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HOW DOES EMOTIONALITY AFFECT MEMORY IN CHILDREN WITH AUTISM?

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HOW DOES EMOTIONALITY AFFECT MEMORY IN CHILDREN WITH AUTISM?

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ABSTRACT

Meints, Samantha Marie. M.S., Purdue University, December 2013. How Does Emotionality Affect Memory in Children with Autism? Major Professor: John McGrew.

The purpose of the current study was to investigate the impact of emotionality on the memory of children with an autism spectrum disorder. Although emotional events enhance memory in adults and children without an autism spectrum disorder, there are different memory patterns among individuals on the autism spectrum. Specifically, individuals with autism may show a decreased advantage in memory for emotional content and may have deficits in memory for information that is not presented visually. Currently, however, there are no studies that look at how emotional content affects memory specifically in children with autism. In the current study, children with and without autism were presented with stimuli contrasting emotional and neutral content using one of two modalities, auditory and visual, and then completed memory recognition tasks for the stimuli. Results indicate that children with an autism spectrum disorder did not demonstrate enhanced memory for emotional information. Rather, they were equally able to remember emotional and neutral stimuli. Additionally, individuals on the spectrum demonstrated better memory for visual stimuli compared to their neurotypical peers. These results support the notion that individuals with an autism

spectrum disorder may learn and remember material differently than those without the disorder and that educators need to acknowledge these differences as children with autism spectrum disorders continue to be integrated into classroom settings.

CHAPTER 1. INTRODUCTION

1.1 Introduction

Autism, a developmental disorder affecting 1 of every 88 children, is characterized by communication deficits, sensory motor fixations, and impaired social skills and abilities (Centers for Disease Control and Prevention, 2012). The current study focuses on factors associated with impairments in social skills. One factor thought to underlie these social skills impairments is a deficit in the ability to accurately detect and attend to emotions in the environment, a prerequisite for socially appropriate behavior. Current theorizing suggests that this impairment may be due to an abnormality in the amygdala, which has a central role in forming and retrieving emotional memories.

A further complicating factor is that people with autism avoid eye contact as well as avoid looking directly at faces (Dalton et al., 2008; Kliemann et al., 2010; Riby and Hancock, 2009; Richer & Coss, 1976). This avoidance may lead to missing critical emotional cues in visually presented material, which could further impair the ability to act appropriately in social situations. Prior research has been largely limited to adults or adolescents. The current study examines a possible deficit in identification of and memory for visual and auditory emotional stimuli in children with an autism spectrum disorder (ASD).

1.2 Autism

Autism is a pervasive developmental disorder evident during the first three years of life involving impairment in social interactions and communication and a tendency to use restricted and repetitive behaviors (DSM-IV-TR, 2000). People with autism may demonstrate abnormal non-verbal behavior such as a lack of eye contact or inappropriate facial expressions and body posture. They also often fail to develop peer relationships, which may be due to a lack of sharing personal interests and enjoyment. In addition, they generally display a delay or lack of spoken language and an inability to initiate or maintain conversation.

Although there is no single cause of autism, several etiological theories have been proposed that help to inform the current study. For example, in helping to explain social deficits, the extreme male brain theory of autism proposes that there are five types of brains: female, male, balanced, extreme female, and extreme male. People with autism are thought to have the extreme male form (Baron-Cohen, 2002). These brain types are differentiated by how well one can empathize (a requirement for social behavior) vs. systemize. Those with a male brain are thought to be better able to systemize, or predict the behavior of a system and therefore control it, those with a female brain are thought to be better able to empathize, or predict human behavior and understand how others feel, and those with a balanced brain can do both equally well. As postulated by the theory, research shows that typical females are better than males at responding with empathy to those in distress, even at a young age (Hoffman, 1977). Furthermore, girls are better than boys at inferring what others are thinking (Happe, 1995) and interpreting body language (Hall, 1978).

Consistent with the predictions of the extreme male theory, individuals with autism tend to show an extreme or exaggerated pattern of strengths and weaknesses compared to those with typically developing male brains. For example, persons with autism are actually worse than typical boys at predicting others' feelings and behaviors (Happe, 1995) and discriminating emotions in facial expression (Baron-Cohen et al., 1997). Additionally, they show an even more pronounced interest in systematic toys and closed systems, such as computers, just as those with a male brain do (Baron-Cohen & Wheelwright, 1999). Thus, a propensity toward extreme male brain-type may characterize those with autism, and help to explain some of the social deficits observed. However, it is also important to note that the extreme male brain theory cannot explain all the symptoms associated with autism (e.g., mental retardation, language delay). Explaining the full range of autistic symptoms across individuals likely will require a multi-theoretical approach.

Another theory of autism is the amygdala theory. The amygdala is an area of the brain that is central to proper social functioning in both humans and primates. For example, primates with neonatal damage to their limbic system caused by experimental lesions to the amygdala showed signs of socio-emotional impairment across their lifespan (Beversdorf et al., 1998). These monkeys became isolated and did not respond to social gestures appropriately. Similarly, a study of rhesus monkeys with lesions on the mesial temporal lobe structures, including the amygdala, showed that they were more socially withdrawn from peers and initiated fewer social contacts (Bachevalier, 1994). Researchers have also examined the effects of amygdala lesions in humans, finding similar social impairments in humans (Adolphs, Sears, & Piven, 2001).

The pattern of social abnormalities found in both primates and humans is similar to the social abnormalities of those on the autism spectrum, and has led researchers to study the role of the amygdala in the social functioning of persons with autism. In fact, a number of researchers have suggested that dysfunction in the amygdala may underlie some of the characteristics of autism (Baron-Cohen et al., 2000; Damasio & Maurer, 1978). Consistent with this suggestion, studies have shown increased cell packing density in the amygdala of people with autism (Bauman & Kemper, 2003) and imaging studies have shown increased amygdala size in those with the disorder (Howard et al., 2000). Interestingly, increased amygdala size also has been correlated with social group size in primates: as the size of the amygdala increases, the size of the primate's social group decreases. In this case, group size represents social complexity (Emery et al., 1998), that is, larger amygdalae are associated with lower levels of social complexity. More recently, investigators have examined brain function associated with the amygdala during socio-emotional tasks in those with autism. Groups of neurologically normal and autistic adults were asked to judge emotion based solely on pictures of pairs of eyes while undergoing an fMRI. Patients with high-functioning autism spectrum disorders were poorer at identifying emotion and showed less amygdala activation than those without autism, suggesting that the amygdala has a significant effect on a person's social intelligence and that amygdala abnormalities are associated with Autism Spectrum Disorders (Baron-Cohen et al., 1999). In fact, clinical patients with acquired amygdala lesions demonstrate impairments in social judgments and have been described as having "acquired autism" **(**Stone, Baron-Cohen, Calder, Keane, & Young, 2003)**.**

1.3 Memory

Deficits in emotional memory also are associated with amygdala dysfunction and may underlie some of the social deficits in those with autism. This next section will overview what we know about general memory function as well as emotional memory in those with and without autism. Because the current study focuses on children, particular attention will be paid to studies with this age group.

Prior to reviewing this literature, however, it is important to note that there are many different types of memory (e.g., short term, long term) and there are several ways to measure each type (e.g., recall, recognition). When examining memory, it is best to describe a memory profile. In this first general section, however, I will focus on aspects of emotional memory.

Memory for events that elicit emotions is often stronger than memory for neutral events (Christianson & Loftus, 1987; Heuer & Reisberg, 1990). Autobiographies demonstrate this concept well. Emotional experiences are usually recalled in autobiographies because one remembers these events more clearly and forgets them more slowly (Berntsen & Rubin, 2002).

Identification of emotions occurs at an early age. In fact, children four years of age can identify emotions and match facial expressions to those emotions (Camras & Allison, 1985). Not only do young children identify emotions, but the effects of those emotions on memory are found across the life span. For instance, pre-school students can easily recall emotional events from their lives and can use emotional labels to describe those events (Fivush, Berlin, McDermott Sales, Mennuti-Washburn, & Cassidy, 2003; Lagattuta & Wellman, 2002; McDermott Sales, Fivush, & Peterson, 2003). Furthermore, children age seven through eleven recall emotional information better than neutral information from stories and from pictures (Davidson, Luo, & Burden, 2001; Dolcos, LaBar, & Cabeza, 2004). For example, Cahill and McGaugh (1995) showed control and experimental subjects the same series of slides accompanied by two different stories, one emotional and one neutral. Subjects who heard the emotional story remembered more than those who heard the neutral story.

A recent series of studies by Davidson and colleagues explored whether emotional intensity or valence affected memory for emotional events in six-, eight-, and ten-year-old neurotypical children (Davidson, 2006; Davidson et al., 2001). The children heard short stories containing neutral events and behaviors, as well as positive and negative emotional ones, sometimes with and sometimes without their emotional labels. The children then freely recalled the stories. One study also manipulated the strength of the emotion depicted, for example, a strong negative emotional event would be the death of a parent while an event that evokes a moderate negative emotion would be losing your favorite toy. In both studies, emotional events were recalled better than neutral ones and better than the simple emotional label (e.g., sad). However, the strength of the emotion was not a factor in recall; children recalled events high and low in emotionality equally well. The results also indicated that the emotional valence of the behaviors was unimportant. There was no difference in memory for positive and negative emotional behaviors (Davidson et al., 2001). Although emotional labels were not remembered well, their presence did increase memory for the emotional events and behaviors, possibly because labels help the children correctly identify the emotion. Widen and Russell

(2004), support this interpretation, also reporting that children are better at recognizing emotions when a label is present.

Gender may also play a role in emotional memory as women have been shown to recall more emotional autobiographical events than men in timed tests; additionally, women produce these memories more quickly and with greater intensity than men (Fujita, Diener, & Sandvik, 1991). In contrast, as suggested by the extreme male brain theory, females and males with autism may demonstrate equally poor memory for emotional events because both exhibit the extreme male version of the brain.

Research suggests that the amygdala plays a central role in these emotional memories (Cahill, 2000; McGaugh, Ferry, Vazdarjanova, & Roozendaal, 2000). Using fMRI, researchers have documented activity in the amygdala and medial temporal lobe when individuals view emotional stimuli (Dolcos et al., 2004). When examining memory for emotional material, studies have shown that the amygdala, medial prefrontal cortex, hippocampus, lateral prefrontal cortex, and the parietal cortex are all involved in the successful retrieval of emotional memories (Buchanan, 2007). The right amygdala, in particular, is critical for retrieving intense and unpleasant autobiographical events (Buchanan, 2007). As the strength of the emotional arousal increases, so does the amygdala's ability to enhance memory (Cahill & McGaugh, 1998). Although details may not be remembered, the amygdala enhances memory for the gist of emotional stimuli, focusing resources on the most salient information (Adolphs, Tranel, & Buchanan, 2005). As a result, damage to the amygdala is associated with a lack of enhanced memory for emotional material (Adolphs, Tranel, & Denburg, 2000; Babinsky et al., 1993; Hamann, Lee, & Adolphs, 1999; Phelps et al., 1998).

1.3.1 Memory in Those with Autism

Given the striking increase in the number of children being diagnosed with autism, now estimated at 1 in 88 (CDC, 2012), and the need to integrate these children into school settings, research is critically needed to examine how those with autism learn and remember new material. However, although a number of studies have focused on how memory is affected by autism (Minshew & Goldstein, 1998; Minshew & Goldstein, 2001; Minshew, Goldstein, Muenz, & Payton, 1992; Minshew, Goldstein, Taylor, & Siegel, 1994; Williams, Goldstein, Minshew, 2005; Williams, Goldstein, Minshew, 2006; Mottron, Morasse, & Belleville, 2001), with most reporting that the general memory function of autistic individuals differs from the norm, there is relatively little research on school-aged persons with autism.

In reviewing this literature, it is important to keep in mind that there are key differences across studies in the stimulus (e.g., modality—auditory vs. visual, content—emotional vs. neutral), the type of memory assessed (e.g., long term vs short term), and how memory is measured (recall vs recognition). When discussing the research on memory in autism, I will attempt to summarize salient differences in the literature along the following dimensions: how memory is measured (delayed vs. immediate memory and recognition vs. recall memory), and the method and content of stimulus presentation (visual vs. auditory, narrative vs. non-narrative, complexity, social content, and emotionality of the information to be remembered.)

There is evidence that immediate recognition memory and all delayed memory are intact for individuals with autism (Barth, Fein, & Waterhouse, 1995; Bennetto, Pennington, & Rogers, 1996; Minshew et al., 1992; Minshew et al. 1994; Minshew &

Goldstein, 2001; Williams, Goldstein, & Minshew, 2006). Children and adolescents with autism performed equally well compared to those without autism on both an immediate and delayed recognition word tasks (Bennetto, Pennington, & Rogers, 1996). Similar results showing intact immediate and delayed recall and recognition memory for both verbal and visual tasks in children with autism were reported by Williams and colleagues (2006).

Although it is generally believed that individuals with autism have problems processing information presented verbally, the current research suggests that while there is a preference or perhaps even an advantage for visually presented information, there are no deficits in remembering auditory information relative to neuro-typical individuals. Adolescents and young adults with autism performed just as well on a delayed verbal memory task as those without the disorder and performed better on a delayed visual memory task than their unaffected peers (Minshew & Goldstein 2001). However, consistent with the findings of Williams, Goldstein, and Minshew (2006), the complexity of the information did impact memory. Both children and adults with autism demonstrated memory deficits when the complexity of the material increased and this was true for both visual and auditory stimuli. Adults with autism scored lower on a story memory task and a task recalling letters, words, and oral direction sequences of increasing semantic complexity compared to their neuro-typical counterparts (Minshew & Goldstein, 2001). Children with autism had poor memory for both complex visual and auditory stimuli, but had intact verbal working memory (Williams, Goldstein, & Minshew, 2006). The memory impairments documented in these studies were attributed to an inefficient use of semantic structure and were not due to modality. That is, memory ability was the same regardless of whether the material was presented visually or auditorily. As the complexity of the task increased, however, the memory of individuals with autism decreased.

In summary, the data indicates that immediate and delayed recognition and recall memory are intact in those with autism. Although there was no consistent effect of modality of information presentation (visual vs. auditory), the complexity of the information impacted memory ability. As stimuli complexity increases, memory for the stimuli decreases, a trend that is more pronounced in those with autism.

Another factor affecting memory is the content of the stimuli. Consistent with this idea, a critical deficit in those with autism, as posited by both the extreme male brain and amygdala theories of autism, is difficulty expressing empathy and interpreting socially important emotional cues from others. However, surprisingly few studies have directly examined memory for emotional or social material in those with autism. For example, because individuals with autism exhibit social deficits, Williams, Goldstein, and Minshew (2005) wanted to examine their memory for social stimuli. They found that adults with autism showed impaired memory for faces and social scenes, but not for word pairs and stories or for verbal working memory. Thus, in contrast to previously cited research, this suggests that those with autism may have difficulty remembering visual stimuli when it is socially-based. Alternatively, they may not attend to the social aspect of the pictures and scenes and, therefore, will not benefit from the presence of emotionality. That is, the deficit may be in formation rather than in retrieval of the memory.

In another study, adults with autism and neuro-typical controls listened to a recording of 10 high emotion statements intermixed with 10 neutral statements and then recalled all of the sentences. Though there was no group differences in overall recall memory, subjects without autism recalled the high emotion statements better than the neutral ones, but the subjects with autism did not show a preference, recalling the high emotion and neutral statements equally well (Beversdorf et al., 1998). In a second study, adults with autism viewed two sets of slides, each accompanied by a short story. One story contained an emotionally arousing component while the other did not; however, each set of slides contained an aversive picture, whether or not the accompanying story was meant to be emotionally arousing. Results of the study demonstrated that adults with autism did have enhanced memory for the section of the story with the accompanying aversive picture regardless of whether the story was emotional or neutral, suggesting that an emotionally aversive visual stimulus enhances memory whereas an emotional narrative does not (Sollinger, 2005). That is, those with autism spectrum disorders have deficits for verbally presented stimuli with social content, but their memory is aided when the verbal stimuli is accompanied by visually presented stimuli containing aversive emotional content. To date, however, these findings have not been replicated in children with autism.

1.4 Summary and Conclusions

Abnormal patterns of eye contact, specifically active avoidance of eye contact, are typical for individuals with autism. This can be viewed as another manifestation of the social impairments that are characteristic of people with the disorder. Individuals with autism have difficulty empathizing and understanding the perspective of others and, therefore, often engage in activities that require little socialization. Instead, those with autism tend to enjoy activities with set rules and that are part of a consistent system. The Extreme Male Brain Theory attributes this preference to a brain type that resembles the typical male brain. Those with a male brain are better at systematizing, while those with a female brain are better at empathizing. However, because individuals with autism are all thought to have an extreme male brain, there may not be a gender advantage for females vs. males with autism in their ability to process emotional information.

Researchers have yet to determine the specific cause of autism, however, they have found evidence of impaired amygdala functioning and abnormal amygdala size in those with the disorder. The amygdala is not only associated with appropriate social functioning, it is also integral in processing emotional memories.

Although we know that emotional events enhance memory in healthy children and adults, there is evidence that people with an autism spectrum disorder remember information differently than those without the disorder. While recognition and recall memory seem to be intact, persons with autism tend to show memory deficits when the information presented is complex in nature, may have impaired memory for stimuli that is not presented visually, and may show a decreased advantage in memory for emotional content. Currently, however, there are no studies that look at how emotional content affects memory specifically in children with autism.

The current study examined the individual and interactive impact of two factors on recognition memory in neurotypical individuals and individuals with autism spectrum disorders: type of stimuli (auditory vs. visual) and emotional content (emotional vs.

neutral). Because previous research indicates that individuals with an autism spectrum disorder may have memory deficits for complex material, I used simple stimuli to control for any effects of complexity. Based on the above evidence, I expected to find:

Autism vs neurotypical

Areas of equivalence

1) Overall, memory for neutral stimuli will be equivalent for those with and without an autism spectrum disorder (Bennetto, Pennington, & Rogers, 1996; Williams, Goldstein, & Minshew, 2006).

2) Memory for auditory stimuli will be equivalent for those with and without and an autism spectrum disorder spectrum disorder (Minshew & Goldstein 2001).

Areas of non-equivalence

3) Compared to neurotypical controls, individuals with an autism spectrum disorder will have better memory for visual stimuli (Minshew & Goldstein 2001).

Within autism group

Areas of equivalence

4) Those with an autism spectrum disorder will remember emotional and neutral stimuli equally well (Beversdorf et al., 1998).

5) In contrast to neurotypical individuals, females and males with an autism spectrum disorder will show equivalent memory for emotional material (Happe, 1995).

Within neurotypical group

Areas of non-equivalence

6) Neurotypical controls will remember emotional stimuli, both visual and auditory, better than neutral stimuli (Davidson, Luo, & Burden, 2001; Dolcos, LaBar, & Cabeza, 2004).
7) Restricted to those without an autism spectrum disorder, females will show better memory for emotional material than males (Fujita, Diener, & Sandvik, 1991).

Total Sample

Areas of non-equivalence

8) Memory for emotional stimuli will be better for all children when the emotion is labeled (Davidson et al., 2001; Widen & Russell, 2004).

CHAPTER 2. METHODS

2.1 Participants

To recruit individuals with an autism spectrum disorder, I contacted several organizations, including the Hamilton and Johnson County Autism Support Groups, schools, and ABA centers in the Indianapolis area that work with children with autism. Parents of interested individuals contacted the investigator by telephone or email. Parents of potential participants were then screened over the phone to verify eligibility for the study using the Childhood Autism Rating Scale-2nd Edition (CARS-2) Parent/Caregiver Questionnaire (described below in measures). The researcher scored the CARS-2 independently using the parent information. Children who scored in the autism range on the CARS-2 (greater than 30) were included in the autism spectrum disorder group.

To attempt to recruit "matched" participants for the neurotypical control group, the parent or guardian of each child with an autism spectrum disorder was asked to provide the name and contact information for a child they knew who does not have autism. However, very few matched pairs were obtained (only three age-matched children and four additional children who did not match closely on age) because either parents did not provide names or the names they did provide were not age- and gender-matched. Thus, to obtain the needed neurotypical control sample, I also advertised the study in JagNews, a group email that is periodically sent out to members of the IUPUI community, and IndyChild, a website for parents living in the Indianapolis area. Most of the neurotypical control sample (n=8) was obtained using these outlets and, thus, was predominantly a convenience sample, not a matched sample. Only neurotypical children who scored below 24 on the CARS-2 were included. Children scoring between 24-29 were excluded from the study. In addition, control participants were required to be able to communicate verbally and not to have an intellectual disability.

Of the thirty-two parents that responded to the advertisements, all thirty-two children were eligible to participate. One child, however, missed his scheduled testing time, could not be reached to reschedule the appointment and therefore was not included. The final sample consisted of thirty-one children, ranging in age from nine to fifteen years of age (see Table 3 for participant characteristics). Fifteen were neurotypical controls and sixteen had an autism spectrum disorder, either autism (n=6), Asperger's Disorder (n=7), or a pervasive developmental disorder-not otherwise classified (n=3). A comparison of the autism spectrum disorder and neurotypical groups indicated that there were no significant differences in age, gender, socioeconomic status, reading level, and short term memory ability between the groups (see preliminary analyses).

2.2 Stimuli

Auditory and visual stimuli were created for the study. In addition to varying the modality of presentation, the stimuli were designed to vary the emotion depicted and whether the emotion was labeled or unlabeled.

2.2.1 Auditory

The auditory stimuli included 24 sentences, depicting one of three emotions (See appendix A). Eight sentences depicted happy events, eight depicted sad events, and eight depicted neutral events. Sentences were constructed to be appropriate for children between the ages of eight and fifteen. Each sentence included a person, who is the subject of the sentence, and an action. Four of the happy sentences and four of the sad sentences also explicitly labeled the person's emotional reaction to the activity. To ensure that the memory load was equivalent across the three emotion sets, sentence length was matched between emotion sets. The eight sad, happy and neutral sentences were selected from an initial pool of 16 sad, 16 happy and 8 neutral sentences (see appendix C for pilot stimuli). The initial pool of sentences was piloted with a convenience sample of ten neurotypical adults to confirm that the sentences depicted the correct emotion and to select the eight sentences that best depicted each emotion. Participants read the sentences, and were asked to identify the emotion portrayed in the sentence. Participants also ranked the happy and sad sentences within type, from 1 to 16, with 1 indicating the sentence that was least representative of the depicted emotion and 16 indicating the most representative. To be retained, every person had to label the sentence with the correct emotion. Of the retained sentences, the eight sentences of each type rated as most representative of the emotion were used for auditory stimuli (see appendices E and F for pilot data).

2.2.2 Visual

The visual stimuli included 24 photographs, depicting one of three emotions (See appendix B). Eight photographs displayed a happy emotion, eight displayed a sad emotion, and eight displayed neutral events. The photographs included a person, who is the subject of the photograph completing an action. The subjects of the happy and sad stimuli were photographed from either the front or the side, while those in the neutral stimuli were photographed from the side or the back, never the front. To ensure that these photos portrayed the sought after emotion or lack of emotion, they were piloted with the same convenience sample of ten neurotypical individuals described above (see appendix D for pilot stimuli). Out of a pool of 11 happy, 11 sad, and 11 neutral pictures, subjects identified the emotion in each photo (either happy, sad, or neutral), and then ranked the happy and sad pictures within type, from 1 to 11, with 1 indicating the least representative of the depicted emotion and 11 indicating the most representative. To be retained, every person had to label the picture with the correct emotion. Of the retained photos, the eight of each type rated as the most representative of the emotion were chosen as visual stimuli (see appendices G and H for pilot data).

2.3 Measures

2.3.1 Demographic Questions

The demographic questionnaire asked for age, race, gender, and grade level of the participant. Additional questions asked whether or not the child has corrected vision or a hearing impairment, and, if so, how it is corrected or managed. The questionnaire asked if the child has been diagnosed with an autism spectrum disorder or any other physical, emotional, or cognitive disability, and, if so, the specific diagnosis (e.g., autism, PDD-

NOS), when the diagnosis was made, and by whom. Furthermore, to assess comparability of the groups, questions about household income and parental education level were included.

2.3.2 Childhood Autism Rating Scale-Second Edition

The Childhood Autism Rating Scale-Second Edition (CARS-2) was used to verify autism diagnosis. The CARS-2 is a 15-item rating scale used to identify children over the age of 2 with autism (Schopler, Van Bourgondien, Wellman, & Love, 2010). The range of scores for the CARS-2 is 15-60. Scores of 30 or above indicate autism. The CARS-2 has a high degree of internal consistency and good inter-rater reliability. It also has good sensitivity and specificity (.81 and .87, respectively).

2.3.3 Wide Range Achievement Test-Fourth Edition

The Wide Range Achievement Test-Fourth Edition (WRAT-4) was used to assess overall academic skill. The WRAT-4 can be used to assess academic skill in individuals age 5 to 94 (Dell, Harrold, & Dell, 2006). It contains four subtests, Word Reading, Sentence Comprehension, Spelling, and Math Computation. Reading ability can be assessed using the Word Reading and Sentence Completion subtests. Complete administration of the assessment takes from 35 to 45 minutes for children 8 years or older. The WRAT-4 has good internal consistency reliability for Reading Ability (.95) and is a moderate to good predictor of full-scale-IQ (r=.72) (Wilkinson & Robertson, 2006).

2.3.4 General Memory

The Digit Span task was used to assess general memory ability. Digit Span is a test of working memory taken from the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV). Participants hear increasingly long strings of numbers and are asked to verbally recall them in order. For each string of numbers correctly recalled, the participant receives one point. The points are summed after completion of the task; higher scores equate to better short-term working memory.

2.3.5 Auditory Recognition

To assess recognition, participants read a set of three sentences, one from the original 24 auditory stimuli (described earlier) they heard previously and two distracters. The participant identified which sentence they heard previously. There were 24 sets of three statements, one set for each sentence the participants previously heard, presented in random order. Participants earned one point for each stimulus recognized correctly. (See Appendices I and K for items and item difficulty scores).

2.3.6 Visual Recognition

To assess recognition, participants identified the photographs they had already seen. Participants saw a series of three photos, one from the original 24 visual stimuli they saw (described earlier) and two distracters. There were 24 sets of three photos, one set for each photo the participants previously saw. Participants viewed the photo sets in random order. They earned one point for each stimulus recognized correctly. (See Appendix J and L for items and item difficulty scores).

To create specific measures to test the hypotheses, I created scale scores based on the mean number correct for the following item sets: neutral stimuli, emotional stimuli, neutral visual stimuli, emotional visual stimuli, total visual stimuli, auditory stimuli with labels, and auditory stimuli without labels. These scale scores were then used in all analyses.

2.4 Procedure

As described earlier, for each prospective child participant, his/her parent was contacted first via telephone and asked a series of screening questions to assess the child's appropriateness for inclusion in the study. Prior to providing screening information, parents or guardians of all participants were asked to provide verbal consent via telephone. Each eligible child and his/her parent was then invited to be tested individually in a laboratory at IUPUI, in a quiet room at his or her home, or in a private room at a local library. This ensured that distractions were limited. Prior to participating in the face-to-face data collection, parents also provided written informed consent for their child to participate in the study. In addition, all child participants provided written assent. After informed consent was obtained, the parent was asked to leave the room during the testing procedure to keep the administration of the protocol standardized. After completion of the data collection, each child participant was provided with candy to thank them for participating.

Participants were presented with the auditory and visual stimuli described above. Presentation order of visual and auditory stimuli was counterbalanced to avoid order effects. Half of the participants saw the visual stimuli first followed by the auditory stimuli and the other half heard the auditory stimuli first, followed by the visual stimuli.

A recording of the auditory stimuli (8 happy, 8 sad, and 8 neutral sentences) was played. Stimuli were presented in a monotone followed by a brief pause. The types of sentences (happy, sad and neutral) were intermixed and there were two versions of the recording, each presenting the sentences in a different order. Half of the participants heard one version and half heard the other to control for order effects. After the participant heard all of the sentences, the examiner presented the sentence recognition questions via slides on a computer screen. Each slide contained three sentences, two were new and one that the participant had already heard. The participant read each sentence and then verbally indicated which sentence he had already heard. This continued for all 24 sentence recognition questions while the examiner recorded each response by hand.

The visual stimuli (8 happy, 8 sad, and 8 neutral photographs) were presented on a computer monitor and the child viewed each picture for 5 seconds. The types of photographs (happy, sad and neutral) were intermixed and there were two versions of the slide show, each presenting the photographs in a different order. Half of the participants viewed one version and half viewed the other to control for order effects. After the participant viewed all of the photographs, the examiner presented the visual recognition questions via slides on a computer screen. Each slide contained three pictures, two that were new and one that the participant had already viewed. The participant looked at each picture and verbally indicated which one he had already viewed. This continued for all 24 visual recognition questions while the examiner recorded each response by hand.

After the memory tasks, as a manipulation check, the examiner presented the child with each sentence and each picture from the visual and auditory stimuli. The child was asked to identify which, if any, emotion was depicted in each sentence or photograph. Afterward, the examiner administered a digit span task to test for overall short-term working memory and the Word Reading and Sentence Comprehension subtests of the Wide Range Achievement Test (WRAT4) to test for overall reading ability.

2.5 Statistical Analyses

Table 1 outlines the hypotheses and the operationalization of each hypothesized variable.

2.5.1 Tests of Non-equivalence

To test hypotheses comparing individuals with and without an autism spectrum disorder, I performed independent samples *t*-tests. For example, for hypothesis three, I compared memory scores for visual stimuli between individuals with and without an autism spectrum disorder. For within group comparisons, I used paired samples *t*-tests. For example, for hypothesis 6, I compared memory for emotional stimuli and neutral stimuli in neurotypical controls. I also had planned to perform a series of independent samples *t*-tests comparing memory for emotional stimuli between males and females with an autism spectrum disorder (hypothesis 5) and males and females without an autism spectrum disorder (hypothesis 7). However, because our sample had too few females, I was unable to complete these analyses.

2.5.2 Tests of Equivalence

Null hypothesis statistical significance testing is commonly misused to test for statistical equivalence (Wellek, 2003). To test for equivalence, I used traditional tests for statistically significant differences; however, I used an increased alpha level of .20 to ensure that if statistical differences existed, they were identified. For example, for hypothesis two, using an alpha level of .20, I conducted an independent samples *t*-test comparing memory of neutral stimuli and auditory stimuli for those with and without an autism spectrum disorder.

CHAPTER 3. RESULTS

3.1 Preliminary Analyses

Tables 3 and 4 present the demographic variables for the neurotypical and autism spectrum disorder samples. Participants were, on average, 12 years old and in the sixth grade. The majority of the children were male. Only two of the children with an autism spectrum disorder (12.5%) and four of the neurotypical controls (26.7%) were female. Additionally, the sample was primarily Caucasian. There was only one neurotypical participant who was African American (6.7%). According to parent report, several of the individuals with an autism spectrum disorder also had one or more additional disabilities, including emotional (n=3) and physical disabilities (n=1), and one of the neurotypical control participants had a cognitive disability (Dyslexia). To determine if the inclusion of the control participant with dyslexia altered the findings, analyses were performed twice, once including and once excluding the neurotypical control participant with Dyslexia. Any differences in findings are noted in the Results section.

I compared the autism spectrum disorder and neurotypical control group on the demographic and clinical variables. The clinical group did not significantly differ from the neurotypical control group on any of the demographic variables collected. Participants in the two groups were similar in age, short-term memory ability, and reading level. As expected, individuals in the autism spectrum disorder group scored significantly higher on the CARS-2 than those in the neurotypical control group, M_{autism}=36.16 vs. $M_{control}$=15.27, $t(29) = -20.99$, $p < .001$. I also compared the groups on two socioeconomic indicators, parent education and household income. Again, there were no significant differences between the neurotypical and autism spectrum disorder groups (see Table 4). Parents of participants in each group had similar levels of education and household income. Most participants (36% of the sample) had a household income over $100,000 per year, had a father that graduated from college (39%), and had a mother with post-collegiate education (36%).

Additionally, as a manipulation check, I compared groups on their ability to correctly identify the emotion (or lack of emotion) for each stimulus. Individuals with and without an autism spectrum disorder were equally able to identify emotions depicted in both the auditory and visual stimuli.

I also investigated whether there were significant differences within the ASD group based on diagnosis. I compared those with autism, Asperger's Disorder, and Pervasive Developmental Disorder-Not Otherwise Specified on demographics, CARS-2 scores, reading level, and short term memory ability. As shown in Table 5, there were no differences between diagnostic groups on these variables.

As a final preliminary analysis, I compared groups based on where they were tested (see Table 6). Results of a chi-square analysis indicate the groups differed significantly on where they were tested. Although 6 individuals without an autism spectrum disorder were tested in the IUPUI lab, no children with an autism spectrum disorder were. Additionally more children with an autism spectrum disorder were tested at a local library than those without a disorder.

3.2 Test of Hypotheses

To test hypothesis one, that memory for neutral stimuli would be the same for those with and without an autism spectrum disorder, I performed an independent samples *t*-test. As noted above, because I expected memory for neutral stimuli to be equivalent between groups, I used an alpha value of .20. Thus, data with a probability level of .20 or lower are considered evidence that the hypothesis is incorrect, that the groups are not equivalent. Results of the *t*-test suggest that those with and without an autism spectrum disorder tend to be different in memory for neutral stimuli $t(29) = -1.47$, $p = .15$, $d = .46$ (see Table 7), thus I cannot confidently reject the hypothesis that memory for neutral stimuli is equivalent.

Hypothesis two posited that children with and without an autism spectrum disorder would demonstrate equivalent memory abilities for auditory stimuli. To test this, an independent samples *t*-test with an increased alpha value of .20 was conducted comparing memory for auditory stimuli between individuals with and without an autism spectrum disorder. Results indicated no differences in memory for auditory stimuli between the groups, $t(29) = -.07$, $p = .94$, $d = 0$ (see Table 7).

Hypothesis three posits that children with an autism spectrum disorder will have better memory for visual stimuli than their neurotypical counterparts. To test this, I conducted an independent samples *t*-test comparing the groups on memory for visual stimuli. Results indicate a trend (one-tailed) suggesting that children with an autism spectrum disorder have better memory for visual stimuli than those without an autism spectrum disorder, $t(29) = -1.58$, $p = .06$, $d = .57$ (see Table 7).

To test hypothesis four, that memory for emotional and neutral stimuli would be equivalent in children with an autism spectrum disorder, I conducted a dependent samples *t*-test using an alpha of .20. There were no significant differences in memory for emotional and neutral stimuli in children with an autism spectrum disorder, $t(15) = 1.20$, $p = .25$, $d = .29$ (see Table 8) at the $p<.20$ level, indicating that memory for emotional and neutral stimuli in this sample is likely equivalent.

To test hypothesis six, which posited that individuals without an autism spectrum disorder would remember emotional stimuli better than neutral stimuli, I conducted a dependent samples *t*-test comparing memory for emotional and neutral stimuli in neurotypical controls. Consistent with the hypothesis, there was a trend suggesting that neurotypical controls remember emotional stimuli better than neutral stimuli, $t(14) = -1.59$, $p = .07$, $d = .23$ (see Table 9). However, when I ran this same analysis excluding the individual with a learning disability, I found no significant differences between memory for emotional and neutral stimuli for neurotypical controls, $t(13) = -1.28$, $p = .11$, $d = .22$ (see Table 9).

Hypothesis eight posited that, for the entire sample, memory for emotional stimuli would be better when the emotion was labeled. To test this, I conducted a dependent samples *t*-test comparing memory for emotional auditory stimuli when the emotion was labeled vs. not labeled. There were no differences in memory between stimuli with labeled vs. unlabeled emotion, $t(30) = -1.51$, $p = .14$, $d = .26$ (see Table 10). I also performed exploratory follow-up dependent samples *t*-tests separately within each group comparing memory for labeled and non-labeled stimuli. Although there were no differences for labeled and non-labeled stimuli for neurotypical controls ($t(14) = 0.0$, $p = 1.00$), surprisingly, individuals with an autism spectrum disorder remembered non-labeled stimuli better than labeled stimuli, $t(15) = -2.33$, $p = .03$, $d = .54$ (see Tables 8 and 9).

I was unable to test the two additional hypotheses regarding gender, hypotheses five and seven, because too few females participated.

3.3 Additional Analyses

To test whether short-term memory ability overall was equivalent between groups I performed an independent samples *t*-test comparing Digit Span scores for each group. The analysis indicated no support for a finding of significant differences in short term memory (Digit Span score) between the groups, $t(29) = .86$, $p = .40$, $d = .31$ (see Table 7). The interpretation of this result is that short-term memory ability was likely equivalent between groups.

I then conducted 2 X 2 analyses of variance (ANOVAs) to further understand the results. The first compared memory for auditory and visual stimuli between groups (see Table 11) to see if there was a potential interaction, such that, those with an autism spectrum disorder showed a preference for visual stimuli relative to auditory stimuli compared to neurotypical controls. There were no group differences ($F(1,29) = 1.07$, $p = .31$, $n^2 = .04$) or differences based on presentation modality ($F(1,29) = 2.89$, $p = .10$, $n^2 = .09$). Further, there was no group by modality interaction ($F(1,29) = 2.55$, $p = .12$, $n^2 = .08$).

The second 2 X 2 ANOVA compared memory for emotional and neutral stimuli between groups (see Table 12). The critical test was an interaction, to see if neurotypical controls showed a preference for emotional stimuli relative to neutral stimuli compared to those with an autism spectrum disorder. The results replicated the t-test results for hypothesis six, indicating a trend, such that emotional stimuli were remembered better than neutral stimuli, $F(1,29) = 3.83$, $p = .06$, $n^2 = .12$. However, there were no group differences or group by emotionality interactions.

I also conducted a 2 X 3 ANOVA comparing memory for happy, sad, and neutral stimuli between groups. There was a significant effect of emotionality, $F(2,28) = 11.53$, $p<.01$, $n^2 = .45$ (see Table 13). Post-hoc *t*-tests indicated that sad stimuli were remembered better than happy and neutral stimuli although there were no differences between happy and neutral stimuli (see Table 14). The interaction between emotion and group was not significant, $F(2,28) = .59$, $p = .56$, $n^2 = .04$.

CHAPTER 4. DISCUSSION

This study was designed to examine the impact of varying the sensory modality of presentation (auditory vs. visual) and the emotional content of stimuli on recognition memory in children with an autism spectrum disorder compared to neurotypical peers. Specifically, the study attempted to evaluate whether the difficulty processing and understanding emotion that is thought to be associated with autism spectrum disorders would interfere with the ability of children on the autism spectrum to utilize emotion when trying to remember information. Further, it examined differences between memory for auditory and visual information to determine if children on the spectrum do, in fact, have a preference for visual material while memory for auditory information remains intact relative to neurotypical children. Overall, the results provided mixed support for the hypotheses.

There is ample evidence suggesting immediate and delayed recognition and recall memory is intact in individuals with an autism spectrum disorder (Barth, Fein, & Waterhouse, 1995; Bennetto, Pennington, & Rogers, 1996; Minshew et al., 1992; Minshew et al. 1994; Minshew & Goldstein, 2001; Williams, Goldstein, & Minshew, 2006) and, thus, I expected children on the autism spectrum to have equivalent memory for neutral stimuli compared to neurotypical peers. However, I was unable to confidently support this conclusion based on the current data. On the one hand, memory for neutral stimuli was not statistically different between children with an autism spectrum disorder and neurotypical controls when assessed using a traditional p-level of .05; on the other hand, there were small differences that could indicate a trend finding when applying a more generous alpha level especially given the moderate effect size (d = .46). In contrast, however, using the Digit Span task, results were consistent with previous research and indicated that short-term memory overall was equivalent for children with and without an autism spectrum disorder. Thus, the results were mixed. Although I am unable to conclude firmly that memory was equivalent in this sample, the evidence for non-equivalence is even weaker (not significant). Thus, on balance, the current results fail to rise to a level that would seriously question the validity of prior findings of equivalence.

Past research has shown that in the general population, children tend to recall emotional events more easily than neutral ones (Davidson, Luo, & Burden, 2001). I, therefore, expected children without an autism spectrum disorder to remember emotional stimuli better than neutral stimuli. However, the data did not support this prediction in the current sample. Although, there was a trend consistent with the hypothesis (p = .07), once the control participant with dyslexia was removed from the sample, there was no longer evidence for a trend (p=.11). Further, there was only a small effect size both when all participants were included and when the individual with dyslexia was removed, d = .23 and d = .22, respectively. Thus, I was unable to confirm prior findings of a recall preference for emotional events for neurotypical individuals. However, the mean differences were in the expected direction and given a larger sample size may have been significant.

Another key question was whether the memory advantage for emotional stimuli found in neurotypical samples, extends to those with an autism spectrum disorder. Prior research has found that adults without an autism spectrum disorder remember emotional statements better than neutral ones, but those with an autism spectrum disorder do not show a preference for emotional statements (Beversdorf et al., 1998). I expected similar results when examining this phenomenon in children. As predicted, children with an autism spectrum disorder remembered the emotional and neutral stimuli equally well. That is, there was no apparent recall benefit from the presence of emotion. However, the interpretation of this result is complicated by the fact that, in this data, there also was no statistically reliable advantage for emotional stimuli relative to neutral stimuli in the neurotypical sample, although the means were in the expected direction. Thus, those with an autism spectrum disorder and neurotypical controls responded similarly to emotional vs. neutral stimuli. It is possible that the experimental stimuli, which were created for the study and had not been used in prior work, were overly easy to remember, regardless of whether they included emotion. That is, perhaps the advantage for emotional cues is dependent on the difficulty of the material to be recalled. It is also possible that the emotionality of the experimental stimuli were not sufficiently powerful. Past research has demonstrated that stimuli eliciting stronger emotional responses are remembered with greater vividness (Christianson, 1992). Perhaps the experimental stimuli in this study did elicit a strong enough emotional response from the participants, and therefore were not remembered better than the neutral stimuli. Moreover, the sample size was small and perhaps effects were undetected due to low power. However, further research will be needed to more clearly understand these results.

It is commonly believed that individuals with an autism spectrum disorder have difficulty processing information presented verbally; however current research suggests that while there may be a preference for visually presented information, there are no deficits in remembering auditory information relative to neurotypical individuals (Minshew & Goldstein, 2001). Therefore, in addition to emotional content, the study also manipulated the modalities in which stimuli were presented. I expected children with an autism spectrum disorder to demonstrate better memory for visual stimuli when compared to their neurotypical counterparts and to exhibit no differences in memory for auditory stimuli. As anticipated, children with an autism spectrum disorder did show a preference for visual stimuli when compared to children without an autism spectrum disorder. Additionally, memory for auditory stimuli was equivalent between the groups. By acknowledging that children with an autism spectrum disorder prefer visual material, educators can use this to their advantage to enhance the learning process. By utilizing both modalities, teachers increase the chances for success in children with an autism spectrum disorder.

Previously, researchers found that when asking neurotypical individuals to remember emotional stimuli, explicitly labeling the emotion has improved memory for the stimuli (Davidson et al., 2001, Widen & Russel, 2004). Because individuals with an autism spectrum disorder already have difficulty predicting others' feelings and behaviors (Happe, 1995) and discriminating emotions in facial expression (Baron-Cohen et al., 1997; Baron-Cohen et al., 1997), I predicted that children with ASD also will demonstrate better memory for emotional stimuli when the emotion is labeled. Surprisingly, however, in contrast to predictions and to prior research, there were no differences in memory for emotional stimuli when labeled or unlabeled for the sample as a whole. Interestingly, follow up analyses indicated no difference in memory for labeled and unlabeled stimuli in neurotypical individuals, but better memory for unlabeled emotional stimuli within the ASD group. It is important to note that the manipulation check indicated that individuals in both groups were able to reliably identify the emotions depicted in all the stimuli. Thus, it is unlikely that differences are due to an inability to identify the emotion depicted. Perhaps because the stimuli contained only basic emotions that had been selected to be easily identifiable, neurotypical individuals did not find benefit in the explicit labeling of the emotion. However, individuals on the spectrum may have been distracted by the presence of the emotional label rather than finding benefit in it. For the recognition task, distracters for labeled sentences also contained emotional labels (see Appendix B). Therefore, there was an explicit emotional component (the label) as well as an implicit emotional component (the emotionality conveyed by the sentence content) in both the stimuli and the distracters. If children with an autism spectrum disorder were distracted by the emotional labels, they may have preferentially encoded the explicit emotion (the label—happy) and neglected the sentence content (Holly's school was closed so she played with friends in the snow—implicit emotion) leading to later difficulty remembering the implicit stimuli or content. Because these results are inconsistent with previous findings, further research on the effect of labeling emotions is needed. In my additional analyses, I found that participants remembered sad stimuli better than neutral and happy stimuli across groups. Previous research, however, found no difference in memory for positive and negative emotional stimuli (Davidson et al., 2001). However, the current findings cannot differentiate between emotion type and emotional responsiveness. That is, there was no attempt to make emotional reactivity equivalent across emotion types. Thus, the finding may index differences in emotional responding irrespective of type of emotion, rather than true differences between types of emotions.

There are several limitations to the current study. First, the sample size is small. With such a small sample size, power to detect differences was limited, which may have resulted in fewer significant results, although I did observe trends. A G*Power analysis indicated that a sample of 128 participants, 64 with an autism spectrum disorder and 64 neurotypical controls, would have been needed to produce sufficient power to detect a moderate effect size. It is possible then, that with a larger sample size, these trends would reach statistical significance. Second, I only included high-functioning children with an autism spectrum disorder. It is unknown whether the results of this study would generalize to children throughout the autism spectrum, such as those with intellectual disability. Due to the small sample, I was also unable to examine differences based on participants' specific diagnosis. Given the differences between diagnoses, future studies should examine such differences. Furthermore, the presentation of recognition questions for the auditory task was visual rather than auditory. Mixing the two modalities may have confounded our results I chose this method, however, to limit the memory load during the recognition task. In addition, this study does not include a measure of brain functioning limiting the interpretation of results. Although I can speculate that differences in brain functioning, e.g, amygdala, are causing differences in memory and social function between children with and without an autism spectrum disorder, I cannot validate this suggestion without including functional imaging techniques. An additional limitation is that participants completed the memory tasks at different locations, which could have influenced results. Because I was unable to financially compensate participants, it would have proven more difficult to recruit a large enough sample that was willing to travel to the lab at IUPUI. Furthermore, children with autism spectrum disorder often have increased anxiety in new environments. Therefore, by testing them either at their home or in a local library, these children were more likely to perform at their full potential rather than be hindered by high levels of anxiety. Finally, although I made gender-related hypotheses, I was unable to test them due to having too few female participants. This underrepresentation may have been a further consequence of our small overall sample size. That is, because males are four times more likely to be diagnosed with an autism spectrum disorder, given a total sample of 16 children with an autism spectrum disorder, the expected number of females in the sample is only 3.2.

Although not an explicit focus of the study, the results also have implications for the feasibility of studying children with autism spectrum disorders with unfunded research. Due to limited funding, participants were compensated only with candy. It is my impression that this level of reinforcement was inadequate and lead both to increased difficulties in recruiting children with autism and to lack of motivation among participants once recruited. Participants, while given breaks, were asked to complete cognitively taxing tasks for one to one and one-half hours. Given the age and diagnoses of the participants, keeping them motivated was challenging. A modification of the testing location was also necessary in order to ease participants' anxiety and decrease the burden of commuting to the IUPUI campus laboratory. While testing this population in the future is certainly feasible, increasing participants' compensation would likely be of benefit.

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TABLES

Table 1 Operationalization of Variables

Hypothesis	Variable	Operationalization
1	Memory for neutral stimuli	Percentage of correct responses for neutral stimuli (Range 0.0-1.0)
2	Memory for neutral visual stimuli	Percentage of correct responses for neutral visual stimuli (Range 0.0-1.0)
	Memory for emotional visual stimuli	Percentage of correct responses for emotional visual stimuli (Range 0.0-1.0)
3	Memory for emotional stimuli	Percentage of correct responses for emotional stimuli (Range 0.0-1.0)
	Memory for neutral stimuli	Percentage of correct responses for neutral stimuli (Range 0.0-1.0)
4	Memory for emotional stimuli	One point per correct response for emotional stimuli (Range 0-32)
5	Memory for emotional stimuli	Percentage of correct responses for emotional stimuli (Range 0.0-1.0)
	Memory for neutral stimuli	Percentage of correct responses for neutral stimuli (Range 0.0-1.0)
6	Memory for emotional stimuli	Percentage of correct responses for emotional stimuli(Range 0.0-1.0)
7	Memory for unlabeled emotional auditory stimuli	Percentage of correct responses for unlabeled emotional auditory stimuli (Range 0.0-1.0)
	Memory for labeled emotional auditory stimuli	Percentage of correct responses for labeled emotional auditory stimuli (Range 0.0-1.0)

Table 2 Ideal Timeline of Events for Administering Study Protocol

Time (in minutes)	**Task**
	Contact parent via telephone
5	Ask demographic questions
15	Administer CARS-2 Parent/Caregiver Questionnaire
5	Schedule on-campus testing (when applicable)
	Parent and child arrival
5	Greet parent and child
5	Parental consent and child assent
5	Pair with child
3	Play auditory recording for child
10	Auditory recognition task
5	Break
5	Play visual slideshow for child
10	Visual recognition task
10	Break
10	Manipulation check
5	Digit Span task
20	WRAT
10	Wrap up
25	**Telephone Total**
103	**On-campus Total**
128	**Total**

Table 3 Results of *t*-tests and X^2 Tests for Differences Between Groups on Demographic Characteristics for Child Participants

		Mean (*SD*)	*t*	X^2	Effect Size
Number of Participants	ASD	16			
	NT	15			
Female (%)	ASD	2 (12.5)		1.00	.18
	NT	4 (26.7)			
Caucasian (%)	ASD	16 (100)		1.10	.19
	NT	14 (93.3)			
Age	ASD	11.94 (2.32)	.25		.09
	NT	12.13 (2.03)			
Reading Ability	ASD	103.25 (12.17)	-.56		.20
	NT	100.67 (13.73)			
Digit Span	ASD	8.00 (2.85)	.86		.31
	NT	8.73 (1.75)			
CARS-2 Scores	ASD	36.16 (3.81)	-20.99*		7.75
	NT	15.27 (.06)			
Auditory Manipulation	ASD	.96 (.09)	-.55		.20
	NT	.94 (.11)			
Visual Manipulation	ASD	.95 (.07)	.30		.00
	NT	.95 (.07)			
Overall Manipulation	ASD	.95 (.07)	-.22		.00
	NT	.95 (.09)			

ASD = Individuals with an autism spectrum disorder
NT = Neurotypical individuals
t used for continuous data
X^2 used for categorical data
Cohen's *d* used for effect size for *t* statistic
φ used for effect size for X^2 statistic
*Sig. (2-tailed) $p<0.001$

Table 4 Results of X^2 Tests for Differences Between Groups on Parent Variables

			Count (%)	X^2	*Effect Size(φ)*
Father's Education				4.12	.36
	Less than HS	ASD	1 (6.2)		
		NT	0 (0)		
	HS diploma/GED	ASD	0 (0)		
		NT	2 (13.3)		
	Some college	ASD	4 (25)		
		NT	4 (26.7)		
	College Grad	ASD	6 (37.5)		
		NT	6 (40)		
	Post-collegiate	ASD	4 (25)		
		NT	3 (20)		
	Other	ASD	1 (6.2)		
		NT	0 (0)		
Mother's Education				1.89	.25
	Less than HS	ASD	0 (0)		
		NT	0 (0)		
	HS diploma/GED	ASD	2 (12.5)		
		NT	1 (6.7)		
	Some college	ASD	4 (25)		
		NT	4 (26.7)		
	College Grad	ASD	3 (18.8)		
		NT	5 (33.3)		
	Post-collegiate	ASD	6 (37.5)		
		NT	5 (33.3)		
	Other	ASD	1 (6.2)		
		NT	0 (0)		
Household Income				1.07	.19
	$25-39K	ASD	1 (6.2)		
		NT	1 (6.7)		
	$40-59K	ASD	4 (25)		
		NT	2 (13.3)		
	$60-79K	ASD	3 (18.8)		
		NT	4 (26.7)		
	$80-99K	ASD	3 (18.8)		
		NT	2 (13.3)		
	$100K +	ASD	5 (31.1)		
		NT	6 (40)		

ASD = Individuals with an autism spectrum disorder
NT = Neurotypical individuals

Table 5 Results of *t*-tests and X^2 Tests for Differences in Demographic Characteristics Within ASD Group based on Diagnoses

		Mean (*SD*)	*F*	X^2	Effect Size
Number of Participants	Autism	6			
	Asperger's	7			
	PDD-NOS	3			
Female (%)	Autism	1 (16.67)		0.54	0.18
	Asperger's	1 (14.29)			
	PDD-NOS	0 (0)			
Caucasian (%)	Autism	0 (0)		0.00	0.00
	Asperger's	0 (0)			
	PDD-NOS	0 (0)			
Age	Autism	10.83 (2.14)	1.27		0.16
	Asperger's	12.86 (2.27)			
	PDD-NOS	12.00 (2.65)			
Reading Ability	Autism	98.17 (11.00)	0.88		0.12
	Asperger's	107.14 (14.96)			
	PDD-NOS	104.33 (2.31)			
Digit Span	Autism	6.17 (3.25)	3.30		0.33
	Asperger's	9.71 (1.60)			
	PDD-NOS	7.67 (2.52)			
Cars-2 Scores	Autism	35.75 (3.42)	0.55		0.08
	Asperger's	37.21 (4.28)			
	PDD-NOS	34.5 (4.00)			

F used for continuous data
X^2 used for categorical data
η^2 used for effect size for *F* statistic
φ used for effect size for X^2 statistic
*Sig. (2-tailed) p<.05

Table 6 Results of X^2 Tests for Differences Between Groups on Testing Location

			N(%)	X^2	*p*	Effect Size
Testing Location	ASD	Home	7 (43.8)	8.23	0.02*	0.52
		Lab	0 (0)			
		Library	9 (56.3)			
	NT	Home	5 (33)			
		Lab	6 (40)			
		Library	4 (26.7)			

φ used for effect size for X^2 statistic
*Significance (2-tailed)

Table 7 Results of *t*-tests Comparing Digit Span and Memory for Neutral, Auditory, and Visual Stimuli between NT and ASD Groups

		Mean (*SD*)	*t*	*p*	*d*
Neutral Stimuli	ASD	.89 (.07)	-1.47	*.15*	.46
	NT	.83 (.17)			
Digit Span	ASD	8.00 (2.85)	.86	.47	*.31*
	NT	8.73 (1.75)			
Auditory Stimuli	ASD	.86 (.11)	-.07	.94	*0*
	NT	.86 (.15)			
Visual Stimuli	ASD	.95 (.08)	-1.58	.06**	*.57*
	NT	.86 (.21)			

ASD = Individuals with an autism spectrum disorder

NT = Neurotypical individuals

**Although not reaching statistical significance (1-tailed), results suggest a trend

Table 8 Results of *t*-tests Comparing Memory for Emotional Versus Neutral Stimuli and Labeled Versus Unlabeled Stimuli within Autism Spectrum Disorder Group

		Mean (*SD*)	*t*	*p*	*d*
Emotionality	Emotional Stimuli	.91 (.07)	-1.20	*.25*	.29
	Neutral Stimuli	.89 (.07)			
Label	Labeled Emotion	.84 (.16)	2.33	.03*	*.54*
	Unlabeled Emotion	.91 (.09)			

*Significance (2-tailed)

Table 9 Results of *t*-tests Comparing Memory for Emotional Versus Neutral Stimuli and Labeled Versus Unlabeled Stimuli within Neurotypical Group.

		Mean (*SD*)	*t*	*p*	*d*
Emotionality	Emotional Stimuli	.87 (.18)	-1.59	*.06***	.23
	Neutral Stimuli	.83 (.17)			
Emotionality*	Emotional Stimuli	.87 (.18)	-1.28	.11	*.22*
	Neutral Stimuli	.83 (.18)			
Label	Labeled Emotion	.89 (.19)	0.00	1.00	*0*
	Unlabeled Emotion	.89 (.17)			

*Analysis excludes neurotypical individual with a learning disability
** Although not reaching statistical significance (1-tailed), results suggest a trend

Table 10 Results for *t*-test Comparing Labeled Versus Unlabeled Stimuli within Entire Sample

		Mean (*SD*)	*t*	*p*	*d*
Label	Labeled Emotion	.86 (.17)	1.51	.14	*.26*
	Unlabeled Emotion	.90 (.13)			

Table 11 Results of Exploratory ANOVAs Comparing Memory for Visual and Auditory Stimuli Between ASD and NT Groups

Effect	df	Error df	*F*	*p*	η^2
Modality	1	29	2.89	*.10*	.09
Group	1	29	1.07	.31	.04
Modality X Group	1	29	2.55	.12	*.08*

ASD = Individuals with an autism spectrum disorder
NT = Neurotypical individuals

Table 12 Results of Exploratory ANOVA Comparing Memory for Emotional and Neutral Stimuli Between ASD and NT Groups

Effect	df	Error df	*F*	*p*	η^2
Emotion	1	29	3.83	*.06***	.12
Group	1	29	1.37	.25	.05
Emotion X Group	1	29	1.18	.29	*.04*

ASD = Individuals with an autism spectrum disorder
NT = Neurotypical individuals
** Although not reaching statistical significance (2-tailed), results suggest a trend

Table 13 Results of Exploratory ANOVA Comparing Memory for Happy, Sad, and Neutral Stimuli Between ASD and NT Groups

Effect			Mean *(SD)*	df	Error df	*F*	*p*	η^2
Emotionality				2	28	11.53	0.00*	0.45
	Happy	ASD	.89 (.09)					
		NT	.86 (.18)					
	Sad	ASD	.93 (.07)					
		NT	.89 (.18)					
	Neutral	ASD	.89 (.07)					
		NT	.83 (.17)					
Group				1	29	1.07	0.31	0.04
		ASD	.90(.07)					
		NT	.86 (.17)					
Emotionality X Group				2	28	0.59	0.56	0.04

*Significance (2-tailed)

Table 14 Results of Post-Hoc *t*-tests Comparing Memory for Happy, Sad, and Neutral Stimuli

		Mean (SD)	*t*	*p*	*d*
Emotionality	Happy	0.87(.14)	-3.37	0.002*	0.30
	Sad	0.91(.13)			
Emotionality	Happy	0.87(.14)	0.65	0.522	0.07
	Neutral	0.86(.13)			
Emotionality	Neutral	0.86(.13)	-3.36	0.002*	0.38
	Sad	0.91(.13)			

*Significance (2-tailed)

FIGURES

Figure 1 Results for *t*-test Comparing Memory for Neutral Stimuli between ASD and NT Groups

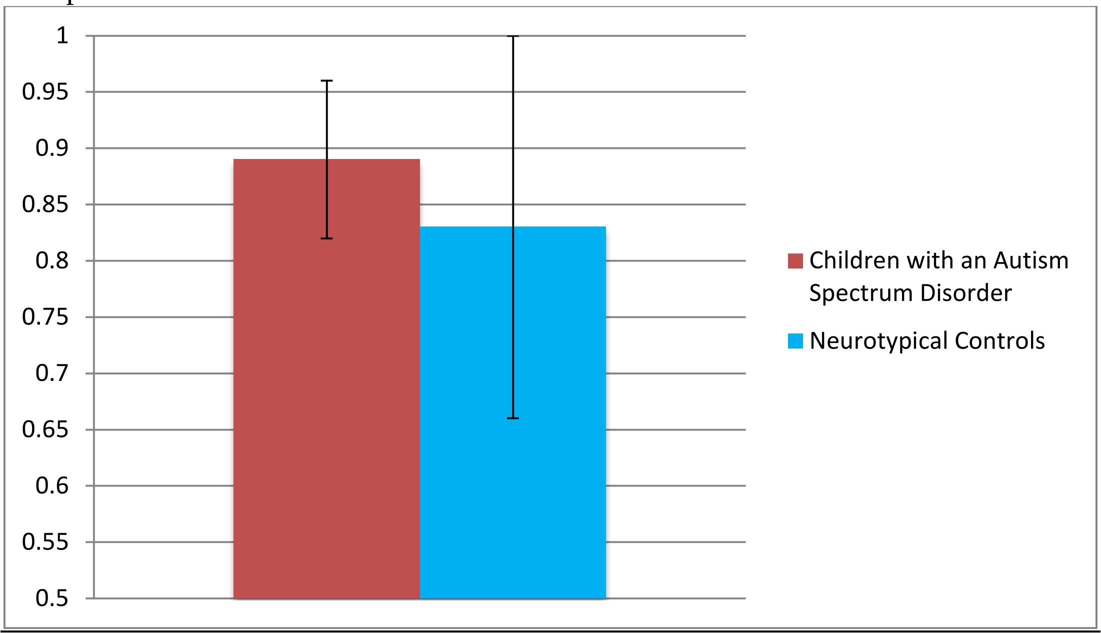
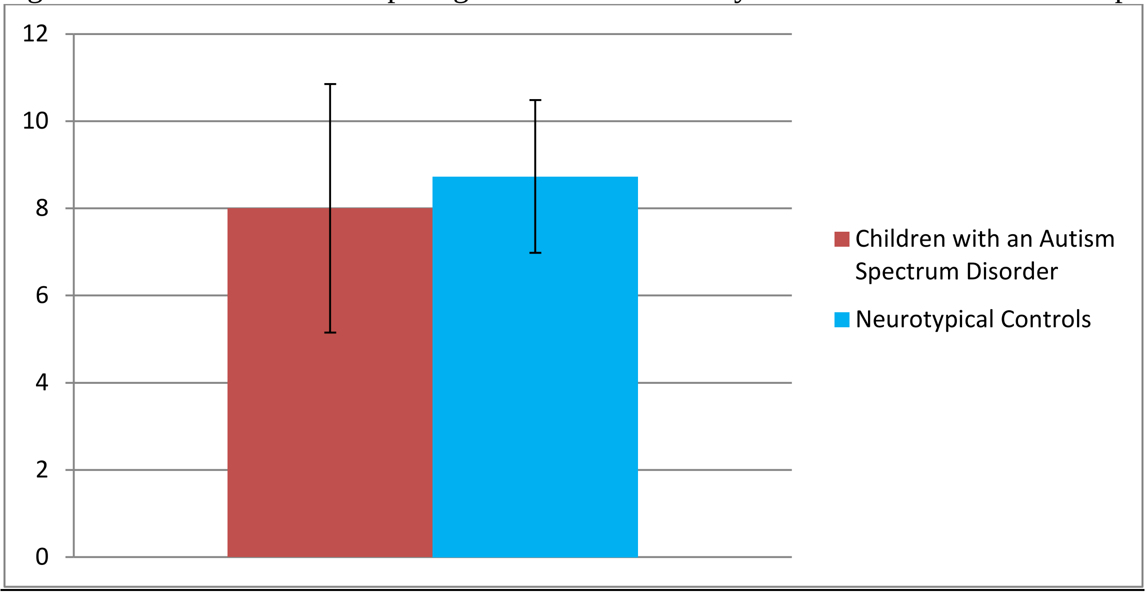


Figure 2 Results of *t*-test Comparing Short-term* Memory between ASD and NT Groups



*Short-term memory was assessed using Digit Span task

Figure 3 Results of *t*-tests Comparing ASD and NT Groups for Memory for Auditory Stimuli

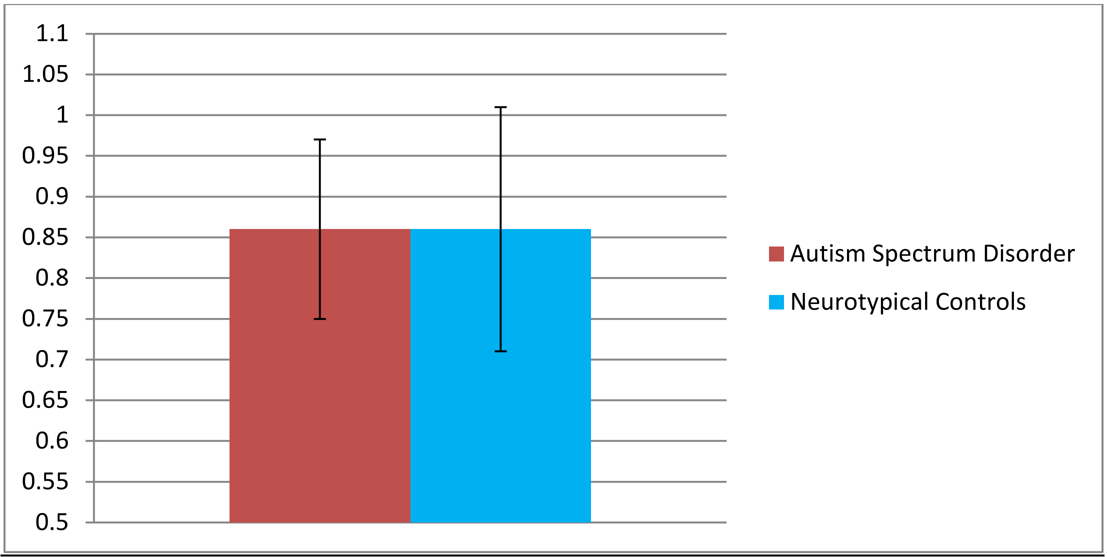
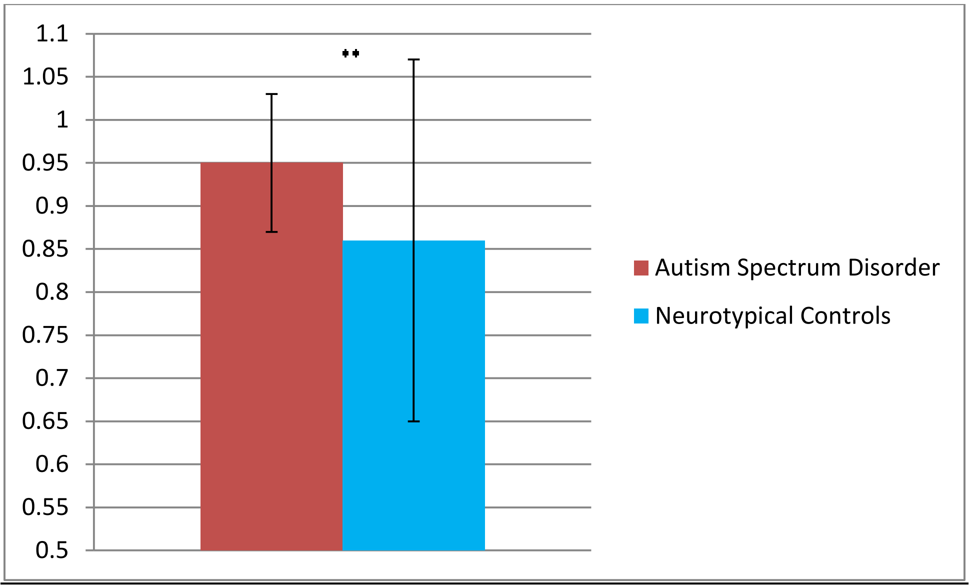


Figure 4 Results of *t*-tests Comparing ASD and NT Groups for Memory for Visual Stimuli



**Although not reaching statistical significance (2-tailed), results suggest a trend

Figure 5 Results for *t*-tests Comparing Memory for Emotional Stimuli for ASD and NT Groups

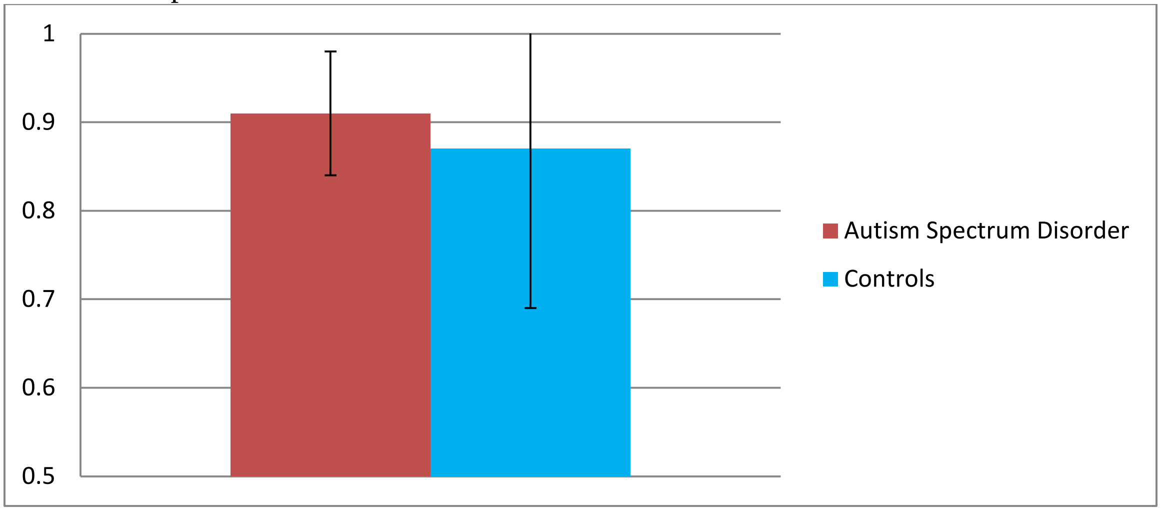


Figure 6 Results for *t*-tests Comparing Memory for Neutral Stimuli8 for ASD and NT Groups

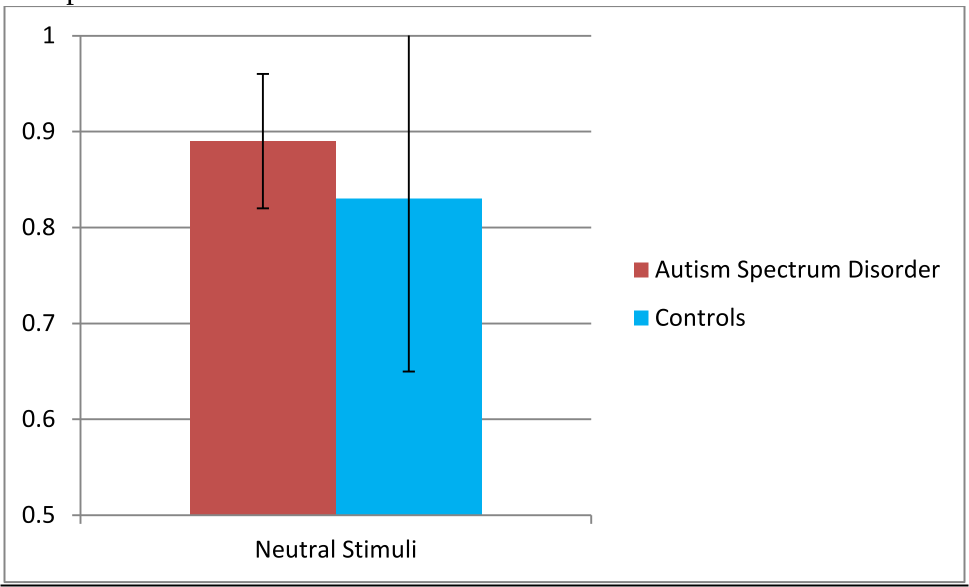


Figure 7 Results for *t*-tests Comparing Memory for Auditory Stimuli Containing a Label in ASD and NT Groups

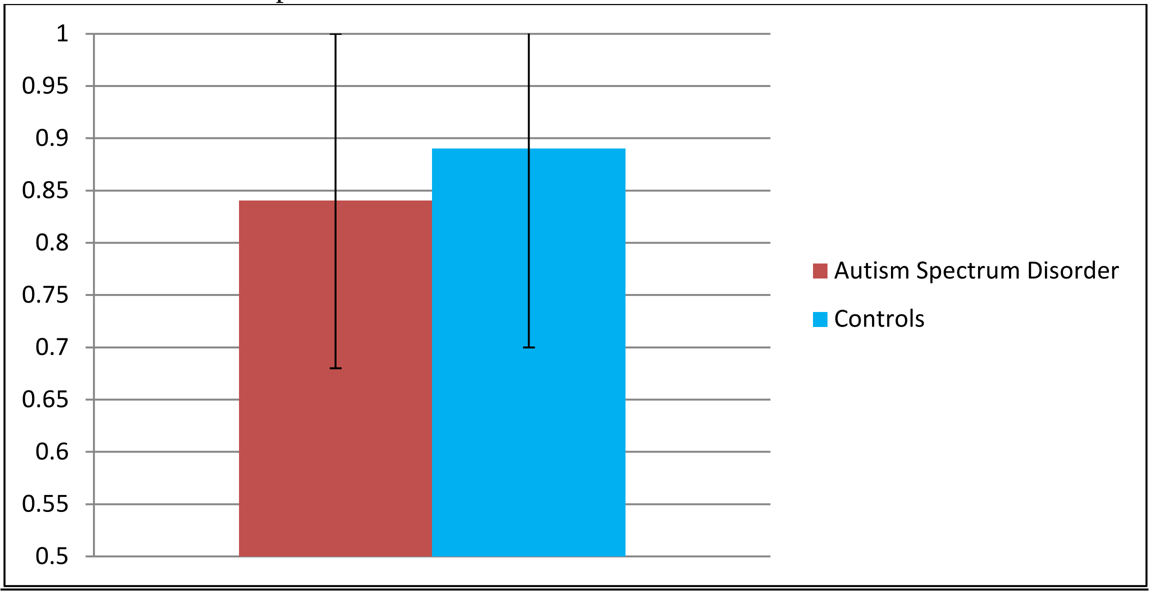
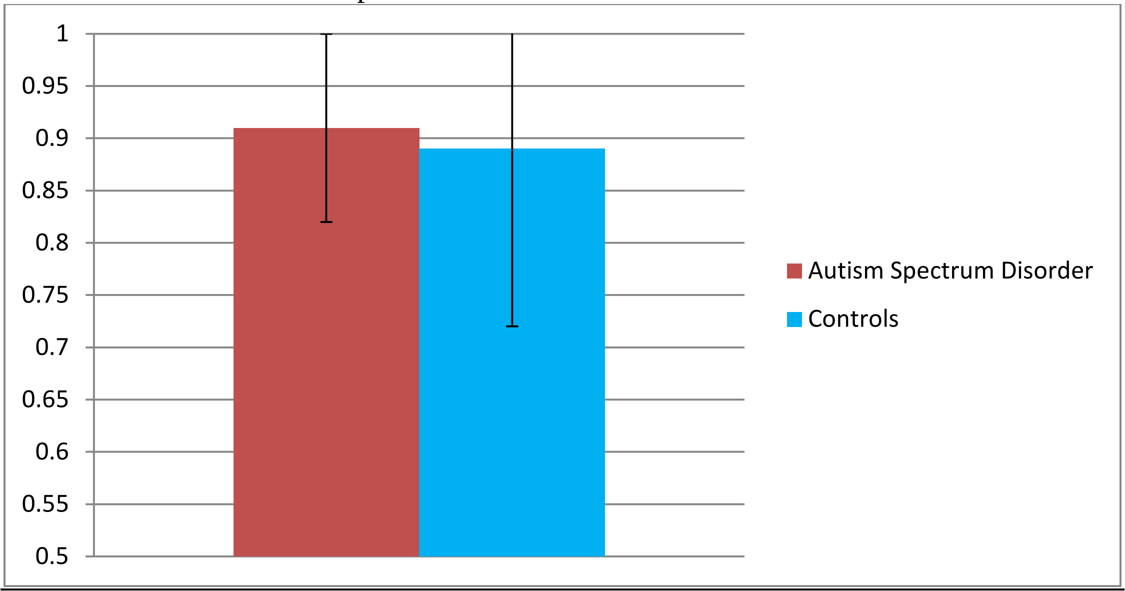


Figure 8 Results for *t*-tests Comparing Memory for Auditory Stimuli Not Containing a Label in ASD and NT Groups



APPENDICES

Appendix A Auditory Stimuli

Happy

James was happy his hit won the game.
Ashley was happy to go to the birthday party.
Jimmy loved the car he got for his birthday.
David was going to Disney World with his best friend.
Zach was happy to meet the star of his favorite movie.
Suzy’s mom bought her the puppy she had been asking for.
Natalie was happy to play with all her friends at the park.
Holly's school was closed so she played with friends in the snow.

Sad

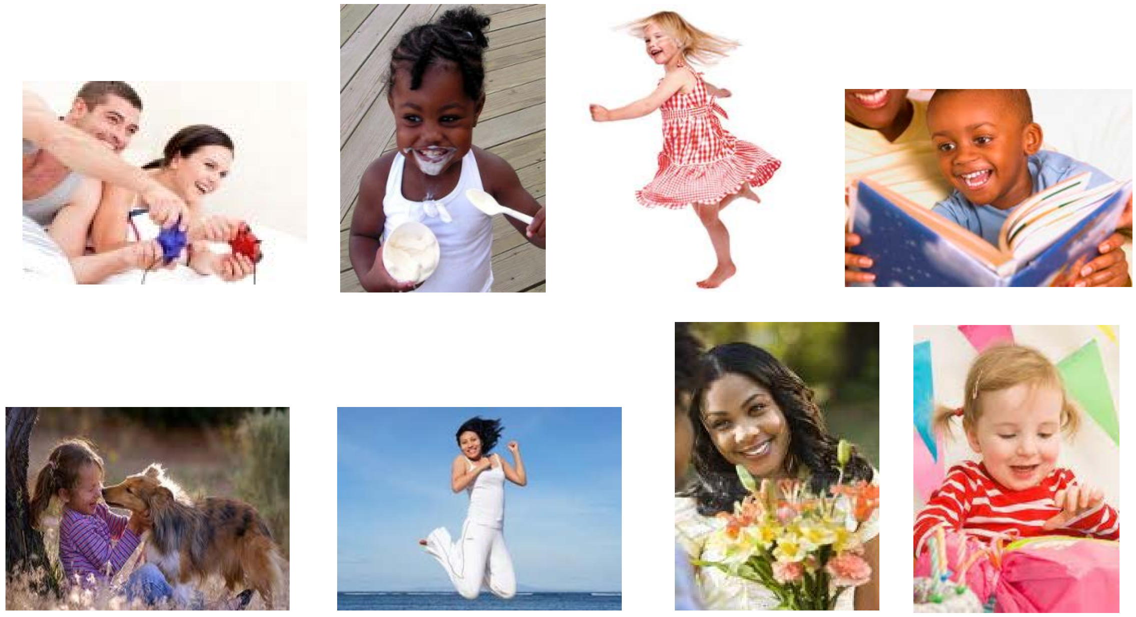
Ted was sad his cat died last night.
Jeremy is sad because his dog is very sick.
Jessica’s friends left her all alone at the carnival.
Bradley found out that his father has been very sick.
Jenny is sad because her best friend is moving far away.
George struck out and his baseball team lost the championship game.
Mary was sad no girls picked her to be in their group.
Madeline was not allowed to play with her friends all summer long.

Neutral

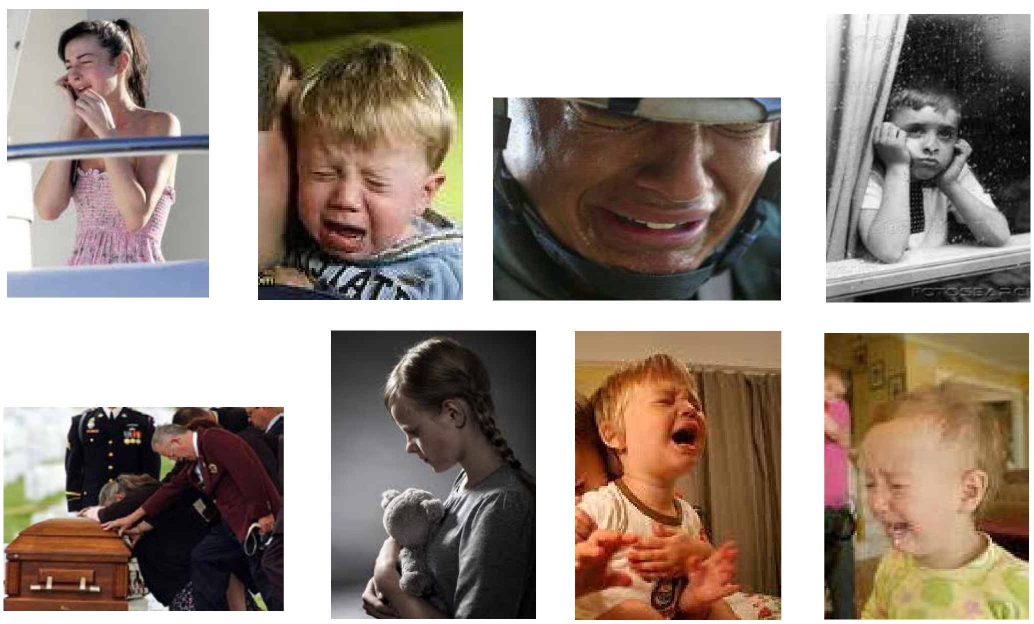
Adam opened the car window to get air.
Megan walked down the hall and entered her bedroom.
Josh turned on the light and closed the door.
Sara sat on the couch and looked out the window.
Allison laid on the bed and looked up at the ceiling.
Tim drank his milk and put the glass in the sink.
Pamela just started her car this morning and turned on the radio.
Roy read the magazine and put it down when he was finished.

Appendix B Visual Stimuli

Happy

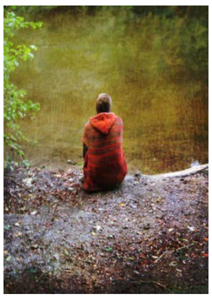


Sad



Neutral






Appendix C Auditory Pilot Stimuli

Happy

1. “Holly’s school was closed so she got to play with friends in the snow.”
2. “Jordan hit a homerun to win the game.”
3. “Zach got to meet the star of his favorite movie.”
4. “Ashley had fun at her birthday party.”
5. “Jack won the biggest bear at the carnival.”
6. “Jill’s mom let her pick any toy she wanted from the store.”
7. “Danielle rode her favorite ride at the carnival.”
8. “David was going to Disney World with his best friend.”
9. “Cathy’s boyfriend took her to her favorite restaurant for dinner.”
10. “Andrea won the beauty pageant.”
11. “Andrew was the MVP of the game.”
12. “Nate played with all of his friends at the park.”
13. “John won first place in the big race.”
14. “Suzy’s mom bought her the puppy she had been asking for.”
15. “Diana’s mom made pizza, her favorite food, for being such a good girl.”
16. “Jimmy loved the car he got for his birthday.”

Sad

1. “Jessica’s friends left her all alone at the carnival.”
2. “No one picked Kevin to be on their team.”
3. “Brady found out that his father was very sick.”
4. “Lauren dropped her brand new iPod in the pool.”
5. “Christina got hit by a car and hurt her arm.”
6. “Tyler’s cat of 15 years died suddenly.”
7. “Michelle found a bird with a broken wing.
8. “Brad lost his new sunglasses.”
9. “Jeremy’s dog is very sick.”
10. “George struck out and his team lost the game.”
11. “Jim’s best friend is moving away.”
12. “Brenda ruined her favorite shirt by getting paint on it.”
13. “Chris’s girlfriend dumped him.”
14. “Dawn’s new purse was stolen from her gym locker.”
15. “No one would play with Simon at recess.”
16. “Madeline was not allowed to play with her friends all summer.”

Neutral

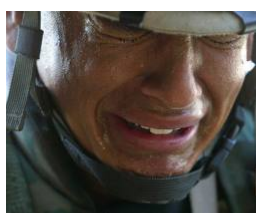
1. “Pamela just started her car this morning and turned on the radio.”
2. “Tim drank his milk and put the glass in the sink.”
3. “Roy read the magazine and put it down when he was finished..”
4. “Sara sat on the couch and looked out the window.”
5. “Adam opened the car window to get air.”
6. “Megan walked down the hall and entered her bedroom.”
7. “Allison laid on the bed and looked up at the ceiling.”
8. “Josh turned on the light and closed the door.”

Appendix D Visual Pilot Stimuli

Happy

1. 
2. 
3. 
4. 
5. 
6. 
7. 
8. 
9. 
10. 
11. 

Sad

1. 
2. 
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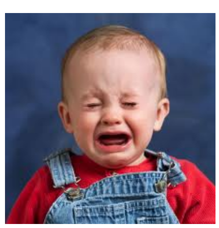
5. 
6. 
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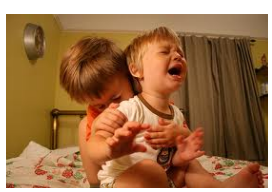
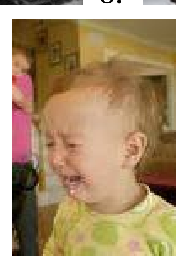
9. 
10. 
11. 

Neutral

1. 
2. 
3. 
4. 
5. 
6. 
7. 
8. 
9. 
10. 
11. 

Appendix E Pilot Data for Auditory Stimuli Rankings

Stimulus	Minimum	Maximum	Mean	Std. Deviation
Happy Auditory				
1	11.00	16.00	14.50	1.72
2	10.00	16.00	13.80	1.87
3	9.00	16.00	13.20	2.62
4	6.00	16.00	13.10	2.92
5	9.00	15.00	12.40	1.84
6	8.00	15.00	11.20	2.35
7	9.00	14.00	10.40	1.70
8	8.00	13.00	10.20	1.69
9	7.00	11.00	9.00	1.49
10	2.00	8.00	6.40	1.84
11	3.00	7.00	5.60	1.35
12	3.00	7.00	4.50	1.43
13	2.00	6.00	3.90	1.37
14	1.00	8.00	3.80	2.53
15	1.00	6.00	2.60	1.71
16	1.00	4.00	2.00	1.05
Sad Auditory				
1	13.00	16.00	15.10	0.99
2	11.00	16.00	14.10	1.66
3	9.00	16.00	14.20	2.10
4	9.00	15.00	11.70	1.70
5	8.00	14.00	11.50	1.84
6	2.00	15.00	11.30	3.65
7	4.00	13.00	9.80	2.66
8	6.00	13.00	8.70	2.31
9	5.00	11.00	8.40	1.78
10	6.00	10.00	8.00	1.25
11	2.00	11.00	5.30	2.63
12	1.00	8.00	4.80	2.15
13	2.00	8.00	4.40	1.96
14	1.00	6.00	3.10	2.18
15	1.00	5.00	2.90	1.29
16	1.00	5.00	2.40	1.35

Appendix F Pilot Data for Auditory Stimuli Emotion Identification

Stimulus	Happy	Sad	Neutral	Total
Happy Auditory				
1	10.00	0.00	0.00	10.00
2	10.00	0.00	0.00	10.00
3	10.00	0.00	0.00	10.00
4	10.00	0.00	0.00	10.00
5	10.00	0.00	0.00	10.00
6	10.00	0.00	0.00	10.00
7	10.00	0.00	0.00	10.00
8	10.00	0.00	0.00	10.00
9	10.00	0.00	0.00	10.00
10	10.00	0.00	0.00	10.00
11	10.00	0.00	0.00	10.00
12	10.00	0.00	0.00	10.00
13	10.00	0.00	0.00	10.00
14	10.00	0.00	0.00	10.00
15	10.00	0.00	0.00	10.00
16*	9.00	0.00	1.00	10.00
Sad Auditory				
1	0.00	10.00	0.00	10.00
2	0.00	10.00	0.00	10.00
3	0.00	10.00	0.00	10.00
4	0.00	10.00	0.00	10.00
5	0.00	10.00	0.00	10.00
6	0.00	10.00	0.00	10.00
7	0.00	10.00	0.00	10.00
8	0.00	10.00	0.00	10.00
9	0.00	10.00	0.00	10.00
10	0.00	10.00	0.00	10.00
11	0.00	10.00	0.00	10.00
12*	1.00	9.00	0.00	10.00
13	0.00	10.00	0.00	10.00
14	0.00	10.00	0.00	10.00
15	0.00	10.00	0.00	10.00
16	0.00	10.00	0.00	10.00
Neutral Auditory				
1	0.00	0.00	10.00	10.00
2	0.00	0.00	10.00	10.00
3	0.00	0.00	10.00	10.00
4	0.00	0.00	10.00	10.00
5	0.00	0.00	10.00	10.00
6	0.00	0.00	10.00	10.00
7	0.00	0.00	10.00	10.00
8	0.00	0.00	10.00	10.00

*Discarded

Appendix G Pilot Data for Visual Stimuli Rankings

Stimulus	Minimum	Maximum	Mean	Std.
Happy Visual				
1	9.00	11.00	10.10	0.74
2	4.00	11.00	9.30	2.26
3	5.00	11.00	8.50	2.01
4	5.00	10.00	8.00	1.70
5	4.00	10.00	7.00	1.89
6	4.00	8.00	6.10	1.45
7	2.00	9.00	5.30	2.06
8	1.00	8.00	3.90	2.33
9	1.00	7.00	3.10	1.85
10	1.00	5.00	2.90	1.45
11	1.00	3.00	1.80	0.63
Sad Visual				
1	8.00	11.00	9.90	0.99
2	7.00	11.00	9.30	1.70
3	7.00	11.00	8.70	1.42
4	4.00	10.00	7.60	2.01
5	5.00	10.00	7.10	1.60
6	3.00	11.00	5.70	2.26
7	1.00	11.00	5.60	2.95
8	1.00	8.00	3.70	2.41
9	2.00	5.00	3.60	1.17
10	1.00	4.00	2.60	1.17
11	1.00	8.00	2.20	2.15

Appendix H Pilot Data for Visual Stimuli Emotion Identification

Stimulus	Happy	Sad	Neutral	Total
Happy Visual				
1	10.00	0.00	0.00	10.00
2	10.00	0.00	0.00	10.00
3	10.00	0.00	0.00	10.00
4	10.00	0.00	0.00	10.00
5	10.00	0.00	0.00	10.00
6	10.00	0.00	0.00	10.00
7	10.00	0.00	0.00	10.00
8	10.00	0.00	0.00	10.00
9	10.00	0.00	0.00	10.00
10	10.00	0.00	0.00	10.00
11	10.00	0.00	0.00	10.00
Sad Visual				
1	0.00	10.00	0.00	10.00
2	0.00	10.00	0.00	10.00
3	0.00	10.00	0.00	10.00
4	0.00	10.00	0.00	10.00
5	0.00	10.00	0.00	10.00
6	0.00	10.00	0.00	10.00
7	0.00	10.00	0.00	10.00
8	0.00	10.00	0.00	10.00
9	0.00	10.00	0.00	10.00
10	0.00	10.00	0.00	10.00
11*	0.00	8.00	2.00	10.00
Neutral Visual				
1	0.00	0.00	10.00	10.00
2*	0.00	2.00	8.00	10.00
3	0.00	0.00	10.00	10.00
4	0.00	0.00	10.00	10.00
5	0.00	0.00	10.00	10.00
6	0.00	0.00	10.00	10.00
7*	0.00	1.00	9.00	10.00
8*	0.00	1.00	9.00	10.00
9	0.00	0.00	10.00	10.00
10	0.00	0.00	10.00	10.00
11	0.00	0.00	10.00	10.00

*Discarded

Appendix I Auditory Stimuli Recognition Questions

Instructions: Research says, "Which sentence did you hear?" for each set of sentences. The correct answer is in **Bold.**

1. Andrea was happy she won the beauty pageant.

   James was happy he got a new game.

   James was happy his hit won the game.

2. **Ashley was happy to go to the birthday party.**

   Amy was happy she got to stay up late.

   Dawn was happy her mom made her favorite pizza.

3. Daniel rode his favorite ride at the county fair.

   Jimmy loved the car he got for his birthday.

   Courtney celebrated her first wedding anniversary with her husband.

4. **David was going to Disney World with his best friend.**

   Cathy's boyfriend took her to her favorite restaurant for dinner.

   Carly had a beautiful wedding with her family and friends.

5. Briana was happy her husband took her to the Nutcracker ballet.

   Andrew was happy to be the MVP of the championship game.

   Zach was happy to meet the star of his favorite movie.

6. Jill's mom bought her any toy she wanted from the store.

   Suzy's mom bought her the puppy she had been asking for.

   Kaden got to stay up late to watch his favorite movie.

7. Brandon was happy to have perfect attendance at school this past year.

   Natalie was happy to play with all her friends at the park.

   John was happy he won first place in his first big race.

8. **Holly's school was closed so she played with friends in the snow.**

   Jack won the biggest bear ever playing the ring toss carnival game.

   Kyle played his best game of chess ever in his match yesterday

9. Chris was sad because his girlfriend dumped him.

   Tyler was sad his cat died last night.

   Taylor was sad because she missed her mother.

10. Braden was sad because he lost his new sunglasses.

    Tony was sad no one came to his party.

    Jeremy is sad because his dog is very sick.

11. Sebastian moved away from all of his close friends.

    Michael found a baby bird with a broken wing.

    Jessica's friends left her all alone at the carnival.

12. **Brady found out that his father has been very sick.**

Diane’s brand new purse was stolen from her gym locker.

Scott's money was all stolen from inside his back pocket.

13. Lauren was sad she dropped her new iPod in the pool.

Jenny is sad because her best friend is moving far away.

Tom was sad because his dog ate his brand new toy.

14. **George struck out and his baseball team lost the championship game.**

Christina got hit by a car and hurt her left arm.

Tori stayed home while her whole family went to the zoo.

15. Leslie was sad she had to miss the party to do homework.

Simon was sad because no one would play with him at recess.

Mary was sad no girls picked her to be in their group.

16. **Madeline was not allowed to play with her friends all summer long.**

Brenda ruined her favorite shirt by getting paint on it during art.

Rita sat in the corner by herself while her friends played games.

17. Nicole lives with her older brothers and sisters.

Adam opened the car window to get air.

Danny sat quietly on the tall bar stool.

18. **Megan walked down the hall and entered her bedroom.**

Shannon filled the glass with water and drank it.

Paul carried several grocery bags down the long hall.

19. Greg entered the building and walked into the office.

Karen closed each window before she laid in bed.

Josh turned on the light and closed the door.

20. Stephanie looked at the pictures on each of the walls.

Ron turned on the ceiling fan to circulate the air.

Sara sat on the couch and looked out the window.

21. **Allison laid on the bed and looked up at the ceiling.**

Vincent made six trips up and down three flights of stairs.

Alexandra put the shirt on the hanger and into the closet.

22. Eli turned off the light and tried to go to sleep.

Tim drank his milk and put the glass in the sink.

Samantha plugged the cord into the electric socket in the kitchen.

23. **Roy read the magazine and put it down when he was finished.**

Emily finished her drink and threw the empty bottle in the trash.

Erin heated up her lunch in the faculty microwave at her work.

24. Devin washed his dirty hand and dried them with a clean towel.

Pam just started her car this morning and turned on the radio.

Jay stood up when he heard the lady call out his name.

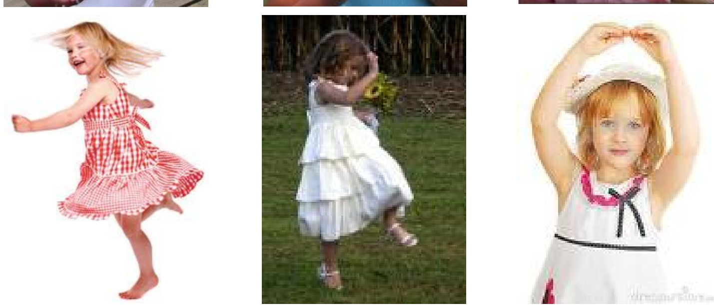
Appendix J Visual Stimuli Recognition Questions

Instructions: Researcher will say, “Which picture did you see?” for each set of three pictures.

1.

2.

3.



4.

5.

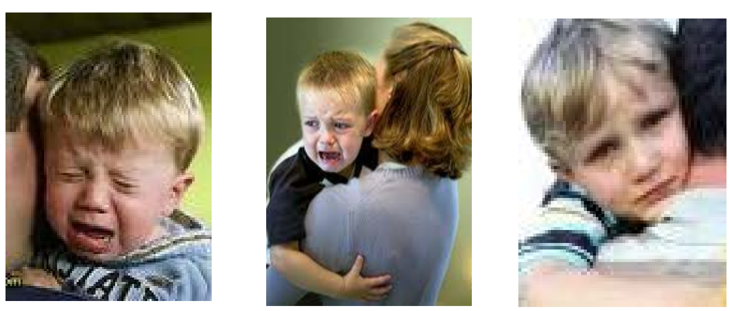
6.

7.

8.

9.

10.



11.

12.

13.

14.

15.

16.

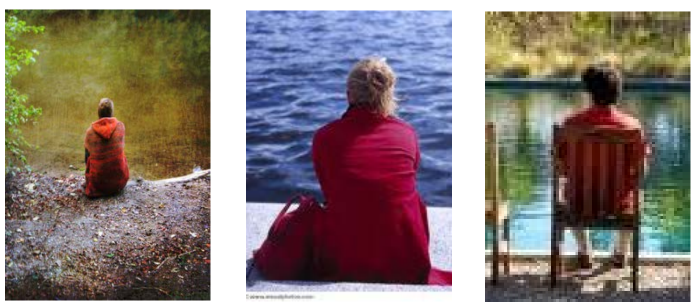
17.

18.

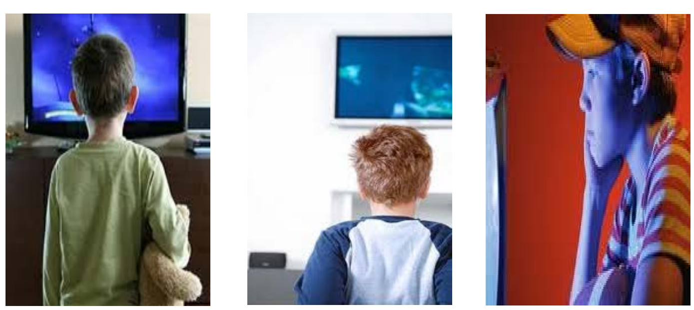
19.

20.

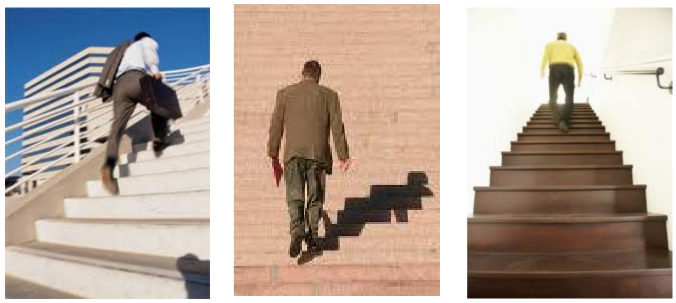
21.



22.



23.



24.

Appendix K Item Difficulty Values for Auditory Recognition Questions

Item	Item difficulty		
	Entire Sample	NT	ASD
Auditory 1	1.0000	1.0000	1.0000
Auditory 2	.9677	.9333	1.0000
Auditory 3	1.0000	1.0000	1.0000
Auditory 4	.8065	.6667	.9375
Auditory 5	.9032	.8667	.9375
Auditory 6	.7097	.7333	.6875
Auditory 7	.9355	.9333	.9375
Auditory 8	.8065	.9333	.6875
Auditory 9	.8387	.8667	.8125
Auditory 10	.9677	1.0000	.9375
Auditory 11	.9677	.9333	1.0000
Auditory 12	.6774	.7333	.6250
Auditory 13	.9355	.9333	.9375
Auditory 14	.7742	.8000	.7500
Auditory 15	.9032	.9333	.8750
Auditory 16	.8710	.8667	.8750
Auditory 17	.8387	.8667	.8125
Auditory 18	.8387	.8000	.8750
Auditory 19	.9032	.9333	.8750
Auditory 20	.8710	.8667	.8750
Auditory 21	.9355	.9333	.9375
Auditory 22	.7742	.8000	.7500
Auditory 23	.7097	.6000	.8125
Auditory 24	.6452	.6000	.6875

Appendix L Item Difficulty Values for Visual Recognition Questions

	Item Difficulty		
	Entire Sample	NT	ASD
Visual 1	0.9677	0.9333	1.0000
Visual 2	.9355	.8667	1.0000
Visual 3	0.9032	0.9333	0.8750
Visual 4	.9355	.8667	1.0000
Visual 5	.8710	.8000	.9375
Visual 6	.9032	.8667	.9375
Visual 7	.9355	.8667	1.0000
Visual 8	.9032	.8667	.9375
Visual 9	.9355	.8667	1.0000
Visual 10	.9032	0.9333	.8750
Visual 11	.9677	.9333	1.0000
Visual 12	.8710	.8667	.8750
Visual 13	.9032	.8667	.9375
Visual 14	.7742	.6667	.8750
Visual 15	.9355	.8667	1.0000
Visual 16	.9355	.8667	1.0000
Visual 17	1.0000	1.0000	1.0000
Visual 18	.9355	.9333	.9375
Visual 19	.9032	.8667	.9375
Visual 20	.8710	.7333	1.0000
Visual 21	.8065	.7333	.8750
Visual 22	.9355	.8667	1.0000
Visual 23	.7419	.6667	.8125
Visual 24	.9355	.9333	.9375