistic features of language, socialisation, and cognition. They also compared the groups' performance IQ levels with the Wechsler Adult Intelligence Scale-Revised. Participants were also classified as "eccentric," "somewhat eccentric," or "not eccentric" based on the interviewer's notes. The author who classified the participants was blind to the AP status of the participant. As there were only 13 adults with AP and 33 without AP (all from the same orchestra to avoid any bias caused by participants' volunteering to participate) in the study, only preliminary findings were reported. Although the questionnaire and interview scores did not differ statistically between groups, 83% of those with AP compared to 40% of those without AP showed some deviance on the scales (a statistically significant difference). The interviewers' ratings of the participants revealed a statistically significant difference: 6 of the 13 with AP and 5 of the 33 without AP were classified as eccentric. Compared to controls, those with AP performed relatively better on block design tasks, as would be expected in those with autism.

1.3 Deficient Auditory Processing and the Presence of Language Problems in Those with Autism

Recent neurobiological research has shown that the notion of music processed in the right hemisphere and language in the left hemisphere is over-simplistic. Recent research has revised this notion. Zatorre, Belin, and Penhune (2002) showed that the auditory cortex of the right hemisphere processes spectral features of sound, and is thus more involved in music processing, while the left hemisphere processes temporal features of sound, and is thus more involved in language processing. Neural processing of auditory stimuli, however, is not exclusive to one hemisphere or the

other. Recent evidence has shown that individuals process analogous structural features of music and language in the same brain areas (Maess, Koelsch, Gunter, & Friederici, 2001; Patel, 2003). There is thus more similarity of musical and language processing, both universals in all civilisations, than previously thought. The potential divergent processing of music and language in those with autism is particularly intriguing for this reason.

Preserved musical skills in those with autism contrast with impaired speech and language abilities that are a hallmark of this condition. Simmons and Baltaxe (1975) analysed the language patterns of 7 individuals with autism (age range = 14-21) and compared these results to their scores on the Seashore Test for Musical Ability. Their analyses revealed that 4 of the 7 participants were language impaired. The researchers ran a Goldfarb Analysis by systematically assessing various features of each participant's language (e.g., voice and speech, rhythm, articulation, and symbolic use of language). The language impaired participants with autism exhibited problems with phonation, rhythm, and symbolic (i.e., pragmatic) language use, while there were few disturbances of articulation. The researchers showed that the scores on the Seashore Test of Musical Ability correlated with the child's language abilities. This finding though should be handled cautiously because the validity of the Seashore Test is questionable and because it relies heavily on receptive language abilities. Perhaps those who could handle language better understood the instructions of the musical test to enable them to score higher than those with language difficulties. In other words, this correlation of language and musical abilities could simply be an artifact of the language demands of the musical test and may not be a valid indicator of musical and language processing in autism. They also concluded that those with autism could be classified into linguistic subgroups. The proposition of linguistic

subgroups of those with autism has become the topic of more recent inquiries into the language profiles of those with autism (Kjelgaard & Tager-Flusberg, 2001; Tager-Flusberg & Joseph, 2003).

Jarrold, Boucher, and Russell (1997) reported that those with autism exhibited flat language profiles with no differences in vocabulary and grammar production and comprehension. Investigations by Kjelgaard and Tager-Flusberg (2001) and Tager-Flusberg & Joseph (2003), however, have shown that although pragmatic language skills are a central deficit of those with autism who are verbal, the profiles of their language deficiencies are heterogeneous in terms of the delay of the onset of language and the difficulties with vocabulary and syntax. Kjelgaard and Tager-Flusberg carried out a battery of language assessments, ranging from the Peabody Picture Vocabulary Test III to the Goldman-Fristoe Test of Articulation and the Clinical Evaluation of Language Fundaments (CELF), with 89 children with autism. The researchers drew some general conclusions: (a) children all over the IQ spectrum exhibited a wide range of language abilities, (b) a discrepancy of receptive and expressive vocabulary was not found, (c) in those with poor language, vocabulary was less impaired than grammar, (d) in a quarter of the children, no language problems were seen, (e) articulation skills seemed to be spared in the verbal population with autism, and (f) those with the lowest level of language resembled those with specific language impairment (SLI), a disorder characterised by language problems in the context of otherwise typical development. The researchers used a nonsense word repetition task to test phonological short term memory. They reported that although children with autism often exhibit echolalia, many, especially those with lower language levels performed surprisingly poorly on nonsense word repetition. The researchers reasoned that the children who did not perform well on this task might have had difficulty

because it could not be accomplished through rote memory, but required the holding of phonetic information in working memory so that it could be produced verbally.

Bishop, Maybery, Wong, Maley, Hill, and Hallmayer (2004) also reported phonological processing deficits in 80 probands with autism or PDDNOS compared to 59 typically developing children, group-matched on age and gender. Bishop et al. reported that the control group performed significantly better than the group with autism on tests of nonword repetition. The nonword repetition scores correlated with verbal IQ scores, and there was no evidence of impaired phonological processing in those with normal verbal ability. The group finding indicating impaired phonological processing in those with autism is even more surprising given the research on musical abilities that has shown repeatedly that those with autism appear to process the fine grained details of sound extremely well. Perhaps these individuals do not profit from these abilities while navigating the linguistic world. After all, anecdotal accounts by those with autism, including Harold Stone, have indicated that music provides a means of communication that language does not.

Other research has indicated that auditory processing deficits may arise in the language domains. Recent investigations using speech-in-noise paradigms have revealed auditory processing deficits in the language domain of individuals with autism. Alcántara, Weisblatt, Moore, and Bolton (2004) used speech reception thresholds, the speech-to-noise ratio at which 50% of speech is correctly understood, to evaluate the speech-in-noise perception of 11 adults with autism and 9 age and IQ-matched controls. An analysis of the results across all noise backgrounds revealed that those with autism exhibited higher thresholds (i.e., worse performance) during all the speech-in-noise tasks although, when simple analyses were carried out, the adults with autism seemed to show the greatest problems whenever temporal dips took place

in the background sound. While typically developing individuals used background dips to improve their understanding of speech, those with autism seemed not to take full advantage of this background to help them in their understanding of speech. This might explain why individuals with autism are reported to have difficulties attending to the salient features of dialogue.

Using event related potentials (ERP), Čeponienė, Lepistö, Shestakova, Vanhala, Alku, Näätänen et al. (2003) confirmed that those with autism have trouble attending to the important features of speech. The researchers set up a paradigm to assess the reactions to standard and deviant speech and tone sounds of 8 children with autism and 10 control children who took part in the study. Participants experienced three testing conditions: vowels, complex tones, and simple tones. For the vowel condition, a synthesised vowel (Finnish/ö/) was produced with known formants, which are a measure of the resonance of the vocal tract and are expressed as a frequency. The vowel sounded like a natural speaking voice. The deviant of the vowel sound was formed by raising the formants of the vowel by 10% each. The complex tone was formed by combining four sinusoidal tones, with the intensity and frequency matched to the strongest harmonics in the vicinity of the vowel's formants. The simple tone was composed of the strongest formant of the vowel (458 Hz). To form the deviants of the two tone types, simple and complex, all of the frequencies were individually raised by 10%. The participants were presented with three blocks of each type of stimuli, with each stimulus presented 400 times per block (a total of 1,200 exposures per stimuli). In each block, the standard was presented 86% of the time with the deviants presented the rest of the time. Each sound lasted for 260 ms and was delivered via two loud-speakers on either side of a television monitor. Participants were told not to pay attention to the sound as they watched a movie of their choosing

on mute. The speakers were placed on either side of the television monitor, just outside of the participant's spatial focus, to elicit the P3a, indicative of active attention. The researchers were most interested in the P3a and the presence or absence of a mismatch negativity (MMN), indicative of a response to a deviant stimulus during passive listening. Both the P3a and the MMN were measured from the difference waves obtained from the subtraction of the ERPs of the standard-stimulus from that of the deviant-stimulus for all three stimulus classes. It is unusual to assess both the P3a, dependent upon attention, and the MMN, elicited when participants are not attending, in the same study. The researchers argued, however, that the P3a "is an index of involuntary attention switch . . . that might have subcomponents that index even subconscious stages of attention recruitment." Thus, they argued that although participants were told not to attend to the auditory stimuli that the presence of the loud speakers "were nearby or within the attended attentional space" to facilitate "the elicitation of the P3a" (R. Čeponienė, personal communication, May 17, 2005). The instruction to the children not to attend to the stimuli remains as a potential confound of this study that aimed to assess the difference of hearing and attending to both vowel and tonal stimuli. It is certainly possible that the children with autism obeyed instructions better than the typically developing children by not attending to the deviant stimuli.

For all three stimulus classes, both groups exhibited a significant mismatch negativity (MMN). Thus, the children with autism were able to discriminate the changes in all three types of auditory stimuli as well as the typically developing controls. While both groups of children exhibited significant P3a responses, indicative of involuntary attention switch, to the complex tones and simple tones, the children with autism showed an absence of a P3a response in the vowel condition. The

typically developing children exhibited a significant P3a for all three conditions, although it was largest for the simple tones and smallest for the vowel sounds. The children with autism exhibited no P3a to the vowel sounds at all. Thus, these data show that the children with autism exhibited problems in attending to auditory stimuli even though they did hear them, and that these deficiencies were specific to the language domain. These findings would thus support a theory of top down deficiencies in auditory processing of language in autism.

Other ERP evidence using tones as stimuli showed abnormality in the P3b of those with autism even though the children responded to changes in tone behaviourally (Lincoln, Courchesne, Harms, & Allen, 1993). Although Lincoln et al. did not report an abnormality in P3a, they did reach the same conclusion that those with autism have difficulties with context updating and picking out the salient features of speech in the auditory domain. Perhaps these researchers would have found P3a deficits if they had used speech stimuli like Čeponienė et al.

In another recent study (Jansson-Verkasalo et al., 2003), researchers worked with 12 children with Asperger's Syndrome (AS) and 12 healthy controls to assess their ERP responses to standard and deviant syllables ("taa" standard vs. "kaa" deviant) and tones (1000 Hz standard and 1100 Hz deviant). Participants heard four sequences of each stimulus type of 300-400 stimuli. These stimuli were not acoustically matched. The researchers examined the P1, N2, and N4 peaks and the MMN. The researchers stated that "in children, the P1 and N2 peaks index the transient encoding of acoustic sound features" (p. 197). Using grand averages of the ERP data, the P1 was determined from the standard-stimulus ERP as the most prominent positive peak within 50-150 ms, the N2 came within 180-300 ms, and the N4 come within 320-500 ms. The MMN was determined by subtracting the standard-

stimulus ERP from the deviant-stimulus ERP. In both the consonant and tone conditions, the participants with AS exhibited a smaller P1 amplitude compared to that of controls, but the P1 latency was not different. The clinical group's N2 amplitude was diminished compared to controls only in the tone condition at the right central electrode, and the N2 peak's latency was delayed for the tone stimuli only in the frontal and central electrodes. The researchers also reported that there were not hemispheric differences in P1 and N2 peaks, and no group differences in the N4 peak presentation. In the consonant condition, the MMN occurred significantly later in the sample with AS than in controls in the right hemisphere only. In the tone condition, there was also a longer latency of the MMN in both the right and left hemispheres.

In summary, the researchers argued that their sample with AS exhibited abnormal P1 in both the tone and syllable condition, N2 in the tone condition, and MMN in both the consonant and tone condition. These researchers also reported that the MMN latency was more delayed in tones than in speech stimuli, and they went on to suggest dysfunction of the right hemisphere, often associated with pitch and musical processing. These findings are surprising given the research on musical processing in those with autism and the previous work by Čeponienė et al. (2003). The argument in this investigation is that auditory processing of both tones and consonants seems to be problematic in those with AS at the central auditory processing level, and thus bottom up processing may be faulty. Given this seemingly contradictory study, it is important to keep in mind that a lot of information on various components of ERP data are not fully understood in typical development. Thus, although further research is definitely necessary in this area, it is crucial to keep in mind that that our knowledge of these cortical processes during typical development is limited. There were also methodological issues that could have impacted the result

in Jansson-Verkasalo et al. (2003). The deviant speech stimulus crossed a phonemic boundary and was thus more salient than the raised frequency of a tone as the deviant. It is also noteworthy that the tonal deviant was of a larger frequency difference in the present study (100 Hz) than in Čeponienė et al. (45 Hz). Also, the formants of the speech and tonal stimuli were not frequency matched as they were in the Čeponienė et al. paper. The presentation qualities of the speech and tonal frequency were also different with the tonal stimuli presented with shorter durations than the syllables (100 ms vs. 190 ms), less intensity than the syllables (65 dB HL vs. 75 dB HL), and shorter stimulus onset synchrony (time from onset of one stimulus to onset of the next) than the syllables (600 ms vs. 650 ms). The authors do mention the difficulty in comparing performance across conditions due to these differences. All of these factors could have potentially confounded performance. For these reasons, the Čeponienė et al. paper makes a more convincing and sound argument of speech vs. tonal auditory processing in autism. It remains unclear, however, if the speech vs. tonal response contrast in those with autism would be similar if more musical stimuli, instead of tonal, were used and contrasted to speech stimuli. Of the ERP evidence in the literature, no study has compared language to musical stimuli in individuals with autism.

One aspect of auditory processing that is regarded as important for language development is rapid temporal processing, which has been studied predominantly in non-autistic children with language impairments. Lincoln, Dickstein, Courchesne, Elmasian, and Tallal (1992) trained individuals with autism (mean age = 19.9 years), individuals with developmental receptive language disorder (DRLD), which is the same as SLI (mean age = 24.4), and typically developing children (mean age = 17.7 years) to recognise two tones, with fundamental frequencies of 100 and 300 Hz,

respectively. Since those with DRLD have been shown to exhibit an impairment of rapid sound memory and processing through age 10, this study evaluated the skills of older individuals with this language disorder and compared these abilities to those with autism and controls, who were in a similar age range as the two experimental groups. The researchers set up a paradigm where the participants had to identify, by pressing one of two buttons, the two tones as they became parts of increasing sequences from two to seven tones, with shorter and longer pauses between sets of stimuli sequences (these pauses are known as interstimulus interval or ISI). To go on to the next set of tone sequences, the participants had to score correctly on 60% of their responses. All groups performed less well as the number of tones in the sequence increased and did better with longer ISIs. The children with DRLD scored less well than the typically developing sample and the children with autism, who did not score significantly differently than controls. The researchers argued that the deficiencies in short term auditory memory and rapid auditory processing in those with DRLD may negatively impact normal language acquisition in those with this disorder. Since the children with autism had been reported not to exhibit short term memory deficits, a finding that has been confirmed by more recent work (Minshew & Goldstein, 2001), and had intact rapid auditory processing, the authors then reasoned that the roots of their language problem may be different than those with DRLD. Ironically, a member of this research team later argued for the use of rapid auditory processing training through the use of the program *Fast ForWord* even though no deficits in this area were shown in the Lincoln et al. empirical study (Merzenich et al., 1999).

1.4 Questions from the Scientific Literature

Many questions emerge in investigating studies on the auditory processing of individuals with autism in the domains of music and language. Is autism associated

with superior musical processing, even in non-savants? If so, can results be explained in terms of the weak central coherence theoretical model? Are these advantageous musical processing skills present throughout the autism spectrum or just in those who are high functioning? Studies thus far have only worked with such individuals. Do language and musical abilities correlate in those with autism or can they be dissociated? This thesis attempts to resolve these emergent questions.

1.5 Thesis Overview

Studies 1 and 2 (presented in Chapters Two and Three, respectively) assess musical and language processing in high functioning children with autism. Chapter Four presents a critical review of the literature on music therapy with individuals with autism. This area of therapy is the most related form of intervention to investigations of the musical processing of individuals with autism. This critical review serves as background for study 3, presented in Chapter Five. Study 3 is an exploratory, music therapy-like study that was set up to assess the potential effects of music therapy and the musical abilities of young children with severe autism. Chapter Six provides some concluding remarks on research in this area of musical processing in those with autism and presents two proposals of appropriate future investigations based on the studies presented in this thesis.

Chapter Two

Study 1:

Explorations of Music and Language Processing in High Functioning Individuals with Autism

Empirical research on the musical abilities of those with autism has attempted to break musical stimuli down into components to see how individuals with autism perform on tasks of pitch memory and disembedding, frequency discrimination, and contour assessment. Overall, research has shown that those with autism may exhibit auditory processing similar to that of those with absolute pitch, a characteristic of the musical savant, by memorising pitches to which they have been pre-exposed and being able to disembed them from chords better than typically developing controls (Heaton, 2003). Bonnel et al. (2003), Heaton et al. (2001), and Heaton (2005) have shown that those with autism exhibit superior frequency discrimination, particularly when it comes to differentiating fine differences in pitch. While Mottron et al. (2000) claimed that those with autism exhibit enhanced recognition of the differences of two melodies when one contains note differences that do not alter contour, Heaton (2005) argued that those with autism exhibit the same pattern of decreased success at contour discrimination as typically developing controls when asked to differentiate pairs of melodies that are the same, different when contour is changed, and different when contour is not changed. Foxton et al. (2003) found similar results to Heaton (2005) and showed that those with autism are less affected by global interference when asked

to differentiate contours. Applebaum et al. (1979) were the first to attempt to use more complex musical stimuli with children with autism, albeit a very small number, and concluded that the children with autism did as well and sometimes better than controls when asked to repeat back lines of music they heard.

Based on this prior research on the musical processing of those with autism, this study has three main aims: to analyse the extent of musical abilities in individuals with autism, to analyse the nature of these abilities, and to assess the relationship of these musical abilities to language abilities. By looking at the extent of the musical abilities, the aim is to see if only a sub-set of individuals show these advantageous methods of auditory processing of music or if all those with autism exhibit uniform superiority when compared to chronological age and nonverbal IQ matched controls. By analysing the nature of these musical abilities, I investigated the qualitative differences of the musical processing of those with autism using more complex musical paradigms. Do enhanced pitch memory and disembedding generalise to enhanced memory and disembedding of melodies? Could the theory of weak central coherence apply to the processing of entire melodies and not just pitches within them? Finally, I investigated the relationship between the musical and language profiles of these children. Is it just that music may be a strength and language a weakness, or is there a relationship between the two?

In study 1, a task of melodic processing, adopted from the work of Heaton (2003), was used to evaluate the extent and nature of musical abilities in those with autism. Since children with autism have been shown to exhibit pitch processing similar to the mechanisms used in those with AP, one of the features of a savant condition in music, it was hypothesised that children with autism might process sound in such a way that causes them to exhibit a predisposition to a savant condition in

music. Since the two other qualities of a musical savant are an innate understanding of key relationships and an extraordinary musical memory, it was of interest to analyse these facets of musicality in those with autism. Study 1 assessed musical memory by utilising a paired associate learning paradigm, with animal pictures matched to melodic fragments, to assess identification and memory of these musical lines after pre-exposure. Of the literature on the musical abilities of children with autism, the closest study to this is Applebaum et al. (1979), which assessed musical memory, but was limited by the small number of participants. It did, however, show that these children did just as well as and sometimes better than typically developing controls on musical memory tasks, assessed by having to repeat back melodies. Based on the enhanced pitch identification that has been reported and the possibility of enhanced abilities to reproduce melodies heard, it was hypothesised that the children with autism would exhibit enhanced identification and memory of musical lines. Heaton (2003) showed that those with autism could not only identify pitches better than typically developing controls, but could also disembed single notes from chords better than controls. Although both groups did less well on the disembedding than on the identification of the notes, the children with autism were hypothesised to do better at disembedding than controls due to their tendency to focus on the notes of the chord as opposed to the entire chord, as claimed by the theory of weak central coherence. Similarly, in the present paired associate learning paradigm, the musical fragments had been embedded after participants were cued and pre-exposed to the "part" of the melody to identify in the context of a longer musical gesture, the "whole." The fragments were embedded in the two ways that melodic fragments are found in music: as part of a melodic gesture and as part of a harmonic gesture. The harmonic embedding resembled the embedding of a note within a chord as in Heaton (2003),

with the addition of a melody with chords before and after the fragment to be identified. The melodic embedding, with the melodic fragment placed in the middle of a longer melody, was an exploratory manipulation based on how music is often composed to see if such an embedding would alter the children's abilities to disembed the melodic fragment. It was hypothesised that the children with autism would be able to pick out the familiar melodic fragment better than controls based on the cognitive style of weak central coherence. In this paradigm, the melodic fragment was the part and the longer melodic or harmonic gesture was the whole. Also, it was thought that both groups would show a pattern of better performance on identification than disembedding based on the pitch work by Heaton (2003) that showed that disembedding pitches was more difficult for all children than identification. If group differences failed to emerge, then it was thought that musical pattern recognition performance would correlate more with age and nonverbal IQ abilities in the typically developing children with autism than in the children with autism.

To explore further the nature of these musical abilities, I also tested frequency discrimination in a simple task of a three tones in which children had to judge which of three pitches was the "odd man out." It was hypothesised that the children with autism would perform better than controls on this task based on the findings of enhanced discrimination of small intervals by Bonnel et al. (2003), Heaton (2005), and Heaton et al. (2001).

To analyse the relationship of musical and language processing in the auditory domain, this study aimed to look at facets of hearing that influence language by evaluating receptive vocabulary and phonological short term memory. Given the evidence of language deficits in previous research on the language profiles of those with autism, it was hypothesised that the group of children with autism would perform

less well than the group of typically developing children on phonological short term memory, assessed by a nonword repetition task, and receptive vocabulary, assessed by the British Picture Vocabulary Scale II. It was further hypothesised that the auditory processing in the musical and frequency discrimination domains would be in stark contrast to the language processing of the sample of children with autism.

2.1 Method

2.1.1 Participants

Experimental group with autism. Thirty children initially participated in the experiment, but many children were eliminated because they could not carry out all the tasks of the study, or because of their age, which was later determined to be too young to participate in the study. The group of children with autism was narrowed to 11 high functioning children with autism, recruited from special units for children with autism and through local autism societies in Oxfordshire, England and New York and New Jersey, USA. All children had normal hearing. The children's nonverbal IQs were assessed on the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999). None of the children exhibited a savant condition, extreme hyperacusis (i.e., extreme distress brought about by sound), or a hearing deficiency. All of the children's first language was English. All parents filled out a musical exposure and training questionnaire about their child. The children with autism's age, nonverbal IQ, gender, nationality, and musical exposure are summarised in Table 1. All of the children with autism underwent the Developmental, Diagnostic, and Dimensional Interview (3dI) for autism spectrum disorder (Skuse et al., 2004). Since there is increasing evidence that high functioning autism and Asperger's Syndrome are not discrete developmental disorders, children who met 3dI criteria for an autism (n = 7), atypical autism (n = 1), or Asperger's Syndrome (n = 1) diagnosis were

included (Attwood, 1998; Macintosh & Dissanayake, 2004). Two other children were included in this sample even though the 3dI diagnosed them as having a Pervasive Developmental Disorder not Otherwise Specified (PDDNOS). These children narrowly missed the cut off for a diagnosis on the autism spectrum, and their scores were in the autistic range on two of the three main domains of the 3dI assessment. The first child had a medical diagnosis of Asperger's Syndrome and received special classroom services for his condition. On the 3dI, he showed abnormal repetitive and stereotyped behaviours and use of language and other social communication skills. On the scale of reciprocal social interaction, however, he scored a 7.1, when the minimum score of abnormality was a 10. It is also worth noting that his Children's Communication Checklist (CCC) score (as assessed through the 3dI) was 121 (abnormal pragmatic communication is indicated by a score below 133). The second child also was above abnormal threshold in two of the three main scales of the 3dI, reciprocal social interaction and use of language and other social communication skills. He was, however, just below threshold on the scale of repetitive and stereotyped behaviour where he scored 2.3 with 3 as the minimum for abnormality. His CCC score was 130. He attended a special unit for children with autism spectrum disorders and had also received a medical diagnosis of Asperger's Syndrome.

Table 1

Demographic Data for Children with Autism and Typically Developing Children

	With Autism (n = 11)			Typically Developing (n = 11)			
	Range	Mean	SD	Range	Mean	SD	*p* value
Age	10.00-15.42	12 82	1.80	10.08-15.67	12.41	1.78	.597
WASI Nonverbal IQ Score (Mean of 100, SD of 15)	69-121	95.73	14 79	67-119	97.36	15 98	.806
Musical Exposure (of 27)	0-12	4 18	4 33	0-16	6.82	4.94	198
Male:Female		10:1			9 2		
British:American		9 2			8:3		

Typically developing control group. In total, 27 typically developing children participated in the study with participants eliminated based on the need to match the nonverbal IQ and ages of the groups, abnormal communication and/or socialisation as assessed by parental questionnaires, or age, which was later determined to be too low for this study. After eliminating many participants, 11 typically developing control participants were group-matched to the autism group on gender, nonverbal IQ (assessed by the WASI), musical exposure, and chronological age as summarised in Table 1. Children were recruited from primary and secondary schools in Oxford, England and Briarcliff Manor, New York, USA. All children had normal hearing. All of the children's first language was English. All children scored in normal ranges on the CCC (scores above 133) as well as the Social Communication Disorders Checklist (SCDC) (scores below 9), an abbreviated, checklist version of the 3dI that screens for autistic traits (see Appendix 1). Although one child was reported to have "mild dyslexia," he was kept in the study based on his CCC score of 158, and his SCDC score of 0.

As summarised in Table 1, the groups did not differ on nonverbal IQ, musical exposure and training, and age. All of the dates of birth of the children in both groups were based on the day when the music tasks were administered (in some cases, IQ assessment was calculated prior to working with the child) on the music tasks. None of the children was under the age of 10. This cut-off seemed appropriate because Sloboda (1993) reported that most individuals develop musical skill by age 10.

2.1.2 Materials

The Developmental, Diagnostic, and Dimensional Interview (3dI). To confirm the diagnosis of autism in each child in the experimental group, the 3dI was used (Skuse et al., 2004). The 3dI is a computerised, semi-structured parental interview that

provides a dimensional analysis of the child. The evaluation of the validity of the 3dI as compared to the Autistic Diagnostic Interview-Revised (ADI-R) is excellent, as is the test-retest and inter-rater reliabilities. After computer pre-entry of forms filled out by parents and teachers prior to the interview, the interview itself takes one hour to complete. It is more efficient than the ADI-R and thus more appropriate for research purposes. In addition to providing a diagnosis of any developmental delays (including most co-existing disorders in addition to those on the autism spectrum), the interview provides three major sub-scale scores on the use of language and other social communication skills, reciprocal and social interaction, and repetitive and stereotyped patterns of behaviour. A researcher (RA) trained to carry out the 3dI conducted these interviews with one or both parents prior to or during a break from working with the child. If parents requested information on the findings after the interview, I provided a summary of the findings of the diagnostic interview, specifically carried out for research purposes.

Social Communication Disorders Checklist (SCDC). The SCDC is a brief questionnaire of autistic traits. Filled out by parents, the survey is comprised of 12 questions, answered by responding to "not true" (scored as 0), "quite or sometimes true" (scored as 1), and "very or often true" (scored as 2). Statements to be evaluated span the various domains of autistic traits and include, "Behaviour often disrupts family life" and "Does not respond when told to do something" (see Appendix 1). The questionnaire, which has been shown to have high inter-rater reliability and test-retest reliability, is based on the 3dI and has a maximum score of 24, with a cut-off of 9 for

a PDD diagnosis shown to have high sensitivity and specificity (Skuse, Mandy, & Scourfield, 2005)[1].

The Children's Communication Checklist (CCC). The CCC (Bishop, 1998a) was developed to assess a child's expressive and pragmatic language. The list, which was filled out by parents of children in both groups, contains 70 items where the parent must answer if a characteristic "does not apply," "applies somewhat," or "definitely applies" with "unable to judge" as an option as well. Questions cover nine domains. In the speech domain, for example, one statement to evaluate is, "People can understand virtually everything he/she says." In the rapport domain, one statement is, "Makes good use of gestures to get his/her meaning across." Other domains are syntax, inappropriate initiation, coherence, stereotyped language, use of context, social relationships, and interests. A pragmatic composite score is calculated by summing the scores on five domains (inappropriate initiation, coherence, stereotyped language, use of context, and rapport). The checklist has been shown to have fair inter-rater reliability and good internal consistency (Bishop, 1998b; Bishop & Baird, 2001). The parents of children with autism filled out this checklist as part of the 3dI pre-entry forms because the CCC has been incorporated into the 3dI and comprises the bulk of questions in the communication domain.

Musical exposure and training questionnaire. Heaton recently devised this parental questionnaire of a child's extrinsic and intrinsic musical exposure and ability. There is not yet published normative data on this questionnaire (see Appendix 2), which contains questions on both extrinsic exposure to music such as parental musical training, child's music lessons, and music therapy and intrinsic interest in music such as a child's choosing to listen to music, singing back tunes, and ability to memorise

[1] The version of the SCDC used in this study was the pre-published version, which appears in Appendix I. The published version that appears in Skuse et al. (2005) is slightly revised and re-titled, "Social and Communication Disorders Checklist."

tunes. The first set of questions on extrinsic exposure was scored to establish the level of musical exposure and training of each child (maximum score = 27).

Nonverbal subtests of Wechsler Abbreviated Scale of Intelligence (WASI). The WASI is an abbreviated version of the Wechsler Scales of Intelligence with sub-scales chosen that have been shown to correlate most highly to how individuals do on the overall battery (Wechsler, 1999). There are two performance sub-scales: block design and matrix reasoning, and two verbal sub-scales: vocabulary and similarities. Each sub-scale takes approximately 15 minutes to administer. The WASI provides standardised scores for individuals ages 6 to 89 years. Only the nonverbal components were utilised during this study.

Melodic identification, disembedding, and memory. A "musical fragment matched to animal picture paradigm" was created, based on Heaton's "pitch matched to animal picture paradigm" (2003). Animal pictures were used for this paired associate learning task on the basis of Celani's (2002) finding that while children with autism do show a preference for inanimate objects over human beings, they show a preference of animals over inanimate objects as do typically developing children and children with Down's Syndrome. This choice was made to increase the likelihood of attention to the task by the group with autism. During one-on-one sessions, the children were exposed to 3 quasi-randomised rounds of 4 melodic fragments matched to the four animal pictures (cow, horse, kangaroo, and elephant), presented 4 times each during each round of 16 trials. Thus, the children were pre-exposed to each animal picture and melodic fragment pair 12 times (4 times during each of the 3 rounds). The fragments had been pre-recorded with an electronic keyboard onto a laptop computer. The children were told that the fragment was the animal's favourite with the instructions:

We are going to play some games with musical tunes to see how children like you understand the music they hear. You are going to see pictures of four different animals and then hear a brief tune. The tune you hear is the animal's favourite. Listen carefully so that when you hear the tune you remember the right animal. Please listen very closely. [*This is the kangaroo's favourite tune. This is the cow's favourite tune.* Etc. Can also remind child to listen closely. And say things like, "Are you listening closely so you can hear the differences. Can also tell child that they will be asked to identify which tune is which animal's if they seem not to be paying attention or during the pause between rounds.]

The tasks were devised to encourage the children with autism to attend. The animal pictures were presented on a computer screen, using Microsoft PowerPoint, with the musical segment playing from the computer. The computer presentation of the stimuli was chosen because of Ozonoff's (1995) finding that children with autism performed better at tasks, like the Wisconsin Card sorting task, when they were presented on computers rather than those presented in ways involving direct human interactions. The musical fragments were original compositions so to control for familiarity with the tunes that could influence the results. I utilised 1960s rock conventions because pilot data (Accordino, Comer, & Heller, 2004, October) had shown a trend of increased on-task behaviours and decreased maladaptive behaviours in the classroom when children with autism were exposed to 1960s rock during receptive music therapy (i.e., music listening). The tunes were all singable and did not contain note values longer than an eighth. Each fragment was 12 notes in length, comprised of half, quarter, and eighth notes. To control for differences, all fragments were made of the same rhythm, were in 2/4 time, and in the key of C major. The contour of the melodies was not controlled for, based on the work of Dowling (1994) that has shown that repeated listening to a melody causes the listener to hear the intervallic changes more saliently than the contour changes. Thus, after the 3 rounds of pre-exposure the contours of the melodies should not have been as salient as when they were first heard.

Microsoft PowerPoint was also used during tests of melodic identification, disembedding, and memory. During the identification task, 16 trials (4 of each fragment) were presented with one fragment played and four pictures on the screen with the animal pictures lighting up at the conclusion of the tune. On each trial, the pictures were presented in varying orders, and the size of the pictures was the same as those that were originally presented in the pre-exposure rounds. The child had to point to the animal whose favourite tune was played, and was instructed:

Now I am going to play some of the tunes, and I want you to point to the animal whose favourite tune I am playing. You will know that the tune is done because the animal pictures will light up. You will only hear each tune once. [If the children repeatedly points to the same picture or go off task, they can be reminded what to do with a repetition of the instructions, "Remember to choose the picture of the animal whose favourite tune is playing!"]

Next, the children were told that the melodic fragments had been incorporated into longer musical segments. They first experienced one additional pre-exposure round of 16 of the animals' favourite tunes to refresh their memories. Then, they were presented twice with the elephant's favourite tunes and two examples of a longer tune that contained the elephant's favourite tune, one melodically embedded and one harmonically embedded. The children were presented with two rounds of 16 embedded segments in quasi-randomised order with eight melodically embedded and eight harmonically embedded fragments in each round. Each round contained the melodic and harmonic embedding of each fragment twice. In the melodic embedding condition, an eight measure melody was played. For the harmonic embedding condition, an eight measure melody with harmony was played. The horse's favourite tune with its melodic and harmonic embeddings are presented in Figure 3 as an example. As prescribed by 1960s rock conventions, only the sub-dominant (IV), dominant (V), and tonic (I) chords were utilised. In both cases, the animal's favourite tunes became measures 3 through 5 of the longer tunes that were in 2/4 time and in

Figure 3
The Horse's Favourite Tune (a), its Melodic Embedding (b), and Its Harmonic Embedding (c)



the key of C major. The two conditions were presented together in each round to control for any effects that one type of disembedding could have had on the other. During the disembeddings, the full segment was played and then the animal pictures would light up. The children were asked to point to the animal whose favourite tune they heard. Within each round of 16 trials, two of the animal's favourite tunes, in their original, unembedded forms, were inserted to check the child's identification skills of the four tunes. The researcher gave the instructions:

You're doing so well. We are first going to review each of the animal's favourite tunes. (One round of: "This is the kangaroo's favourite tune." Etc.) *Now you will here some longer tunes that contain one of animal's favourite tunes. I would like you to point to the animal whose favourite tune you hear. Each longer tune only contains one of the animals' favourite tunes. So, here is the elephant's favourite tune. And here are some examples of longer tunes that contain the elephant's favourite tunes.* [A melodically embedded and harmonically embedded example are played after the original elephant tune.] *Did you hear it?* [Play both once more to make sure they hear it.] *And any of the animals' favourite tunes, not only the elephant, can become part of a longer tune. When you listen to these longer tunes, I want you to point to the animal whose favourite tune is being played. You will know that the entire tune is done because the animal pictures will light up. You may also just hear the animal's favourite tune. Remember to listen very closely for one of the animal's favourite tune, and then point to the animal whose favourite tune you hear.* [If the children repeatedly point to the same picture or go off task, they can be reminded what to do with a repetition of the instructions, "Remember to choose the picture of the animal whose favourite tune is playing or a tune similar to it!"]

Approximately two hours later, memory of the animals' favourite tunes was assessed with another round of 16 identifications presented in the same way as the first round of identifications. The identification task was presented in a quasi-randomised order, different from that of the original identification task. Before the break, none of the children was told that they would be tested on the animal tunes again. After two hours, the children were instructed:

A little while ago, I showed you some animals and played you their favourite tunes. Now I am going to play some of the tunes, and I want you to point to the animal whose favourite tune I am playing. Listen very closely so that you remember as best you can. [If the children repeatedly point to the same picture or go off task, they can be reminded what to do with a repetition of the instructions, "Remember to choose the picture of the animal whose favourite tune is playing!"]

There were A and B versions of all of the music tasks. The B version was composed of the reverse order of the A version of each round of pre-exposure, identification, melodic and harmonic disembedding, and memory. The A and B versions were administered to the same number of participants in each group (6 with A, 5 with B). The maximum score on each music task (melodic identification, melodic disembedding, harmonic disembedding, and melodic memory) was 16.

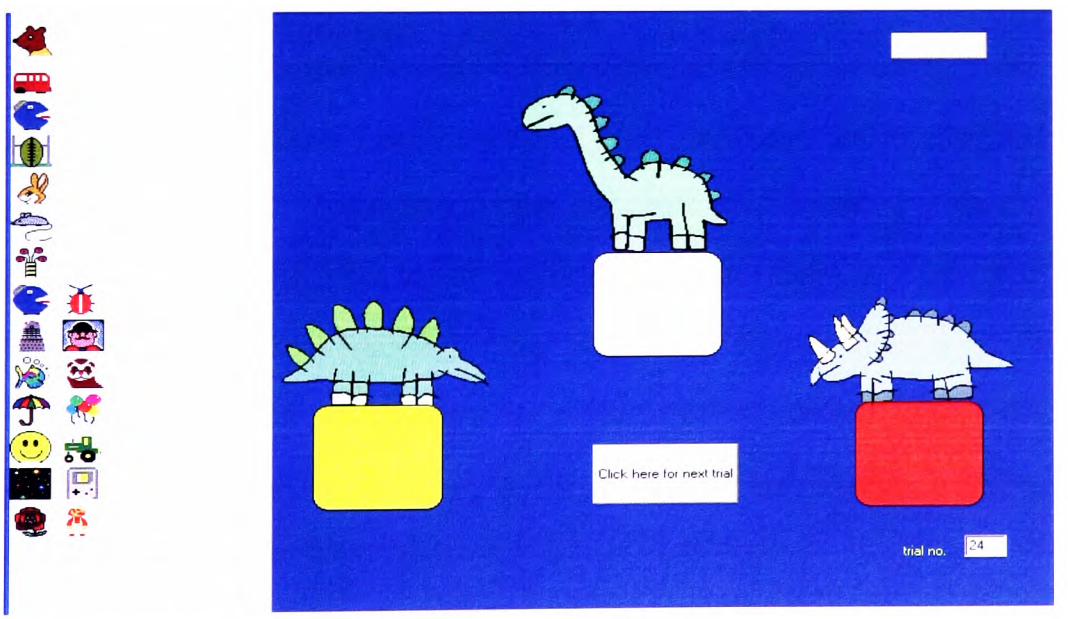
Nonword repetition (NWR) task. To assess phonological short term memory, which has been shown to be an excellent indicator of SLI (see Bishop, 1997), a NWR task was carried out from the Developmental Neuropsychological Assessment Battery (NEPSY) (Korkman, Kirk, & Kemp, 1998). The items were recorded by a British speaker, and there were 13 nonwords, ranging from two to five syllables of increasing difficulty (examples included "in-dob-tree-lob" and "ress-tow-fay-le-tees"). The children heard the item as it was played from a computer through headphones, and the children had to repeat back each nonword. A disyllabic practice item ("ee-poh") was administered before testing, and feedback was given. The children listened to the words through headphones and were tape recorded with a body microphone. One point was awarded for each correctly uttered syllable during online scoring, and scores were verified after listening to the tapes after testing. Norms for individuals ages 6 to 20 were established from data collected by the Oxford Study in Children's Communication Impairments Laboratory Group.

Frequency discrimination task. This task assessed frequency discrimination (FD) with a three-tone, two-alternative forced choice paradigm. The participants heard three tones, and then had to decide whether the first or third tone was different from the second tone. The participant was thus searching for the "odd man out." Since only adjacent tones needed to be compared, it was possible to come to the correct response after listening to the first two tones, which were either the same or different. The third tone then provided confirmatory information for the response. By creating a game-like format to evaluate FD, a stable estimate of FD (i.e., the minimum difference in frequency that the participant could discern) is established (Bishop, Adams, Nation, & Rosen, 2005). The task in Study 1 was the same as Bishop et al., but stimuli were pure tones rather than glides as in Bishop et al. A three-tone task

such as this has been shown to be more of a reliable indicator of FD than tasks involving two tones where participants need to name which is higher or lower or if they are the same or different (Sutcliffe & Bishop, 2005). These two-tone tasks are problematic because they rely on verbal labels, which may be a problem for those with language difficulties. Same-different tasks also may introduce the potential response bias where a participant may be reluctant to say if the pitches are different unless they are very different, while another participant may say that the pitches are different if they are not entirely convinced that two pitches are the same.

The task, presented on a laptop, involved three dinosaurs on the screen as shown in Figure 4. On each trial, three tones were presented, separated by 500 ms. Each tone corresponded to one of the dinosaurs that jumped when the tone was

Figure 4
Dinosaurs Frequency Discrimination Computer Game



sounded. The dinosaur corresponding to the middle tone, the standard, was located in the middle of the screen above the other two dinosaurs, and the researcher (RA) explained that the task was to figure out which of the two dinosaurs (left or right)

made a different sound from the central dinosaur. The child then pointed to the dinosaur on the left or right, and the researcher used a mouse to click on the child's response. The task was first demonstrated, and testing did not begin until the participants answered correctly on their own. The task was self-paced, with the researcher initiating the next trial when the participant was ready to continue. A correct response was rewarded with a small picture of an item that was then added to a stack of icons on the left of the screen. An incorrect response led to a "sigh" sound and no icon. The children could ask for the tone sequence to be repeated before making a judgement. The task was explained with the instructions:

Here are three dinosaurs. When I press the button, each dinosaur will make a noise. Listen carefully and see if you can work out which of these two dinosaurs (point) makes a different noise from the middle dinosaur (point). (Show the child the correct response on trial 1.) *I got it right, so I get a little picture.* (Then give them the chance to select the correct response on trials 2 and 3. If the child gets it wrong say, "I think it was this one!" and demonstrate the correct response. Keep demonstrating until child does get it right.)

The difficulty level of the frequency discrimination task was adaptively varied according to the participant's level of accuracy. Very easy discriminations were first presented. Then, smaller step sizes were used to increase difficulty until an error was made. Once an error was made, the discrimination was made easier (i.e., a reversal in difficulty level occurred). The step size was progressively reduced until a threshold was reached of 75% correct responses. The smallest frequency difference was 2 Hz. Testing continued until 8 reversals or 60 trials had taken place. The threshold was computed as the average presentation level after the 4^{th} reversal.

To analyse these data, the optimal score was chosen after each child was tested twice (during the testing sessions before and after the break). Scores, however, were discounted if the standard deviation of the threshold was greater than 5 or if the child was guessing (as indicated by a binomial test, $p < .05$). After discounting these scores,

some children only had one appropriate threshold to analyse. There were two participants with neither score appropriate for analysis, and they were eliminated from the sample.

British Picture Vocabulary Scale II (BPVS II). The BPVS II tests receptive vocabulary. After examples are given with feedback, the researcher recites a word, and the participant must point to one of four pictures, displayed in the testing picture book, that depicts the word. Norms are available for children ages 3;00 to 15;08.

Hearing test. Hearing was assessed using an audiometer. A DSP Pure Tone Audiometer, manufactured by Micro Audiometric Corporation, was used. Hearing was tested by having the children raise their hands whenever they heard a tone. After demonstrating the task at higher volumes with the researcher in front of the participant, the researcher stood behind the participant so that the participant did not receive any visual cues as the researcher pressed the button to produce a tone. At 20 dB, tones were played at 500, 1000, 2000, and 4000 Hz. If the participants did not raise their hands, then the volume was raised and then lowered to 20 dB to see if the participants could then hear the tone. One ear was tested at a time. For hearing to be classified as normal and for the child to be kept in the study, the hearing in one ear had to have an average of 25 dB across frequencies.

2.1.3 Design and Procedure

All efforts were made to ensure that the testing room was as quiet as possible. Testing took place in either the child's home or school or in a testing room in the Department of Experimental Psychology at the University of Oxford. All participants met with the researcher (RA) in one-on-one sessions during which they were positively encouraged throughout. As shown in Table 2, all participants followed the same schedule. All parental consent forms and parent questionnaires were filled out prior to research with

Table 2

Order of Presentation of Tasks

(Testing before break lasted one hour, and testing after break lasted 20 minutes.)

I. Wechsler Abbreviated Scale of Intelligence (WASI) Nonverbal Sections
II. Training of animal and favourite tunes (3 rounds of 16 trials each)
III. NEPSY Nonword Repetition Task
IV. Melodic identification task (1 round of 16 trials)
V. Melodic and harmonic disembedding tasks (2 rounds of 16 trials plus 2 identifications in each round)
VI. Dinosaurs frequency discrimination game trial 1
VII. Hearing test for dB of speech frequencies with portable audiometer
Two hour break
VIII. Melodic memory task (1 round of 16 identifications)
IX. British Picture Vocabulary Scale II
X. Dinosaurs frequency discrimination game trial 2

the child. For the children with autism, teachers were asked to fill out some questionnaires as part of the 3dI. The 3dI was carried out by a trained interviewer (RA) with parents either prior to working with the child or during the break from working with the child. The first session of testing lasted for approximately one hour and began with the administration of the WASI. Then, the children experienced either the A or B version of the music task, starting with the three rounds of pre-exposure to the four animals' favourite tunes. Next, the NWR task was run before the children were tested on the music. The placement of the NWR task, which accesses working memory, was deliberate because working memory has been shown not to be involved in interval processing in those with AP processing (Zatorre et al., 1998). Since the music tasks would require holding the musical tunes in long-term memory, accessing working memory in a task during a break before the musical tests would prevent rehearsal of the tunes. Next, the children went through one round of identification and two rounds of disembedding (including one additional round of pre-exposure and examples of embeddings prior to testing of harmonic and melodic disembeddings).[2] Next, the participants played the dinosaurs game of frequency discrimination followed by the hearing test. The hearing test was done at the end of the first round of

[2] During piloting, only those children who performed above chance on the identification task went on to the disembedding taks. One child from each group was included in the sample and did not contain data for the disembedding tasks.

testing because the headphones of the audiometer were tight fitting and could have been problematic for those with autism who exhibited hypersensitivity around their ears. The hearing test was placed at the end of the first round of testing in the hope that the researcher and child would have established rapport by then so that the child would be able to wear the headphones during the short period of time needed to carry out the hearing test. At the conclusion of the hearing test, a 2 hour break (plus or minus 2 minutes) began before the second round of testing.

The second session of testing, which lasted for approximately 20 minutes, began with the memorisation test of the musical tunes and then continued with the administration of the BPVS II and then one more round of frequency discrimination with the dinosaurs game.[3] During all auditory tasks administered from the computer involving hearing (all music tasks, NWR, and dinosaurs game), the children wore Compact Disc Digital Stereo Headphones that fit circum-aurally. For the hearing test, however, Telephonics TDH-39 Audiometric Headphones were used.[4]

2.2 Results

2.2.1 Music Tasks

Data from the music tasks are shown in Table 3 and Figure 5. On the music tasks, the chance of selecting the correct response by chance is 1 in 4 (.25). When considering the performance of individual children, one can use the binomial theorem to identify a score of 7 as indicating that the child was doing better than would be possible by simply guessing (p = .027). Although the mean score of the group as a whole was well above 4, some children did not meet the more stringent criterion of demonstrating a

[3] Due to time constraints, two children were tested on the BPVS II after the hearing test in session one. Timing of the two hour break, however, began at the end of the hearing test so that the child's break was not longer than that of the other children. One other child did the hearing test during the second session because of time constraints of the first session, but this also did not affect the timing of the break.

[4] One child with autism could not tolerate the headphones for all the tasks and only wore them for the hearing test, which could not be administered without the headphones.

Table 3

Results for the Children with Autism and the Typically Developing Children on Music and Language Tasks

	With Autism (n = 11)			Typically Developing (n = 11)			
	Range	Mean	SD	Range	Mean	SD	*p* value
Identification Score (of 16)	3-16	8	4.75	2-16	7.09	4.89	
Melodic Disembedding Score (of 16)	3-16	8.2	4.05	2-13	7.9	3.9	
Harmonic Disembedding Score (of 16)	3-16	7.2	3.74	1-11	7.5	3.21	
Identification Check During Disembeddings (of 4)	0-4	1.6	1.35	0-3	1.6	1.17	
Memory Score (of 16)	0-16	7.55	5.09	3-15	9	3.85	
Music Summary Score (of 64)	12-64	32.2	15.68	13-53	32.3	13.69	
Nonword Repetition Standardised Score (of a mean of 10, SD of 3)	3-13	8.73	2.87	8-14	10.73	2.15	.079
Frequency Discrimination Score (in Hz)	2-174.2	30.66	55.18	3-65.14	17.98	18.29	.522
British Picture Vocabulary Scale II Standardised Score (of a mean of 100, SD of 15)	40-123	88.45	23.93	88-140	111.18	16.33	.024

score above 7; the numbers of individuals who achieved this level of performance are shown in Table 4.

A 2 x 4 repeated measures ANOVA was run with group (typically developing or with autism) as the between subjects factor and music task (identification score, melodic disembedding score, harmonic disembedding score, or memory score) as the within subjects factor. The between subjects factor of participant group was not significant, $F(1,18) = .000$, $p = .988$. The within subjects factor of music task was also not significant, $F(3,54) = 1.396$, $p = .254$, nor was the interaction between music task and group, $F(3,54) = .659$, $p = .581$.

As shown in Figures 6a and 6b, the identification check, which tested identification of the original tune during the two rounds of disembedding correlated highly with both melodic ($r = .667$, $p = .035$) and harmonic ($r = .767$, $p = .01$) disembedding performances in both rounds for the group with autism. In the typically developing group as well, the identification check score correlated highly with both

Figure 5
Boxplots Showing Distribution of Scores on Music Tasks by Group

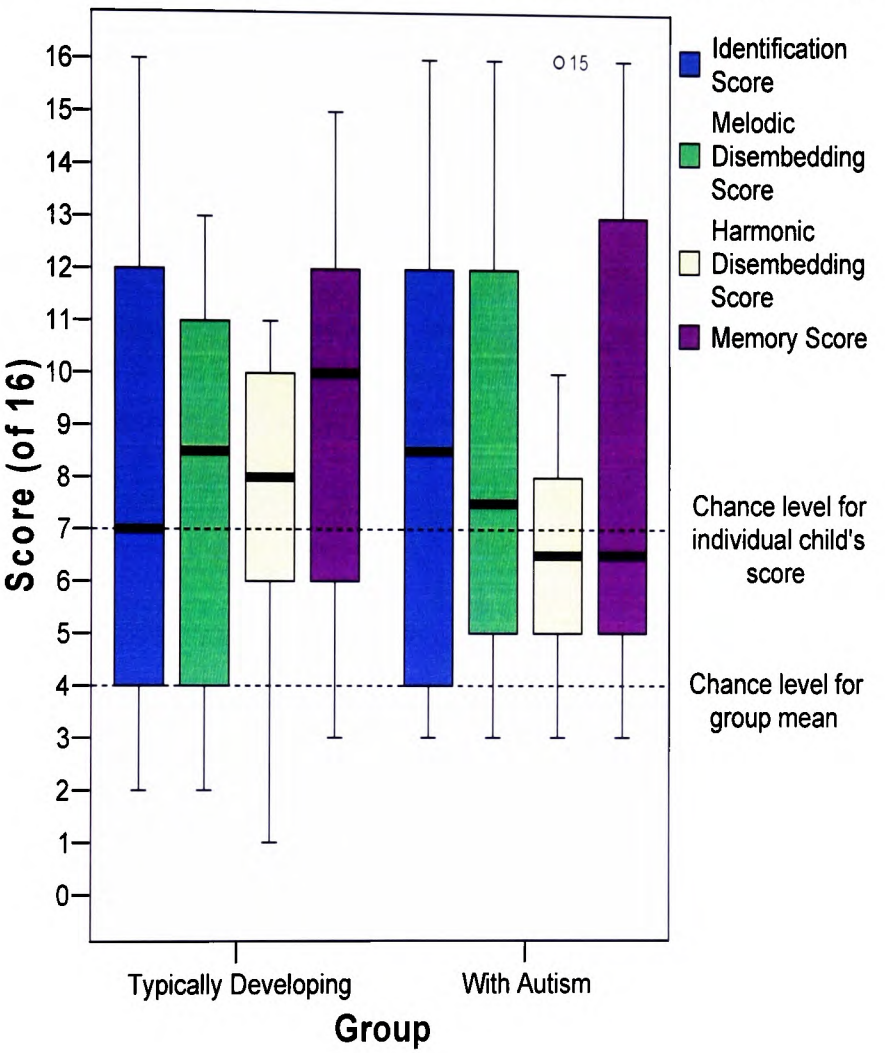
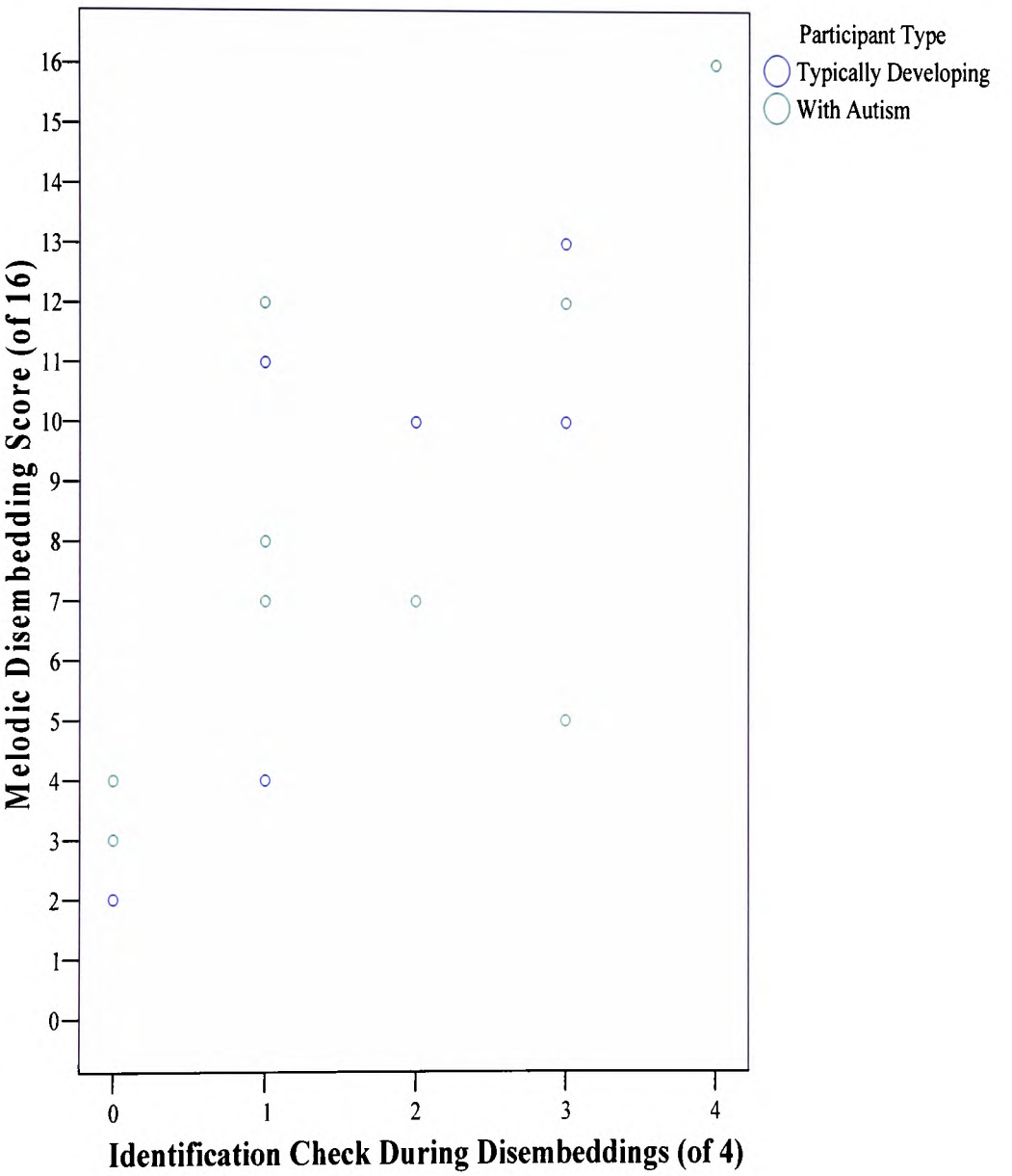


Table 4
Number of Children with Autism and Typically Developing Children who Scored Above Chance (7 or More Correct) on Music Tasks

	With Autism (n = 11)	Typically Developing (n = 11)
Melodic Identification	6	6
Melodic Disembedding	7	7
Harmonic Disembedding	5	7
Melodic Memory	4	7

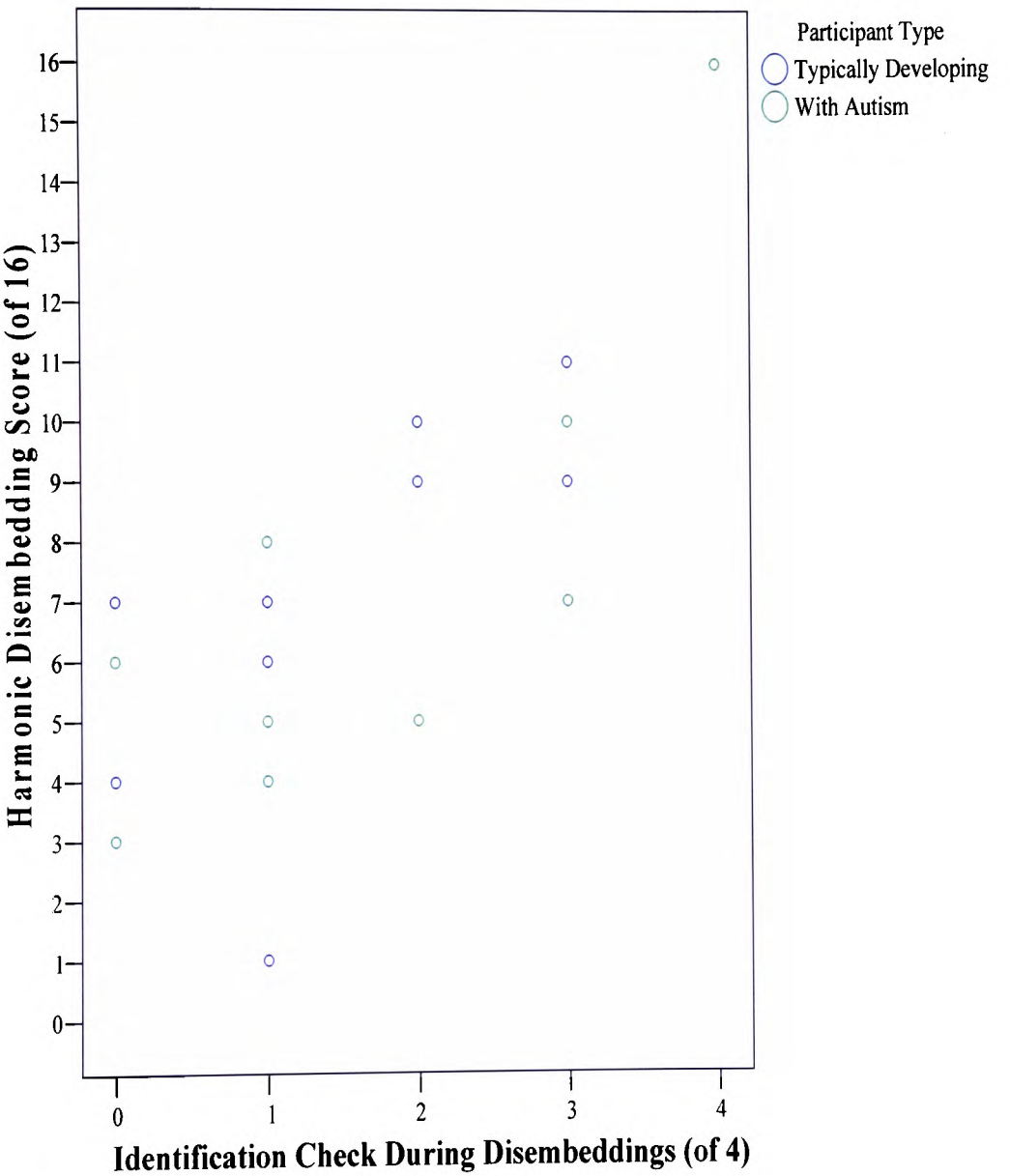
melodic (r = .840, p = .002) and the harmonic (r = .738, p = .015) disembedding scores in both rounds of testing.

Figure 6a
Scatter Plot of Identification Check and Melodic Disembedding Score



For further analyses and comparisons of these music task scores to language measures, a music summary score was calculated by adding the scores of each child's identification, melodic disembedding, harmonic disembedding, and memory scores (maximum score = 64). Since there was not an effect of music task on performance, carrying out a summary score in this fashion was appropriate. These data are summarised in Table 3.

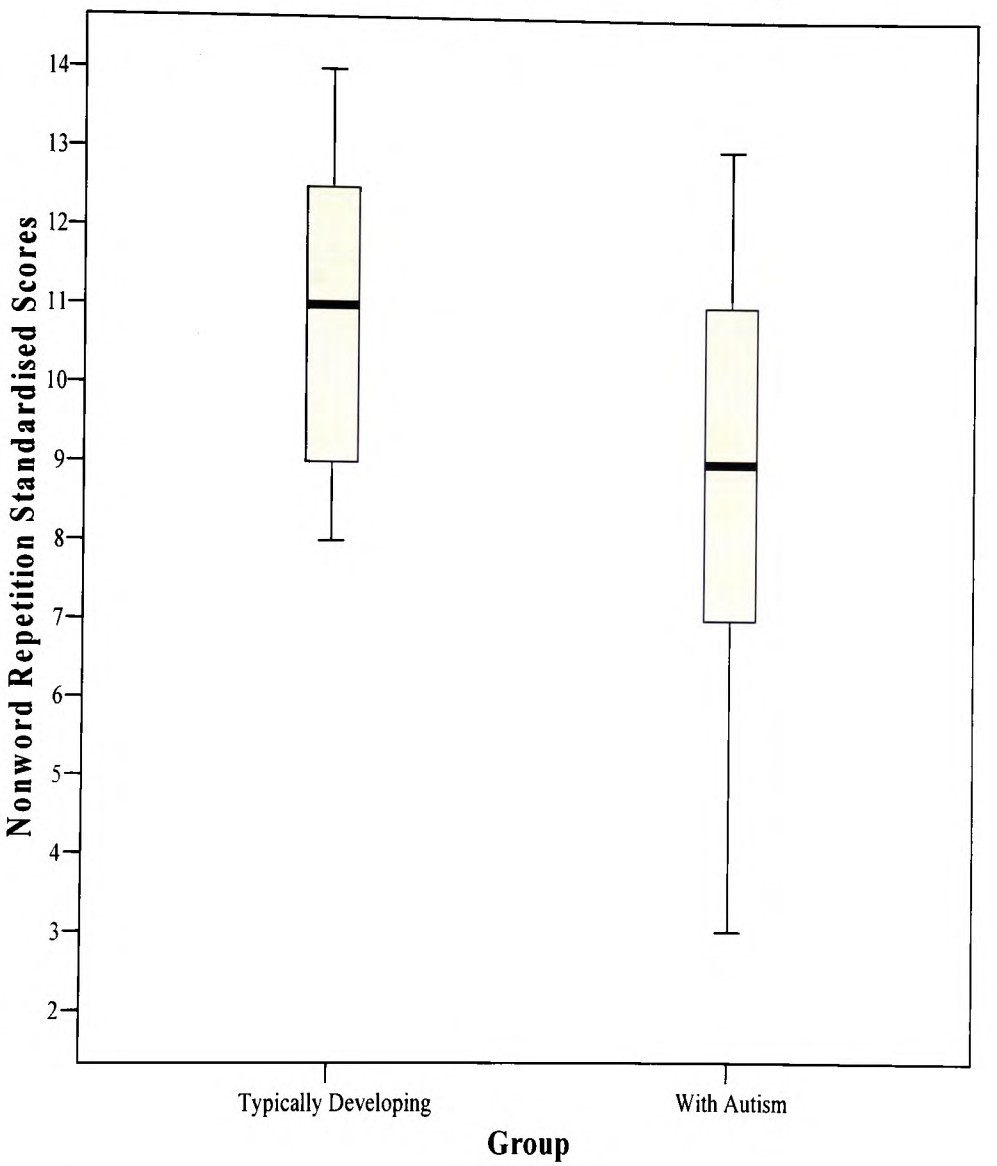
Figure 6b
Scatter Plot of Identification Check and Harmonic Disembedding Score



2.2.2 NWR Task

Data are summarised in Table 3 and Figure 7. An independent samples t-test was run to compare the means and revealed a trend for higher scores in the control group, $t(20) = 1.851, p = .079$.

Figure 7
Boxplots Showing Distribution of Nonword Repetition Standardised Scores by Group



2.2.3 Frequency Discrimination Task

Tables 3 and 5 summarise the optimal frequency discrimination threshold data. Since 2 participants in each group had both scores eliminated based on their large standard deviations or guessing as indicated by performance below chance, each group had 9 children. To reduce the skew of the data, log transformations were carried out and an independent samples t-test was run to reveal a nonsignificant difference between

groups, $t(16) = .269$, $p = .791$. These log transformed data were used for further analyses. As these data were skewed, the individual scores are displayed as back-to-back stem-and-leaf plots in Table 5.

2.2.4 BPVS II

As indicated in Table 3, when the receptive vocabularies of the two groups were compared with an independent samples t-test, the difference was significant and indicated higher scores in the control group, $t(20) = 2.451$, $p = .024$.

Table 5

Back-to-Back Stem-and-Leaf Plots Showing Distribution of Scores (in Hz) on Frequency Discrimination Task for Typically Developing Control Group and Group with Autism

Each Number Denotes One Case

Typically Developing	Score	With Autism
993	0	2255
87611	1	02
	2	3
	3	9
	4	
	5	
5	6	
	...	
	17	4
17.98	**Mean**	30.66
18.29	**SD**	55.18

2.2.5 Relationships of Music and Language Performance

Several correlations were run to compare both groups of participants' performance on music, frequency discrimination, and language tasks. The only significant correlations that emerged were between the BPVS and NWR standardised scores for the group of children with autism indicating that the two scores correlated positively, $r = .898$ $p = .000$, and the typically developing group's scores correlated positively as well, $r = .703$, $p = .016$.

Scores on tasks were also compared to data from the Musical Exposure and Training Questionnaire. The typically developing participants' scores on the

frequency discrimination task significantly correlated to Musical Exposure and Training Questionnaire scores, r = -.705, p = .034. Since high frequency discrimination scores mean worse performance, this correlation indicates that the higher the score on the Musical Exposure and Training Questionnaire, the better the performance on the frequency discrimination task. This correlation did not emerge in the group with autism. In the group with autism, Musical Exposure and Training Questionnaire scores positively correlated with the summary scores of music tasks, r = .829, p = .003. This significant correlation did not emerge in the typically developing group.

All correlations that were run are summarised in Appendix 4.

2.2.6 Qualitative Observations

Some children with autism exhibited more "musical" devices, such as humming the tunes or picking out the tunes' salient features, than typically developing controls while carrying out these tasks. For example, two children with autism hummed during the music tasks. The mother of one of these children reported that when the child was growing up, she would sing instructions to him, and he could understand and would respond to them better than if she spoke the instructions. The other child who hummed picked up and commented on the salient features (e.g., "that melody has a large jump at the end") of the melodic fragments that he then used to identify and disembed them. One child with autism seemed as though he was only passively listening to the musical examples, and then scored perfectly on every music task. He was the only child in the study to do so. His parents reported that although he plays several instruments, he is not a prodigious player of any of them. He does, however, have an excellent ear for music and often has music "running" in his head. His parents often have to tell him to turn the music off in his head to ensure that he concentrates

on what they are saying. His parents also reported that they could turn off the radio while he is singing along, and if he continues singing, his lyrics will line up perfectly with the radio when it is put back on.

2.3 Discussion

The present study tested children with autism and typically developing matched controls on several tasks to assess the nature and extent of these children's musical abilities and how they relate to language abilities. In this section, each part of the present study is discussed starting with the melodic memory and disembedding task and then the frequency discrimination task and finally the language measures relationship to these music tasks.

2.3.1 Musical Processing

Study 1 assessed the melodic memory and processing of children with autism and typically developing children through a paired associate learning task based on Heaton's (2003) paradigm with pitches and chords. Since melodies are perceived as ordered sets of pitches (Dowling, 1994), this study was a logical continuation of the work that has been done to assess the pitch, interval, and contour processing of those with autism. This study was a next step in research on musical processing in those with autism because it tested another facet of the musical savant, exceptional musical memory. Since prior research (Bonnel et al., 2003; Heaton, 2003; Heaton, Hermelin & Pring, 1998) has shown that those with autism may process musical notes in ways similar to those with AP, it has been hypothesised that those with autism have a pre-disposition to a savant condition in music. Study 1 assessed this theory using more complex musical stimuli. Success on these music tasks could have been accomplished through several skills such as pattern recognition or musical memory.

Based on prior research, it was hypothesised that the children with autism would perform better on all tasks of melodic memory and disembedding, and that, overall, both groups would find the disembedding tasks more difficult than the identification task. These hypotheses were not confirmed. Both groups showed similar profiles of performance, with some doing very well and some not doing well, and the type of music task did not affect the performance of either group. Since the two groups performed similarly, it may be that musical processing is a preserved area, among many deficits associated with autism. Given evidence of problematic memory of complex stimuli (Minshew & Goldstein, 2001), the fact that musical memory in these tasks is not deficient may be indicative of intact musical processing in those with autism in the context of deficits in processing other complex stimuli. It may also be that although these children do not exhibit musical skill, they may nevertheless exhibit unusual interest in music. Also counter to predictions, music task performance of the typically developing children did not correlate more to age and nonverbal IQ than in the group of children with autism.

Dowling (1994) described a melody as a gestalt. In this study, the melodic fragments were considered the local stimulus, and the longer melodic or harmonic gesture was considered the global stimulus. After pre-exposure, to cue the local stimulus, the children with autism did not show enhanced performance on tasks of identification, disembedding or memory of this stimulus. These findings thus provide evidence counter to the theory of weak central coherence and enhanced perceptual processing that both argue that those with autism exhibit enhanced "local" or "part" processing.

In analysing these results of the musical memory processing tasks, it is important to keep in mind that these tasks were clearly difficult, with some children in

both groups not performing above chance. This is a limitation of the present study and must be kept in mind for future investigations in this area. Also, since a null effect is being reported, these tasks will need to be validated. Another slightly mysterious limitation of the study was that although both groups' performances on the melodic and harmonic disembeddings did indeed correlate to the identification check of the musical tunes, some participants performed well above chance on the disembeddings after receiving a score of only 1 out of 4 on the identification check. This finding cannot be explained with task switching demands because the children had to be able to identify the animal's favourite tune before they could disembed it. Thus, one would expect identification to be easier than disembedding. This did not appear to be the case all the time. A child, for example, could get disembeddings correct for a certain animal's favourite tune and then misidentify the animal's favourite tune they had disembedded. It is also important to note that these errors were not consistent and might indicate that participants found the tasks difficult.

2.3.2 Frequency Discrimination

The predictions of enhanced frequency discrimination abilities by those with autism was also not confirmed because the sample with autism performed similarly to the typically developing controls. This discrepancy with the results of Heaton (2005) and Heaton et al. (2001) may be a consequence of the paradigm used to assess frequency discrimination. The tasks of the previous studies involved the discrimination of two pitches whereas the dinosaurs game involved the discrimination of two pitches in the context of three. Although task success could be achieved by listening to only two of the pitches, since the task involved three pitches, it could have been viewed as an assessment of contour discrimination. There is disagreement in the literature on the role of perceptual discrimination in the differentiation of contour. While Foxton et al.

(2003) and Heaton (2005) argued that those with autism do not exhibit enhanced abilities to differentiate melodies that have note changes and preserved contour, Mottron et al. (2000) argued that the perceptual discrimination of those with autism causes them to be particularly competent at such a task. Their findings though were not totally substantiated statistically. On more simple paradigms, Bonnel et al. (2003), Heaton et al. (2001), and Heaton (2005) showed enhanced interval discrimination, particularly of fine detail, in those with autism. The question then arises if the children with autism always exhibit enhanced auditory discrimination or if this finding is an artifact of the paradigms used. In other words, these enhanced abilities to differentiate the frequencies of pitches might only be present in paradigms involving interval, and not contour, processing. Foxton et al. and Heaton (2005) found that those with autism were as good as, but not better than, typically developing children in analysis of contours, which is similar to the results of study 1. This interpretation, however, is admittedly post-hoc.

Since the task is predominantly a test of frequency discrimination, if the finding of enhanced frequency discrimination were robust, one would expect such findings across paradigms. The odd man out paradigm used in the present investigation has been shown to be a more reliable indicator of frequency discrimination than two-pitch tasks, and thus may be more indicative of frequency discrimination in this population. It is, however, surprising that Heaton (2005) and Heaton et al. (2001) have shown enhanced performance in the group with autism using tasks that relied on labelling two pitches as ascending or descending because one would have thought that such task demands would make the tasks more difficult for the children with autism. It is also surprising that the results do not support the

findings of Bonnel et al. (2003) who used a signal detection analysis, which should have corrected for the response bias inherent in same-different paradigms.

2.3.3 Relationship of Musical Abilities to Language Abilities

Although significant correlations between music and language assessments failed to emerge, there was some support for the hypothesis that the group with autism exhibited intact musical processing in the context of a deficient language profile compared to typically developing controls. The children with autism showed deficient receptive vocabulary, as indexed by the BPVS II, and there was a trend of deficient performance on the phonological short term memory task. This result on the NWR repetition task is surprising given that Bishop et al. (2004) found that phonological processing measures correlated with verbal IQ (VIQ), with those who were not impaired on VIQ scoring in normal ranges on NWR. The result in the present study highlights the differences in language processing of the two groups of children in the context of similar musical processing. In the current study, there was no VIQ measure, but it was possible to consider the correlation with BPVS II. This revealed a highly significant correlation in the group with autism. Since Bishop et al. (2004) and Kjelgaard and Tager-Flusberg (2001) reported normal NWR scores in highly verbal children with autism, the emergence of a trend is potentially interesting and unexpected because the sample with autism was verbal and high functioning.

It is also worth noting that music task summary scores correlated with scores on the Musical Exposure and Training Questionnaire in the group with autism and not the typically developing group. It is important to note that children with autism were more likely to have higher scores on this questionnaire than the typically developing children because of the music therapy question, which would probably not be applicable to the typically developing children. Even when that limitation is

considered, this correlation suggests that children with autism who did well on the music tasks were the ones with more musical training and exposure than the ones who did not perform well. This finding could also be interpreted as evidence counter to Heaton's suggestion that musical ability is a feature of the autistic cognitive profile. It also suggests that the difference in the language and musical profiles may emerge from a greater interest in music than language in some children with language. As these interpretations emerge only from a correlation, these suggestions should be evaluated with caution.

2.3.4 Further Clarification Needed on the Nature and Extent of Musical Abilities

The present study showed that although the sample of children with autism exhibited deficient language compared to a sample of typically developing exhibited, the two groups of children exhibited similar musical processing. Participants were tested on melodic identification, melodic disembedding from both melodic and harmonic contexts, melodic memory, and frequency discrimination to assess the nature and extent of their musical ability. In all areas, the children with autism did as well as the matched controls.

Although the children with autism demonstrated age-appropriate abilities on tests of musical processing, they did not show the kind of enhanced abilities reported by Heaton (2003). This raises the question of whether Heaton's task is specifically sensitive to the musical abilities that children with autism may possess or if these abilities are only present in a sub-group of individuals with autism. The claim of enhanced pitch processing in those with autism was tested in study 2.

Chapter Three

Study 2:

A Computerised Replication of Heaton (2003)

The music tasks of study 1 that assessed melodic identification, disembedding, and memory were mostly based on the pitch processing work of Heaton (2003) that showed enhanced pitch memory and disembedding from a chord after note pre-exposure that cued participants to the "part" in the "whole" of a chord. From this and other findings, it was hypothesised that those with autism might hear, remember, and be able to disembed notes in such a way that causes them to utilise cognitive factors similar to those with AP. Heaton, Hermelin, and Pring (1998) argued that this might be a pre-cursor to a savant condition in music, since AP is one requirement of this condition. Heaton worked with 14 participants with autism (mean age = 10.75 years), and compared their performance to two control groups matched on chronological age, gender, and verbal ability (based on performance on the Peabody Picture Vocabulary Test) or nonverbal ability (based on performance on the Raven's Matrices). For this study, I once again worked with the two groups of children from study 1 to carry out a computerised replication of the Heaton (2003) task.

Heaton's original task was presented using computers. It was hypothesised that use of a computerised presentation might enhance the performance of the children with autism on both the pitch identification and disembedding from chords task

because such a form of the evaluation would reduce direct human contact (Ozonoff, 1995).

3.1 Method

3.1.1 Participants

Experimental group with autism. All children who were included in study 1 participated in the present study 8-11 months later.

Typically developing control group. All control children who were included in study 1 participated in study 2 8-10 months later. Revised demographic data for both groups are summarised in Table 6.

Table 6
Demographic Data for Children with Autism and Typically Developing Children

	With Autism (n = 11)			Typically Developing (n = 11)			
	Range	Mean	SD	Range	Mean	SD	*p* value
Age	10.67-16.17	13.60	1.78	10.83-16.33	13.14	1.79	245
Number of months between study 1 and study 2	8-11	9.18	87	8-10	8.73	.91	.550
Male:Female		10:1			9:2		

3.1.2 Materials

Pitch memory and disembedding from chords. A computerised version of the Heaton (2003), "pitch matched to animal picture" paradigm was used. The same animal pictures as in study 1 were used for this study. In this case each animal (horse, elephant, kangaroo, and cow) was matched to a note (D4, F#4, A4, and D5), which was pre-recorded from an electronic keyboard onto a laptop computer for presentation. During one-on-one sessions with a researcher (RA), the children were exposed to 3 quasi-randomised rounds with each of the four pitch matched to animal picture pairs presented 4 times during each round of 16 trials. Thus, the children were pre-exposed to each animal picture and note pair 12 times (4 times during each of the 3 rounds). In Heaton's original task, children were presented with animal pictures,

and the researcher played the note on a keyboard, out of view of the participant. In the first and third round, the researcher presented the child with all four animal pictures and pointed to the animal whose favourite note was being played. In the second round, the animal pictures were removed so that the researcher said whose favourite note was sounded and then played the note. In the present investigation, all pre-exposure rounds were presented with a laptop showing the animal picture and the note sounding through its loudspeaker to maximise the use of the computer. The children were told that the pitch was the animal's favourite with the instructions:

We are going to play some games with musical notes to see how children like you understand the music they hear. You are going to see pictures of four different animals and then hear a note. The note you hear is the animal's favourite. Listen carefully so that when you hear the note you remember the right animal. Please listen very closely. [*This is the cow's favourite note. This is the kangaroo's favourite note.* Etc. Can also remind child to listen closely. And say things like, "Are you listening closely so you can hear the differences?" Can also mention ID task coming up, "You will soon see all four animals and be asked to choose which animal's favourite note you hear. So, listen closely!"]

The researcher then engaged the child in a conversation for 2 ½ minutes on an unrelated topic. This was done after pre-exposure to attempt to disrupt working memory since those with AP have been shown to use long term memory, and not working memory, to remember pitches (Zatorre, 1998).[1]

Following the break, the children underwent one round of pitch identification where they were presented with the four animal pictures on the computer screen and heard a note. On each trial, the pictures were presented in varying orders and the size of the pictures was the same as those that were originally presented in the pre-exposure rounds. The child had to point to the animal whose favourite note was played, and was instructed:

[1] Because of experimenter error, 1 child in the autism group experienced the 2 ½ minute conversation after the identification round instead of after the rounds of pre-exposure. His data was kept in the sample though because his presence or absence in the sample did not change the results of the study.

Now I am going to play some of the notes, and I want you to point to the animal whose favourite note I am playing. You will only hear each note once. [If the children repeatedly point to the same picture or go off task, they can be reminded what to do with a repetition of the instructions, "Remember to choose the picture of the animal whose favourite note is playing!"]

The children were positively encouraged throughout the testing session. After the identification task, the children heard one more round of pre-exposure to the animal and note pairs (16 trials, 4 of each animal). The animals' favourite notes (D4, F#4, A4, and D5) formed a D Major triad (the same chord used in Heaton (2003)). The participants then began the disembedding from chords task and were told that they were going to hear a chord with three of the animals' favourite notes and one left out. They were asked to point to the animal whose favourite note was missing with the instructions:

You're doing so well. We are first going to review each of the animal's favourite notes (One round of "This is the kangaroo's favourite note." Etc.) *Now I am going to play three of the animals' favourite notes together, and I am going to leave one out. Can you point to the animal whose favourite note is missing?* [If the children repeatedly point to the same picture or go off task, they can be reminded what to do with a repetition of the instructions, "Remember to choose the picture of the animal whose favourite note is missing!"]

There were A and B versions of all of the music tasks. The B version was comprised of the reverse order of the A round of each round of pre-exposure, identification, and disembedding. The A and B versions were administered to the same number of participants in each group (6 with A, 5 with B). The maximum score on each of the two note tasks (identification and disembedding) was 16.

All efforts were made to ensure that the testing room was as quiet as possible. Testing took place in either the child's home or school or in a testing room in the Department of Experimental Psychology at the University of Oxford. The single testing session lasted for approximately 20 minutes.

3.2 Results

3.2.1 Music Tasks

The data from the note identification and disembedding tasks are summarised in Table 7, along with the results from Heaton (2003) paper's group with autism and nonverbal matched control group for comparison purposes. Scores of 7 and above on each test were above chance as defined by a binomial test (p = .027). The numbers of

Table 7
Results for the Children with Autism and the Typically Developing Children on the Note Identification and Disembedding Tasks
(Results of the Heaton (2003) task are presented in parentheses for her group with autism and nonverbal matched controls)

	With Autism (n = 11)			Typically Developing (n = 11)		
	Range	Mean	SD		Mean	SD
Identification Score (of 16)	0-16	7 (11.21)	5.59 (4.67)	7-16	11.27 (6.21)	2.72 (3.35)
Disembedding Score (of 16)	2-12	5.55 (7.50)	3.01 (4.83)	1-10	5.64 (3.71)	2.50 (3.40)

children who performed above chance in each group are listed in Table 8.

Table 8
Number of Children with Autism and Typically Developing Children (of 11 in Each Group) who Scored Above Chance on Note Identification and Disembedding Tasks

	With Autism	Typically Developing
Note Identification	6	11
Note Disembedding	3	4

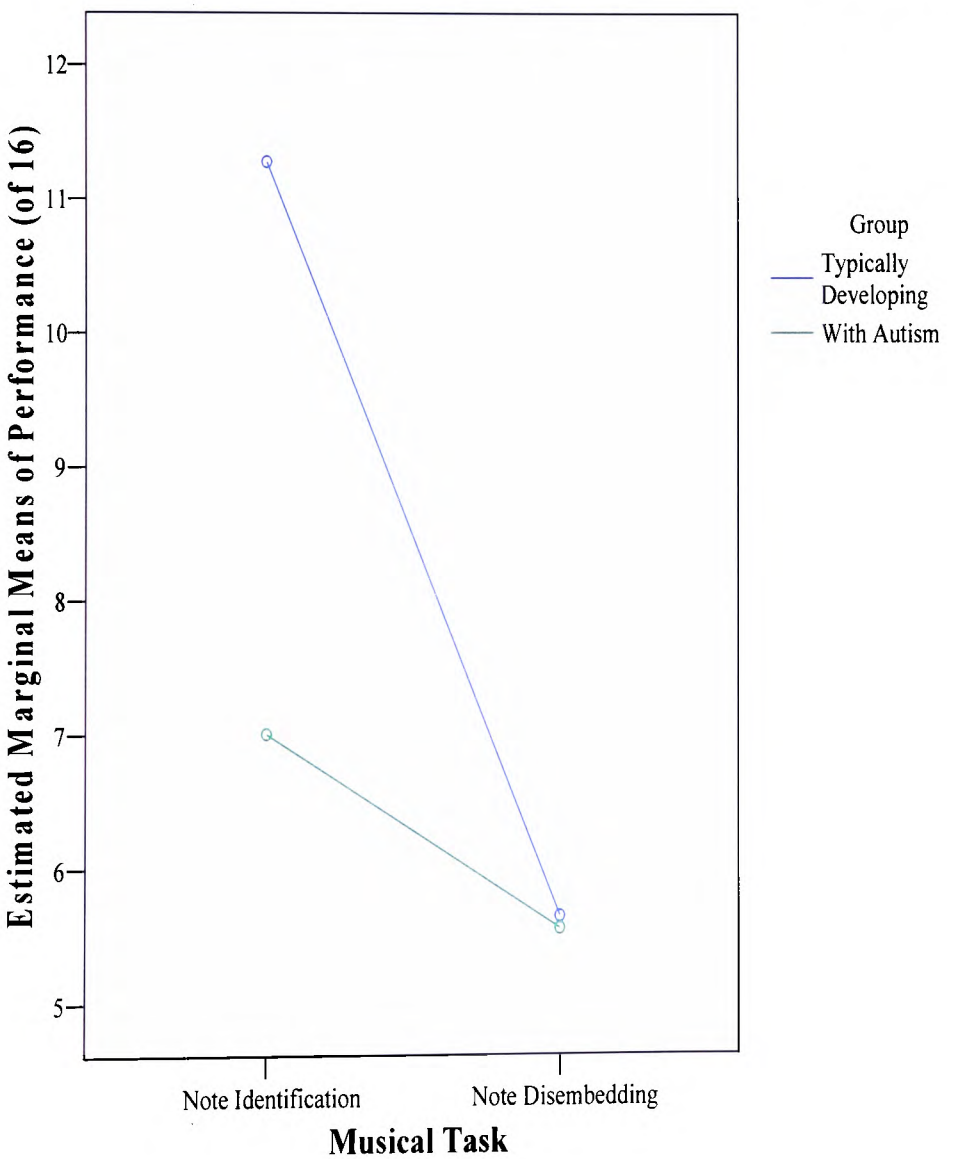
A 2 x 2 repeated measures ANOVA was run with group (typically developing or with autism) as the between subjects factor and music task (tone identification score or disembedding score) as the within subjects factor. The between subjects factor of group was not significant, $F(1,20) = 2.646$, $p = .119$. The within subjects factor of music task was highly significant, $F(1,20) = 19.525$, $p = .000$, as was the interaction between music task and group, $F(1,20) = 7.791$, $p = .017$. This interaction is shown with marginal means in Figure 8.

Pairwise comparisons were carried out to explore the statistically significant interaction. Independent samples t-tests were used to analyse performance on

identification and disembedding. The typically developing group performed better than the group with autism on the note identification task, $t(20) = 2.286$, $p = .033$. The groups performed similarly on the note disembedding task, $t(20) = .077$, $p = .939$.

Since these results were unexpected, correlations were carried out to see how results from this study related to the music and language tasks of the study 1.

Figure 8
Estimated Marginal Means of Performance by Music Task by Each Group



3.2.2 Relationships of Scores

Participants' performance from the language, frequency discrimination, and music tasks of study 1 were compared to their performance on the tasks of the present study. Results from study 2 were also compared to the data from the Musical Exposure and Training Questionnaire.

The only significant correlation that emerged in the typically developing group was that raw score performance on the BPVS correlated to note identification scores, $r = .805$, $p = .003$.

In the group with autism, performance on the note identification and note disembedding tasks of the present study correlated significantly, $r = .650$, $p = .030$. The note identification task also correlated significantly with the summary scores of the tasks of musical performance from study 1, $r = .648$, $p = .043$, and the note disembedding scores from the present study also correlated significantly with the study 1 music summary scores, $r = .676$, $p = .032$. The note identification scores from the present study also correlated significantly with the results from the Musical Exposure and Training Questionnaire, $r = .692$, $p = .018$, as did the note disembedding scores, $r = .819$, $p = .002$. In the group with autism, there were no significant correlations between music and language measures.

All correlations examined are summarised in Appendix 4.

3.3 Discussion

The prediction, that a computerised version of the Heaton task would optimise enhanced performance by the children with autism on both tone identification and tone disembedding after pre-exposure, was not supported. The Heaton (2003) findings of enhanced performance were not replicated, with those with autism performing less well than controls on identification and performing similarly to controls on

disembedding. The scores did, however, follow the same pattern of better performance by both groups on the identification than the disembeddings.

These findings are seemingly contradictory, with the group with autism exhibiting preserved melodic memory and disembedding and frequency discrimination in study 1 and deficient tone identification and preserved tone disembedding in study 2. There was no evidence of enhanced note identification or disembedding as Heaton showed in her sample. The presented finding and the work of Heaton speaks to the heterogeneity of those with autism who do not all exhibit such skills. As in study 1, in the group with autism and not the typically developing group, the children's scores on the Musical Exposure and Training Questionnaire correlated significantly with both music tasks in the present study, note identification and disembedding. This finding suggests that the children with autism's performance had to do with their musical backgrounds and was not due to some innate ability to process music as Heaton suggested. Children in the current study had preserved performance on the frequency discrimination task but deficient performance on Heaton's note identification task, suggesting they exhibited relative pitch mechanisms and not absolute pitch mechanisms. This finding is surprising and also contrary to Heaton's hypothesis, including the notion that those with autism may exhibit auditory processing that causes them to be pre-disposed to a savant condition in music.

There are several reasons for the failure to replicate Heaton's results. Although it is unlikely, it is a possibility that the computerisation had a negative effect on the children with autism. This seems unlikely given that past research has shown that these children perform better on tasks presented on computer than the same task presented in such a way that involves human contact (Ozonoff, 1995). Another, more compelling possibility may have to do with diagnosis. In the present study, each

diagnosis was confirmed, and many children were eliminated from the sample if diagnostic criteria were not met. Heaton relied solely on placement in a specialised school for those with autism as an indicator of diagnosis. Children often receive an autism label for the sake of services, so some children may not have met full diagnostic criteria. Also, Heaton sampled children with autism from only one school and the typically developing children from only one school whereas I sampled from several different schools for both of my groups. It is possible that the school from which Heaton sampled for her children with autism often exposed children to music, while this was not the case in the school where her typically developing sample attended. Since Heaton did not match her samples on musical exposure as I did, this factor could have influenced performance.

One final possible cause of my results conflicting with Heaton's is that there may be a sub-group of children with autism who exhibit enhanced musical skills. This sub-group might be one from which Heaton happened to sample heavily, and from which I happened not to sample.

Chapter Four

Searching for Music's Potential: A Critical Examination of Research on Music Therapy with Individuals with Autism

One of the most exciting potential ramifications of research on the musical processing of those with autism is the potential for this research to aid our understanding of this disorder of development and our therapeutic techniques for individuals on the autism spectrum. Music therapy (MT) could most directly be influenced. This chapter critically reviews the literature on MT with individuals with autism as background for study 3, presented in the next chapter.

Many parents of children with autism report the effective use of MT with their children. Special schools for children with autism often have sessions with music therapists as part of the normal curriculum. In a postal survey study of the use and recommendation of MT for children with autism in Germany, researchers found that 56% of child psychiatrists and 14.5% paediatricians recommended MT for the treatment of autism. Also, 25.1% of paediatricians considered MT useful for those with autism. These percentages are particularly impressive given the lack of empirical research support for MT (Evers, 1992).

4.1 Method

Given the acceptance and use of MT with individuals with autism, and the interest in their modes of processing music, it is important to review the scientific

literature on the use of MT with this population to highlight the strengths and weaknesses of the field. Since the literature in the field is often in the form of the narrative case study (the pros and cons of which are later discussed), the form of this literature review is also deliberately narrative in nature so to include the details necessary to evaluate and understand the therapy used. Although theoretical books with illustrative examples of MT with children with autism have been published (see Alvin & Warwick, 1991; Berger, 2002), this chapter presents the first thorough narrative literature review of the field. Wigram (2002) presented a narrative account of several studies on MT and autism, but the author wrote that the literature review was not exhaustive. Whipple (2004) presented a meta-analysis of music used in intervention with children with autism, but the author included several studies where music was used in the broadest sense during therapy and not necessarily in the form of MT. The author also drew heavily from unpublished manuscripts and did not provide a narrative account of the studies. Also of note in this field is the protocol for a Cochrane review on MT for autistic spectrum disorder (Gold & Wigram, 2003). The actual review has not yet been published.

Current MT research could inform not only future MT studies, but also investigations of musical and sound processing abilities of those with autism. In searching for studies, I aimed to include all published studies on MT for individuals with autism. Since MT is distinct from music education, studies that tended to focus on music education more than therapy were not included (see Wager, 2000) as well as studies that focused primarily on another form of therapy while using music (see Brownell, 2002). Auditory integration training, however, a controversial therapy where altered music is systematically used for intervention, is included in the present

literature review even though some consider it more of a "sound" therapy than a form of "music" therapy.

4.2 Music Therapy

In 1950, MT became a formalised area of research, study, and practice (Dileo, 2000; Peters, 2000; Schoen & Schullian, 1971; Van de Wall, 1946). In *Music Therapy: An Introduction*, Jacqueline S. Peters (2000) writes:

> . . . music therapy may be defined as a planned, goal-directed process of interaction and intervention, based on assessment and evaluation of individual clients' specific needs, strengths, weaknesses, in which music or music-based experiences (e.g., singing, playing musical instruments, moving or listening to music, creating or discussing songs and music) are specifically prescribed . . . to influence positive changes in an individual's condition, skills, thoughts, feelings and behaviours (p. 2).

During the therapy, a client's increased musical abilities are usually by-products of treatment and are not direct goals. There are five types of MT. In practice, however, a music therapist may use a variety of types of therapy or a specific form that does not neatly fit into one of these categories. *Receptive* MT involves listening to live or recorded music that may elicit certain reactions or emotions in the client. *Compositional* MT involves the creation of original music by the client. *Improvisational* MT involves the therapist guiding the client to creating music spontaneously (Dileo, 2000; Peters, 2000). *Recreative* MT requires the client to learn how to play an instrument and then rehearse and perform a piece. *Activity* MT involves structured musical games set up by the therapist for the client (Dileo, 2000). The effectiveness of the therapy is mostly based on anecdotal evidence. There are

very few data demonstrating its efficacy. A critique of MT research pointed out the need for scientific testing of MT to design studies other than case reports, anecdotal accounts, and small group studies (Marwick, 1996).

4.3 MT in the Treatment of Autism: Current Research

Despite immense creativity in the design of MT reports that have shown the effects of MT on the behaviours, socialisations, and communication of those with autism, there are several consistent flaws in the research that will become apparent as the literature is reviewed. These studies and case reports are grouped into categories based on the area or areas of symptoms of autism that the therapy aims to target and are summarised in Table 9.

4.3.1 MT in the Treatment of the Social Abnormalities of Autism

Wimpory, Chadwick, and Nash (1995) used musical interaction therapy to increase the social participation, reciprocal interactions, and eye contact between one 3-year-old child and her mother. She participated in 20-minute sessions of musical interaction therapy 2 times each week in her home for 7 months. To help the child anticipate the actions of her mother, the mother's motions were synchronised with the therapist's playing on the harp. The mother also imitated the actions of the child during the sessions. The researchers monitored the child's development of social skills outside of the sessions by videotaping semi-structured settings in the home 6 times over a 4-month baseline, 7 times during 7 months of MT, and, after an additional 5 months of MT, a follow-up 20 months later.

Data were analysed using a binomial test by establishing the significance of data during therapy when compared to the developmentally projected baseline data. The researchers reported some changes in social interactions, including a decrease in the amount of time it took the child to acknowledge the mother and an increase in eye

Table 9

Characteristics of Studies on Music Therapy with Individuals with Autism

	Study		Participants		Therapy	Outcome
Author	Year	Design	*n*	Age	Type	Area of Symptomology Addressed
Bettison	1996	Experimental, control groups	80	3 to 17	Auditory integration training	Social, Behavioural, Communicative
Edelson et al	1999	Pair matched experimental, control groups	19	4 to 39	Auditory integration training	Social, Behavioural, Communicative
Edgerton	1994	Within subjects, ABA	11	6 to 9	Improvisational	Communicative
Gillberg & Wheeler	1997	Pre- and post-treatment within subjects	9	3 to 16	Auditory integration training	Social, behavioural, communicative
Griggs-Drane et al	1997	Case study	1	Adolescent	Receptive, improvisational, activity	Behavioural
Hoelzley	1993	Case study	1	6	Activity, melodic intonation therapy	Communicative
Hollander & Juhrs	1974	Experimental group	30	4-16	Activity, improvisational, group	Social, behavioural, communicative
Keats	1995	Case study	1	40	Improvisational	Social, communicative
Mahlberg	1973	Case study	1	7	Improvisational, activity	Social, behavioural, communicative
Miller & Toca	1979	Case study	1	3	Adapted melodic intonation therapy	Communicative
Mudford et al	2000	Crossover	16	5 75-3 92	Auditory integration training	Social, behavioural, communicative
Orr et al	1998	Case study	1	11	Rhythmic entrainment	Behavioural
Ricketts	1976	Case studies	2	4, 9	Improvisational	Social, behavioural, communicative
Rimland & Edelson	1994	Experimental, control groups§	445	4 to 41	Auditory integration training	Social, behavioural, communicative
Rimland & Edelson	1995	Experimental, control groups	17	4 to 21	Auditory integration training	Social, behavioural, communicative
Saperston	1973	Case study	1	8	Musical synchronization	Social, communicative
Starr & Zenker	1998	Case studies	3	5, 6, 4	Improvisational, activity, musical synchronization, behavioural	Social, behavioural, communicative
Wimpory et al	1995	Case study	1	3	Musical interaction therapy	Social
Wimpory & Nash	1999	Case study	1	*	Musical interaction therapy, musical synchronization	Social, communicative
Zollweg et al	1997	Experimental, control groups	30**	7 to 24	Auditory integration training	Social, behavioural, communicative

Note *Not reported **Only 9 of the 30 participants in this study had a diagnosis of autism The other 21 were had a diagnosis of "ognitive impairment " §Control group from 1995 study with 9 participants used since all 445 participants in this study were in an experimental group, using various AIT devices and different filtering conditions.

contact and initiations of involvement with the mother. As stated in the paper, the researchers were unable to conclude how much increased socialisation was due to MT and how much was due to the child's maturation during the course of the two years between study and follow-up (Wimpory et al., 1995).

Starr and Zenker (1998) used keyboard sharing during MT sessions to help increase the socialisation of a 5-year-old male with autism. Their supposition was that the child would allow more human contact through the use of a shared instrument. At the start of sessions, the child would only allow 2 minutes of shared keyboard use with the therapist. After 3 MT sessions, the child played with the therapist on the keyboard for up to 9 minutes when the therapist played his favourite song. Researchers also reported that eye contact increased during the sessions. As they noted, the researchers failed to analyse these socialisations outside of therapy sessions. They also failed to use any statistical analyses to evaluate the child's progress. Researchers only used two songs during therapy and noted that Tom enjoyed the second song more and showed improved socialisations during it. It would have been helpful if they had examined other songs to see if the single song that had a positive effect was an anomaly.

4.3.2 MT in the Treatment of the Behavioural Abnormalities of Autism

Starr and Zenker (1998) also presented the case report of a 6-year-old boy with autism who was verbal and high functioning, but exhibited major problems with changes to his routine and waiting in line. The therapist intended to decrease the child's anxiety and aggression due to change by enabling him to wait more easily in the classroom. Starr and Zenker used an original song, "Line Up," to help the child understand the need to wait to leave the classroom. The therapist used visual cue cards, showing the various steps of waiting, to show the child what he was expected to do during each

part of the song. He listened to the song on the way to school in addition to during MT sessions. During therapy sessions, his anxiety and aggression associated with waiting decreased, as assessed by the therapist on a subjective scale. As stated in the study, the researchers should have analysed the child's behaviours outside of therapy to see if the child's improvement generalised.

Griggs-Drane and Wheeler (1997) had a blind, female adolescent with autism listen to various musical theatre, children's, rock, folk, country, and originally composed songs; sing along to music; and play instruments to lessen her self-destructive behaviours. Researchers used the music with functional assessment charts to document which types of music were most effective. A decrease in destructive behaviours was noted during the sessions, but was not statistically analysed outside of or during sessions.

Orr, Myles, and Carlson (1998) used rhythmic entrainment to lessen headjerking and screaming in an 11-year-old girl with autism. Entrainment was defined by the researchers as "us[ing] music to aid in relaxation by introducing externally produced rhythms that are specifically designed to re-entrain the body to its natural rhythmic patterns" (Orr et al., p. 163). Therapists used music at 50 to 60 beats per minute to increase alpha waves, those responsible for relaxation. Researchers analysed 30 days of data utilising an ABAB design, with alternating baseline and musical intervention periods. Researchers analysed the child's headjerks and screaming during the first 20 minutes of class during both conditions. The average number of screams and headjerks on days with therapy was lower than that of baseline days.

As with preceding work with one participant, the generalisability of the work of Orr et al. is questionable. It is also unfortunate that researchers only recorded the

participant's behaviours during the set 20 minute period each day and failed to use statistical measures to analyse these results. Since the participant often exhibited a wide frequency of headjerks and screams during the specified time period, it would have been helpful if the researchers had surveyed the frequency of these occurrences outside of the set period of time.

4.3.3 MT in the Treatment of the Communicative Abnormalities of Autism

Miller and Toca (1979) used melodic intonation therapy with a 3-year-old, nonverbal male with autism. In melodic intonation therapy, therapists use simple melodic fragments to intone short phrases and sentences. As they sing to clients, the therapist taps the rhythm of the words on the client's body. The goal of therapy is to intone speech so that the clients' understanding of spoken language increases and to guide the clients to intone their own words and phrases. Therapists expect the intoned utterances to lead to nonintoned speech. Sessions started out by teaching the client manual signs combined with tones. The therapist taught him to imitate the signs. The child then began speaking words in and outside of therapy sessions. After 35 sessions, he started to combine words and could respond to intoned questions or statements. After the study, he continued with intoned therapy sessions on a daily basis. He could produce up to four words together in an intoned fashion to make sentences and began to understand and respond to nonintoned questions. While the results of this study were very encouraging for the one participant, the researchers failed to include quantitative analysis of the changes in the child's communication.

Hoelzley (1993) hypothesised that novel sounds, those in a register different than that of speech, like those of a wind instrument, would bring about communicative increases in children with autism. The author hypothesised that sounds outside the realm of those that the child usually encounters would break down

the resistance to communication to elicit positive, imitative responses. Hoelzley provided a case study of one 6-year-old female with autism who mimicked the trombone with low, grunting noises. During sessions with a therapist on a trombone, the girl's grunts led to speech-like vocalisations on pitch after the therapist continually sang sentences using the melodic fragments played on the trombone. The client eventually sang words. A year later, the child could speak the phrases that she had sung. Hoelzley, however, failed to acknowledge the possibility of the natural development of the child's speech during this period of time, not influenced by therapy.

Edgerton (1994) conducted a study using one-on-one improvisational MT with 11 children with mild to severe autism, ranging in age from 6 to 9. The clients participated in therapy for a half-hour each week for 10 weeks. This comprehensive study analysed communicative improvements inside and outside of therapy with the communicative responses/acts score sheet (CRASS). During sessions, the therapist utilised the piano, snare drum, and cymbal to create nonverbal improvisational communication between the child and music therapist. CRASS scores were taken for each child during a 10-minute interval randomly selected, through time interval sampling, prior to each therapy session. After the study, speech therapists, parents, and teachers rated the communicative, social/emotional, and musical behaviours of the children on the Behaviour Change Survey. The general scheme of therapy consisted of intervention followed by one session of withdrawal and then intervention. During intervention, the therapist played improvised music to the child, and the child would play back based on the approach of Creative MT (see Nordoff, 1972; Nordoff & Robbins, 1964, 1968, 1977). During the withdrawal session, the therapist played and sang composed music. The CRASS scores of all 11 children consistently rose

during intervention, fell during withdrawal, and rose again during intervention. All individual scores on the CRASS were higher after the last session than after the first session. Using a Wilcoxon Matched-Pairs Signed Ranks Test, the researchers showed that the scores of the last session were significantly higher than those of the first. The Behaviour Change Survey indicated 'no change' to a 'slight change' in each of the children.

The Edgerton study is unique in its number of participants and "objective methods of control, observation, and data reporting" (Edgerton, 1994, p. 51). Many music therapists would argue that since MT is individually tailored to a client, the case study is the ideal way to measure success. This empirical investigation shows that such studies can effectively take place in the field without diminishing the individual nature of the therapy.

Starr and Zenker (1998) used MT on a child with autism to try to increase his language skills and appropriate use of first person pronouns because he exhibited echolalia and pronoun confusion. He participated in 6 to 8 one-on-one, 30 minute MT sessions each week. The therapist used activity MT to create a musical game entitled, "Beat that Drum." The therapist spoke to the child using pronouns properly and rewarded the child with the drum each time he imitated the therapist and used pronouns correctly. With this behavioural therapy, the child used the "I" pronoun more frequently and used longer sentences, but the researchers failed to assess the participant's performance outside of therapy.

4.3.4 MT in the Treatment of the Social and Communicative Abnormalities of Autism

Saperston (1973) conducted a study of an 8-year-old male with autism, who participated in half-hour improvisational MT sessions three times a week. The

therapist accompanied the child's individual movements with different gestures on the piano. For example, music ceased when the client stopped moving, and the therapist played a low G when the client stepped with his left foot and a high G when the client stepped with his right foot, or a tone cluster when the child stomped. As the client became increasingly aware of his ability to influence the music played, the client began to smile at and make eye contact with the therapist. Session length increased from 7 to 30 minutes of activity, and the client began to sit next to the music therapist at the start of a session. The client also greatly increased his amount of eye contact and began to vocalise frequently. He also generalised the ability to interact with people outside of therapy sessions. Unfortunately, Saperston failed to substantiate many of his results by not quantifying and statistically analysing the client's increased socialisation and communication even though the data collection in the study could have made this possible.

Keats (1995) described 18 months of MT sessions conducted with a nonverbal, 40-year-old male with autism, severe hearing impairment, and limited vision. The participant used finger spelling to communicate. The therapist set up four music-making stations, each with percussive instruments and different mallets, to use rhythm as a nonverbal means of communication. Station one, "Hello," consisted of an alto xylophone, melodic cowbells, a triangle, a conga drum, and temple blocks. The sessions started here with a musical conversation between client and therapist that usually increased in rhythmic complexity. Most improvisations were based on the pentatonic scale. Station two, "How are you today?" utilised the drums, a cowbell, and a cymbal to encourage socialisation. Their playing was a full body experience that depicted the client's emotions with dynamics and accents. Station three, "What's new," consisted of a basic drum set that the therapist taught the client to play. Station

four, "Let's jam," involved a concert size marimba with a gong and cymbal and enabled the client to express his creativity and imagination. Keats stated that the client enjoyed himself as he and the therapist took turns soloing through improvisation. This study unfortunately lacked an analysis of the client outside of therapy sessions and any quantification of the client's socialisations and communication.

Wimpory and Nash (1999) used the previously mentioned musical interaction therapy to increase the communication and socialisation of a girl with autism. For 4 months, researchers videotaped the mother and daughter's interactions to establish a baseline. For 7 months after the baseline, the child underwent MT twice a week at home to increase the child's interactions with her mother. Therapy involved lap play, play routines, and songs to increase tactile interactions between mother and daughter. The music therapist provided music to accompany the interactions between mother and child and to help the child to anticipate the mother's actions. During therapy, the child and mother exhibited increased eye contact, communication, pretend play, and socialisation. The client also increased her pretend play and the frequency of initiating pretend play with her mother. Researchers claimed that the therapy also had an effect on the relationship between mother and child outside of therapy by increasing their communication and socialisation. After 7 months of monitored therapy, therapy continued for another 5 months in an unmonitored fashion. A 20 month follow-up, a rare and necessary inclusion in this field, revealed that many of the positive effects of the musical interaction therapy remained.

4.3.5 MT in the Treatment of the Social, Behavioural, and Communicative Abnormalities of Autism

Mahlberg (1973) created a daily MT plan for a 7-year-old boy with autism who was prone to tantrums, did not pay attention to noises, had significant speech deficits,

displayed social avoidance, pinched himself, and was hyperactive. The therapist used a tambourine to create a rhythmic pattern with speech to teach nonverbal communication, used clapping with and without music and imitation in songs to increase his attention span, and had the child march and dance in tempo with music to lessen maladaptive behaviours. The therapist used songs to help the child gain greater awareness of his body. The child eventually learned some words and exhibited increases in socialisation by sitting on the therapist's lap during sessions and beginning to relate to the therapist.

This study is a first attempt at using MT to treat a large range of symptoms of autism. This study lacks a methodical means of evaluating the client's performance and has biased outcome measures that rely solely on the therapist's observations. The study also lacks proper follow-up and any observations outside of therapy sessions.

Hollander and Juhrs (1979) conducted a study using the Orff-Schulwerk treatment method to increase social, communicative, and behavioural symptoms of autism in 30 4- to 16-year-olds with autism. Based on humanistic therapy, the Orff-Schulwerk method uses music set to the tempi of body movements and speech to elicit responses in children with autism. To express themselves, the children used instruments, including percussive types. Therapists also used the instruments and sign language to develop language skills during the therapy sessions three times each week. To bring about behavioural changes, the therapists taught the children rhythmic motions to replace their ritualistic ones. The children also played with instruments to improve fine motor coordination. To increase social skills, the children interacted with and imitated one another in groups of 4 to 6. As these relationships developed and imitations increased, the children's awareness of other maladaptive behaviours increased, and rates of these behaviours then decreased in all children.

Like the Mahlberg (1973) study, the Hollander and Juhrs study attempted to address a wide range of symptoms of the child with autism yet did not fully implement adequate controls. For one, the study simply states observations of the results of therapy and failed to calculate the statistics associated with this presumed progress of the children due to the therapy. The study also does not address the children's progress outside of the classroom or contain a follow-up.

Ricketts (1976) used improvisational MT with two boys with autism whom he described in case reports. The first was a 4-year-old who exhibited ritualistic behaviours by constantly arranging objects. Although he could produce high pitched sounds, he exhibited neither functional speech nor eye contact. After 3.5 years of improvisational MT, the child started making eye contact, speaking with a vocabulary of 50 words, responding to simple sentences, and playing games. The second boy described was 9 years old and had perfect pitch and excellent musical abilities. He spoke with short sentences and exhibited maladaptive behaviours. After 6 years of improvisational MT, although his behaviours remained "bizarre," he reached a high enough level of function to go to a music conservatory where he played violin and piano and composed music (Ricketts, p. 587). In these two suggestive and brief cases studies, Ricketts failed to describe the details of and devices used during the improvisational MT sessions.

Ironically, auditory integration training (AIT) is the most empirically researched area of music therapy for those with autism and is also the most controversial due to the claim by Stelhi (1991 as cited in Rimland & Edelson, 1995) that her daughter with autism experienced dramatic emotional and cognitive improvements after just 10 hours of AIT. Of the six published empirical investigations on AIT for those with autism, all summarised in Table 9, Rimland &

Edelson (1994; 1995) and Edelson, Arin, Bauman, Lukas, Rudy, Sholar, et al. (1999) reported the potential benefits of AIT, and Bettison (1996); Gillberg, Johansson, Steffenburg, and Berlin (1997); Zollweg, Palm, and Vance (1997)[1]; and Mudford, Cross, Breen, and Cullen (2000) failed to find positive effects from AIT. This review critiques the most recent investigations of both sides of this controversial therapy.

Edelson et al. (1999) produced an empirical study of the effects of AIT on people with autism. Comprised of 20 half-hour sessions, AIT involves the listening to machine "modulated" music on headphones by participants. The researchers describe "modulation" as using

> wide band filters to attenuate the volume of a specific frequency range. The onset and duration of the modulated stimulus is determined randomly by the AIT device. At one moment, the volume of the frequencies between 20 Hz and 1000 Hz may be attenuated; at another moment, the volume of the frequencies at 1000 Hz and higher may be attenuated. An analogy would be rapidly switching the output of a hi-fi stereo between treble and bass at random intervals. The attenuated sounds vary in duration from 0.250 to 2 seconds (Edelson et al.: 73).

Attenuation eliminates certain frequencies that may be particularly troubling to those with autism. AIT was once used exclusively for people with autism with sound sensitivity, and previous studies showed effectiveness in this area (Rimland & Edelson, 1994). Other studies showed that AIT might also increase the language comprehension and cause behavioural changes in individuals with autism (Rimland & Edelson, 1995). One leading theory of how AIT works is that modulated music catches people's attention better than conventional music due to the constant changes

[1] Only 9 of the 30 participants in this study had a diagnosis of autism. The other 21 were had a diagnosis of "cognitive impairment."

in frequency of the altered music. This process inspires greater attentiveness to the music. The claim of the therapy is that this attentiveness may generalise to one's environment and lessen maladaptive behaviors.

To elaborate further on the sensations experienced after AIT, I interviewed a parent who underwent the therapy before allowing for her son to take part in it. She commented that "background sounds [were] more distinct." She felt that sounds "stuck out" more, and she was more aware of these separated sounds as opposed to the normal jumble of background sounds heard in our daily lives (T. Demeo, personal communication, March 19, 2003).

The Edelson et al. study (1999) used surveys filled out by participants' guardians to assess behaviours that were exhibited by the 19 participants with autism, ranging in age from 4 to 39 with a mean age of 11.58 years. Clients, 17 males and 2 females, were placed in either the placebo or experimental group. The placebo group listened to music on headphones two times a day for 30 minutes during 10 consecutive days. The experimental group listened to modulated music two times a day for 30 minutes during 10 consecutive days. Previous studies had shown that the results from AIT were present within 3 months post-therapy (Rimland & Edelson, 1994). Guardians and parents of those individuals with autism in the experiment filled out behavioural surveys regularly after the experiment. At three months post therapy, results on the Aberrant Behaviour Checklist, revealed a significant difference between the placebo and experimental groups. There were no differences between groups on the Conner's Rating Scales, which evaluate hyperactivity and social behaviour, and the Fisher's Auditory Problems Checklist.

The empirical nature of the Edelson et al. study is unique in the field of MT and autism. The investigators, however, failed to see if the positive effects of the AIT

lasted after three months. The researchers also did not include details of the music used. Without these details, the placement of this controversial therapy in the area of MT is further complicated. It would be helpful to know the type of music used during AIT, particularly in response to the criticism of those who may argue that AIT is not a form of MT.

Responding to the work of Rimland and Edelson (1994, 1995), Mudford et al. (2000), conducted a similar study that detected no behavioural benefits for individuals with autism after AIT. Sixteen children with autism listened to modified music on headphones for two 30-minute sessions two times a day for 10 consecutive business days. Before the withdrawal of 5 participants from the study, the mean age of the 17 male and 4 female participants was 9.42, and all attended special schools. The researchers utilised a within subjects design where all children experienced AIT and baseline conditions, with at least 4 months between them. Seven children started with the AIT condition, and 9 children began with baseline, during which participants wore headphones, but did not hear anything through them. Parents, teachers, and the researchers filled out behavioural questionnaires for each child before, during, and after the experimental and control conditions. The parents and teachers used the Aberrant Behavior Checklist and the Nisonger Child Behaviour Rating Form Hyperactivity.

Mudford et al. (2000) analysed 14 months of data and did not replicate Rimland and Edelson's findings (1994, 1995). According to the parent ratings on the Aberrant Behaviour Checklist, a significant reduction in maladaptive behaviours took place during baseline. Parental ratings on the Nisonger Child Behaviour Rating Form Hyperactivity revealed that scores for poor behaviours were more reduced during baseline than during AIT. Researcher observations of inappropriate behaviours

showed that maladaptive behaviours involving the ear actually increased after AIT. Mudford et al. argued that AIT could be dangerous for children and could create false hopes in parents. Mudford et al. also criticised Rimland and Edelson's (1995) design where families had to pay for the treatment and travel and hotel expenses. The parents were thus not blind to treatment type, and the financial demands could have influenced them to view the therapy in a positive light in addition to the possibility of experimenter expectancy effects (Kazdin, 1998 as cited in Mudford et al.). In the Mudford et al. study, researchers paid all costs for participants, and parents were blind to the order of therapy conditions in which the child participated.

Like the Edelson et al. (1999) study, Mudford et al. (2000) tested multiple participants in an empirical study with a control group. Such characteristics are not often found in research in this area. The researchers failed to elaborate on the musical stimuli used during therapy. Mainstream music therapists often consider AIT a form of "sound" therapy, distinctly different from mainstream MT. The writing on AIT, however, reports that music is used in a systematic way for the purpose of intervention. This music, however, is neither defined nor discussed, and it certainly should be. From what the AIT researchers report, however, it does seem logical that AIT be considered a form of MT as defined by the definition presented earlier in this chapter. This classification would be greatly strengthened with the identification of the exact music used during therapy. The researchers noted another weakness of the design was the lack of music during the control period. Previous studies (Bettison, 1996; Rimland & Edelson, 1995; Zollweg et al., 1997) used unmodified music for the control condition. The crossover design of the present study, however, did not allow for such music to be played because the Society for Auditory Intervention Techniques

advises against the playing of music through headphones after experiencing AIT (Society, 1999 as cited in Mudford et al).

A Cochrane report (Sinha, Silove, Wheeler, & Williams, 2004) summarised the findings of all of the AIT studies mentioned in this review and reported the need for more systematic research in the field to resolve its controversy.

4.4 Discussion

The preceding critique of the current literature shows that MT has been used to address and alter activities in areas where individuals with autism are particularly deficient including behaviour; sensory and motor skills; language and communication; interpersonal skills and abilities to express themselves; and self-help and survival skills. Therapists have utilised several different types of MT with their clients with autism including: adapted melodic intonation therapy, AIT, rhythmic entrainment, improvisational MT, musical synchronisation, musical interaction therapy, activity MT, and receptive MT.

Music therapists and researchers of MT need to reflect upon past research to improve the consistent flaws in the literature. While the research with more than one client may lack the detail of a case study, it is much more generalisable than a case report that only notes changes in a single participant (Marwick, 1996). Of the work reviewed in this paper, with the exception of the AIT studies, all but two of the pieces of research were case studies, and one of these investigations with more than a single participant contained no formal analyses of the results (Hollander & Juhrs, 1974). Music therapists have argued that only case studies are appropriate since the treatment schedules are individualised for each client, and thus, the same regimen cannot be followed during therapy for several participants in a study. Researchers, however, can account for these subtle differences in therapy in sound empirical designs, which have

not yet taken place in this field. Other forms of individualised therapy (cognitive behavioural therapy, for example), have been empirically researched. It is also important that changes that may occur during therapy are monitored outside of therapy sessions and during follow-ups after formal sessions. Studies also need control groups. Additionally, MT is no different than any other scientific area of research in its need for statistical analyses to test the significance of any improvements of individuals with autism. It was disappointing to see the number of reports on MT and autism that included no statistical analysis, necessary for the MT field to make the claim that its work is advantageous to the population with autism. It is dangerous to assume that MT may not bring about negative side effects. Since individuals with autism often exhibit hyperacusis, it certainly is conceivable that MT could have a negative effect for some as has been argued in Mudford et al. (2000) in reference to AIT. MT must undergo the same scrutiny as other therapies. In the AIT studies, it is imperative that the specific music used is reported. Although all elements of therapy reported in the study are in line with the definition of MT, the reporting of the music used during therapy would be helpful to sharpen this classification of AIT as a form of MT.

In evaluating the performance of the clients, rater bias may play a large role in many of the studies assessed since the clients were not evaluated blindly by a second rater to confirm the reports of the therapists, naturally biased in their assessments. This was unfortunately the case with Edgerton (1994), the other non-AIT multi-participant study in this review. Finally, there is a large void in the literature of studies with comparative outcome designs to see how MT compares to other forms of therapy used to treat those with autism. Although some existing research compares the effects

of MT to the absence of therapy, more work of a comparative nature is still needed in this area.

Gold, Voracek, and Wigram (2004) carried out a meta-analysis of 11 empirical investigations of MT for children and adolescents with highly varied psychopathology. Furthermore, conditions treated were extremely varied and included sexual abuse, emotional handicaps, developmental delays, and autism. Other studies in this field were excluded if they did not meet the authors' strict criteria including addressing the effects of music only (not used in a therapeutic fashion) or music education, only having one participant, and using MT with another form of therapy and not clearly stating the effects of the MT alone. Of these 11 studies, only 1 concerned children with autism (Edgerton, 1994). When the authors analysed the overall effect size of the studies, the Edgerton study had to be removed since it was an outlier due to its potentially biased outcome measure by the therapist only. So, unfortunately, the Gold et al. meta-analysis effect size did not include a study on children with autism.

The researchers established that MT exhibited a highly significant, medium to large effect on outcomes. Based on other analyses, the authors suggested that eclectic forms of MT, borrowing from various types and models, are most effective with children with psychopathology. Although the outcome of the meta-analysis is promising, the authors commented on the small number of studies used in this first summary investigation of MT for this population. As this chapter has suggested, Gold et al. also commented on the need for more empirical research of MT with unbiased and controlled paradigms to answer the questions of what types of therapy are most effective to achieve a specific outcome with a client. The study presented in the next

chapter was an attempt at an empirical, systematic study at the effects of a receptive music therapy-like paradigm on young children with severe autism.

Chapter Five

Study 3:

An Exploratory, Observational Study of the Socialisations and Musical Gestures of Young Children with Severe Autism in Response to Music

Although studies 1 and 2 cast doubt on the likelihood of musical ability as an enhanced feature of the autistic cognitive profile, they suggest that children with autism may have better ability to respond to musical than to verbal stimuli. This raises the possibility that music might provide a way of communicating with children with severe autism who have limited verbal skills. As previously mentioned, it may also be possible that those with autism exhibit musical interest and not musical skill. If they exhibit such an interest, then one would expect children throughout the spectrum to exhibit such a preference. All research on the musical processing of those with autism thus far has focused on high functioning individuals with autism. The present study was exploratory in nature and aimed to provide an initial look at the musical processing of young children with severe autism by setting up a music therapy-like set-up to attempt to test empirically its effectiveness.

During this within-subjects experiment, children's socialisations, musical gestures, and levels of activity were scored during a baseline condition of silence and two musical conditions, one with many changes (in dynamics, key, meter, etc.) and one with very few changes. A within subjects design was chosen for this study

because it would have been logistically unfeasible to match these children with autism to typically developing children in a sensible way. Based on prior reports on the effects of music therapy with children with autism, it was hypothesised that the children would exhibit the most socialisations and musical gestures during the music-with-changes condition, and the fewest during the silence condition. Musical gestures were thought to be an indicator of "musical ability" in this group which would not have been able to be tested directly on musical tasks on the computer as is appropriate with older, higher functioning children with autism. It was further hypothesised that the children's level of activity would be highest during the music-with-changes condition and lowest during silence.

5.1 Method

5.1.1 Participants with Autism

Twenty-one children in a special school for individuals with autism were given permission from their parents to participate in the present study. A 3dI, a semi-structured, computerised diagnostic interview for pervasive developmental disorders was run by a trained researcher (RA) before any child was included in the study. (See study 1 for an explanation of the 3dI.) This diagnostic exclusion reduced the sample of participants with autism to 16, all of whom scored up as having deficits in the domains of communication, socialisation, and behaviour of the interview. All participants had normal hearing and English was their first language. All were Australian. Their demographic data are summarised in Table 10.

5.1.2 Materials

Revised version of musical exposure and training questionnaire. This was the same questionnaire as study 1 except that a "0" choice was added for the four sub-questions of question 4 concerning musical activities (see Appendix 3). The maximum score

was still 27. Parents filled out this questionnaire, and the results are summarised in Table 10.

Table 10
Psychometric Data of Children with Autism
(Psychometric testing was not appropriate for those children who would not attend to tasks.)

	n	Range	Mean	SD
Age	16	4.75-9.25	5.91	1.38
Musical Exposure (of 27)	16	0-6	2	1.79
Male:Female	16	12:4		
British Picture Vocabulary Scale II Standardised Score (of a mean of 100, SD of 15)	8	40-95	71.5	18.996
WPPSI-R Object Assembly (of a mean of 10, SD of 3)	13	1-18	5.54	5.04
WPPSI-R Block Design (of a mean of 10, SD of 3)	9	1-16	4.89	5.04
WPPSI-R Animal Pegs (of a mean of 10, SD of 3)	8	1-10	3.63	3.11

BPVS II. This test of receptive vocabulary was used (see study I for an explanation). This test was appropriate for 8 of the children whose scores are summarised in Table 10.

Nonverbal Subtests of Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R). WPPSI-R (Wechsler, 1989) was developed to assess Verbal and Nonverbal IQ in young children. There are norms for children ages 3;00 to 7;03. There are six performance sub-tests: object assembly, geometric design, block design, mazes, picture completion and the optional animal peg sub-test. In the current study, three of the nonverbal sub-tests were chosen to administer to get some sense of the nonverbal abilities of the participants. Although the three tests used (object assembly, block design, and animal pegs) were chosen due to the likelihood of the children with autism attending to them, not all of the children were able to take part in the tasks. In the case of the two participants whose ages were above the WPPSI-R standardised

score availability, the highest bracket's standardised scored were used. Table 10 summarises these data and includes the number of children who participated.

Musical responsiveness paradigm. A paradigm was set up to assess the children with autism's responses to music without any task demands. Children were placed in a classroom and asked to sit and play. Their favourite silent toys and games were laid out in a semi-circle in front of them. The items were carefully chosen by their parents and teachers to increase the likelihood of the children remaining on task. The items included dolls, figurines, toy trains, books, magazines, and colouring books. In close proximity to the child was a boom box. Three musical conditions were chosen for the study, and they were all approximately the same duration. There was a baseline silence condition for 9:32 minutes. There was a music-with-changes condition. This condition featured approximately the first 9:32 minutes of Gershwin's Rhapsody in Blue, which was chosen due to the many changes, some subtle and some very obvious, within it. These changes occurred in key, tempo, meter, texture, dynamic, etc. of the piece. Although it was originally planned that several excerpts of musical changes would be played in succession for the music-with-changes condition, it was thought that having one piece of music during this condition would be more indicative of how music is actually heard. The third condition featured music without changes for 9:31. Like the Gershwin piece, this recording of "Irish Lullaby" by the Melbourne Symphony Orchestra was indeed an orchestral piece. It was, however, deliberately composed to avoid changes in the score so that it could be soothing and relaxing. The entire piece lasted for 9:31 minutes. The order of the three conditions was completely counterbalanced over six types of presentations, four of which were played for three children each, and two of which were played for two children each.

The researcher (RA) told the children to play with all the toys in the room and encouraged them to stay seated near the toys. The play time was not structured, as this could have influenced the spontaneous reactions of the children (Jarrold, 2003; Willemsen-Swinkels, Buitelaar, & van Engeland, 1997). The researcher (RA), a teacher, or parent (depending on what the child was most comfortable with) was in the room, sitting near the child as a passive observer. While the child could interact with the passive observer and the observer was instructed to reciprocate normally, the observer was asked not to initiate any task or interaction with the child. This set up was chosen based on research showing that active engagement with a child with autism could influence socialisations during free play (McHale, 1983).

Hidden in a corner of the testing classroom was a digital camcorder that recorded the session so that the tapes could be scored by multiple raters. The total session lasted less than a half hour, and the researcher (RA) then met with the child once more to work on psychometric and vocabulary testing for approximately a half hour.

The tapes were then scored by the researcher (RA) and another rater, blind to the musical condition, who watched the tapes muted. The socialisations to score were chosen based on the children's actions during the study and details within reports of children's increased socialisations due to music therapy (see Chapter 4). The musical gestures to score were also chosen based on the children's actions and qualitative pilot data that showed children with severe autism responding in such a way during receptive music therapy (Accordino, 2003). Musical gestures seemed to be the most appropriate way to attempt to evaluate musical ability in this group of children with severe autism. An evaluation with task demands would not have been appropriate for this group of children. Both the duration of musical gestures and socialisations, as

outlined in Table 11, were scored using the program, Activity Timer 1.2a (Jackson, 2004), which allowed for the scoring of two activities. In this case, one activity was the presence of a musical gesture and the other was the presence of a socialisation. The program calculates the duration of each of these activities, and the duration corresponds to the amount of time the button for each activity is pushed. The durations were scored instead of frequencies based on the previous observational study work of Willemsen-Swinkels et al. (1997) that argued that frequency scoring is a limited means of analysing observational data.

Table 11

Socialisations and Musical Gestures in Response to Music

Socialisations (With passive observer in camera's view):	Musical Gestures:
Kissing person	Playing with CD player
Hugging person	Pointing at CD player
Pointing for person to do something	Conducting
Bringing person to do something	Gazing at CD player
Giving something to person	Dancing (in the broadest and most
Showing something to person	liberal sense—any running with
Sharing something with person	expressive movement)
Enabling person to carry out task with child	Clapping
Gazing at person	Conducting gesture
Touching person	Turning deliberately to CD player
Turning deliberately to person	Jumping (except when on a trampoline)

The researcher (RA) and another blind rater also scored the child's level of activity. Initially, activities were going to be scored separately to quantify the nature and durations of activities exhibited by each child during each music condition. Since the children played in unconventional ways with their toys, it was often unclear when activities started and stopped. For this reason, the three experimental conditions were ranked according to the child's global activity level.

5.2 Results

5.2.1 Inter-Rater Reliability

The participants' durations of socialisations and musical gestures and global activity levels for each of the three conditions by each of the two raters were compared using Pearson correlations. Across all conditions (silence, music with changes, and music without changes for each rater) and that which is being rated (socialisations, musical gestures, or activity level), the correlations were highly significant as shown in Table 12.

Table 12

Inter-Rater Reliability Correlations of Scores of Two Raters

Condition	*r*	*p*
Socialisations During Music with Changes Condition	0.986	0.000
Socialisations During Music without Changes Condition	0.990	0.000
Socialisations During Silence Condition	0.999	0.000
Musical Gestures During Music with Changes Condition	0.916	0.000
Musical Gestures During Music without Changes Condition	0.878	0.000
Musical Gestures During Silence Condition	0.996	0.000
Activity Level During Music with Changes Condition	0.770	0.003
Activity Level During Music without Changes Condition	0.836	0.000
Activity Level Gestures During Silence Condition	0.672	0.004

5.2.2 Socialisations

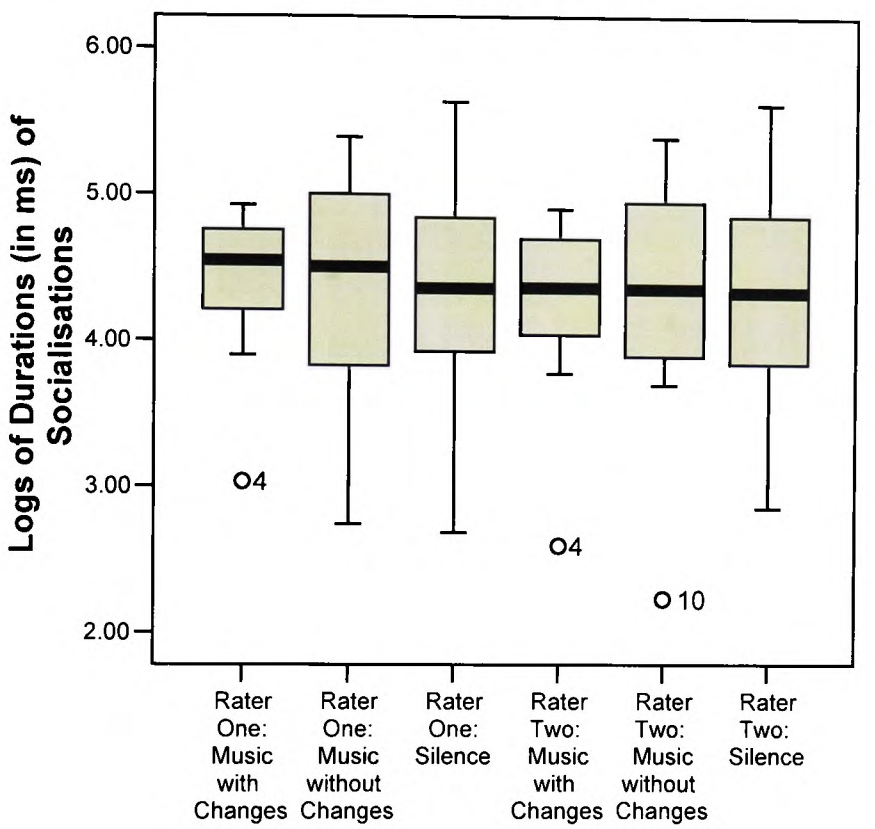
Since these data (see Table 13) were skewed, they were log transformed (see Figure 9) before being analysed with a 3 x 2 repeated measures ANOVA. The within subjects factors were music condition (silence, music with changes, or music without changes) and rater (one or two). There was not a statistically significant main effect for music condition, $F(2,18) = .007$, $p = .993$. There was also not a statistically

Table 13

Duration Scores (in ms) of Both Raters During Different Music Conditions

	Rater One			Rater Two		
Condition	Range	Mean	SD	Range	Mean	SD
Music w/ Changes: Socialisations	0-242247	40818.75	60240.19	0-238390	35923.56	58929.02
Music w/o Changes: Socialisations	0-247749	46608.88	72632.00	0-249441	43300.06	72082.45
Silence: Socialisations	0-436440	55412.06	121338.83	0-424026	56735	118666.21
Music w/ Changes: Musical Gestures	0-147220	29735.06	35863.64	436-140605	16761.25	34003.63
Music w/o Changes: Musical Gestures	0-93238	21233.44	28037.80	0-69557	12678.31	17052.00
Silence: Musical Gestures	0-123560	27658.13	39394.67	0-106797	23140.94	34781.52

Figure 9
Boxplots Showing Duration of Socialisations by Music Condition as Scored by Both Raters

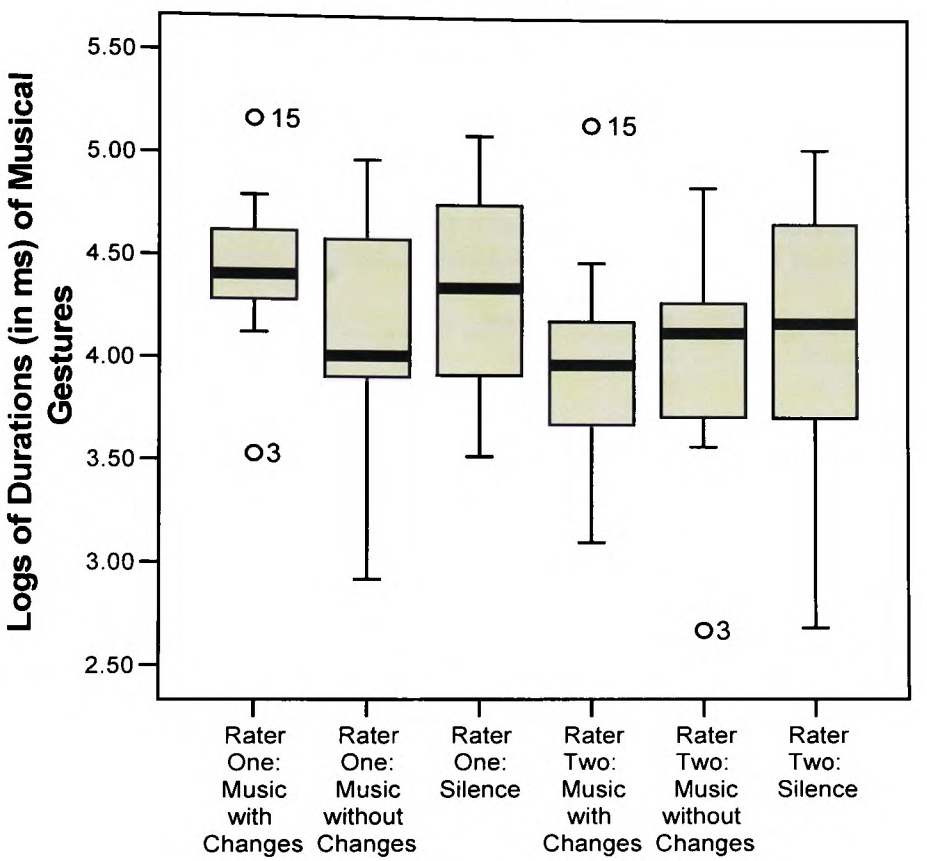


significant main effect for rater, $F(1,9) = 1.309$, $p = .282$. The interaction between these factors was also not significant, $F(2,18) = 2.557$, $p = .105$.

5.2.3 Musical Gestures

Since these data (see Table 13) were also skewed, they too were log transformed (see Figure 10) before being analysed with a 3 x 2 repeated measures ANOVA. The within subjects factors were music condition (silence, music with changes, and music without changes) and rater (one or two). There was not a statistically significant main effect of music condition, $F(2,20) = .516$, $p = .605$. There was a statistically significant main effect of rater, $F(1,10) = 35.710$, $p = .000$. There was not a main effect of the music condition and rater interaction, $F(2,20) = 2.812$, $p = .084$.

Figure 10
Boxplots Showing Duration of Musical Gestures by Music Condition as Scored by Both Raters



The rater who listened to the music conditions (RA) noticed that there might have been an order effect with children making musical gestures during the silence condition to get the music turned on when one of the music conditions preceded the silence during testing. An independent samples t-test was then run to compare the silence condition during the presentations when it came first or when it came second or third, and thus after a musical condition. This difference was not significant for either of the raters, so this issue was not further explored.

5.2.4 Level of Activity

The ordinal data of both raters, as shown in Table 14, underwent a 3 x 2 repeated measures ANOVA. The within subjects factors were music condition (silence, music

with changes, or music without changes) and rater (one or two). There was not a statistically significant main effect for music condition. There was also not a statistically significant main effect for rater. The interaction between these factors was also not significant.

Table 14
Level of Activity Scores of Both Raters During Different Music Conditions
(Ordinal scores were assigned: 3 = High Activity Level, 2 = Medium Activity Level, 1 = Low Activity Level)

	Rater One			Rater Two		
Condition	Range	Mean	SD	Range	Mean	SD
Music w/ Changes	1-3	2.31	.793	1-3	2.13	.885
Music w/o Changes	1-3	1.88	.806	1-3	1.94	.680
Silence	1-3	1.81	.834	1-3	1.94	.929

5.3 Discussion

Although there was not support for the hypotheses of increased socialisation, musical gestures, and levels of activity due to music with changes compared to music without changes and silence, this observational design with excellent inter-rater reliability seemed to work methodologically, which is a potentially useful first step. Unfortunately, this study did not provide further empirical support for music therapy with individuals with autism. It also did not provide support for the presence of musical ability, as assessed through the presence of musical gestures, in children with severe autism. The statistically significant main effect of rater for the musical gestures analysis might have been caused by the fact that one of the raters (RA) was a musician and could have been more sensitive to assessing musical gestures than the other rater.

5.3.1 Limitations of Study

One of the major limitations of an observational study like this one is that one is forced to make the basic assumption that what the rater sees participants do is indicative of their intentions and motivations at a given time. Such assumptions can

be problematic. For example, when a participant grabbed the passive observer's arm, it may not have been social at all. Instead it may have been to get help on a task, but this gesture would nonetheless be scored as a socialisation given the observational criteria, which were appropriate most of the time. There was unfortunately no way of correcting for assumed intentions of acts. Conversely, I witnessed several children sit, seemingly enthralled by the music, but not carrying out a musical gesture as described on the list. Thus, this subtle, but important, reaction to the music could not be scored as a musical gesture. It is also possible that the child's activity with their favourite toys and games during the sessions could have caused them to tune out the music.

Although the silence condition did not seem to elicit fewer musical gestures when it came first than when it came after a musical condition, order may have still had an effect on the results. The number of participants limited the number of possible analyses that could have been done by dividing up the sample.

Chapter Six

General Discussion and Future Investigations

This thesis set out with admittedly ambitious aims in trying to understand better the musical processing of children with autism. The goal of this thesis was to move the literature forward, but with several surprising findings, the results of the studies presented in this thesis caused further questions to emerge. The overarching goal of the thesis was to analyse the nature and extent of musical abilities in children with high functioning autism and severe autism in addition to analysing their relationship to language processing in children with high functioning autism.

6.1 Overview of Studies 1 and 2

This thesis began with an overview of the literature to date on the auditory processing, in the domains of language and music, of individuals with autism. An emergent theme of this literature is the possibility that while the processing of language is deficient, the processing of music may be enhanced in this population. The thesis then presented two original studies to explore the musical and language processing of high functioning children with autism. These studies were based on prior research that has argued that those with autism exhibit enhanced processing of musical, non-linguistic auditory stimuli. In study 1, 11 children with high functioning autism were group-matched to 11 typically developing children on chronological age, nonverbal IQ, gender, and musical training and exposure. The two groups were tested on their ability to identify brief melodies after three rounds of pre-exposure to them through a paired associate learning paradigm where four different animals each had a favourite tune. They were then tested on their ability to pick out the tunes, which were

embedded in a longer melodic gesture or a longer melodic gesture with harmony. Two hours later, their memory of the melodies was tested again. These tasks were intended to be an expansion of Heaton (2003), which showed that children with autism exhibited enhanced abilities at identifying, remembering, and disembedding notes to which they were pre-exposed in a similar paired associate learning paradigm. It was hypothesised that the children with autism would show enhanced abilities on these tasks or that task performance would correlate more to age and nonverbal IQ in the typically developing children. This hypothesis was also based on the work of Applebaum et al. (1979), which assessed musical memory in a very small number of children with autism and typically developing children, and showed that children with autism did as well and sometimes better than controls when asked to repeat back memories they heard.

An "odd man out" game was used to test frequency discrimination. Participants had to point to one of the two dinosaurs that made a different sound from another dinosaur in the middle of the two. It was hypothesised that the children with autism would perform better than the group of typically developing children based on the findings of enhanced discrimination of small intervals by Bonnel et al. (2003), Heaton (2005), and Heaton et al. (2001).

Two language measures were used to compare the groups' language to musical profiles. The children were tested on a nonword repetition task to assess their phonological short term memory and the British Picture Vocabulary Scale II to assess their receptive vocabulary. Compared to the controls, it was hypothesised that the children with autism would be deficient in both of these areas based on the work of Bishop et al. (2004), Kjelgaard and Tager-Flusberg (2001), and Tager-Flusberg and Joseph (2003).

On the melodic identification, memory, and disembedding tasks, the groups performed similarly. This result, however, needs to be interpreted cautiously due to the small number of participants and several in each group not performing above chance. In the harmonic disembedding task and the melodic memory task, there were 2 and 3 more children, respectively, in the typically developing group who performed above chance. Since a null effect is being reported, it is not certain if this task is testing melodic identification, disembedding and memory, for which it was intended. Nevertheless, this finding was surprising given the work of Heaton (2003) and Applebaum et al. (1979). It also calls into question Heaton's hypothesis of a pre-disposition to a savant condition in music in children with autism. As previously discussed, a musical savant exhibits absolute pitch (AP), innate understanding of key relationships, and an extraordinary musical memory. While Heaton (2003) showed evidence of children with autism using AP mechanisms to accomplish tasks of pitch identification, disembedding, and memory, the present study's findings did not present any evidence of exceptional musical memory in children with autism and thus does not add support to the notion of a pre-disposition of a savant condition in music in children with autism. Heaton's (2003) work was based on the theory of weak central coherence, which argues that those with autism focus on the details of the stimuli at the expense of processing the whole. Heaton's finding of enhanced disembedding of notes from chords by the children with autism was argued as further support of this theoretical framework. In the present study, the disembedding of melodic fragments (the "part") from longer melodies and harmonies (the "whole") was used to assess weak central coherence. With the children with autism not performing better than controls on these task, there was no support from this study for the theory of weak central coherence.

The frequency discrimination (FD) task, which had been used in prior studies and shown to be a valid measure of FD, revealed no group differences between the children with autism and typically developing children when the 9 children in each group with a score above chance were compared. This finding was surprising given past research that has used other paradigms and argued that children with autism exhibit better ability at assessing differences in pitch. Bonnel et al. (2003) tested a group with autism's ability to name the sameness or difference of two notes and carried out a signal detection analysis to show that children with autism performed better on these tasks than typically developing children. The researchers argued that this finding supported the enhanced perceptual processing model, which argues that low-level processing is overdeveloped in autism. Heaton (2005) and Heaton et al. (2001) showed that children with autism performed better than typically developing children when asked if a small interval (1-4 semitones) ascended or descended. Perhaps these findings are specific to the paradigms used, and the abilities of the children with autism are not robust enough to show up on all tasks assessing interval processing or FD. The finding of the present study, however, is surprising indeed and worth investigating further.

With the language measures, the children with autism did show deficient receptive vocabulary, and a trend emerged of deficient phonological short term memory in the group with autism. Given that the group of children with autism in the present study were high functioning, the presence of a trend of deficient phonological short term was somewhat surprising given that past research (e. g., Bishop el al. (2004)) showed that those children who were not impaired on verbal IQ exhibited normal phonological short term memory. Although there was not a verbal IQ measure

taken in the present study, a correlation between BPVS II and nonword repetition scores was run and was found to be highly significant in the group with autism.

From study 1, the overall profile of the children with autism is that they performed similarly on the music and FD tasks to controls and less well on receptive vocabulary and phonological short term memory tasks than the controls. This profile of potentially deficient language processing in the context of normal processing of non-linguistic sounds was shown in Čeponienė et al. (2003) where the researchers used ERPs and found that those with autism had trouble attending to features of speech, while they did attend to divergent features of tones. As this is the only known study making such an argument, it is important to investigate this potentially exciting finding further.

It cannot be overstated that the findings of the musical and FD tasks of study 1 were surprising. It thus became important to assess the validity of some of the work on which study 1 was based. Study 2 was a computerised replication of the note identification and disembedding tasks by Heaton (2003) and was carried out with the same group of participants as study 1. A paired associate learning paradigm was set up in a similar fashion to Heaton's. Children in both groups underwent three rounds of pre-exposure to train them that each of the four different animals had a favourite note. The children were then tested on their ability to identify which animal whose note they heard, and then, after another round of pre-exposure, they were asked which animal's note was missing from a chord containing the other three notes.

Heaton's results were not replicated; children with autism performed less well than the typically developing controls on the note identification task and as well as controls on the disembedding task. On the note identification task, all typically developing children performed above chance, while only 6 of the 11 children with

autism performed above chance. These results were counter to predictions. On the identification task, compared to Heaton's research, there was almost a reversal of group scores between the children with autism and the controls. On the disembedding task, Heaton had reported enhanced performance by the children with autism, claiming that this supported the theory of weak central coherence. The present study, with its null effect on the disembedding task, did not provide support for this theoretical framework.

6.2 Limitations of Studies 1 and 2 and Suggestions for Future Research

One limitation of the current studies is the relatively small sample size (11 participants per group), raising the question of whether low statistical power might account for the null results.. However, it should be noted that Heaton had reported very large effect sizes, and claimed that superior musical processing was a characteristic of all children with autism. For the identification task, if there really was an effect of the size that Heaton claimed (d = 1.25), the chance of my showing it at the .05 level in a sample of 11 per group would be 85%. In the disembedding task, if there really was an effect of the size that Heaton claimed (d = 0.92), the chance of my showing it at the .05 level in a sample of 11 per group would be 66%. Thus, for the identification task, where the findings compared to Heaton's results were particularly surprising, the number of participants should have been adequate to find a statistically significant difference. For the disembedding task, it would have been better to have a higher number of participants.

With hindsight, it would have been better to carry out study 2 first, to validate the work of Heaton before building on it. The failure to replicate her findings suggested that, if superior musical processing was found in autism, it was not

universal in this population. This observation might have taken the research in a different direction—that of looking for correlates of good musical performance in a larger sample of children with autism. For instance, with a larger sample, it would have been possible to conduct additional analyses with the dimensional data from the 3dI to try to assess which characteristics of the children with autism led to their success or lack of success on Heaton's tasks. In place of study 1, there could have been more in-depth analyses of the musical processing of different sub-groups of children with autism. If a sub-group were found that performed better than controls on these tasks, perhaps the nature of these children's musical abilities and their relationship to language processing could have tested with the use of the musical tasks set up in study 1. Perhaps members of this sub-group would have all performed above chance which would have thus supplied more reliable data on the melodic processing tasks. The first two studies of this thesis, however, were unfortunately based on the claims of Heaton that these musical processing abilities would be found in all children with autism. This theory was taken for granted and led to surprising outcomes in both studies 1 and 2.

Future studies of this kind should attempt to determine the characteristics of the children who perform better than controls on these musical tasks. Perhaps these skills are only present in a sub-set of those with autism. This would not be surprising given the heterogeneity of most features of the autistic cognitive profile. Indeed, given the evidence for the potential of different language sub-groups in those with autism, sub-groups of varying musical abilities would not be surprising. One observation that did emerge in this study was that within the group with autism, the music scores of study 1 and the performance on the study 2 tasks significantly correlated with the musical exposure and training questionnaire scores; this suggests that it may be that

this high achieving musical group with autism is a group of children that is particularly interested in and exposed to music. This would make sense intuitively, but is counter to Heaton's notion of enhanced musical processing as a core facet of the autistic cognitive profile.

Heaton found that pitch identification and disembedding correlated significantly with block design in her 1998, but not in her 2003 paper, an expansion of the 1998 version. My data did not show such a correlation. The sample was admittedly small and the power low, but it is noteworthy that, the participant with autism who performed at ceiling on all of the melodic music tasks did not have excellent block design. Nevertheless, it would have been useful to test weak central coherence directly (with an embedded figures task, for example) with the groups of children in studies 1 and 2. Although it seems as though it would be difficult to find consistent traits of those who do and do not perform well on the musical tasks of studies 1 and 2, attempts should still be made to try to clarify why such divergent findings emerged in Heaton (2003) and study 2 of this thesis.

The most intriguing finding was the potential divergence of language and musical abilities in children with autism. With hindsight, there could have been more language measures used in study 1 to get a more complete understanding of the language processing of the children in the study. However, there were limits on how much testing children could be expected to endure, and it was felt that priority should be given to the musical tasks. Future studies should look at more complete language batteries to compare them to musical performance and attempt to devise musical measures that are more closely analogous to the language measures. This could rule out the possibility that differences in performance may be due to the demands of the music and language tasks. In the present paired associate learning paradigms,

language tasks of memory and disembedding would be far easier than musical ones and not appropriate. It would be possible, however, to set up a similar "odd man out" paradigm with linguistic instead of tonal sounds to compare performance on such tasks with a group with autism and a typically developing group. Establishing thresholds as in the FD task used in study 1 is a more sensitive measure than tallying correct responses, and may thus provide further insights into the potential difference of music and language processing in those with autism. Assessing musical skill and interest is admittedly difficult because there are no valid standardised measures. Given that the melodic processing tasks of study 1 were difficult with children in both groups not performing above chance, perhaps these tasks were only appropriate for those children who performed well on Heaton's original note identification and disembedding tasks. As was previously mentioned, it would have perhaps been fruitful to assess only the sub-group of musically high achieving children with autism on the study 2 musical tasks.

6.3 Strengths of Studies 1 and 2

Although studies 1 and 2, did not clarify the extent and nature of musical abilities in children with high functioning autism and led to the need for future explorations of the potential musical and language processing divergence in those with autism, there were some important methodological improvements in the present studies compared to the studies on which this thesis was based.

The heterogeneity of autism and the potential for sub-groups of children's language and musical profiles made it all the more important to match the groups on musical exposure and training. With the potential for great heterogeneity in those with autism, the need for such matching could not be understated. Another area which often plagues autism research in general, and certainly the literature on auditory

processing and autism, is the need for the confirmation of an autism diagnosis and the re-affirmation of typical development in the control group. Great efforts were made in the present studies in this thesis to ensure that children with a diagnosis confirmed by the 3dI were included in the autism group and that only children with typical development scores, based on the Children's Communication Checklist and the Social Communication Disorders Checklist, were included in the control group. These improvements from past research were an attempt to set the story straight, particularly in study 2, in what has become a controversial field of research.

6.4 Overview of Study 3

This thesis presented a critical examination of the literature on music therapy with individuals with autism as background for study 3. Research on music therapy has been published mostly in the form of the case study. Two studies that do not use auditory integration training have been published on the effects of music therapy on children with autism, but one (Hollander & Juhrs, 1974) had no formal statistical analyses and another (Edgerton, 1994) had outcome measures that relied solely on the potentially biased observer of the therapy, the therapist herself. Study 3 was an attempt to look at the effects of receptive music therapy in a structured setting and was exploratory in nature given the little empirical work that has been done in this area. This study was an attempt to provide empirical validation of music therapy with individuals with autism. It also tried to assess musical processing in a group of young children with severe autism. All empirical work, albeit limited, on the musical processing of those with autism has been with higher functioning older children, teenagers, and adults with autism. For the notion of musical ability as a part of the autistic cognitive profile to be valid, it would have to be present in children across the ranges of age and severity of autism. This study was also a first attempt to assess a

group of children's musical abilities for whom the musical and frequency discrimination tasks in studies 1 and 2 would not be appropriate.

It was hypothesised that during the music with changes condition, the children with autism would show the highest levels of activity, musical gestures, and socialisations during the music with changes conditions compared to silence. This was based on the music therapy literature that has shown such findings due to music. The scoring of musical gestures were intended to be an indicator of "musical ability" in this group with autism.

The third study was a music therapy-like exploratory, within-subjects, observational experiment of musical responsiveness in a group of 16 young children with severe autism whose levels of activity, musical gestures, and socialisations were assessed over a condition of silence and music with and without many changes (in dynamics, tempo, key, meter, etc.). Two raters, one blind to the musical condition, scored the children's duration of musical gestures and socialisations and ranked the levels of activity across the three conditions during a free play exercise with their favourite toys and games and a passive observer close by.

Although statistically significant differences in musical gestures, socialisations, and levels of activity were not found, this observational paradigm, with high inter-rater reliability, served as a starting point for future investigations with this under-researched population.

Study 3 was exploratory in nature and certainly a first attempt at looking music processing in a lower-functioning population. In the context of the findings of the previous studies, it might be asked whether it was advisable to look at music processing in young children with severe autism. However, it should be borne in mind that study 3 was not attempting to demonstrate superior musical skill of children with

autism vs. a control group, so much as to evaluate the idea, implicit in music therapy, that children with autism are sensitive to music and respond positively to its presence. Also implicit in many forms of music therapy is that music might be a particularly useful way of making contact with children whose language skills are very limited; in this regard, the participants from study 3 were highly suitable for providing an empirical test of this idea.

This study, then, should be seen as attempting to provide an empirical test of some of the underlying tenets of music therapy, which is frequently used in the treatment of autism and not empirically validated. It is important for the field of music therapy to carry out empirical studies that compare the use of the therapy to other, empirically tested forms of treatment of autism. It was disappointing not to find support for music therapy in this study, but it could be argued that the study nevertheless moved the field forward by demonstrating that responsiveness to music can be objectively studied in a sound experimental design and using measures that showed excellent inter-rater reliability.

6.5 On the Importance of Future Investigations on the Musical Processing of Individuals with Autism

Research in the area of musical processing of those with autism is potentially very exciting in its mission to find preserved or enhanced facets of the autistic cognitive profile. For this very reason, it is research that parents, teachers, and carers like to hear about, and it is thus research that receives lots of publicity. The research could also have potentially exciting ramifications in the fields of education of and communication and therapy with children with autism. With these potential ramifications and the public nature of positive findings in this field, the need for solid, well designed and well controlled research is all the more important.

Future studies on high functioning children with autism need to have participant groups large enough to divide into sub-groups of varying musical abilities. In each of these sub-groups, there needs to be full batteries of language and musical processing to see if the relationships between these two areas vary based on the sub-group. Perhaps there is a divergence of language and music in only certain children with autism or perhaps all children show a divergence of language and music, but only some exhibit a level of musical skill that exceeds that of typically developing children. While carrying out these studies, researchers must play close attention to the paradigms used and need to be careful with the claims they make when different paradigms are used to assess similar areas of musical processing. With relatively few studies in the field, it is important that there be solid replications of these studies before they are accepted as standard findings. It is also imperative that diagnoses are confirmed all the time and that groups are matched on not only age and nonverbal IQ, but also musical exposure and training, which could play a huge role in the performance of the children on musical tasks.

Just as there is great potential for positive ramifications of findings in this field, there is also the inherent risk of parents, teachers, and carers developing false hopes of the potential of a child with a developmental disability. There is thus a great need for future research to clarify the state of affairs in this controversial field.

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Appendix One

Social Communication Disorders Checklist

For each of the 12 items below, please mark one box indicating ***Not True***, Quite ***or Sometimes True*** or ***Very or Often True***. It would help us if you answered all of these items the best you can, even if you are uncertain or the item seems inappropriate to your child.
Please give your answers on the basis of the child's behaviour in the **last six months**.

Child's Name.....

Date of Birth..... **Age**.....

Today's Date.....

Over the past six months...	**Not True**	**Quite or Sometimes True**	**Very or Often True**
Not aware of other people's feelings			
Does not realise when people are upset or angry			
Does not notice effect of his/her behaviour on other members of the family			
Behaviour often disrupts family life			
Very demanding of people's time			
Difficult to reason with when upset			
Does not seem to have an understanding of social skills; e.g. Persistently interrupts conversations			
Does not pick up on body language			
Does not understand how to behave when out e.g. In shops or in other people's homes			
Does not realise if behaviour is offensive to other people			
Does not respond when told to do something			
Has difficulty following commands unless they are carefully worded			

Do you have any other comments or concerns?
If 'yes', please describe

Appendix Two

Musical Exposure and Training Questionnaire

(Questions were quantified with score values in red. These values did not appear on actual questionnaire.)

1a) Have you had any formal musical training?
(for example individual music lessons)
(*Please tick*)

Yes
No

b) If yes, for how long?
(*Please circle)*

0-1 yr	2-4 yrs	5-10 yrs
1	2	3

2a) Has your partner had any formal musical training?
(for example individual music lessons)?
(*Please tick*)

Yes
No
N/A

b) If yes, for how long?
(*Please circle*)

0-1 yr	2-4 yrs	5-10 yrs
1	2	3

3) Has your child had any formal musical training?
(*Please tick*)

Yes
No

b) If yes, for how long?
(*Please circle*)

Less than One year	1-2yrs	2-3 yrs	3-4yrs	4+yrs
1	2	3	4	5

4) Does your child engage in any of the following musical activities?
If so for how long? (Please circle)

		½ hr	1hr	1½hr	2+hrs
a)	Individual music lesson	1		3	4

b)	Class music lessons	½ hr	1hr	1½hr	2+hrs
		1	2	3	4
c)	Music therapy	½ hr	1hr	1½hr	2+hrs
		1	2	3	4
d)	Dance/movement classes	½ hr	1hr	1½hr	2+hrs
		1	2	3	4

Total Score = 27

Appendix Three

Musical Exposure and Training Questionnaire-Revised

(Questions 1-4 were quantified with score values in red. These values did not appear on actual questionnaire.)

1a) Have you had any formal musical training?
(for example individual music lessons)
(*Please tick*)

Yes ☐
No ☐

b) If yes, for how long?
(*Please circle)*

0-1 yr	2-4 yrs	5-10 yrs
1	2	3

2a) Has your partner had any formal musical training?
(for example individual music lessons)?
(*Please tick*)

Yes
No
N/A

b) If yes, for how long?
(*Please circle*)

0-1 yr	2-4 yrs	5-10 yrs
1	2	3

3) Has your child had any formal musical training?
(*Please tick*)

Yes
No

b) If yes, for how long?
(*Please circle*)

Less than One year	1-2yrs	2-3 yrs	3-4yrs	4+yrs
1	2	3	4	5

4) Does your child engage in any of the following musical activities?
If so for how long? (Please circle)

		0 hr	½ hr	1hr	1½hr	2+hrs
a)	Individual music lesson	0	1	2	3	4

b)	Class music lessons	0 hr	½ hr	1hr	1½hr	2+hrs
		0	1	2	3	4
c)	Music therapy	0 hr	½ hr	1hr	1½hr	2+hrs
		0	1	2	3	4
d)	Dance/movement classes	0 hr	½ hr	1hr	1½hr	2+hrs
		0	1	2	3	4

Total Score = 27

Appendix Four

Correlations of Studies 1 and 2

Study 1 Correlations for Children with Autism

		Age	WASI Block Design Raw Score	WASI Matrix Reasoning Raw Score	Music Tasks Summary Score	Frequency Discrimination Optimal Score	BPVS Raw Score	NWR Raw Score	Musical Exposure and Training Questionnaire Score
Age	*r*	1	0.297	0.378	0.169	0.072	-0.064	-0.209	0.165
	p		0.376	0.252	0.641	0.853	0.852	0.538	0.629
WASI Block Design Raw Score	*r*	0.300	1	0.223	-0.197	-0.125	0.367	0.311	-0.002
	p	0.380		0.510	0.585	0.748	0.267	0.352	0.995
WASI Matrix Reasoning Raw Score	*r*	0.380	0.223	1	0.394	0.098	0.562	0.691	0.159
	p	0.250	0.510		0.260	0.802	0.072	0.018	0.641
Music Tasks Summary Score	*r*	0.170	-0.197	0.394	1	-0.207	0.406	0.314	0.829
	p	0.640	0.585	0.260		0.623	0.244	0.377	0.003
Frequency Discrimination Optimal Score	*r*	0.070	-0.125	0.098	-0.207	1	-0.278	-0.065	-0.466
	p	0.850	0.748	0.802	0.623		0.469	0.869	0.206
BPVS Raw Score	*r*	0.060	0.367	0.562	0.406	-0.278	I	0.898	0.013
	p	0.850	0.267	0.072	0.244	0.469		0.000	0.969
NWR Raw Score	*r*	0.209	0.311	0.691	0.314	-0.065	0.898	1	0.012
	p	0.538	0.352	0.018	0.377	0.869	0.000		0.972
Musical Exposure and Training Questionnaire Score	*r*	0.165	-0.002	0.159	0.829	-0.466	0.013	0.012	1
	p	0.629	0.995	0.641	0.003	0.206	0.969	0.972	

Study 1 Correlations for Typically Developing Children

		Age	WASI Block Design Raw Score	WASI Matrix Reasoning Raw Score	Music Tasks Summary Score	Frequency Discrimination Optimal Score	BPVS Raw Score	NWR Raw Score	Musical Exposure and Training Questionnaire Score
Age	*r*	1	0.801	0.514	0.503	-0.460	0.874	0.564	0.699
	p		0.003	0.106	0.138	0.213	0.000	0.071	0.017
WASI Block Design Raw Score	*r*	0.801	1	0.610	0.290	-0.399	0.844	0.711	0.440
	p	0.003		0.046	0.416	0.288	0.001	0.014	0.176
WASI Matrix Reasoning Raw Score	*r*	0.514	0.610	1	0.549	-0.890	0.644	0.568	0.654
	p	0.106	0.046		0.100	0.001	0.032	0.068	0.029
Music Tasks Summary Score	*r*	0.503	0.290	0.549	1	-0.457	0.548	0.352	0.509
	p	0.138	0.416	0.100		0.254	0.101	0.318	0.133
Frequency Discrimination Optimal Score	*r*	-0.46	-0.399	-0.890	-0.457	1	-0.553	-0.525	-0.705
	p	0.213	0.288	0.001	0.254		0.122	0.147	0.034
BPVS Raw Score	*r*	0.874	0.844	0.644	0.548	-0.553	1	0.703	0.548
	p	4E-04	0.001	0.032	0.101	0.122		0.016	0.081
NWR Raw Score	*r*	0.564	0.711	0.568	0.352	-0.525	0.703	1	0.536
	p	0.071	0.014	0.068	0.318	0.147	0.016		0.090
Musical Exposure and Training Questionnaire Score	*r*	0.699	0.440	0.654	0.509	-0.705	0.548	0.536	1
	p	0.017	0.176	0.029	0.133	0.034	0.081	0.090	

Studies 1 and 2 Correlations for Children with Autism

		Study 1 Music Tasks Summary Score	Frequency Discrimination Optimal Score	BPVS Raw Score	NWR Raw Score	Study 2 Note Identification Score	Study 2 Note Disembedding Score	Musical Exposure and Training Questionnaire Score
Study 1 Music Tasks Summary Score	*r*	1	-0.207	0.406	0.314	0.648	0.676	0.829
	p		0.623	0.244	0.377	0.043	0.032	0.003
Frequency Discrimination Optimal Score	*r*	-0.207	1	-0.278	-0.065	-0.462	-0.507	-0.466
	p	0.623		0.469	0.869	0.210	0.163	0.206
BPVS Raw Score	*r*	0.406	-0.278	1	0.898	0.363	0.092	0.013
	p	0.244	0.469		0.000	0.272	0.788	0.969
NWR Raw Score	*r*	0.314	-0.065	0.898	1	0.343	-0.058	0.012
	p	0.377	0.869	0.000		0.302	0.866	0.972
Study 2 Note Identification Score	*r*	0.648	-0.462	0.363	0.343	1	0.650	0.692
	p	0.043	0.210	0.272	0.302		0.030	0.018
Study 2 Note Disembedding Score	*r*	0.676	-0.507	0.092	-0.058	0.650	1	0.819
	p	0.032	0.163	0.788	0.866	0.030		0.002
Musical Exposure and Training Questionnaire Score	*r*	0.829	-0.466	0.013	0.012	0.692	0.819	I
	p	0.003	0.206	0.969	0.972	0.018	0.002	

Studies 1 and 2 Correlations for Typically Developing Children

		Study 1 Music Tasks Summary Score	Frequency Discrimination Optimal Score	BPVS Raw Score	NWR Raw Score	Study 2 Note Identification Score	Study 2 Note Disembedding Score	Musical Exposure and Training Questionnaire Score
Study 1 Music Tasks Summary Score	*r*	1	-0.457	0.548	0.352	0.521	0.584	0.509
	p		0.254	0.101	0.318	0.123	0.076	0.133
Frequency Discrimination Optimal Score	*r*	-0.457	1	-0.553	-0.525	-0.265	0.063	-0.705
	p	0.254		0.122	0.147	0.492	0.872	0.034
BPVS Raw Score	*r*	0.548	-0.553	1	0.703	0.805	0.262	0.548
	p	0.101	0.122		0.016	0.003	0.437	0.081
NWR Raw Score	*r*	0.352	-0.525	0.703	1	0.477	0.019	0.536
	p	0.318	0.147	0.016		0.138	0.957	0.090
Study 2 Note Identification Score	*r*	0.521	-0.265	0.805	0.477	1	0.266	0.480
	p	0.123	0.492	0.003	0.138		0.430	0.135
Study 2 Note Disembedding Score	*r*	0.584	0.063	0.262	0.019	0.266	1	0.464
	p	0.076	0.872	0.437	0.957	0.430		0.151
Musical Exposure and Training Questionnaire Score	*r*	0.509	-0.705	0.548	0.536	0.480	0.464	1
	p	0.133	0.034	0.081	0.090	0.135	0.151	