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Identifying Sex-Specific Cognitive And Diagnostic Profiles Of Children On The Autism Spectrum

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IDENTIFYING SEX-SPECIFIC COGNITIVE AND DIAGNOSTIC PROFILES OF CHILDREN ON THE AUTISM SPECTRUM

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DEDICATION

This dissertation is dedicated to Brandon and Sammy for their love, patience, and understanding. Only we truly understand everything that went into this process, and I appreciate you being by my side during the good times, the bad times, and everything in between. None of this would have been possible without you.

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CHAPTER 1: INTRODUCTION

The idea that males and females differ in ways beyond biology is not new. Ancient Chinese philosophers from as early as the third century B.C.E. used the yin-yang symbol to visually represent the stark contrast between males and females (Wang, 2005). In the fifth century B.C.E, the Hippocratic Corpus first discussed health-related differences in males versus females (Cadden, 1993). Although sex differences in general have received plenty of attention in research, there has been relatively less research dedicated to deciphering sex differences within disorders that have a known male preponderance, such as autism (Lai, Lombardo, Auyeung, & Chakrabarti, 2015). The current paper will discuss autism spectrum disorder (ASD) and what is known thus far about sex differences in ASD within the domains of cognitive ability and the core features of autism. This will set the stage for the current study, which is an investigation into the ways in which male and female children with ASD differ in autism symptom expression and cognitive ability, and highlights particular shortcomings in the ways in which variables have been defined and used in research of sex differences in ASD.

Autism Spectrum Disorder (ASD)

Autism spectrum disorder (ASD) refers to a class of developmental disorders that are characterized, in varying degrees, by difficulties in social interaction and communication, and restricted or repetitive behaviors and interests (American Psychiatric Association [APA], 2013). According to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition-Text Revision (DSM-IV-TR; APA, 2000), there were five distinct disorders under the ASD umbrella (collectively referred to as “pervasive developmental disorders”): autistic disorder, Asperger syndrome, pervasive developmental disorder-not otherwise specified (PDD-NOS), Rett’s disorder, and childhood disintegrative disorder. Now, since the release of the DSM-5 (APA, 2013), autistic disorder, Asperger syndrome, and PDD-NOS are now nonexistent categories that are replaced by the term "autism spectrum disorder" (ASD), although it is still common to use the labels of Asperger's and PDD-NOS or to use the word "autism" in place of ASD.

The Centers for Disease Control and Prevention (CDC; 2016) estimates that one in every 68 children in the United States has a diagnosis on the autism spectrum by eight years of age. These estimates from the Autism and Developmental Disabilities Monitoring (ADDM) Network were derived from data collected in 2012 from health and special education records of children living in the 11 states with ADDM Network sites: Arizona, Arkansas, Colorado, Georgia, Maryland, Missouri, New Jersey, North Carolina, South Carolina, Utah, and Wisconsin (Christensen et al., 2016). Across the ADDM Network sites, estimated ASD prevalence among the children studied was one in 42 boys and one in 189 girls. The overall male-to-female ratio for ASD prevalence was 4.5 (95% CI: 4.2 - 4.8; $p < 0.001$) to one; male-to-female prevalence ratios from individual ADDM Network sites ranged from 4.1 to one (in Colorado) to 6.3 to one (in Maryland), and each was statistically significant (Christensen et al., 2016).

Nine states in the ADDM Network (Arizona, Arkansas, Colorado, Georgia, Maryland, New Jersey, North Carolina, South Carolina, and Utah) had available data on intellectual ability for ≥70% of the children studied. The percentage of children with ASD classified in the intellectual disability range (IQ score ≤70 or the existence of an examiner's report of intellectual disability) varied widely across the nine sites, ranging from 20% (in Utah) to 50% (in Arkansas). The percentage of children with ASD and intellectual disability was significantly higher among females compared with males in all nine sites (37% for females and 30% for males; $p < 0.01$). There was a greater male-to-female prevalence ratio for ASD without intellectual disability (5.1:1; 95% CI: 4.6–5.7:1; p<0.001) than for ASD with intellectual disability (3.7:1; 95% CI: 3.2–4.3:1;

$p < 0.001$) (Christensen et al., 2016). Although these are the most current estimates, previous estimates of the male-to-female ratio in ASD without intellectual disability were as great as nine males to every one female (Fombonne, 2003).

Diagnosis of ASD. The Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2000) and the Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994) are considered to be the "gold standard" tools for diagnosing autism. The ADOS is a play-based, semi-structured assessment of functioning in areas most relevant to ASD: social interaction, communication, and restricted or repetitive behaviors and interests. The ADOS is standardized in terms of the order of activities, the allowable procedures within those activities, the items used, and the rules for coding behaviors. It is administered for children and adults suspected of having autism or other pervasive developmental disorders, and the module used (one of five) depends on the developmental level of the individual and chronological age, although the ADOS cannot be used with adolescents or adults who are nonverbal. The Toddler Module is administered to toddlers from 12 to 30 months of age who are either nonverbal, use single words, or inconsistently use simple phrases. Module 1 is administered to children older than 31 months of age who cannot or do not consistently use phrases, Module 2 is used with those who use phrases but are not verbally fluent, Module 3 is used with verbally fluent children from age 3 to early adolescence, and Module 4 is used with verbally fluent older adolescents and adults.

The assessment kit includes a series of toys and items that allow the examiner to engage in activities with the person being assessed to determine whether he or she exhibits behaviors identified as important to the diagnosis of ASD. In addition to these structured activities, the examiner observes certain unstructured activities, which may, depending on the module used, include a play sample where the examiner observes the caregiver playing with his or her child as they normally would. The responses to each activity are recorded and, at the end of the assessment, global ratings are chosen that reflect the examinee's overall functioning in the areas of social interaction, communication, and restricted or repetitive behaviors and interests. Each item is scored on a 4-point scale, with 0 indicating no occurrence of the specified behavior relevant to ASD and 3 indicating frequent occurrence of the specified behavior relevant to ASD (detailed scoring criteria are given for each item and vary between items, but higher scores always indicate greater severity related to ASD). An algorithm comprised of specific items is then used to determine whether he or she qualifies for a diagnosis on the autism spectrum. Scores exceeding specific thresholds are indicative of a classification of "autism" or "autism spectrum," versus "non-spectrum."

Examples of potential behaviors suggestive of a possible ASD diagnosis include, but are not limited to: 1) Lack of appropriate eye contact; 2) Not using language in a social way (e.g., only using language to make requests, label objects, say thank you, et cetera); 3) Inappropriate response to his or her own name; 4) Flat affect or mechanical vocalizations; 5) Lining up toys in a row; 6) Not engaging in make-believe play; 7) Not responding appropriately to bids by the examiner; 8) Not drawing others' attention to objects in the distance.

To get the parents' perspective of their child's development and gain a more complete picture of the child's functioning, clinicians often use the Autism Diagnostic Interview (Revised), or ADI-R, in conjunction with the ADOS in the diagnosis of ASD. The ADI-R is a standardized, semi-structured interview administered by a clinician to the caregivers of a child or adult that is suspected to have ASD. It has 93 questions that address the child's functioning in three different areas: social interaction, communication and language, and repetitive, restricted and stereotyped interests and behavior. Examples of items assessing the quality of social interaction include failure to use eye-to-eye gaze, lack of social smiling, using a range of facial expressions to communicate, failure to develop peer relationships, lack of imaginative play with peers, and seeking to share in one's own enjoyment. Examples of items assessing the quality of communication and language include delay or lack of spoken language, failure to point to express interest, failure to initiate or sustain conversations, and lack of conventional gesture usage. Examples of items used to determine whether repetitive, restricted and stereotyped interests and behaviors are present include repetitive use of objects, unusual preoccupations, compulsions or rituals, and unusual sensory interests.

Items are coded as 'no definite behavior of the type specified' (0), 'behavior of the type specified probably present but defining criteria not fully met' (1), and 'definite abnormal behavior of the type described in the definition and coding' (2). A code of 3 is not used often, but indicates extreme severity on that behavior or domain. These items are scored based on the caregiver's description of the child and whether they indicate that specific behaviors are present, except for a few behaviors that are scored based on their occurrence during specific age periods (e.g., imaginative play is only scored between the ages of 4 and 10, and the item referencing reciprocal friendships is only scored after the age of 10). Scores are then summed and a diagnosis of autism is given when scores in each of the three domains meet or exceed the predetermined cutoffs. The total cutoff score for the communication and language area is 8 for verbal individuals and 7 for nonverbal individuals. For all subjects, the cutoff for the social interaction domain is 10, and the cutoff for restricted and repetitive behaviors is 3.

Influence of Culture in ASD Diagnosis. The ADOS and ADI-R have given clinicians the ability to diagnose autism in a standardized and valid way, but they were not designed to consider differences between cultures. The ADOS has been translated into numerous languages, but more research needs to be conducted on the possibly confounding impact of cultural variables. The original paper describing the ADOS written by the authors of the instrument states this limitation very clearly: “Specific effects of cultural factors have not yet been addressed systematically in research, though the ADOS has been used in many European and some Asian countries. For valid scoring, the examiner should consider the appropriateness of a child or adult’s behavior within that individual’s cultural context” (Lord et al., 2000; p. 222). Although this is mentioned briefly as a caveat, the authors offer no suggestions as to how individuals from various cultures may exhibit different behaviors that are and are not indicative of autism. Thus, it is very likely that the use of ADOS and ADI-R criteria across cultures can be inaccurate. For example, Kim and colleagues (2011) conducted an epidemiological study of ASD in South Korea using the ADOS and ADI-R and found that 1 in 38 children would qualify for a diagnosis of ASD using these instruments. It seems possible that cultural differences in talkativeness and rules for relating to adults might be influencing this figure.

Moreover, direct translation of some of the ADI-R items may not even make sense in other languages or cultures. For instance, if you try to ask whether a child “separates easily from caregivers,” a direct translation of this phrase would not represent the same idea in German or Swedish. Another direct translation that would not be understood in some other languages or cultures is the item about whether a child invites his or her peers to play. This would be difficult to capture in Cantonese and Mandarin translations because this is not something that occurs in those cultures. There are also places in the world where it is not customary to point with your fingers, nor is it customary to celebrate birthdays with an American-style birthday party, so the parts of the ADOS and ADI-R that examine whether the person points with their finger or responds appropriately to bids from the examiner during a simulated birthday party (including singing the

Happy Birthday song, cutting and handing out slices of cake) are not valid for use in some other cultures. Also, one of the behaviors that is usually indicative of an impairment associated with ASD in other cultures is an inability to change one's language to respond appropriately to a person based on their status. Suffixes that represent the status of a person you are speaking with are present in many other languages but are not present in English, and are therefore not a part of the ADOS or ADI-R.

One of the core difficulties experienced by individuals with ASD is with reciprocal social interaction. Cultures vary in the degree to which they feel certain social behaviors are appropriate, so this may impact the accuracy of an ASD diagnosis. In some Asian cultures, direct eye contact with persons of authority is considered disrespectful (Lian, 1996; Sue & Sue, 2008). Lack of direct eye contact is considered a sign of ASD, so Asian children that avoid eye contact because of the social norms of their culture may appear as if they exhibit signs of ASD when perhaps they do not. Similarly, the use of index finger pointing as a communicative bid to share interest is not a common practice in some Asian cultures, and may not be considered an important acquisition in children's social development in these cultures (Zhang, Wheeler, & Richey, 2006). Moreover, cultures that place a priority on respect for authority, as in Asian and Hispanic cultures, may engage in less bi-directional, interactive communication with adults (Rogers-Adkinson, Ochoa, & Delgado, 2003).

According to Daley (2004), in some Indian cultures, a child who does not relate socially with peers his or her age might be considered mature because of the child's ability to relate better to adults. Also, Indian boys tend to use language much later than children in western cultures, and an Indian child who keeps quiet is often perceived as a good child because he or she is compliant and respectful. Not relating with peers socially and not using language are considered signs of ASD, so these children may appear as if they exhibit signs of ASD.

Japan is considered a collectivist culture, meaning that the Japanese value the group over the individual and tend to be other-directed. As such, the Japanese are very sensitive to and concerned about their relationships and preserving harmony. The Japanese consider the “self” as consisting of two separate parts, the inner self and outer self, or “social self.” The outer self is what is typically shown to others, while the inner self remains private. The central, underlying part of the inner self is the *kokoro*, a “reservoir of truthfulness and purity that remains private and is not shared with outsiders” (Gardiner & Kosmitzki, 2011, p. 154). Moreover, it is part of Japanese culture that individuals often avoid direct communication and are very careful to maintain control over their emotions and actions. This allows for the Japanese to mask their feelings and, as a result, sometimes appear to outsiders as if they are extremely timid or modest. Even if the Japanese individual is very confident, he or she is taught not to behave in an outwardly confident manner according to cultural expectations. This lack of engagement in social communication and appearance of flat affect may make the child appear as if they have symptoms of autism.

Sex/Gender and ASD Diagnosis. Leo Kanner’s (1943) original study that gave us the first description of what we now know as autism included a sample of nine Anglo-Saxon children and two Jewish children, and the vast majority of the individuals he observed in practice were of Anglo-Saxon descent. The children studied by Hans Asperger (1944; translated by Frith [1991]) were also predominantly Anglo-Saxon. Consequently, the identification and initial descriptions of autism and Asperger syndrome were based on samples of children of a relatively uniform race, and the majority of research for decades has neglected to thoroughly investigate racial or cultural issues related to autism. In addition to ignoring racial, ethnic, or cultural variations, these studies also ignored the potential impact of gender. In Kanner’s (1943) study, eight out of the eleven participants were male, and all four of the cases in Asperger’s (1944) work were male. In fact, Asperger (1944) stated that he believed Asperger syndrome did not occur in females. Therefore, the descriptions on which we based our understanding of autism and Asperger syndrome were derived based on the behaviors and clinical features of autism and Asperger syndrome as they present in males of Anglo-Saxon descent. Moreover, the standardization and norming process of the ADOS and ADI did not factor in differences between males and females with ASD, therefore there are no specific diagnostic criteria or norms for males versus females. Although the gold-standard diagnostic instruments for diagnosing ASD do not take into account sex differences, there is a screening measure, the Social Responsiveness Scale (SRS; Constantino & Gruber, 2005), that has demonstrated higher mean scores for males versus females and has sex-specific score cut-offs, with a lower threshold for females compared to males (Constantino & Gruber, 2005). These are, however, just for ASD screening and not diagnosis, and are questionnaires that are completed by parents or teachers. Although they have been found to demonstrate adequate sensitivity and specificity, they are still susceptible to the same issues of social desirability and bias as other questionnaire and parent-report measures.

The lack of females in the norming samples and lack of consideration of sex differences in ASD has led to the underrepresentation of females in research and a male-biased understanding of ASD. As a result, some researchers have suggested that perhaps many females with ASD are never referred for diagnosis because of the lack of knowledge of how ASD presents in females, and are thus missing from prevalence estimations, even though they may indeed have ASD and could benefit from diagnosis and intervention services (Ehlers & Gillberg, 1993; Wing, 1981). It may also be that females with ASD have the same underlying deficits or yet-to-be-discovered mechanisms that cause ASD, but are better able to camouflage their autistic-like traits or are less disruptive than males with ASD, and are therefore less likely to be referred for diagnosis.

According to Rynkiewicz and colleagues (2016), females with ASD with higher than average IQ and language have a series of compensatory skills, including better use of eye contact and gestures, superior observational learning skills, better emotion regulation, stronger adherence to social rules, and better ability to camouflage their autistic-like traits. This ability to compensate for or camouflage their autistic-like traits may involve consciously or subconsciously adopting the social roles they observe in others or more closely following social scripts (Lai et al., 2011). Another study (Dworzynski, Ronald, Bolton, & Happé, 2012) found that girls were less likely than boys ages 10 to 12 years to meet ASD diagnostic criteria (as assessed by a parent interview, the Development and Well-Being Assessment; Goodman, Ford, Richards, Gatward, & Meltzer, 2000), even when they had equivalent levels of ASD symptomatology, according to a trait measure of ASD, the Childhood Autism Spectrum Test (CAST; Scott, Baron-Cohen, Bolton, & Brayne, 2002), which is a parent-report questionnaire. The authors then concluded that girls have better adaptation or compensatory skills and are therefore less likely to obtain an ASD diagnosis despite having the same level of ASD symptomatology as their male counterparts, but these results could also indicate that there are true sex differences in ASD that may not be captured by questionnaires relying on parent report, and highlight the importance of using well-validated assessments for diagnosing ASD that are administered by trained clinicians. Moreover, if the ASD diagnostic criteria are based on the presentation of ASD in males, it is possible that less females would qualify for a diagnosis even though they descriptively seem to be on the autism spectrum, but display a divergent ASD profile.

Sex Differences in ASD

Cognitive ability. The cognitive ability of males versus females with ASD has been debated in research (Lai, Lombardo, Auyeung, Chakrabarti, & Baron-Cohen, 2015; Rivet &

Matson, 2011; Rubenstein, Wiggins, & Lee, 2015). It is often stated that females with ASD tend to have a more severe form of the disorder than males with ASD, exhibiting impaired adaptive skills and cognitive ability (Volkmar, Szatmari, & Sparrow, 1993), as well as lower receptive language skills (Tsai & Beisler, 1983) and nonverbal intelligence (Ankenman, Elgin, Sullivan, Vincent, & Bernier, 2014; Banach et al., 2009; Baron-Cohen & Hammer, 1997; Lord, Schopler, & Revicki, 1982). Another study, however, only found superior verbal, not nonverbal, skills in male toddlers with ASD compared to females (Carter et al., 2007). Other research has indicated that boys with ASD perform better on measures of both verbal and nonverbal intelligence compared to girls (Frazier et al., 2014; Volkmar, Szatmari, & Sparrow, 1993). With regard to sex differences within other types of cognitive abilities, high-functioning girls with ASD have been found to exhibit poorer performance on cognitive flexibility measures (from the Wisconsin Card Sorting Test; Kongs, Thompson, Iverson, & Heaton, 2000) compared to boys (Memari et al., 2013), whereas older male children with ASD tend to present with superior visual attention to detail (using the Block Design subtest from the Wechsler intelligence Scales; Wechsler, 1991) when compared to females (Bölte, Duketis, Poustka, & Holtmann, 2011). Spatial reasoning ability was also shown to favor boys as opposed to girls with ASD in one study (Tarampi, Heydari, & Hegarty, 2016).

In contrast, Carter and colleagues (2007) found that female toddlers with ASD demonstrated better nonverbal problem solving abilities and better visual perception compared to their male counterparts. Bölte and colleagues (2011) found that girls with high-functioning ASD outperformed boys on executive functioning measured by the Trail Making Test B-A, which is a neuropsychological test of visual attention and task switching (Reitan, 1955), whereas males outperformed females in visual attention to detail as measured by the Block Design Test. In addition, executive functioning difficulties were associated with stereotyped behaviors and interests. Other studies found that boys with ASD outperform girls on visual attention to detail, which is characterized by a tendency to focus on local features or details as opposed to the bigger picture, and was measured by the Embedded Figures Test (Joliffe & Baron-Cohen, 1997). Boys with ASD also outperformed girls on the Tower of Hanoi, which measures executive functions such as cognitive flexibility and conceptual planning (Nydén, Hjelmquist, & Gillberg, 2000).

Examination of sex differences in overall intelligence has revealed that boys with ASD have significantly higher overall IQ scores than girls with ASD (Frazier et al., 2014; Lord, Schopler, & Revicki, 1982; Volkmar, Szatmari, & Sparrow, 1993). Other studies investigating the general cognitive ability of boys versus girls with ASD have found no significant effect of sex (Kumazaki et al., 2015; Mandy et al., 2012), although both studies were limited to children with high-functioning autism and the study by Kumazaki and colleagues (2015) was limited to children between the ages of five and nine years old.

Other research of sex differences in cognitive ability in ASD has focused on the discrepancies between verbal and nonverbal intelligence, although research in this area is quite limited. According to Frazier and colleagues (2014), the discrepancy between verbal and nonverbal intelligence is less pronounced in females with ASD, with males more likely to show discrepantly high nonverbal skills and females more likely to show discrepantly high verbal skills. In addition to finding that males with ASD score higher than females on measures of nonverbal intelligence and do not differ in terms of verbal intelligence, Ankenman and colleagues (2014), using a sample of high-functioning children with autism, also found a greater percentage of males with discrepantly high nonverbal versus verbal intelligence compared to females, and a greater percentage of females without a verbal-nonverbal discrepancy compared to males. Examination of the discrepancies between verbal and nonverbal reasoning skills for males versus females with ASD could help elucidate the contradictory findings in research of sex differences within ASD, in that perhaps composite scores representing cognitive ability collapse across verbal and nonverbal intelligence in such a way that it reduces variance, and differences in ability between males and females in specific cognitive domains are not as easily ascertained.

In sum, most sex differences in ASD within the cognitive domain are found in nonverbal and verbal intelligence, visuospatial processing, executive functioning, and the presence of a discrepancy between verbal and nonverbal intelligence, although findings are mixed and often contradictory. The fact that different diagnostic criteria and instruments have been used to diagnose ASD in the studies of sex differences conducted thus far means that this could be contributing to the contradictory findings (Lord & Schopler, 1985). Moreover, previous studies that used the original description of autism to identify participants for their studies likely only included very low functioning children with severe autism, as the criteria were not previously sensitive enough to identify individuals across the entire autism spectrum, and could have also included many individuals with unidentified comorbid diagnoses that would have a confounding impact on analyses. Furthermore, the research thus far on sex differences in cognitive ability within ASD has either included a narrow age range focusing on very young children (Carter et al., 2007; Lord, Schopler, & Revicki, 1982; Pilowsky, Yirmiya, Shulman, & Dover, 1998; Tsai & Beisler, 1983), or had samples spanning a large age range that included both children and adults with ASD, and also included only those with intellectual disability or combined those with and without intellectual disability (see Van Wijngaarden-Cremers et al., 2014).

Core features of autism. There have been relatively few studies of sex differences in the core features of autism—deficits in reciprocal social interaction and communication, and repetitive, stereotyped behaviors and interests—and available findings are inconsistent. Lord and colleagues (1982) found that females with ASD ages three to eight had more social deficits (from the Vineland Adaptive Behavior Scales; Sparrow, Cicchetti, & Balla, 2005) than males with ASD. Using scores from the Developmental Profile (Alpern & Boll, 1972) and the Symbolic Play Test (Lowe & Costello, 1976), Tsai and Beisler (1983) found that boys had greater social and play skills than girls with ASD. Similarly, Hartley and Sikora (2009) found that toddler boys with ASD have better social communication skills than their female counterparts, using the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000). Carter and colleagues (2007) also found that male toddlers with ASD showed better social interaction skills (from the Autism Diagnostic Interview-Revised) and better socialization skills (from the Vineland Adaptive Behavior Scales) compared to female toddlers with ASD, although no significant sex differences were found in reciprocal social interaction from the ADOS-G or social relatedness from the Infant-Toddler Social and Emotional Assessment (ITSEA; Carter, Briggs-Gowan, Jones, & Little, 2003). In an adult sample with ASD, females were found to have fewer socio-communication difficulties during interpersonal interaction compared to males (Lai et al., 2013).

In contrast, other studies have not found sex differences in social skills for children with ASD (Andersson, Gillberg, & Miniscalco, 2013; Dawson et al., 2007; Holtmann, Bölte, & Poustka, 2007; Mandy et al., 2012; Mayes & Calhoun, 2011; Pilowsky, Yirmiya, Shulman, & Dover, 1998). Using the Broader Phenotype Autism Symptom Scale, Dawson and colleagues (2007) found no significant sex differences for children with ASD in the domains of social motivation, expressiveness, conversational skills, or flexibility and range of interests. Pilowsky, Yirmiya, Shulman, and Dover (1998) used the Autism Diagnostic Interview-Revised and Childhood Autism

Rating Scale (CARS; Schopler, Reichler, & Renner, 1988), but still did not find differences between males and females on the symptoms of ASD. Similarly, Szatmari and colleagues (2012) did not identify sex differences in social-emotional reciprocity (from the Autism Diagnostic Interview-Revised) for children with ASD. Mayes and Calhoun (2011) evaluated children with ASD using the Checklist for Autism Spectrum Disorder (CASD; Mayes, 2012) and did not find any sex differences on the 30 core and associated symptoms of ASD. Moreover, adult men and women with Asperger syndrome or high-functioning autism are not significantly different from each other in their social functioning and desire to have close friendships with others, according to research using a self-report questionnaire (Baron-Cohen & Wheelwright, 2003).

Compared to the literature on sex differences in communication and social interaction associated with ASD, the findings related to sex differences in restricted and repetitive behaviors and interests is decidedly less inconsistent. Most research suggests that males with ASD have more restricted and repetitive behaviors and interests than females with ASD (Bölte, Duketis, Poustka, & Holtmann, 2011; Carter et al., 2007; Hattier et al., 2011; Rubenstein, Wiggins, & Lee, 2015). Hattier, Matson, Tureck, and Horovitz (2011) found a higher frequency of restricted and repetitive behaviors and interests in males compared to females with ASD, using the Stereotypies subscale of the Diagnostic Assessment for the Severely Handicapped, Second Edition (DASH-II; Matson, 1995). Moreover, high-functioning boys with ASD exhibited more restricted and repetitive behaviors and interests according to the Autism Diagnostic Interview-Revised (Bölte, Duketis, Poustka, & Holtmann, 2011; Szatmari et al., 2012) and Autism Diagnostic Observation Schedule (Bölte et al., 2011), compared to their female counterparts. May, Cornish, and Rinehart (2012) used the parent-report Repetitive Behaviors Questionnaire–Second Edition (RBQ-II; Leekam et al., 2007) and found that males exhibited more repetitive motor movements compared to females with ASD, although another study found that there is no significant effect of sex on the presence of repetitive motor movements (McLennan, Lord, & Schopler, 1993). Male children with ASD also exhibited more restricted interests compared to female children with ASD in some studies (Mandy et al., 2012; May, Cornish, & Rinehart, 2012; Szatmari et al., 2012).

Research investigating sex differences in core ASD symptomatology has uncovered that differences are often impacted by level of intelligence (Holtmann et al., 2007; Pilowsky, Yirmiya, Shulman, & Dover, 1998; Tsai, Stewart, & August, 1981; Volkmar, Szatmari, & Sparrow, 1993), although other studies have found sex differences independent of IQ (Carter et al., 2007; Lord, Schopler, & Revicki, 1982; McLennan, Lord, & Schopler, 1993). This is important to consider in the discussion of sex differences in restricted or repetitive behaviors and interests in ASD, because restricted or repetitive behaviors and interests have been found to be highly associated with intellectual disability, with and without a diagnosis of ASD (Matson et al., 1997; Matson, Hess, & Boisjoli, 2010; Muthugovindan & Singer, 2009; Wilkins & Matson, 2009). If the majority of research of sex differences in ASD has included females with ASD and comorbid intellectual disability, because they were more likely to be identified with ASD and therefore easier to find for research participation, then it is possible that the sex differences in restricted or repetitive behaviors and interests is an artefact of the intelligence level of the sample and is not a true difference between males and females with ASD. Additionally, the presence of intellectual disability within the research sample may also confound findings related to significant sex differences in communication, and verbal and nonverbal reasoning ability, although differences in nonverbal reasoning ability have also been identified in samples comprised of only high-functioning children with autism (see discussion above).

As mentioned previously, different diagnostic criteria and instruments have been used to diagnose ASD in the studies of sex differences conducted thus far. Now that we have improved the diagnostic criteria and the sensitivity and specificity of the diagnostic instruments used to diagnose ASD, it is imperative that we begin to look more closely at sex differences within the autism spectrum to identify where differences occur between males and females with ASD, to improve our diagnostic instruments and to increase our ability to identify early intervention goals appropriate for each individual child.

The Current Study

A review of the literature demonstrates that previous studies investigating distinct cognitive and ASD symptom profiles among males and females with ASD have relied exclusively on samples of children with high-functioning autism, and often relied on the use of parent-report questionnaires as opposed to observational measures to quantify the features indicative of autism. The inclusion of a wider range of abilities, including those with more severe autism, within the sample may allow for the elucidation of whether sex differences exist across the autism spectrum. In addition, due to the relative infrequency of females with ASD (Christensen et al., 2016), the majority of the aforementioned studies lack sufficient statistical power to detect small and medium sex effects, which has led to the reporting of numerous null or contradictory findings that are difficult to interpret. It is also common to use total, summary, or composite scores from measures, as opposed to more detailed subscale scores that may provide more information on the subtleties of sex differences within ASD.

Thus, there is a need for research of sex differences in ASD that includes a larger, more diverse sample of males and females affected and severely affected by ASD, but without comorbid psychopathology or disabilities that may have a confounding effect on analyses. The current study fills the aformentioned gaps in the literature and overcomes prior methodological shortcomings by using a larger, more diverse sample of children with ASD to determine whether there are significant differences between males and females in the domains of cognitive ability (general conceptual ability, and nonverbal reasoning, verbal, and spatial abilities) and the core features of autism (deficits in reciprocal social interaction and communication, and restricted or repetitive behaviors and interests), as defined by widely used observational assessments for assessing cognitive ability and diagnosing ASD. These analyses will also demonstrate the utility of subscale scores, as opposed to total, summary, or composite scores, for providing more accurate and detailed descriptions of the relative strengths and weaknesses of males and females with ASD. The current study also investigates whether a significant discrepancy between verbal and nonverbal reasoning ability varies by sex, and whether this discrepancy is differentially impacted by ASD severity.

CHAPTER 2: METHODS

Participants and Procedures

A sample of children with autism (*N* = 253; *n* = 213 males, *n* = 40 females) was retrieved from the National Database for Autism Research (NDAR), a National Institutes of Mental Health (NIMH) data repository supported by the National Institutes of Health (NIH) for the advancement of ASD research through data sharing and collaboration.

The current study included data from the following NDAR collections (along with submitters): “University of Illinois at Chicago Autism Center of Excellence: Translational Studies of Insistence on Sameness in Autism” (Edwin H. Cook, University of Illinois at Chicago); “Sequencing Autism Spectrum Disorder Extended Pedigrees” (Gerard Schellenberg, University of Pennsylvania; Hilary Coon, University of Utah; and Ellen Wijsman, University of Washington); “Functional Neuroimaging of Attention in Autism” (Benjamin Yerys, Children’s Hospital of Philadelphia); “University of Washington Autism Center of Excellence Extended Family Study” (Bryan King, University of Washington); “Studies to Advance Autism Research and Treatment (STAART)” (Elizabeth Aylward and Geraldine Dawson, University of Washington; Joseph Buxbaum and Eric Hollander, Mount Sinai School of Medicine; Rebecca Landa, Kennedy Krieger Institute; Patricia Rodier, University of Rochester; Marian Sigman, University of California Los Angeles; Helen Tager-Flusberg, Boston University); “Early Pharmacotherapy Guided by Biomarkers in Autism” (Diane C. Chugani, Wayne State University); “Eyeblink Conditioning in School-Aged Children with ASD” (John Welsh, Seattle Children’s Hospital); and “Development of a Screening Interview for Research Studies of ASD” (Catherine Lord and Christopher Monk, University of Michigan; Somer Bishop, Cincinnati Children’s Hospital), because these studies included participants that met the inclusion criteria described below.

Participants were included from the collections mentioned above because they had available data containing the Differential Ability Scales, Second Edition, School-Age Battery (DAS-II; Elliott, 2007a) and the Autism Diagnostic Observation Schedule, Module 3 (ADOS; Lord, Rutter, DiLavore, & Risi, 2000). Participants were also included if they were categorized as either "Autism Spectrum—Affected" or "Autism Spectrum—Severely Affected," according to phenotypes defined by NDAR (phenotype derivations are described below). To exclude individuals who may not have a reliable or stable diagnosis of ASD, or who have confounding comorbidities, participants were excluded if they were categorized as either "Autism Spectrum—Mildly Affected" or "Fragile X," or if they were a non-spectrum control.

NDAR phenotypes are defined based on each participant's scores on various assessments, including the Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003), Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000), and the Vineland Adaptive Behavior Scales, Survey Interview Form (VABS; Sparrow, Cicchetti, & Balla, 2005), which are assessments commonly used in the diagnosis of ASD. Phenotypes are defined by determining whether the participants meet criteria for each category, in the following order:

1. Fragile X
2. Non-Spectrum Controls
    a. Typical
    b. Sibling
    c. Parent
    d. Neurological disorders (subjects with a learning disability, Attention Deficit Hyperactivity Disorder, developmental disability, intellectual disability, or other neurological disorder, other than Fragile X)

3. Autism Spectrum

    a. Severely affected

    b. Mildly affected

    c. Affected

Once a phenotype is defined for a participant, the process stops. For example, if the rules engine determines that a participant has Fragile X, they are defined as such and no determination is made about whether he or she is on the autism spectrum—participants are not assigned multiple phenotypes at any one age. Each assessment has the age, in months, that the assessment occurred for each participant, and a phenotype designation is given for every observation that occurs ±3 months from another observation. For example, if a participant is defined as "Autism Spectrum—Severely Affected" based on their scores at 28 months, no other phenotype is given for observations occurring between 25 and 31 months of age. More detailed information on the phenotype rules and score cut-offs can be found in Appendix A.

For the current study, there are 120 children in the ASD Affected group (47.4% of total participants), with 98 males (46% of all males) and 22 females (55% of all females). There are 133 children in the ASD Severe group (52.6%), with 115 males (54% of all males) and 18 females (45% of all females). The mean age of the participants at the time they were administered the ADOS is 10.37 years (*SD* = 3.05; Range = 5.75 – 16.83) for females, and 10.48 years (*SD* = 2.73; Range = 4.92 – 16.33) for males. For the DAS-II, the mean age is 10.71 years (*SD* = 2.83; Range = 6.08 – 16.83) for females, and 10.79 years (*SD* = 2.67; Range = 4.92 – 16.42) for males.

As noted previously in the section describing the NDAR collections from which the data for the current study were derived, participants were from labs or research centers in California, Illinois, Maryland, Massachusetts, Michigan, New York, Ohio, Pennsylvania, Utah, and Washington.

Measures

Differential Ability Scales, Second Edition (DAS-II), School Age Battery. The Differential Ability Scales, Second Edition (DAS-II), School Age Battery (Elliott, 2007a) is an individually-administered, age-referenced assessment of cognitive abilities for individuals from ages 7 years to 17 years, 11 months. The DAS-II yields scores in Verbal Ability, Nonverbal Reasoning Ability, and Spatial Ability, as well as a composite score representing General Conceptual Ability, which is comprised of scores on the three clusters. The current study used standard scores (M = 100, SD = 15) for General Conceptual Ability, Verbal Ability, Nonverbal Reasoning Ability, and Spatial Ability, and T-scores for the six subtests that comprise the three clusters. Higher scores indicate greater ability, and according to the DAS-II classification schema, standard scores between 90 and 109 and T-scores between 43 and 56 are generally considered to reflect functioning within average limits for age. More detailed information about each cluster and its corresponding subtests is presented below.

Verbal Ability cluster. This cluster measures crystallized intelligence, or the accumulation of verbal concepts and knowledge. This cluster is also thought to reflect the child's language comprehension, expressive language skills, level of vocabulary development, conceptual understanding and abstract verbal thinking, and long-term memory retrieval. This cluster is comprised of two subtests: Verbal Similarities and Word Definitions. Word Definitions tests the child's knowledge of the meaning of single words, whereas Verbal Similarities assesses the child's ability to determine the conceptual relationship between words. For the Word Definitions subtest, a word is presented orally to the child and they are asked to tell the examiner what the word means.

The items are marked as correct or incorrect, based on whether the child expresses concepts that are key to each word's meaning. For the Verbal Similarities subtest, the child is given three words and is asked how they go together, or how they are alike. For example, the child may be given the words "pineapple, strawberry, grape" and would be asked to name the class to which all those items belong. Most items are marked as "pass" (1) or "fail" (0), except for items 27-29 and 32, which are more difficult and are therefore scored on a 3-point scale (0, 1, 2), based on the thoroughness of the given answer.

Nonverbal Reasoning Ability cluster. Nonverbal Reasoning Ability primarily measures nonverbal, inductive reasoning, and requires different levels of complex mental processing. This cluster examines the child's ability to identify rules that dictate features of an abstract problem, and the child's ability to formulate and test hypotheses. It is also thought to approximate the child's analytical reasoning ability and perception of visual details.

The subtests that make up this cluster, Matrices and Sequential and Quantitative Reasoning, are presented visually and require only minimal verbal instructions from the examiner and no required verbal response from the child. For the Matrices subtest, the child is shown an incomplete matrix and they are required to select, from among four or six choices, the figure that completes the matrix. For Sequential and Quantitative Reasoning, the child is shown a series of items in a pattern and then completes the series by finding the missing figure. If the child progresses through enough of the items, they also reach a section in which they are required to find the relationship within each of two pairs of numbers, and then they must apply the relationship to an incomplete pair of numbers and provide the missing number. Individual items are marked as "pass" (1) or "fail" (0) for both subtests.

Spatial Ability cluster. This cluster is thought to reflect the child's ability to navigate complex visual-spatial problems, including their ability to decompose a design into its component parts, to reconstruct a whole from component parts, to visually attend to fine details, and maintain the relative position, size, and angles of different features of a design. The subtests that comprise this cluster are Recall of Designs and Pattern Construction.

The Recall of Designs subtest of the Spatial Ability cluster measures the child's ability to recall abstract designs (line drawings) after a brief display of each figure, and they must draw each item with a pencil and paper. The designs get more complex as the test progresses, but even at the beginning they are substantially challenging, not only because of the designs themselves but also because the exposure to each design is very brief, lasting approximately 5 seconds. This is meant to minimize the contribution of underlying verbal processes. Scoring for this subtest is on a three-point scale (0, 1, or 2), or four-point scale (0, 1, 2, or 3) for later items, and scoring criteria include whether there are any missing components of the drawing, whether there are any distortions, and the correctness of the spatial relationships within and between components. An example of incorrect spatial relationships in a drawing earning the child one point instead of two points is if the drawing had all the correct components but their relative positions were reversed. Moreover, although the child's drawings are scored based on whether they match the target drawing, accuracy of fine details does not play a major role in scoring, therefore children without artistic abilities, so to speak, are not scored unfairly.

The Pattern Construction subtest of the Spatial Ability cluster measures the child's ability to formulate and test hypotheses, visually analyze the fine details of figures and designs, and mentally manipulate the orientation of figures. For earlier items on this subtest, the child is asked to copy a two- or three-dimensional design using wooden blocks. As the child progresses through the test, they may reach other more challenging items that require them to construct the presented design by putting together flat squares or solid blocks with black and yellow patterns on each side. Scores are generally recorded as “pass” (1) or “fail” (0), with some items scored on a three-point scale (0, 1, or 2). Scoring is based on the correct positioning of the blocks, and overlaps or gaps between blocks being no greater than 0.25 inches. Any vertical structure that is created also needs to stand for at least 3 seconds. Additionally, children have the possibility of gaining bonus points for speed on each item for this subtest only. The criteria for bonus points based on response time vary by item, but range from 0 to 4 additional points. For example, for item 17, the child is given 4 bonus points if they correctly build the pattern within 1 to 15 seconds, 3 bonus points if it is between 16 and 20 seconds, 2 bonus points if it is between 21 and 30 seconds, 1 bonus point if it is between 31 to 60 seconds, and 0 bonus points if they take 61 seconds or longer to reach the correct response.

Standardization and psychometric properties of the DAS-II. The DAS-II was standardized and normed on a sample of 3,480 children selected to be a representative sample of children living in the United States in 2005, based on the distribution of age, sex, race/ethnicity, parental educational level, and geographical region within the United States, compared to the October 2005 United States Census populations. The norming sample was judged to be very similar to the general United States population based on these criteria, and rarely differed by more than 1 percentage point. The children were proficient in English and were ages 2 years, 6 months to 17 years, 11 months. Children living in institutions or living with severe disabilities were excluded from the norming sample, although the sample did include children with mild perceptual, speech, and/or motor impairments, so long as these impairments were not judged to affect the validity of the DAS-II administration procedures.

Research indicates that the DAS-II School-Age Battery has sufficient psychometric properties, with a mean internal consistency of .96 for General Conceptual Ability, and inter-rater reliability for the individual clusters ranging from .89 to .95 (Elliott, 2007b). These tests are deemed sufficiently reliable based on the criteria described by Sattler (2008), which is a reliability coefficient at or above .80 for cognitive testing procedures.

Autism Diagnostic Observation Schedule- Second Edition (ADOS-2), Module 3. A more detailed description of the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2000) was presented above. In 2007, the original ADOS algorithms were revised to give researchers the ability to compare across modules, with the new algorithms consisting of the same number of items and of similar content across modules (Gotham, Risi, Pickles, & Lord, 2007). In addition to improving the ability to compare across modules, the revised algorithms also happened to increase the predictive validity and specificity of the ADOS, especially for individuals with ASD and comorbid intellectual disability (Gotham et al., 2007). The revised algorithm now yields scores in two different domains: Social Affect (comprised of two subdomains: Communication and Reciprocal Social Interaction) and Restricted and Repetitive Behaviors and Interests. Another benefit of the revised algorithm is that the Social Affect and Restricted and Repetitive Behaviors and Interests domains were found to be independent of chronological age nonverbal IQ, and verbal IQ (Gotham et al., 2007, 2008).

The current study will use the Social Affect and Restricted and Repetitive Behaviors and Interests domain scores, as well as scores from the Communication and Social Interaction subscales of Social Affect. For the ADOS Module 3, the Communication subscale includes reporting of events, conversation, and descriptive, conventional, instrumental, and informational gestures. The Social Interaction subscale includes the presence of unusual eye contact, the use of facial expressions directed toward the examiner, shared enjoyment in the interaction, the quality of social overtures, the quality of the social response, the amount of reciprocal social interaction, and overall quality of rapport. The Restricted and Repetitive Behaviors and Interests domain includes stereotyped or idiosyncratic use of words or phrases, unusual sensory interest in the play materials or another person, hand/finger and other complex mannerisms, and excessive interest in unusual or highly specific topics/objects or repetitive behaviors.

Psychometric properties of the ADOS. Prior studies have indicated that the ADOS has strong psychometric properties. Lord, Rutter, DiLavore, and Risi (2000) found that the ADOS has excellent sensitivity (.95) and specificity (.92), inter-rater reliability ranging from .84 to .93, and test-retest reliability ranging from .73 to .78 for the Communication, Social Interaction, and Restricted and Repetitive Behaviors and Interests domains. Also, Cronbach's α for the three domains ranged from .74 to .94, indicating good internal consistency. Another study, this time using the revised algorithms, found that ADOS sensitivity ranged from .72 to .84, specificity ranged from .76 to .83, and Cronbach's α ranged from .87 and .92 for the Social Affect domain and .51 to .66 for the Restricted and Repetitive Behaviors and Interests domain (Gotham, Risi, Pickles, & Lord, 2007). Gotham and colleagues (2007) also found that the ADOS demonstrates strong predictive validity when compared to clinicians' best estimate diagnoses.

Statistical Analyses

Power Analysis. The G*Power 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) computer program was used to estimate a sufficient sample size for the current study. Although multiple analyses will be conducted for the current study, a power analysis was performed for the MANCOVA with the largest number of variables in order to obtain the most accurate prediction of a sufficient sample size for the study as a whole. With power set at 80% and a two-tailed significance level (α) of 0.05, a total sample size of 68 will be needed to detect a significant effect, if one exists, for the MANCOVA with two two-level groups, six dependent variables, and one covariate. As suggested by Cohen (1992), a medium effect size of 0.15 was used in the calculations. This indicates that the current study, with 253 total participants, has ample power to evaluate the hypotheses.

Data Screening. The data screening procedures outlined hereafter were defined according to suggestions from Tabachnick and Fidell (2013). First, it was determined that missing data were scarce (< 5%) and appeared to be missing at random, meaning there was not a systematic reason for the missing data. Then, descriptive analyses and histogram plots were run within each cell (for males and females, and for those in the ASD Affected versus ASD Severely Affected groups) in order to detect the presence of univariate outliers. There were not any cases with very large standardized scores (exceeding ±3.30) and that were not in line with the distribution. After the computation of a Mahalanobis Distance for each case within each cell, no multivariate outliers were detected, meaning no case had a value exceeding the critical χ^2 value for $p = .001$. Normality was also assessed using descriptive statistics and histogram plots. Standardized scores for skewness and kurtosis were all less than 3.30, therefore data transformations were not considered. In addition, heteroscedasticity was not apparent after examination of bivariate scatterplots. Finally, the variables were evaluated for multicollinearity and singularity by examining collinearity diagnostics and bivariate correlations. Multicollinearity was not evident, as there were not any condition indices above 30, tolerance levels less than 0.10, VIF scores greater than 10, two or more variables with variance proportions greater than 0.50, or any bivariate correlations above 0.90.

Hypothesis Testing. All analyses were conducted using the Statistical Package for Social Sciences [SPSS], Version 24**.** Pearson product-moment correlations were used to determine the basic associations among study variables and to verify that these correlations are in the expected directions.

A series of one-way multivariate analyses of covariance (MANCOVAs) were used to evaluate the study hypotheses for Aims 1 through 3. The goal of the MANCOVA is to test whether mean differences among groups (males versus females, in this case) on a combination of dependent variables, after adjusting for relevant covariates, are likely to have occurred by chance. This is achieved by creating a single dependent measure from a linear combination of all dependent variables that maximizes the between group differences.

Also, there are additional assumptions of MANCOVA that were checked within the MANCOVA analyses. Box's M was used to test the assumption of homogeneity of the variance-covariance matrices. This assumption means that, across cells, the observed variance-covariance matrices are approximately equal and the vector of the dependent variables has an approximately normal distribution. When the Box's M statistic is significant at the $p < .05$ level, then this suggests that the assumption of homogeneity of the variance-covariance matrices is not met. Box's M is sensitive to large sample sizes and can detect even small amounts of heterogeneity.

As an additional check of homogeneity of variance within the diagonals of the matrices, Levene's tests were examined. This assumption tests the equality of error variances across cells with a separate test for each dependent variable. Similar to Box's M, if a Levene's test statistic is significant at the $p < .05$ level, then this suggests that the assumption of equality of error variances is not met for that particular variable.

Aim 1. The first 2×2 between-subjects multivariate analysis of covariance (MANCOVA) is one with two independent variables with two levels (sex: male and female; ASD severity: affected by ASD and severely affected by ASD), one covariate (age in months), with two dependent variables: General Conceptual Ability standard score from the Differential Ability Scales (DAS-II; comprised of Verbal Ability, Nonverbal Reasoning Ability, and Spatial Ability subscales); and the total score from the Autism Diagnostic Observation Schedule (ADOS-2; comprised of Social Affect and Restricted or Repetitive Behaviors and Interests domain scores).

In line with most previous research of sex differences using samples of high-functioning children with autism, it was hypothesized that females and males would differ in their levels of autism symptomatology and general conceptual ability, such that females would exhibit more severe autism symptomatology but lower cognitive ability compared to males. Despite the exclusion of children with intellectual disability, it was hypothesized that perhaps the girls with ASD in the current sample would still exhibit lower cognitive functioning and more severe autism symptomatology, because they were diagnosed with ASD despite not qualifying for an intellectual disability. Furthermore, it was hypothesized that there would be a significant effect of ASD severity group membership, such that those severely affected by ASD were expected to have greater autism symptomatology and lower cognitive ability than those affected, but not severely, by ASD.

Aim 2a. Then, another 2 × 2 between-subjects multivariate analysis of covariance (MANCOVA) was run, deconstructing the DAS-II and ADOS-2 composite and total scores into their cluster and domain scores to show where the abilities or deficits lie for females compared to males. Therefore, the second MANCOVA was one with two independent variables with two levels (sex: male and female; ASD severity: affected by ASD and severely affected by ASD), one covariate (age in months), with five dependent variables: Social Affect and Restricted or Repetitive Behaviors and Interests from the ADOS-2, and Nonverbal Reasoning, Verbal Ability, and Spatial Ability from the DAS-II.

In concurrence with most previous research of sex differences using samples of high-functioning children with autism not confounded by intellectual disability, it was hypothesized that females and males, and those affected versus severely affected by ASD, would differ in their levels of Social Affect, Nonverbal Reasoning Ability, and Spatial Ability, such that females and those severely affected by ASD would exhibit more severe social deficits and lower nonverbal reasoning and spatial ability compared to males and those not severely affected by ASD. Because of the potentially confounding nature of intellectual disability in previous research concluding that females exhibit more restricted or repetitive behaviors and interests and lower verbal ability, it was not hypothesized that there would be significant sex or ASD severity differences in restricted or repetitive behaviors and interests or verbal ability in the current sample, which was not confounded by intellectual disability.

Aim 2b. Then, a similar 2 × 2 between-subjects multivariate analysis of covariance (MANCOVA) was run to break down the Social Affect domain from the ADOS into its subscales: Reciprocal Social Interaction and Communication. For this second iteration of the previous MANCOVA, these two new dependent variables joined the others from the previous analysis: RRB, Verbal Ability, Nonverbal Reasoning Ability, and Spatial Ability. The resulting conclusions were expected to be identical to that from the previous analysis, with one of the two subdomains of Social Affect, Communication, not being significantly different for males versus females, and those affected versus severely affected by ASD, because of the lack of a confounding influence of intellectual disability that was present in previous research.

Aim 3. For Aim 3, another 2 × 2 between-subjects multivariate analysis of covariance (MANCOVA) was performed, but this time the dependent variables were the subtests that comprise Verbal Ability, Nonverbal Reasoning Ability, and Spatial Reasoning Ability from the

DAS-II: Word Definitions (Verbal), Verbal Similarities (Verbal), Matrices (Nonverbal), Sequential and Quantitative Reasoning (Nonverbal), Recall of Designs (Spatial), and Pattern Construction (Spatial). Independent variables were sex (male and female) and ASD severity (affected and severely affected). Adjustment was made for differences in age at assessment.

Although males and females are expected to differ significantly in nonverbal reasoning and spatial skills in general, this analysis was exploratory in nature to determine specific subtests in which significant differences occur. Significant differences in verbal skills as a whole between males and females were not expected to be found, because of the lack of confounding intellectual disability, but differences in nonverbal reasoning and spatial subtests were expected based on the unique nature of nonverbal intelligence in individuals with ASD compared to the general population.

Aim 4a. A 2 × 2 chi-square test of independence was conducted in SPSS to determine whether sex is associated with ASD severity, prior to determining whether sex and ASD severity are associated with discrepancies between specific cognitive abilities, and whether significant cognitive discrepancies are present in children with ASD more often than in the larger population, according to established norms and criteria for significance from the DAS-II. For this initial analysis, a 2 × 2 chi-square test of independence was conducted in SPSS with two variables: sex (male versus female) and ASD severity (affected versus severely affected). The relationship between sex and ASD severity was not expected to be significant, meaning that there would be no interaction between sex and ASD severity in terms of group membership. This is hypothesized based on the expected wider range of autism symptomatology in both sexes as the result of the exclusion of those with intellectual disability and comorbid medical diagnoses, and the inclusion of individuals from a variety of labs and geographical regions, thereby reducing bias.

Aim 4b. A layered 2 × 2 chi-square test of independence was conducted in SPSS to determine whether sex is associated with significant discrepancies between verbal and nonverbal reasoning skills for children with ASD, and whether there is a significant association for those affected versus severely affected by ASD. Prior to the analysis, a variable representing the difference between Verbal Ability and Nonverbal Reasoning Ability scores from the DAS-II was created. Consistent with the DAS-II manual and statistics computed based on the norming sample, discrepancies of greater than or equal to 9 points in either direction were considered significant in the current study. Using this criterion, for the current chi-square analysis, the verbal-nonverbal reasoning discrepancy variable was divided into 2 groups: those with a significant discrepancy between verbal and nonverbal reasoning skills, and those without a significant discrepancy between verbal and nonverbal reasoning skills.

The chi-square analysis was expected to reveal that there is a significant association between sex and whether there are significant discrepancies between verbal and nonverbal reasoning skills. There was expected to be a greater percentage of females without a discrepancy between verbal and nonverbal reasoning skills, compared to males. It was also expected that more males and females would have discrepantly high nonverbal reasoning skills compared to discrepantly high verbal skills, although the percentage of males with discrepantly high nonverbal reasoning and the percentage of males with discrepantly high verbal skills were each expected to be higher than the percentages for that from their female counterparts.

Aim 4c. To gain more thorough information about the nature of the verbal-nonverbal discrepancies present in this sample, another chi-square test of independence was conducted, this time using a verbal-nonverbal reasoning discrepancy variable divided into three groups: those with greater nonverbal reasoning versus verbal skills, those with greater verbal versus nonverbal reasoning skills, and those without a significant discrepancy between verbal and nonverbal reasoning skills, with discrepancies of greater than or equal to 9 points being considered significant. Thus, a layered 2 × 3 chi-square test of independence was conducted in SPSS to determine whether sex and ASD severity are associated with membership in one of the three cognitive discrepancy groups: discrepantly high nonverbal, discrepantly high verbal, and no significant verbal-nonverbal discrepancy.

It was hypothesized that a verbal-nonverbal discrepancy in either direction (Nonverbal Reasoning Ability > Verbal Ability, or Verbal Ability > Nonverbal Reasoning Ability) would be observed within the current sample of boys and girls with ASD, not confounded by intellectual disability, with greater frequency than expected according to the chi-square test of independence. It was also hypothesized that boys would be more likely to exhibit discrepantly high nonverbal reasoning ability than girls, in line with previous research from Ankenman and colleagues (2014). Divided by ASD severity, the association between sex and verbal-nonverbal discrepancies was expected to be significant for those severely affected by ASD and for those not severely affected by ASD because it is believed that verbal-nonverbal discrepancies occur across the autism spectrum, although this has not been investigated in prior research.

CHAPTER 3: RESULTS

Preliminary Analyses. Bivariate correlations and descriptive statistics by sex are presented in Tables 1 and 2, respectively. Descriptive statistics by sex indicated that age-referenced standard scores (*M* = 100, *SD* = 15) from the DAS-II for females were below average for General Conceptual Ability (*M* = 88.63, *SD* = 19.86), Verbal Ability (*M* = 89.53, *SD* = 19.86), Nonverbal Reasoning Ability (*M* = 88.63, *SD* = 19.86), and Spatial Ability (*M* = 88.63, *SD* = 19.86). In contrast, standard scores from the DAS-II for males were much closer to average for General Conceptual Ability (*M* = 97.33, *SD* = 18.77), Verbal Ability (*M* = 94.80, *SD* = 21.66), Nonverbal Reasoning Ability (*M* = 100.77, *SD* = 18.54), and Spatial Ability (*M* = 96.08, *SD* = 16.61). According to the DAS-II classification schema, the females in the current sample on average scored in the below average range, with percentile ranks ranging from 16 to 24. Males, on the other hand, scored in the average range, with percentile ranks ranging from 25 to 74.

Age-referenced *t*-scores (*M* = 50, *SD* = 10) from the DAS-II were also below average for females on the subtests of Word Definitions (*M* = 44.15, *SD* = 14.39), Verbal Similarities (*M* = 44.70, *SD* = 13.32), Matrices (*M* = 41.67, *SD* = 13.90), Sequential and Quantitative Reasoning (*M* = 42.44, *SD* = 12.51), Recall of Designs (*M* = 41.59, *SD* = 10.71), and Pattern Construction (*M* = 42.93, *SD* = 11.61). Conversely, *t*-scores from the DAS-II for males were closer to average for Word Definitions (*M* = 45.33, *SD* = 14.42), Verbal Similarities (*M* = 45.24, *SD* = 13.38), Matrices (*M* = 50.17, *SD* = 12.15), Sequential and Quantitative Reasoning (*M* = 49.40, *SD* = 10.95), Recall of Designs (*M* = 46.14, *SD* = 10.95), and Pattern Construction (*M* = 48.00, *SD* = 9.91). According to the DAS-II classification schema, the females in the current sample on average scored in the average range for Word Definitions and Verbal Similarities, with percentile ranks ranging from 25 to 74, and score in the below average range for Matrices, Sequential and Quantitative Reasoning, Recall of Designs, and Pattern Construction, with percentile ranks ranging from 16 to 24. Males, on the other hand, scored in the average range on all subtests, with percentile ranks ranging from 25 to 74.

Females in the current study had an average ADOS total algorithm score of 10.8 (SD = 5.42), meaning that on average they would qualify for the classification of autism, according to the ADOS-2 classification schema. Males in the current study had an average ADOS-2 algorithm score of 12.42 (SD = 4.66), also qualifying them for the classification of autism according to the ADOS-2. The males and females in the current sample, on average, would be described as having a moderate to moderate-high level of autism spectrum-related symptoms, according to the ADOS-2, and consistent with the categories of ASD severity (affected versus severely affected) derived by NDAR.

Aim 1. A 2 × 2 between-subjects multivariate analysis of covariance (MANCOVA) was performed on two dependent variables: General Conceptual Ability from the DAS-II, and the ADOS total score. Independent variables were sex (male and female) and ASD severity (affected and severely affected). Adjustment was made for differences in age at assessment. IBM SPSS MANOVA was used for the analyses with the sequential adjustment for nonorthogonality. Order of entry of independent variables was sex, then ASD severity. The total sample size for this analysis was 252, with one case left out because of missing data. Inspection for univariate and multivariate within- and between-cell outliers revealed none at the α = .001 level. Results of evaluation of assumptions of normality, linearity, and multicollinearity were satisfactory. The covariate was judged to be adequately reliable for covariance analysis. According to Box's M, the assumption of homogeneity of variance-covariance matrices was met, Box's M = 11.248, p = .282. Levene's test confirms the assumption of equality of error variances across cells was not violated for ADOS total score, $F(3, 248) = 1.55$, $p = .202$, or General Conceptual Ability, $F(3, 248) = 0.59$, $p = .620$.

With the use of Wilks's criterion, there were significant differences between males and females on the linear combination of dependent variables, $F(2, 246) = 6.20$, $p = .002$. There were also significant differences on the linear combination of dependent variables for those affected versus severely affected by ASD, $F(2, 246) = 22.95$, $p < .001$, but not for the interaction between sex and ASD severity, $F(2, 246) = 1.00$, $p > .05$.

To investigate the impact of each dependent variable on the main effects, a Roy-Bargman stepdown analysis was performed on the dependent variables, after homogeneity of regression was deemed sufficient for each component of the analyses. In the stepdown analysis, each dependent variable was analyzed, in turn, with the other dependent variables treated as covariates within a univariate analysis of variance context. According to the Roy-Bargman stepdown analyses, General Conceptual Ability made a unique contribution to the prediction of differences between males and females, stepdown $F(1, 247) = 7.34$, $p < .01$. Adjusted marginal means demonstrated that males have higher General Conceptual Ability scores (mean GCA = 97.35, $SE = 1.31$) than females (mean GCA = 88.61, $SE = 3.01$). After the pattern of differences measured by General Conceptual Ability was entered, a significant difference was also found between males and females on the ADOS total score, stepdown $F(1, 246) = 4.94$, $p < .05$. Adjusted marginal means demonstrated that males have higher ADOS total scores (mean ADOS = 12.46, $SE = 0.33$) than females (mean ADOS = 10.58, $SE = 0.76$).

Similarly, General Conceptual Ability and the ADOS total score each made unique contributions to the composite dependent variable that best distinguished between those affected and severely affected by autism spectrum disorder. The greatest contribution to ASD severity was made by the ADOS total score, stepdown $F(1, 245) = 35.67$, $p < .001$, which theoretically makes sense. Individuals severely affected by autism had higher ADOS total scores (mean ADOS = 13.31, $SE = 0.49$) than those not severely affected by their autism (mean ADOS = 9.87, $SE = 0.48$). General Conceptual Ability also made a unique contribution to ASD severity, stepdown $F(1, 246) = 8.85$, $p < .01$. Adjusted marginal means demonstrated that individuals severely affected by ASD have lower General Conceptual Ability scores (mean GCA = 89.38, $SE = 2.01$) than those not severely affected by ASD (mean GCA = 96.48, $SE = 1.99$).

Those severely affected by ASD, then, have greater autism symptomatology and lower cognitive ability than those affected, but not severely, by ASD. Moreover, females with ASD have less severe autism symptomatology and lower cognitive ability compared to males with ASD.

Aim 2a. For Aim 2a, the ADOS total scores and General Conceptual Ability scores were deconstructed into their corresponding subdomains in order to show where the abilities or deficits lie for females compared to males. The ADOS total score was broken down into the ADOS subdomains of: 1) Social Affect, and 2) Restricted or Repetitive Behaviors and Interests (RRB). The General Conceptual Ability score from the DAS-II was split into the three subtests that comprise its total: 1) Verbal Ability, 2) Nonverbal Reasoning Ability, and 3) Spatial Reasoning Ability.

A 2×2 between-subjects multivariate analysis of covariance (MANCOVA) was performed on the five dependent variables: Social Affect, RRB, Verbal Ability, Nonverbal Reasoning Ability, and Spatial Reasoning Ability. Independent variables were sex (male and female) and autism spectrum disorder (ASD) severity (affected and severely affected). Adjustment was made for differences in age at assessment. IBM SPSS MANOVA was used for the analyses with the sequential adjustment for nonorthogonality. Order of entry of independent variables was sex, then ASD severity. The total sample size for this analysis was 246, with seven case left out because of missing data. Inspection for univariate and multivariate within- and between-cell outliers revealed none at the $\alpha = .001$ level. Results of evaluation of assumptions of normality, linearity, and multicollinearity were satisfactory. The covariate was judged to be adequately reliable for covariance analysis. According to Box's M, the assumption of homogeneity of variance-covariance matrices was met, Box's M = 44.74, $p = .628$. Levene's test confirmed the assumption of equality of error variances across cells was not violated for Social Affect, $F(3, 242) = 1.89$, $p = .132$; Restricted or Repetitive Behaviors and Interests, $F(3, 242) = 0.54$, $p = .659$; Verbal Ability, $F(3, 242) = 1.08$, $p = .360$; Nonverbal Reasoning Ability, $F(3, 242) = 0.17$, $p = .919$; and Spatial Ability, $F(3, 242) = 0.97$, $p = .410$.

With the use of Wilks's criterion, there were significant differences between males and females on the linear combination of dependent variables, $F(5, 237) = 3.27$, $p = .007$. There were also significant differences on the linear combination of dependent variables for those affected versus severely affected by ASD, $F(5, 237) = 9.79$, $p < .001$, but not for the interaction between sex and ASD severity, $F(5, 237) = 0.75$, $p > .05$.

To investigate the relative influence of each dependent variable on the main effects, a Roy-Bargman stepdown analysis was conducted on the dependent variables, after homogeneity of regression was judged to be adequate for each component of the analyses. In the stepdown analysis, each dependent variable was analyzed, in turn, with the other dependent variables treated as covariates within a univariate analysis of variance context. According to the Roy-Bargman stepdown analyses, Social Affect made a unique contribution to the prediction of differences between males and females, stepdown $F(1, 241) = 4.43$, $p < .05$. Adjusted marginal means demonstrated that males have higher Social Affect scores (mean Social Affect = 9.80, $SE = 0.27$)

than females (mean Social Affect = 8.46, $SE = 0.62$). After the pattern of differences measured by Social Affect was entered, a significant difference was not found between males and females on Restricted or Repetitive Behaviors and Interests (RRB), stepdown $F(1, 240) = 0.17$, $p > .05$. After the pattern of differences measured by Social Affect and RRB were entered, a significant difference was found between males and females on Spatial Reasoning Ability, stepdown $F(1, 239) = 5.27$, $p < .05$. Adjusted marginal means demonstrated that males have higher Spatial Reasoning Ability scores (mean Spatial Reasoning = 96.14, $SE = 1.17$) than females (mean Spatial Reasoning = 89.13, $SE = 2.67$). After the pattern of differences measured by Social Affect, RRB, and Spatial Reasoning were entered, a significant difference was also found between males and females on Nonverbal Reasoning Ability, stepdown $F(1, 238) = 5.82$, $p < .05$. Adjusted marginal means demonstrated that males have higher Nonverbal Reasoning Ability scores (mean Nonverbal Reasoning = 100.07, $SE = 0.94$) than females (mean Nonverbal Reasoning = 94.28, $SE = 2.17$). Finally, after the pattern of differences measured by Social Affect, RRB, Spatial Reasoning, and Nonverbal Reasoning were entered, a significant difference was not found between males and females on Verbal Ability, stepdown $F(1, 237) = 0.41$, $p > .05$.

On the other hand, the second set of Roy-Bargman stepdown analyses, performed with the same order of entry as before, demonstrated that only Social Affect (stepdown $F(1, 241) = 38.82$, $p < .001$) and Spatial Reasoning Ability (stepdown $F(1, 239) = 5.18$, $p < .05$) made unique contributions to the composite dependent variable that best distinguished between those affected and severely affected by autism spectrum disorder, whereas Restricted, Repetitive Behaviors and Interests (stepdown $F(1, 240) = 2.34$, $p > .05$), Nonverbal Reasoning Ability (stepdown $F(1, 238) = 0.48$, $p > .05$), and Verbal Ability (stepdown $F(1, 237) = 1.24$, $p > .05$) did not significantly contribute to the linear composite variable. Adjusted marginal means indicated that individuals severely affected by autism had higher Social Affect scores (mean Social Affect = 10.60, *SE* = 0.39) and lower Spatial Reasoning Ability scores (mean Spatial Reasoning Ability = 90.08, *SE* = 1.82) than those not severely affected by their autism (mean Social Affect = 7.67, *SE* = 0.39; mean Spatial Reasoning Ability = 95.41, *SE* = 1.88).

Those severely affected by ASD, then, have greater social deficits related to autism and lower spatial reasoning ability than those affected, but not severely, by ASD. Moreover, females with ASD have less severe social deficits related to autism, and lower nonverbal reasoning and spatial reasoning ability compared to males with ASD. There are no significant differences in verbal ability or intensity of restricted or repetitive behaviors and interests between males and females with ASD. Moreover, for those affected and severely affect by ASD, autism severity is not associated with the intensity of restricted or repetitive behaviors and interests, nonverbal reasoning ability, or verbal ability.

Aim 2b. For Aim 2b, the same 2 × 2 between-subjects multivariate analysis of covariance (MANCOVA) was performed, but this time with one of the dependent variables, Social Affect, divided into the subdomains that comprise it: Reciprocal Social Interaction and Communication. For the second iteration of the previous MANCOVA, these two new dependent variables joined the others from the previous analysis: RRB, Verbal Ability, Nonverbal Reasoning Ability, and Spatial Reasoning Ability. The resulting conclusions were identical to that from the previous analysis, with the exception that one of the two subdomains of Social Affect, Communication, was not significantly different for males versus females, stepdown $F(1, 240) = 0.05$, $p > .05$. Reciprocal Social Interaction, however, did significantly contribute to the differences between males and females, stepdown $F(1, 241) = 5.44$, $p < .05$. Adjusted marginal means indicated that males had higher scores on Reciprocal Social Interaction (mean Reciprocal Social Interaction = 7.32, *SE* = 0.20) than females (mean Reciprocal Social Interaction = 6.22, *SE* = 0.45).

The resulting conclusions were also identical to that from the previous analysis for differences between those affected and severely affected by ASD, but for this analysis, both Reciprocal Social Interaction ($F(1, 241) = 26.02$, $p < .001$) and Communication ($F(1, 240) = 15.52$, $p < .001$) uniquely contributed to the differences between those affected and severely affected by ASD. Adjusted marginal means indicated that individuals severely affected by autism had higher scores on Reciprocal Social Interaction (mean Reciprocal Social Interaction = 7.67, *SE* = 0.29) and Communication (mean Communication = 2.80, *SE* = 0.14) than those not severely affected by their autism (mean Reciprocal Social Interaction = 5.88, *SE* = 0.29; mean Communication = 2.12, *SE* = 0.14).

Those severely affected by ASD, then, have greater deficits in reciprocal social interaction and communication than those affected, but not severely, by ASD. Moreover, females with ASD have less severe deficits in reciprocal social interaction compared to males with ASD. There are no significant differences in communication skills between males and females with ASD.

Aim 3. For Aim 3, another 2×2 between-subjects multivariate analysis of covariance (MANCOVA) was performed, but this time the dependent variables were the subtests that comprise Verbal Ability, Nonverbal Reasoning Ability, and Spatial Reasoning Ability from the DAS-II: Word Definitions (Verbal), Verbal Similarities (Verbal), Matrices (Nonverbal), Sequential and Quantitative Reasoning (Nonverbal), Recall of Designs (Spatial), and Pattern Construction (Spatial). Independent variables were sex (male and female) and autism spectrum disorder (ASD) severity (affected and severely affected). Adjustment was made for differences in age at assessment. IBM SPSS MANOVA was used for the analyses with the sequential adjustment for nonorthogonality. Order of entry of independent variables was sex, then ASD severity. The total sample size for this analysis was 134, with 119 cases left out because of missing data resulting from certain labs not saving subtest or item-level data in the database. Inspection for univariate and multivariate within-cell outliers revealed none at the $\alpha = .001$ level. Results of evaluation of assumptions of normality, linearity, and multicollinearity were satisfactory. The covariate was judged to be adequately reliable for covariance analysis. According to Box's M, the assumption of homogeneity of variance-covariance matrices was met, Box's M = 101.46, $p = .053$. Levene's test confirmed the assumption of equality of error variances across cells was not violated for Word Definitions, $F(3, 130) = 1.62$, $p = .187$; Verbal Similarities, $F(3, 130) = 0.87$, $p = .460$; Matrices, $F(3, 130) = 0.51$, $p = .673$; Sequential and Quantitative Reasoning, $F(3, 130) = 0.85$, $p = .472$; Recall of Designs, $F(3, 130) = 0.25$, $p = .860$; and Pattern Construction, $F(3, 130) = 1.47$, $p = .225$.

With the use of Wilks's criterion, there were significant differences between males and females on the linear combination of dependent variables, $F(6, 124) = 2.48$, $p < .05$. There were no significant differences on the linear combination of dependent variables for those affected versus severely affected by ASD, $F(6, 124) = 1.84$, $p > .05$, nor for the interaction between sex and ASD severity, $F(6, 124) = 0.48$, $p > .05$.

To investigate the relative contribution of each dependent variable on the main effects, a Roy-Bargman stepdown analysis was performed on the dependent variables, after homogeneity of regression was achieved for each component of the analyses. In the stepdown analysis, each dependent variable was analyzed, in turn, with the other dependent variables treated as covariates within a univariate analysis of variance context. According to the Roy-Bargman stepdown analyses, only Pattern Construction (stepdown $F(1, 127) = 6.31$, $p < .05$) and Matrices (stepdown $F(1, 125) = 6.52$, $p < .05$) made unique contributions to the composite dependent variable that best distinguished between males and females, whereas Verbal Similarities (stepdown $F(1, 129) = 0.08$, $p > .05$), Word Definitions (stepdown $F(1, 128) = 0.06$, $p > .05$), Recall of Designs (stepdown $F(1, 126) = 0.33$, $p > .05$), and Sequential and Quantitative Reasoning (stepdown $F(1, 124) = 1.27$, $p > .05$) did not significantly contribute to the linear composite variable. Adjusted marginal means indicated that males had higher scores on Pattern Construction (mean Pattern Construction = 47.94, *SE* = 0.85) and Matrices (mean Matrices = 49.43, *SE* = 0.89) compared to females (mean Pattern Construction = 43.15, *SE* = 1.70; mean Matrices = 44.20, *SE* = 1.81).

Females with ASD have lower nonverbal reasoning and spatial reasoning ability compared to males with ASD, but only in the domains represented by the Matrices and Pattern Construction subtests, not the Recall of Designs or Sequential and Quantitative Reasoning subtests. There are no significant differences in the verbal ability subtests, Word Definitions and Verbal Similarities.

Aim 4a. The goal of Aim 4a was to determine whether sex is associated with ASD severity, prior to determining whether sex and ASD severity are associated with discrepancies between specific cognitive abilities, and whether significant cognitive discrepancies are present in children with ASD more often than in the larger population, according to established norms and criteria for significance from the DAS-II. For this initial analysis, a 2×2 chi-square test of independence was conducted in SPSS with two variables: sex (male versus female) and ASD severity (affected versus severely affected). The sample size for this analysis was 253. The relationship between sex and ASD severity was not significant, $\chi^2(1, N = 253) = 1.09$, $p > .05$, meaning that there is no interaction between sex and ASD severity in terms of group membership. The distribution of males and females by ASD severity is presented in Table 3.

Aim 4b. A layered 2×2 chi-square test of independence was conducted in SPSS to determine whether sex is associated with significant discrepancies between verbal and nonverbal reasoning skills for children with ASD, and whether there is a significant association for those affected versus severely affected by ASD. Prior to the analysis, a variable representing the difference between Verbal Ability and Nonverbal Reasoning Ability scores from the DAS-II was created. Consistent with the DAS-II manual and statistics computed based on the norming sample, discrepancies of greater than or equal to 9 points in either direction were considered significant in the current study. Using this criterion, for the current chi-square analysis, the verbal-nonverbal reasoning discrepancy variable was divided into 2 groups: those with a significant discrepancy between verbal and nonverbal reasoning skills, and those without a significant discrepancy between verbal and nonverbal reasoning skills. The sample size for this analysis was 249.

The chi-square analysis revealed that there was a significant association between sex and the presence of a significant discrepancy between verbal and nonverbal reasoning skills, $\chi^2(1, N = 249) = 5.16, p < .05$. For those not severely affected by ASD, the association between sex and a verbal-nonverbal discrepancy was also significant, $\chi^2(1, N = 117) = 10.59, p = .001$, but it was not significant for those severely affected by ASD, $\chi^2(1, N = 132) = 0.83, p > .05$.

A visual depiction of the results of this chi-square analysis is presented in Table 4. In the overall sample, not layered by ASD severity, 45.0% of females and 64.1% of males exhibited a significant verbal-nonverbal discrepancy. In other words, females with ASD were more likely to exhibit equivalent performance in verbal and nonverbal reasoning than to have a verbal-nonverbal discrepancy. On the other hand, males with ASD were more likely to exhibit a verbal-nonverbal discrepancy than to have equivalent performance on measures of verbal and nonverbal reasoning. Then, comparing males to females, males were more likely than females to have a verbal-nonverbal discrepancy, and females were therefore more likely than males to not have a significant verbal-nonverbal discrepancy.

The chi-square test of independence also provides expected versus actual counts in each cell. In the overall sample, not layered by ASD severity, there were more females than expected in the group without a verbal-nonverbal discrepancy, and therefore fewer females than expected in the verbal-nonverbal discrepancy group. The opposite was true for males: there were fewer males than expected in the group without a verbal-nonverbal discrepancy, and therefore more males than expected in the verbal-nonverbal discrepancy group.

Of the entire sample, not divided by sex or ASD severity, 61.0% had a significant verbal-nonverbal discrepancy, and 39% had no significant verbal-nonverbal discrepancy. According to the DAS-II manual and statistics computed based on the norming sample, discrepancies of 9 points in either direction are only expected to occur in approximately 25% of the population. Here, we see that a significant verbal-nonverbal discrepancy occurred in 61.0% of the sample, indicating that for children with ASD, verbal-nonverbal discrepancies occur much more often than in the general population.

In the chi-square test layered by ASD severity (affected versus severely affected), we see that for children affected, but not severely affected, by their ASD, 27.3% of females and 65.3% of males exhibited a significant verbal-nonverbal discrepancy. In other words, females affected, but not severely, by ASD were more likely to exhibit equivalent performance in verbal and nonverbal reasoning than to have a verbal-nonverbal discrepancy. On the other hand, males affected, but not severely, by ASD were more likely to exhibit a verbal-nonverbal discrepancy than to have equivalent performance on measures of verbal and nonverbal reasoning. Then, comparing males to females not severely affected by ASD, males were more likely than females to have a verbal-nonverbal discrepancy, and females were therefore more likely than males to not have a significant verbal-nonverbal discrepancy.

Examination of the expected versus actual counts in each cell for those affected, but not severely, by ASD revealed that there were more females than expected in the group without a verbal-nonverbal discrepancy, and therefore fewer females than expected in the verbal-nonverbal discrepancy group. The opposite was true for males: there were fewer males than expected in the group without a verbal-nonverbal discrepancy, and therefore more males than expected in the verbal-nonverbal discrepancy group.

For all males and females affected, but not severely, by ASD, 58.1% had a significant verbal-nonverbal discrepancy, and 41.9% had no significant verbal-nonverbal discrepancy. Here, again, we see that there is a much higher proportion of children affected by ASD that have a significant verbal-nonverbal discrepancy (58.1%) than would be present in the general population (25%), according to the DAS-II manual and statistics computed from the norming sample.

Conversely, for children severely affected by ASD, there was not a significant association between sex and a verbal-nonverbal discrepancy. There were roughly equivalent proportions of males and females in the verbal-nonverbal discrepancy and no significant discrepancy groups, and expected versus actual counts for each cell were not significantly different. Descriptively, however, we see that 63.6% of those severely affected by ASD had a significant verbal-nonverbal discrepancy, which is slightly higher than the proportion of those with a verbal-nonverbal discrepancy in the group affected, but not severely, by ASD, and is also higher than that which would be expected in the general population (25%).

Descriptive statistics revealed that children with a verbal-nonverbal discrepancy had an average absolute discrepancy of 20.11 points (SD = 10.42, N = 151, Range = 9 - 59); the average absolute discrepancy for males in this group was 19.89 points (SD = 10.48, N = 133, Range = 9 - 59), and for females was 21.78 points (SD = 10.06, N = 18, Range = 9 - 40). For those affected, but not severely, by ASD, the average absolute discrepancy was 20.18 points (*SD* = 10.16, *N* = 67, Range = 9 - 59); for males it was 19.67 points (*SD* = 10.22, *N* = 61, Range = 9 - 59), and for females it was 25.33 points (*SD* = 8.57, *N* = 6, Range = 16 - 36). For those severely affected by ASD, the average absolute discrepancy was 20.06 points (*SD* = 10.68, *N* = 84, Range = 9 - 51); for males it was 20.07 points (*SD* = 10.76, *N* = 72, Range = 9 - 51), and for females it was 20.00 points (*SD* = 10.61, *N* = 12, Range = 9 - 40). According to the DAS-II manual and statistics derived from the norming sample, absolute differences between verbal and nonverbal reasoning that are 20 points or greater are only expected in about 5% of the general population, and differences of greater than 30 points are only expected in 1% of the general population. This indicates that children with ASD are significantly more likely to exhibit a verbal-nonverbal discrepancy compared to individuals in the general population, and that their absolute differences between verbal and nonverbal reasoning are larger than that which we would expect to see in the general population.

Aim 4c. To gain more thorough information about the nature of the verbal-nonverbal discrepancies present in this sample, another chi-square test of independence was conducted, this time using a verbal-nonverbal reasoning discrepancy variable divided into three groups: those with greater nonverbal reasoning versus verbal skills, those with greater verbal versus nonverbal reasoning skills, and those without a significant discrepancy between verbal and nonverbal reasoning skills, with discrepancies of greater than or equal to 9 points being considered significant. Thus, a layered 2 × 3 chi-square test of independence was conducted in SPSS to determine whether sex and ASD severity are associated with membership in one of the three cognitive discrepancy groups: discrepantly high nonverbal, discrepantly high verbal, and no significant verbal-nonverbal discrepancy. The sample size for this analysis was 249.

The chi-square analysis revealed that there was a significant association between sex and verbal-nonverbal reasoning discrepancies, $\chi^2(2, N = 249) = 8.14, p < .05$. Divided by ASD severity, the association between sex and verbal-nonverbal discrepancies was significant for those severely affected by ASD, $\chi^2(2, N = 132) = 6.40, p < .05$, and for those not severely affected by ASD, $\chi^2(2, N = 117) = 10.67, p < .01$.

The results of this chi-square analysis are presented in Table 5. In the overall sample, not layered by ASD severity, 20.0% of females and 43.5% of males exhibited a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability, 25.0% of females and 20.6% of males had a verbal-nonverbal discrepancy favoring verbal ability, and 55.0% of females and 35.9% of males had equivalent verbal and nonverbal reasoning skills. In other words, females with ASD were most likely to have roughly equivalent verbal and nonverbal reasoning skills, and for those with a significant verbal-nonverbal discrepancy, it was more common to have a cognitive discrepancy favoring verbal ability rather than nonverbal reasoning ability. On the other hand, males with ASD were most likely to exhibit a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability than to have equivalent verbal and nonverbal skills or discrepantly high verbal skills. Moreover, it was more common for males to have equivalent verbal and nonverbal skills than to have a discrepancy favoring verbal ability. Additionally, comparing males to females, males were more likely than females to have discrepantly high nonverbal reasoning ability, and females were more likely than males to not have a significant verbal-nonverbal discrepancy or to have discrepantly high verbal ability.

The chi-square test of independence also provides expected versus actual counts in each cell. In the overall sample, not layered by ASD severity, there were fewer females than expected in the discrepantly high nonverbal group, more females than expected in the discrepantly high verbal group, and more females than expected in the group without a verbal-nonverbal discrepancy. The opposite was true for males: there were more males than expected in the discrepantly high nonverbal group, fewer males than expected in the discrepantly high verbal group, and fewer males than expected in the group without a verbal-nonverbal discrepancy.

Of the entire sample, not divided by sex or ASD severity, 39.8% exhibited a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability, 21.3% had a verbal-nonverbal discrepancy favoring verbal ability, and 39.0% had equivalent verbal and nonverbal reasoning skills. According to the DAS-II manual and statistics computed based on the norming sample, discrepancies of this magnitude favoring verbal or nonverbal reasoning ability (separately) are only expected to occur in approximately 15% of the population. Here, we see that 39.8% of the sample demonstrated discrepantly high nonverbal reasoning ability, and 21.3% of the sample demonstrated discrepantly high verbal ability, indicating that for children with ASD, verbal-nonverbal discrepancies in both directions occur much more often than in the general population.

In the chi-square test layered by ASD severity (affected versus severely affected), we see that for children affected, but not severely affected, by ASD, 13.6% of females and 37.9% of males exhibited a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability, 13.6% of females and 27.4% of males had a verbal-nonverbal discrepancy favoring verbal ability, and 72.7% of females and 34.7% of males had equivalent verbal and nonverbal reasoning skills. In other words, females affected, but not severely, by ASD were most likely to exhibit equivalent performance in verbal and nonverbal reasoning than to have either verbal-nonverbal discrepancy. On the other hand, males affected, but not severely, by ASD were most likely to exhibit discrepantly high nonverbal reasoning ability than to have equivalent performance on measures of verbal and nonverbal reasoning, or discrepantly high verbal skills. Then, comparing males to females, males were more likely than females to have either verbal-nonverbal discrepancy, and females were therefore more likely than males to not have a significant verbal-nonverbal discrepancy.

Examination of the expected versus actual counts in each cell for those affected, but not severely, by ASD revealed that there were fewer females than expected in the discrepantly high nonverbal group, fewer females than expected in the discrepantly high verbal group, and more females than expected in the group without a verbal-nonverbal discrepancy. The opposite was true for males: there were more males than expected in the discrepantly high nonverbal group, more males than expected in the discrepantly high verbal group, and fewer males than expected in the group without a verbal-nonverbal discrepancy.

For all males and females affected, but not severely, by ASD, 33.3% had a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability, 24.8% had a discrepancy favoring verbal ability, and 41.9% had no significant verbal-nonverbal discrepancy. According to the DAS-II manual and statistics computed based on the norming sample, discrepancies of this magnitude favoring verbal or nonverbal reasoning ability (separately) are only expected to occur in approximately 15% of the population. Here, we see that 33.3% of the sample demonstrated discrepantly high nonverbal reasoning ability, and 24.8% of the sample demonstrated discrepantly high verbal ability, indicating that for children affected by ASD, verbal-nonverbal discrepancies in both directions occur much more often than in the general population.

Similarly, for children severely affected by ASD, there was a significant association between sex and verbal-nonverbal discrepancies. For children severely affected by ASD, 27.8% of females and 48.2% of males exhibited a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability, 38.9% of females and 14.9% of males had a verbal-nonverbal discrepancy favoring verbal ability, and 33.3% of females and 36.8% of males had equivalent verbal and nonverbal reasoning skills. In other words, females severely affected by ASD were most likely to exhibit a verbal-nonverbal discrepancy favoring verbal ability, rather than discrepantly high nonverbal reasoning ability or equivalent performance in verbal and nonverbal reasoning. On the other hand, males severely affected by ASD were most likely to exhibit discrepantly high nonverbal reasoning ability than to have equivalent performance on measures of verbal and nonverbal reasoning, or discrepantly high verbal skills. Then, comparing males to females, males were more likely than females to have discrepantly high nonverbal skills and to have no significant verbal-nonverbal discrepancy, and females were more likely than males to have a significant verbal-nonverbal discrepancy favoring verbal ability.

Examination of the expected versus actual counts in each cell for those severely affected by ASD revealed that there were fewer females than expected in the discrepantly high nonverbal group, more females than expected in the discrepantly high verbal group, and as many females as expected in the group without a verbal-nonverbal discrepancy. The opposite was true for males: there were more males than expected in the discrepantly high nonverbal group, fewer males than expected in the discrepantly high verbal group, and roughly as many males as expected in the group without a verbal-nonverbal discrepancy.

For all males and females severely affected by ASD, 45.5% had a significant verbal-nonverbal discrepancy favoring nonverbal reasoning ability, 18.2% had a discrepancy favoring verbal ability, and 45.5% had no significant verbal-nonverbal discrepancy. According to the DAS-II manual and statistics computed based on the norming sample, discrepancies of this magnitude favoring verbal or nonverbal reasoning ability (separately) are only expected to occur in approximately 15% of the population. Here, we see that 45.5% of the sample demonstrated discrepantly high nonverbal reasoning ability, and 18.2% of the sample demonstrated discrepantly high verbal ability, indicating that for children severely affected by ASD, verbal-nonverbal discrepancies in both directions occur much more often than in the general population.

Descriptive statistics (see Tables 6 and 7) revealed that, in the group severely affected by ASD, females with a verbal-nonverbal discrepancy favoring nonverbal reasoning ability had an average discrepancy of 26.00 points (SD = 11.94, N = 5, Range = 13 - 40). For females in this group, the average verbal score was 66.40 (SD = 24.66, Range = 31 - 88), and the average nonverbal reasoning score was 92.40 (SD = 28.25, Range = 45 - 118). The average discrepancy for males in this group with a verbal-nonverbal discrepancy favoring nonverbal reasoning ability was 21.04 points (SD = 11.43, N = 55, Range = 9 - 51). For males in this group, the average verbal score was 80.42 (SD = 21.13, Range = 31 - 119), and the average nonverbal reasoning score was 101.45 (SD = 17.02, Range = 71 - 136).

In the group severely affected by ASD, females with discrepantly high verbal ability had an average verbal-nonverbal discrepancy of 15.71 points (SD = 7.74, N = 7, Range = 9 - 29). For females in this group, the average verbal score was 98.86 (SD = 28.26, Range = 66 - 145), and the average nonverbal reasoning score was 83.14 (SD = 22.52, Range = 54 - 121). The average discrepancy for males in this group with a verbal-nonverbal discrepancy favoring verbal ability was 16.94 points (SD = 7.71, N = 17, Range = 9 - 41). For males in this group, the average verbal score was 111.24 (SD = 12.41, Range = 92 - 134), and the average nonverbal reasoning score was 94.29 (SD = 12.56, Range = 78 - 117).

In the group not severely affected by ASD, females with discrepantly high nonverbal reasoning ability had an average verbal-nonverbal discrepancy of 28.00 points (SD = 6.93, N = 3, Range = 24 - 36). For females in this group, the average verbal score was 71.00 (SD = 2.00, Range

= 69 - 73), and the average nonverbal reasoning score was 99.00 (*SD* = 8.72, Range = 93 - 109). The average discrepancy for males in this group with a verbal-nonverbal discrepancy favoring nonverbal reasoning ability was 21.86 points (*SD* = 12.14, *N* = 36, Range = 9 - 59). For males in this group, the average verbal score was 89.77 (*SD* = 18.52, Range = 46 - 118), and the average nonverbal reasoning score was 111.63 (*SD* = 20.86, Range = 67 - 158).

For females with discrepantly high verbal ability and not severely affected by ASD, the average verbal-nonverbal discrepancy was 22.67 points (*SD* = 10.69, *N* = 3, Range = 16 - 35). For females in this group, the average verbal score was 115.33 (*SD* = 17.56, Range = 97 - 132), and the average nonverbal reasoning score was 92.67 (*SD* = 27.74, Range = 62 - 116). The average discrepancy for males in this group with a verbal-nonverbal discrepancy favoring verbal ability was 16.73 points (*SD* = 5.90, *N* = 26, Range = 9 - 28). For males in this group, the average verbal score was 113.46 (*SD* = 17.99, Range = 80 - 150), and the average nonverbal reasoning score was 96.73 (*SD* = 19.51, Range = 59 - 138).

For the group without a significant discrepancy between verbal and nonverbal reasoning, females severely affected by ASD had an average verbal score of 80.00 (*SD* = 15.52, Range = 51 - 91), and an average nonverbal reasoning score of 78.33 (*SD* = 14.69, Range = 49 - 89). For males in this group, the average verbal score was 96.71 (*SD* = 20.74, Range = 50 - 151), and the average nonverbal reasoning score was 97.43 (*SD* = 20.73, Range = 52 - 152). Females in the group without a significant discrepancy between verbal and nonverbal reasoning and in the group that is affected, but not severely, by ASD had an average verbal score of 94.88 (*SD* = 17.42, Range = 51 - 120), and an average nonverbal reasoning score of 94.63 (*SD* = 17.05, Range = 56 - 115). For males in this group, the average verbal score was 98.48 (*SD* = 14.38, Range = 68 - 123), and the average nonverbal reasoning score was 98.82 (*SD* = 13.16, Range = 69 - 119).

According to the DAS-II manual and statistics derived from the norming sample, absolute differences between verbal and nonverbal reasoning that are 20 points or greater are only expected in about 5% of the general population, and differences of greater than 30 points are only expected in 1% of the general population. This indicates that children with ASD are significantly more likely to exhibit a verbal-nonverbal discrepancy compared to individuals in the general population, and that their absolute differences between verbal and nonverbal reasoning are larger than that which we would expect to see in the general population.

Table 1

Bivariate Correlations among Study Variables, Separated by Sex (Females Under Diagonal, Males Above Diagonal).

	1	2	3	4	5	6	7	8	9	10	11
1. Age at Time of ADOS	--	-.023	.031	.095	-.087	-.115	.958**	-.043	-.059	-.072	.077
2. ADOS Total Score	.075	--	.918**	.853**	.748**	.636**	-.004	-.159*	-.221**	-.070	-.121
3. Social Affect Domain	.155	.948**	--	.935**	.806**	.278**	.045	-.139*	-.215**	-.059	-.078
4. Reciprocal Social Interaction	.213	.921**	.960**	--	.544**	.247**	.108	-.046	-.116	.010	.008
5. Communication	-.058	.631**	.694**	.465**	--	.245**	-.073	-.252**	-.318**	-.156*	-.198**
6. RRB Domain	-.175	.570**	.280	.301	.113	--	-.098	-.115	-.117	-.055	-.142*
7. Age at Time of DAS	.905**	.083	.146	.220	-.104	-.126	--	-.025	-.020	-.069	.083
8. General Conceptual Ability	-.007	.059	-.013	.074	-.231	.213	-.083	--	.859**	.893**	.814**
9. Verbal Ability	.058	-.033	-.070	.010	-.249	.082	.001	.887**	--	.644**	515**
10. Nonverbal Reasoning Ability	-.078	.021	-.082	-.011	-.232	.275	-.161	.933**	.715**	--	.662**
11. Spatial Ability	-.078	.189	.118	.196	-.133	.268	-.159	.853**	.574**	.823**	--

Note. **p < .01, *p < .05. DAS = Differential Ability Scales, Second Edition, School Age Battery. ADOS = Autism Diagnostic Observation Schedule, Second Edition, Module 3. RRB = Restricted or Repetitive Behaviors and Interests.

Table 2
Descriptive Statistics for Study Variables, Separated by Sex.

		Min.	Max.	*M* (*SD*)	Deviation from 100	Deviation from 50
Females	ADOS Total Score	3	23	10.80 (5.42)		
	Social Affect Domain	2	20	8.45 (4.64)		
	Reciprocal Social Interaction	0	14	6.20 (3.77)		
	Communication	0	6	2.25 (1.46)		
	RRB Domain	0	6	2.35 (1.79)		
	General Conceptual Ability	35	130	88.63 (19.86)	-11.37	
	Verbal Ability	31	145	89.53 (23.16)	-10.47	
	Word Definitions	10	71	44.15 (14.389)		-5.85
	Verbal Similarities	10	83	44.70 (13.32)		-5.30
	Nonverbal Reasoning Ability	45	121	90.08 (19.71)	-9.92	
	Matrices	14	66	41.67 (13.90)		-8.33
	SQR	10	72	42.44 (12.51)		-7.56
	Spatial Ability	36	124	89.35 (17.14)	-10.65	
	Recall of Designs	10	59	41.59 (10.71)		-8.41
	Pattern Construction	14	73	42.93 (11.61)		-7.07
	Verbal-Nonverbal Difference	-40	35	-0.55 (16.49)		
Males	ADOS Total Score	2	25	12.42 (4.66)		
	Social Affect Domain	2	20	9.80 (3.74)		
	Reciprocal Social Interaction	2	14	7.31 (2.64)		
	Communication	0	6	2.49 (1.58)		
	RRB Domain	0	8	2.62 (1.92)		
	General Conceptual Ability	51	155	97.33 (18.77)	-2.67	
	Verbal Ability	31	151	94.80 (21.66)	-5.2	
	Word Definitions	10	90	45.33 (14.42)		-4.67
	Verbal Similarities	10	70	45.24 (13.38)		-4.76
	Nonverbal Reasoning Ability	52	158	100.77 (18.54)	0.77	
	Matrices	20	82	50.17 (12.15)		0.17
	SQR	22	90	49.40 (13.63)		-0.60
	Spatial Ability	52	144	96.08 (16.61)	-3.92	
	Recall of Designs	10	68	46.14 (10.95)		-3.86
	Pattern Construction	26	71	48.00 (9.91)		-2.00
	Verbal-Nonverbal Difference	-59	41	-5.96 (17.19)		

Note. DAS = Differential Ability Scales, Second Edition, School Age Battery. ADOS = Autism Diagnostic Observation Schedule, Second Edition, Module 3. RRB = Restricted or Repetitive Behaviors and Interests.

Table 3

Results of Sex by ASD Severity Chi-Square Analysis.

		ASD Severity		
		Affected	Severe	Total
Females	Count	22	18	40
	Expected	19	21	40
	% of Females	55.0%	45.0%	100.0%
	% within ASD Severity	18.3%	13.5%	15.8%
	% of Total	8.7%	7.1%	15.8%
Males	Count	98	115	213
	Expected	101	112	213
	% of Males	46.0%	54.0%	100.0%
	% within ASD Severity	81.7%	86.5%	84.2%
	% of Total	38.7%	45.5%	84.2%
Total	Count	120	133	253
	Expected	120	133	253
	% of Sex	47.4%	52.6%	100.0%
	% within ASD Severity	100.0%	100.0%	100.0%
	% of Total	47.4%	52.6%	100.0%

Note. χ^2 (1, N = 253) = 1.09, p = .296. ASD = Autism Spectrum Disorder.

Table 4

Results of Sex by Verbal-Nonverbal Reasoning Difference (Yes/No) Chi-Square Analysis, Layered by ASD Severity.

	Females			Males			Total		
	V-NV Diff.			V-NV Diff.			V-NV Diff.		
Affected	No	Yes	Total	No	Yes	Total	No	Yes	Total
Count	16	6	22	33	62	95	49	68	117
Expected	9.2	12.8	22	39.8	55.2	95	49	68	117
% within Sex	72.7%	27.3%	100.0%	34.7%	65.3%	100.0%	41.9%	58.1%	100.0%
% within V-NV Diff.	32.7%	8.8%	18.8%	67.3%	91.2%	81.2%	100.0%	100.0%	100.0%
% of Total	13.7%	5.1%	18.8%	28.2%	53.0%	81.2%	41.9%	58.1%	100.0%

χ^2 (1, N = 117) = 10.59, p = .001

	Females			Males			Total		
	V-NV Diff.			V-NV Diff.			V-NV Diff.		
Severe	No	Yes	Total	No	Yes	Total	No	Yes	Total
Count	6	12	18	42	72	114	48	84	132
Expected	6.5	11.5	18	41.5	72.5	114	48	84	132
% within Sex	33.3%	66.7%	100.0%	36.8%	63.2%	100.0%	36.4%	63.6%	100.0%
% within V-NV Diff.	12.5%	14.3%	13.6%	87.5%	85.7%	86.4%	100.0%	100.0%	100.0%
% of Total	4.5%	9.1%	13.6%	31.8%	54.5%	86.4%	36.4%	63.6%	100.0%

χ^2 (1, N = 132) = 0.08, p = .774

	Females			Males			Total		
	V-NV Diff.			V-NV Diff.			V-NV Diff.		
Total	No	Yes	Total	No	Yes	Total	No	Yes	Total
Count	22	18	40	75	134	209	97	152	249
Expected	15.6	24.4	40	81.4	127.6	209	97	152	249
% within Sex	55.0%	45.0%	100.0%	35.9%	64.1%	100.0%	39.0%	61.0%	100.0%
% within V-NV Diff.	22.7%	11.8%	16.1%	77.3%	88.2%	83.9%	100.0%	100.0%	100.0%
% of Total	8.8%	7.2%	16.1%	30.1%	53.8%	83.9%	39.0%	61.0%	100.0%

χ^2 (1, N = 249) = 5.16, p = .023

Note. ASD = Autism Spectrum Disorder. V-NV Diff. = Difference in scores between Verbal Ability and Nonverbal Reasoning Ability from the Differential Ability Scales, Second Edition, School Age Battery.

Table 5

Results of Sex by Verbal-Nonverbal Reasoning Difference (V>NV, NV>V, V=NV) Chi-Square Analysis, Layered by ASD Severity.

	Females			Males			Total		
	V-NV Diff.			V-NV Diff.			V-NV Diff.		
Affected	NV>V	V=NV	V>NV	NV>V	V=NV	V>NV	NV>V	V=NV	V>NV
Count	3	16	3	36	33	26	39	49	29
Expected	7.3	9.2	5.5	31.7	39.8	23.5	39	49	29
% within Sex	13.6%	72.7%	13.6%	37.9%	34.7%	27.4%	33.3%	41.9%	24.8%
% within V-NV Diff.	7.7%	32.7%	10.3%	92.3%	67.3%	89.7%	100.0%	100.0%	100.0%
% of Total	2.6%	13.7%	2.6%	30.8%	28.2%	22.2%	33.3%	41.9%	24.8%
χ^2 (2, N = 117) = 10.67, p = .005									
	Females			Males			Total		
	V-NV Diff.			V-NV Diff.			V-NV Diff.		
Severe	NV>V	V=NV	V>NV	NV>V	V=NV	V>NV	NV>V	V=NV	V>NV
Count	5	6	7	55	42	17	60	48	24
Expected	8.2	6.5	3.3	51.8	41.5	20.7	60	48	24
% within Sex	27.8%	33.3%	38.9%	48.2%	36.8%	14.9%	45.5%	36.4%	18.2%
% within V-NV Diff.	8.3%	12.5%	29.2%	91.7%	87.5%	70.8%	100.0%	100.0%	100.0%
% of Total	3.8%	4.5%	5.3%	41.7%	31.8%	12.9%	45.5%	36.4%	18.2%
χ^2 (2, N = 132) = 6.40, p = .041									
	Females			Males			Total		
	V-NV Diff.			V-NV Diff.			V-NV Diff.		
Total	NV>V	V=NV	V>NV	NV>V	V=NV	V>NV	NV>V	V=NV	V>NV
Count	8	22	10	91	75	43	99	97	53
Expected	15.9	15.6	8.5	83.1	81.4	44.5	99	97	53
% within Sex	20.0%	55.0%	25.0%	43.5%	35.9%	20.6%	39.8%	39.0%	21.3%
% within V-NV Diff.	8.1%	22.7%	18.9%	91.9%	77.3%	81.1%	100.0%	100.0%	100.0%
% of Total	3.2%	8.8%	4.0%	36.5%	30.1%	17.3%	39.8%	39.0%	21.3%
χ^2 (2, N = 249) = 8.14, p = .017									

Note. ASD = Autism Spectrum Disorder. V-NV Diff. = Difference in scores between Verbal Ability and Nonverbal Reasoning Ability from the Differential Ability Scales, Second Edition, School Age Battery.

Table 6

Descriptive Statistics for ADOS Variables, Separated by Sex, ASD Severity, and Verbal-Nonverbal Reasoning Difference Group Membership.

	NV > V			V > NV			V = NV		
Affected Females	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
ADOS Total	8.33 (1.53)	7	10	10.33 (6.51)	4	17	10.19 (5.49)	3	23
Social Affect	5.00 (0.00)	5	5	8.33 (5.86)	4	15	7.81 (4.72)	2	20
Reciprocal Social Interaction	3.00 (1.00)	2	4	7.00 (5.29)	3	13	5.56 (3.85)	0	14
Communication	2.00 (1.00)	1	3	1.33 (0.58)	1	2	2.25 (1.73)	0	6
RRB	3.33 (1.53)	2	5	2.00 (2.00)	0	4	2.38 (1.93)	0	5
	NV > V			V > NV			V = NV		
Affected Males	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
ADOS Total	11.03 (4.31)	5	23	9.96 (3.84)	2	16	9.64 (3.44)	4	17
Social Affect	8.60 (3.55)	4	19	7.85 (3.18)	2	13	7.94 (2.77)	4	14
Reciprocal Social Interaction	6.54 (2.59)	3	14	6.35 (2.59)	2	11	6.30 (2.21)	3	10
Communication	2.06 (1.57)	0	5	1.50 (1.17)	0	4	1.64 (1.17)	0	4
RRB	2.43 (1.97)	0	7	2.12 (1.77)	0	6	1.70 (1.63)	0	6
	NV > V			V > NV			V = NV		
Severe Females	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
ADOS Total	13.00 (7.58)	3	21	13.57 (4.89)	9	23	8.83 (4.54)	4	15
Social Affect	10.80 (6.26)	3	19	11.14 (3.13)	8	17	6.83 (4.07)	4	13
Reciprocal Social Interaction	8.00 (4.90)	2	14	8.14 (2.54)	5	13	5.33 (3.27)	3	10
Communication	2.80 (1.48)	1	5	3.00 (1.29)	1	5	1.50 (1.05)	0	3
RRB	2.20 (2.28)	0	5	2.43 (2.07)	0	6	2.00 (1.10)	0	3
	NV > V			V > NV			V = NV		
Severe Males	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
ADOS Total	14.69 (4.74)	4	24	13.75 (5.17)	6	25	13.79 (4.05)	7	23
Social Affect	11.65 (3.92)	4	20	10.13 (3.65)	5	18	10.90 (3.41)	6	18
Reciprocal Social Interaction	8.40 (2.64)	4	14	7.69 (2.68)	3	13	7.83 (2.57)	4	14
Communication	3.25 (1.68)	0	6	2.44 (1.46)	0	5	3.07 (1.31)	1	6
RRB	3.04 (1.87)	0	6	3.63 (2.42)	0	8	2.88 (1.81)	0	6

Note. ADOS = Autism Diagnostic Observation Schedule, Second Edition, Module 3. ASD = Autism Spectrum Disorder. NV>V = Discrepantly high Nonverbal Reasoning versus Verbal Ability from the Differential Ability Scales, Second Edition, School Age Battery (DAS-II). V>NV = Discrepantly high Verbal versus Nonverbal Reasoning Ability from the DAS-II. V=NV = Statistically equivalent Verbal and Nonverbal Reasoning Ability from the DAS-II. RRB = Restricted or Repetitive Behaviors and Interests.

Table 7
Descriptive Statistics for DAS Variables, Separated by Sex, ASD Severity, and Verbal-Nonverbal Reasoning Difference Group Membership.

	NV > V			V > NV			V = NV		
Affected Females	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
V-NV Diff.	-28.00 (6.93)	-36	-24	22.67 (10.69)	16	35	0.25 (3.99)	-6	8
GCA	84.00 (5.29)	80	90	103.67 (29.37)	72	130	92.69 (16.26)	52	111
Verbal	71.00 (2.00)	69	73	115.33 (17.56)	97	132	94.88 (17.42)	51	120
Nonverbal Reasoning	99.00 (8.72)	93	109	92.67 (27.74)	62	116	94.63 (17.05)	56	115
Spatial	89.67 (6.66)	82	94	98.67 (29.40)	66	123	91.38 (11.78)	66	111
	NV > V			V > NV			V = NV		
Affected Males	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
V-NV Diff.	-21.86 (12.14)	-59	-9	16.73 (5.90)	9	28	-0.33 (3.89)	-7	8
GCA	101.83 (20.10)	57	142	104.12 (19.52)	67	142	96.88 (14.39)	67	129
Verbal	89.77 (18.52)	46	118	113.46 (17.99)	80	150	98.48 (14.38)	68	123
Nonverbal Reasoning	111.63 (20.86)	67	158	96.73 (19.51)	59	138	98.82 (13.16)	69	119
Spatial	102.34 (18.64)	58	144	99.38 (14.81)	65	120	92.06 (21.45)	0	130
	NV > V			V > NV			V = NV		
Severe Females	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
V-NV Diff.	-26.00 (11.94)	-40	-13	15.71 (7.74)	9	29	1.67 (4.50)	-7	6
GCA	82.60 (28.90)	35	105	87.86 (24.39)	59	129	78.50 (13.53)	53	90
Verbal	66.40 (24.66)	31	88	98.86 (28.26)	66	145	80.00 (15.52)	51	91
Nonverbal Reasoning	92.40 (28.25)	45	118	83.14 (22.52)	54	121	78.33 (14.69)	49	89
Spatial	92.60 (33.45)	36	124	83.43 (16.73)	60	102	83.33 (10.61)	64	94
	NV > V			V > NV			V = NV		
Severe Males	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.	*M* (*SD*)	Min.	Max.
V-NV Diff.	-21.04 (11.43)	-51	-9	16.94 (7.71)	9	41	-0.71 (4.89)	-8	8
GCA	91.58 (18.68)	51	136	99.24 (12.58)	81	127	95.57 (21.29)	60	155
Verbal	80.42 (21.13)	31	119	111.24 (12.41)	92	134	96.71 (20.74)	50	151
Nonverbal Reasoning	101.45 (17.02)	71	136	94.29 (12.56)	78	117	97.43 (20.73)	52	152
Spatial	95.38 (17.60)	52	138	92.35 (12.16)	77	114	92.29 (17.19)	61	132

Note. DAS = Differential Ability Scales, Second Edition, School Age Battery. ASD = Autism Spectrum Disorder. V-NV Diff. = Difference in scores between Verbal Ability and Nonverbal Reasoning Ability from the DAS. NV>V = Discrepantly high Nonverbal Reasoning versus Verbal Ability from the DAS. V>NV = Discrepantly high Verbal versus Nonverbal Reasoning Ability from the DAS. V=NV = Statistically equivalent Verbal and Nonverbal Reasoning Ability from the DAS. GCA = General Conceptual Ability from the DAS.

CHAPTER 4: DISCUSSION

Although there is great interest in identifying sex differences in diseases or disorders that differentially affect males versus females, relatively less effort has been devoted to research on the differences between males and females with autism spectrum disorder (ASD), despite the known male preponderance in ASD. Because of this male preponderance, autism research studies have tended to use samples that are either entirely composed of males or have very few females. As a result, we have been expanding our knowledge of ASD as it relates to males and not females. Many clinicians who work directly with individuals with autism have noted, anecdotally, that females with ASD seem different from their male counterparts in terms of their clinical presentation and needs for intervention. It is important to identify the ways in which males and females with ASD are alike and unalike for these very reasons; if we are unaware of how females with ASD present, we may miss females on the autism spectrum who could benefit from services, and if we are unaware of the specific strengths and weaknesses of females with ASD, then we may not be targeting the correct behaviors and skills for intervention to improve functional, behavioral, social, and cognitive outcomes.

The research that has been conducted on sex differences in ASD thus far has been marred by methodological constraints and limitations, and has resulted in many null or contradictory findings that are difficult to interpret. Previous studies investigating sex differences in autism spectrum disorders (ASD) have relied exclusively on either samples of children with high-functioning autism or samples of children with ASD and concurrent intellectual disability. Research in this area has also relied on the use of parent-report questionnaires as opposed to observational measures to quantify cognitive ability and the clinical features indicative of autism. If observational measures are used as predictor/outcome variables in these studies of sex differences in ASD, as opposed to simply using them to confirm diagnoses or inclusion criteria, it is common for researchers to only use total, summary, or composite scores that collapse across features and abilities, which means they are not capturing the nuances and complexities of ASD in males versus females. Moreover, the sample sizes are often so small that they do not have the statistical power to detect small or medium gender effects, which has also undoubtedly contributed to the lack of consistency in findings between studies.

In sum, there was a need for research of sex differences in ASD that uses a larger, more diverse sample of males and females affected and severely affected by ASD, but without comorbid psychopathology or disabilities that may have a confounding effect on analyses. The current study addressed the aforementioned gaps in the literature and overcame prior methodological shortcomings by using a larger, more diverse sample of children with ASD to determine whether there are significant differences between males and females in the domains of cognitive ability (overall cognitive ability across domains, and nonverbal reasoning, verbal, and spatial reasoning abilities) and the core features of autism (deficits in reciprocal social interaction and communication, and restricted or repetitive behaviors and interests), as defined by widely used observational assessments. There was also less inherent bias in this sample compared to others because, 1) Participants were from a variety of locations and labs, thereby making results more generalizable to the target population; 2) Diagnoses and phenotype categories were confirmed using multiple measures and criteria as defined by the complex NDAR phenotyping algorithm (See Methods and Appendix A); and 3) Approximately equivalent numbers of males and females affected and severely affected by ASD were included in the sample, and those only “mildly affected” by ASD were excluded to reduce the likelihood that individuals without a valid or stable diagnosis of ASD would have a confounding impact on analyses.

Summary of Key Findings

Results of the current study indicate that there are substantial and nuanced differences between male and female children with ASD. These results also demonstrate the utility of subscale scores, as opposed to total, summary, or composite scores, for providing more accurate and detailed descriptions of the strengths and weaknesses of males and females with ASD. Finally, the current study also confirmed that a discrepancy between verbal and nonverbal reasoning ability varies by sex, and that this discrepancy is differentially impacted by ASD severity. More detailed descriptions of the key findings within each aim of the current study are presented below.

Aim 1. The results of Aim 1 indicated that, using the composite score from the DAS-II (General Conceptual Ability) and the total score from the ADOS, those severely affected by ASD have greater autism symptomatology and lower cognitive ability than those affected, but not severely, by ASD. Moreover, females with ASD have less severe autism symptomatology and lower cognitive ability compared to males with ASD.

The hypotheses regarding the effect of gender and ASD severity group membership on general conceptual ability, then, were confirmed. The finding that girls with ASD without intellectual disability exhibit less severe autism symptomatology compared to boys was not hypothesized, but makes sense in the context of the 'female camouflage effect' that is often referenced in research of sex differences in ASD. It could then be that, regardless of cognitive functioning, girls with ASD may be more perceptive and able to adjust and adapt according to the needs of the situation, therefore demonstrating less severe autism symptomatology overall.

Aim 2. After deconstructing the composite and total scores from Aim 1 into the two domains from the ADOS (Social Affect and Restricted or Repetitive Behaviors and Interests) and the three clusters from the DAS-II (Verbal Ability, Nonverbal Reasoning Ability, and Spatial

Ability), results determined that those severely affected by ASD have greater social deficits related to autism and lower spatial ability than those affected, but not severely, by ASD. Moreover, females with ASD have less severe social deficits related to autism, and lower nonverbal reasoning and spatial ability compared to males with ASD. There are no significant differences in verbal ability or intensity of restricted or repetitive behaviors and interests between males and females with ASD. Furthermore, for those affected and severely affect by ASD, autism severity is not associated with the intensity of restricted or repetitive behaviors and interests, nonverbal reasoning ability, or verbal ability.

The hypotheses regarding the effect of gender and ASD severity group membership on nonverbal reasoning and spatial ability, then, were confirmed. Hypotheses regarding the lack of sex and ASD severity differences in verbal ability and restricted or repetitive behaviors and interests were also confirmed. The finding that girls with ASD without intellectual disability exhibit less severe social deficits compared to boys was not hypothesized, but again, makes sense in the context of the 'female camouflage effect' that is often referenced in research of sex differences in ASD.

In addition, after deconstructing the Social Affect domain of the ADOS into its two subscales (Reciprocal Social Interaction and Communication) and repeating the analyses as before, it was found that those severely affected by ASD have greater deficits in reciprocal social interaction and communication than those affected, but not severely, by ASD. Moreover, females with ASD have less severe deficits in reciprocal social interaction compared to males with ASD. There are no significant differences in communication skills between males and females with ASD, which was expected because of the lack of a confounding influence of intellectual disability that was present in previous research.

In addition to demonstrating the more nuanced differences between males and females with ASD, these results also show the utility of subscale scores as opposed to total or composite scores, and how these differences may have been masked in other studies that relied on composite scores, explaining some the contradictory findings in the literature.

Aim 3. After the three clusters of the DAS-II were broken down into their individual subtests (Word Definitions [Verbal], Verbal Similarities [Verbal], Matrices [Nonverbal], Sequential and Quantitative Reasoning [Nonverbal], Recall of Designs [Spatial], and Pattern Construction [Spatial], results suggested that females with ASD have lower nonverbal reasoning and spatial ability compared to males with ASD, but only in the domains represented by the Matrices and Pattern Construction subtests, not the Recall of Designs or Sequential and Quantitative Reasoning subtests. There are no significant differences in the verbal ability subtests, Word Definitions and Verbal Similarities.

This indicates that, compared with males with ASD, females with ASD are more impaired in their ability to formulate and test hypotheses, use verbal mediation in the solving of nonverbal problems, visually analyze figures or designs, integrate verbal-visual information, and visualize or perceive spatial orientation. Moreover, males and females with ASD do not differ in their ability to verbally conceptualize, comprehend, and express information, nor in their general short-term memory, verbal long-term information retrieval, knowledge of quantitative concepts, and sequential information processing, as represented by the DAS-II subtests. Significant differences in verbal skills as a whole between males and females were not expected to be found, because of the lack of confounding intellectual disability, and differences in nonverbal reasoning and spatial skills were expected to be identified, because of the unique nature of nonverbal intelligence in individuals with ASD compared to the general population. In addition to further demonstrating the more detailed differences in cognitive ability between males and females with ASD, these results once again show the utility of subscale scores as opposed to total or composite scores, and how these differences may have been masked in other studies that relied on composite scores, explaining some the contradictory findings in the literature.

Aim 4. The relationship between sex and ASD severity was not significant, meaning that there is no interaction between sex and ASD severity in terms of group membership. More specifically, ASD severity (affected versus severely affected) was not associated with whether the child was male or female- there were approximately equivalent numbers of males and females in the affected and severely affected by ASD groups. Therefore, the hypothesis regarding the lack of an interaction between sex and ASD severity in terms of group membership was confirmed, and also provides justification as to why there were no significant interactions between sex and ASD severity in the MANCOVAs from Aims 1, 2a, 2b, and 3.

Moreover, additional analyses revealed that females with ASD are more likely to exhibit equivalent performance in verbal and nonverbal reasoning than to have a verbal-nonverbal discrepancy. For those with a discrepancy, it is more common to have a cognitive discrepancy favoring verbal ability rather than nonverbal reasoning ability. On the other hand, males with ASD are more likely to exhibit a verbal-nonverbal discrepancy than to have equivalent performance on measures of verbal and nonverbal reasoning, and discrepancies are more likely to favor nonverbal reasoning ability rather than verbal ability. When comparing males to females, males are more likely than females to have a verbal-nonverbal discrepancy, especially one favoring nonverbal reasoning ability. Females are more likely than males to not have a significant verbal-nonverbal discrepancy or to have discrepantly high verbal ability.

Results also showed that a significant verbal-nonverbal discrepancy occurred in 61.0% of the sample, indicating that for children with ASD, verbal-nonverbal discrepancies occur much more often than in the general population (25%), according to statistics provided by the DAS-II manual. Moreover, 39.8% of the sample demonstrated discrepantly high nonverbal reasoning ability, and 21.3% of the sample demonstrated discrepantly high verbal ability, indicating that for children with ASD, verbal-nonverbal discrepancies in both directions occur much more often than in the general population (15%).

The DAS-II manual also suggests that absolute differences between verbal and nonverbal reasoning that are 20 points or greater are only expected in about 5% of the general population, and differences of greater than 30 points are only expected in 1% of the general population. This indicates that, according to the present study, not only are children with ASD significantly more likely to exhibit a verbal-nonverbal discrepancy compared to individuals in the general population, but their absolute differences between verbal and nonverbal reasoning are larger than that which we would expect to see in the general population, and are only seen in around 1% to 5% of the population.

Affected by ASD. In addition, females affected, but not severely, by ASD were more likely to exhibit equivalent performance in verbal and nonverbal reasoning than to have a verbal-nonverbal discrepancy in either direction. On the other hand, males affected, but not severely, by ASD were more likely to exhibit a verbal-nonverbal discrepancy, especially one favoring nonverbal reasoning ability, than to have equivalent performance on measures of verbal and nonverbal reasoning. Then, comparing males to females not severely affected by ASD, males were more likely than females to have a verbal-nonverbal discrepancy in either direction, and females were therefore more likely than males to not have a significant verbal-nonverbal discrepancy.

Here, again, we also found that there was a much higher proportion of children not severely affected by ASD that have a significant verbal-nonverbal discrepancy (58.1%) than would be present in the general population (25%), according to the DAS-II manual and statistics computed from the norming sample. Moreover, 33.3% of those not severely affected by ASD demonstrated discrepantly high nonverbal reasoning ability, and 24.8% of the sample demonstrated discrepantly high verbal ability, indicating that for children affected by ASD, verbal-nonverbal discrepancies in both directions occur much more often than in the general population.

Additionally, descriptive statistics for the group not severely affected by ASD indicated that the average verbal-nonverbal reasoning discrepancy for those with discrepantly high nonverbal reasoning ability was 28.00 points for females (M verbal standard score = 71.00; M nonverbal reasoning standard score = 99.00), and 21.86 points for males (M verbal standard score = 89.77; M nonverbal reasoning standard score = 111.63). This indicates that in the group of those with discrepantly high nonverbal reasoning skills and not severe ASD, females have a larger verbal-nonverbal reasoning discrepancy, and also have lower verbal and nonverbal reasoning scores, compared to males. Moreover, according to the DAS-II classification schema comparing age-referenced standard scores to that in the general population based on their norming sample, the females in this group have, on average, low verbal scores and limited verbal proficiency, whereas males have slightly below average verbal scores and adequate verbal proficiency. Furthermore, on average, females in this group have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency, and males have above average nonverbal reasoning scores and adequate nonverbal reasoning proficiency.

On the other hand, for those with discrepantly high verbal skills in the group without severe ASD, the average verbal-nonverbal discrepancy was 22.67 points for females (M verbal standard score = 115.33; M nonverbal reasoning standard score = 92.67), and 16.73 points for males (M verbal standard score = 113.46; M nonverbal reasoning standard score = 96.73). This indicates that in the group of those with discrepantly high verbal skills and not severe ASD, females have a larger verbal-nonverbal reasoning discrepancy, and also have higher verbal and lower nonverbal reasoning scores, compared to males. Moreover, according to the DAS-II classification schema comparing age-referenced standard scores to that in the general population based on their norming sample, the females in this group have, on average, above average verbal scores and slightly advanced verbal proficiency, whereas males have above average verbal scores and adequate verbal proficiency. Furthermore, on average, females in this group have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency, and males also have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency.

For the group without a significant discrepancy between verbal and nonverbal reasoning, females not severely affected by ASD had an average verbal score of 94.88, and an average nonverbal reasoning score of 94.63. For males in this group, the average verbal score was 98.48, and the average nonverbal reasoning score was 98.82. Therefore, the females in this group have lower verbal and nonverbal reasoning scores than their male counterparts. Moreover, according to the DAS-II classification schema comparing age-referenced standard scores to that in the general population based on their norming sample, the females and males in this group have, on average, average verbal and nonverbal reasoning scores and adequate verbal and nonverbal reasoning proficiency.

Severely Affected by ASD. Conversely, for children severely affected by ASD, there was not a significant association between sex and a verbal-nonverbal discrepancy. There were roughly equivalent proportions of males and females in the verbal-nonverbal discrepancy and no significant discrepancy groups. Descriptively, however, we see that 63.6% of those severely affected by ASD had a significant verbal-nonverbal discrepancy, which is slightly higher than the proportion of those with a verbal-nonverbal discrepancy in the group affected, but not severely, by ASD, and is also higher than that which would be expected in the general population (25%).

When considering discrepantly high verbal and discrepantly high nonverbal reasoning groups separately, versus those with equivalent performance on verbal and nonverbal reasoning ability, females severely affected by ASD were most likely to exhibit a verbal-nonverbal discrepancy favoring verbal ability, rather than discrepantly high nonverbal reasoning ability or equivalent performance in verbal and nonverbal reasoning. On the other hand, males severely affected by ASD were most likely to exhibit discrepantly high nonverbal reasoning ability than to have equivalent performance on measures of verbal and nonverbal reasoning, or discrepantly high verbal skills. Then, comparing males to females, males were more likely than females to have discrepantly high nonverbal skills and to have no significant verbal-nonverbal discrepancy, and females were more likely than males to have a significant verbal-nonverbal discrepancy favoring verbal ability.

Here we found, again, that 45.5% of the sample demonstrated discrepantly high nonverbal reasoning ability, and 18.2% of the sample demonstrated discrepantly high verbal ability, indicating that for children severely affected by ASD, verbal-nonverbal discrepancies in both directions occur much more often than in the general population.

Additionally, descriptive statistics for the severe ASD group indicated that the average verbal-nonverbal reasoning discrepancy for those with discrepantly high nonverbal reasoning ability was 26.00 points for females (M verbal standard score = 66.40; M nonverbal reasoning standard score = 92.40), and 21.04 points for males (M verbal standard score = 80.42; M nonverbal reasoning standard score = 101.45). This indicates that in the group of those with discrepantly high nonverbal reasoning skills and severe ASD, females have a larger verbal-nonverbal reasoning discrepancy, and have lower verbal and nonverbal reasoning scores, compared to males. Moreover, according to the DAS-II classification schema comparing age-referenced standard scores to that in the general population based on their norming sample, the females in this group have, on average, very low verbal scores and very limited verbal proficiency, whereas males have below average verbal scores and limited verbal proficiency. Furthermore, on average, females in this group have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency, and males also have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency.

On the other hand, for those with discrepantly high verbal skills in the severe ASD group, the average verbal-nonverbal discrepancy was 15.71 points for females (M verbal standard score = 98.86; M nonverbal reasoning standard score = 83.14), and 16.94 points for males (M verbal standard score = 111.24; M nonverbal reasoning standard score = 94.29). This indicates that in the group of those with discrepantly high verbal skills and severe ASD, males have a larger verbal-nonverbal reasoning discrepancy, and also have higher verbal and nonverbal reasoning scores, compared to females. Moreover, according to the DAS-II classification schema comparing age-referenced standard scores to that in the general population based on their norming sample, the females in this group have, on average, average verbal scores and adequate verbal proficiency, whereas males have above average verbal scores and adequate verbal proficiency. Furthermore, on average, females in this group have below average nonverbal reasoning scores and limited nonverbal reasoning proficiency, and males have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency.

For the group without a significant discrepancy between verbal and nonverbal reasoning, females severely affected by ASD had an average verbal score of 80.00, and an average nonverbal reasoning score of 78.33. For males in this group, the average verbal score was 96.71, and the average nonverbal reasoning score was 97.43. Therefore, the females in this group have lower verbal and nonverbal reasoning scores than their male counterparts. Moreover, according to the DAS-II classification schema comparing age-referenced standard scores to that in the general population based on their norming sample, the females in this group have, on average, below average verbal scores and limited verbal proficiency, whereas males have above average verbal scores and adequate verbal proficiency. Furthermore, on average, females in this group have low nonverbal reasoning scores and limited nonverbal reasoning proficiency, and males have average nonverbal reasoning scores and adequate nonverbal reasoning proficiency.

Limitations

The results of the current study must be considered in the context of several limitations. The use of the National Database for Autism Research, and many other data repositories, often precludes the examination of sociodemographic information that was either not collected by the original collectors of the data, or was not contributed to the data repository. The current study was not able to inspect sociodemographic variables for their impact on analyses, such as the education level of the parents, socioeconomic status, number of children in the household, or race/ethnicity. Using data from a repository also means that you cannot personally verify the data collection procedures, but all the laboratories that contributed the data used in this project were funded and reviewed by the National Institutes of Health and should therefore be expected to be of high caliber.

Another potential limitation is that there were not equal numbers of males and females in the sample. This is difficult to achieve in research of sex differences in ASD, and the ratio of males to females in the current study (5.3 males for every 1 female) is on target for what we would expect the ratio of males to females to be for children with ASD without intellectual disability (5.1 males for every 1 female) according to the most recent estimates from the Centers for Disease Control and Prevention's Autism and Developmental Disabilities Monitoring (ADDM) Network (Christensen et al., 2016). Additionally, the lack of balance in the numbers of males and females in the current sample might be thought to bias the statistical analyses, but the inspection of assumptions for each analysis indicated that the assumptions were not violated, and the analyses were conducted with bootstrapping resampling procedures and bias-correction, so the unequal numbers of males and females are less of a concern.

Finally, it must be mentioned that the current study investigated sex differences in children who were identified by their parents as being male or female, not considering those who may be intersex, transgender, gender fluid, of any other gender that does not fit into the categories of male or female, or those who do not conform to gender labels at all. Although the National Database for Autism Research has categories of male, female, and transgender in the data repository, there were not any participants in the current study who were in the transgender category, although this does not guarantee that the individual researchers who contributed data to the repository had provided the 'transgender' option on their research protocols. In addition, gender is not a stable or fixed trait, and therefore may vary over time for an individual, which was not considered in the current study.

Implications

Ideally, there would be a biological test to diagnose ASD or identify the presence of markers for ASD, like the tests that identify HIV or assess risk for developing breast cancer through the identification of mutations to the BRCA1 and BRCA2 genes. Given that there is no such test at present, it is imperative that we find a way to correctly and reliably diagnose ASD from the presence of specific clinical features and behaviors, in the context of the child's intellectual functioning and, based on the results of the current study, their sex. More accurate diagnosis of ASD in males and females would mean that we would miss fewer children, especially females, on the autism spectrum, thereby giving them the opportunity to engage in early intervention, which has been known to be efficacious and more beneficial the earlier it begins (Granpeesheh, Tarbox, & Dixon, 2009; Reichow, 2012). When studies compare young children with ASD who receive early intensive intervention to children who do not, results indicate that, on average, the children who received early intensive intervention targeted toward their specific needs end up with higher scores on measures of cognitive, adaptive, and social functioning, and need fewer subsequent services (Rogers & Vismara, 2008).

Future Research

Future research of sex differences in ASD should look longitudinally at changes in cognitive ability and the clinical features of ASD, and whether there are divergent trajectories for males versus females. Ideally, these studies would also use multiple measures of cognitive ability and ASD symptoms to ensure that the results are not an artefact of the measures themselves and are truly measuring distinctions between males and females with ASD. Future research in this domain would also benefit from the use of a control group to compare differences in males and females with ASD to those found between males and females without ASD. In addition, researchers should consider children with ASD who do not identify or express their gender within the gender binary, and those whose gender identity has varied over time. Finally, research is needed in sex differences within the rest of the autism spectrum, namely for those with comorbid intellectual disability and those with various other comorbid diagnoses.

APPENDIX A

Summary Data Approach in NDAR

Date: May 8, 2012

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The National Database for Autism Research (NDAR) supports data sharing across a broad array of clinical, genomic, and brain imaging autism research data. To aid those interested in applying for access, NDAR allows the general public to browse summary data now being shared. There are now three ways to browse the summary data, allowing researchers to find out how much data is available for their area of interest.

Data Browser

Data Distributions, located on the NDAR home page, provides aggregated and detailed views of shared research data that can be mined within the categories of basic data, phenotypic data, neuroimaging data and genomics data. Users can further refine results specific to a research area of interest by selecting a phenotype (e.g. autism spectrum-severely affected, typical control), sub-type (e.g. seizures, regression, verbal IQ, minimally verbal), or attributes (e.g. age, gender, genomics molecule, genomics platform, scanner manufacturer). The rules used to determine phenotype and minimally verbal are defined in the appendix below. The rules used to mine such attributes are expandable to expose and/or aggregate any combination of the 30,000+ data variables within NDAR's data dictionary. Members of the research community are encouraged to work with NDAR staff to further define rules, exposing other phenotypes, sub-types and attributes relevant to autism research. NDAR can be contacted at ndarhelp@mail.nih.gov.

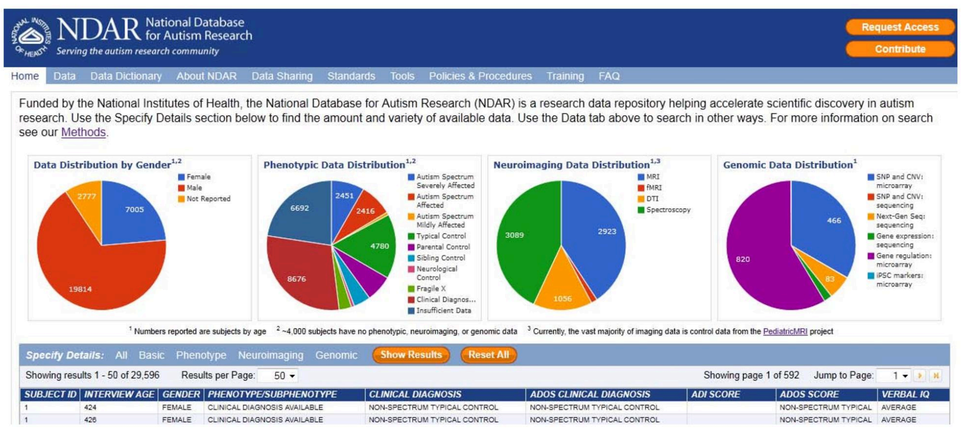

Figure 1 – Data Browser

Data from Labs

Data from Labs, located under the Data tab on the main menu, provides a snapshot of the projects who have shared data in NDAR. Listed are the investigators, publications related to the projects and the number of records and subjects shared by data structure. NDAR users with access to shared data can login to NDAR and download the specific data associated with a lab.

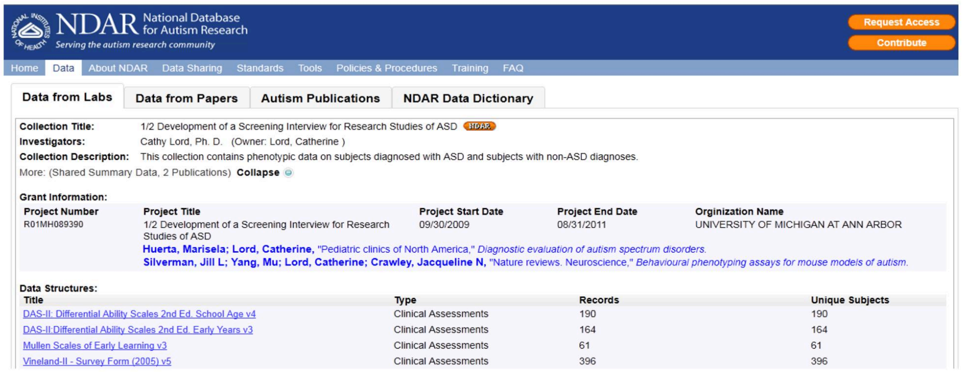

Figure 2 – Data from Labs

Data from Papers

Data from Papers, located under the Data tab on the main menu, displays data specific to a publication. Using the NDAR Study feature within the portal, an approved researcher can define cohorts, assign research subjects to the cohorts, and specify outcome measures, methods, and results all of which can, but is not required to, be linked to a published paper. Once shared, the NDAR Study will appear in Data by Papers, allowing the data associated with an NDAR Study to be easily downloaded. For publications listed in PubMed, NDAR staff will provide a link in PubMed via the linkout feature back to the data made available in NDAR. This capability allows the autism research community to directly associate the publication with the underlying data.

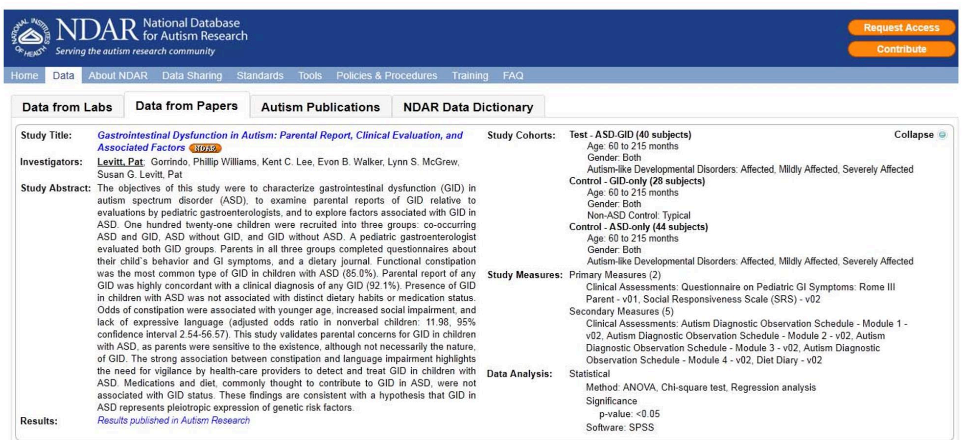

Figure 3 – Data from Papers

Appendix 1: Mechanisms and Rules used for NDAR Data Browser

NDAR's initial focus was to make data submission as simple as possible limiting the cost of data sharing. Through the implementation of an autism data standard and an increasingly sophisticated data validation process, NDAR ensures data is harmonized to a common data standard. This approach has kept submission costs low (see NDAR Cost model). However, receiving data at a detailed level across a variety of instruments makes it more difficult for a researcher to understand the data available for their particular areas of interest. To reduce this burden, NDAR has developed a categorization system that is applied to all shared data. The process categorizes a research subject listing the summary information known for each age that is provided in the data received. NDAR developed categories for phenotype/sub-phenotype and the minimally verbal sub-type and extracted key attributes on genomics, imaging, demographics and other areas of interest. Categorization can be modified and expanded easily allowing the community to expose relevant phenotypes and attributes appropriate for autism research.

Categorizing subjects – especially across sub-phenotypes - is subject to debate. These categories are intended to broadly define the data in NDAR helping scientists ascertain the types and quantity of data available. In a future release these categories may be used as the basis for downloading specific observations (i.e. ADOS/ADI/Images/Pedigree), if a researcher is approved for access, thus allowing a tighter integration into imaging and genomic processing pipelines.

To help understand the process NDAR used for categorization, we have provided an overview of how the phenotype/sub-phenotype and minimally verbal sub type categories were determined, as these are the most complex and thus were used as the test case for the categorization process.

Phenotype/Sub-Phenotype Categorization

For Phenotype categorization, the rules engine makes multiple passes through shared data in NDAR. Once an individual is defined with a phenotype/sub-phenotype, the process moves on to the next research subject to avoid double classification. Categorization is performed based upon the following order:

1. Fragile X
2. Controls
    a. Non Spectrum Typical Control (e.g. typical, sibling, parent)
    b. Non Spectrum Neurological Control
3. Autism Spectrum
    a. Severely Affected
    b. Mildly Affected
    c. Affected

Subjects are evaluated by age in months. To account for observations over multiple visits, observations occurring ± 3 months are considered. So, if a subject is defined for a phenotype of autism spectrum-severely affected at age 24 months, this designation would be applied to observations made at 21 through 27 months. Unless observations are again performed at later ages, a phenotype is not provided. An option to select such subject data will likely be provided in a future version of the Data Browser.

Fragile X

Fragile X is defined according to provided genetic test results for the Fragile X mutation of the FMR1 gene.

Control Subjects

Based upon designations provided by researchers in the data, **Control Subjects** are divided into 4 sub categories:

Non-Spectrum Control:

a) Typical
b) Sibling
c) Parental
d) Neurological disorders

Typical controls are typically developing individuals. Sibling and Parental controls are family members of a research subject. The Neurological disorders sub-phenotype control group includes subjects with a learning disability, Attention Deficit Hyperactivity Disorder , developmental disability, intellectual disability/MR or other neurological disorder, excluding Fragile X and subjects with positive genetic test result for Non-Spectrum Neurological conditions. Rules for diagnosis are made based on the diagnosis data that is provided in a number of fields within NDAR.

Non-Spectrum Control: Typical

In the absence of a diagnosis, NDAR categorizes control subjects based on the following rules based on results from the ADI-R, ADOS, IQ and Vineland Survey assessments.

ADI-R: Non-Spectrum Typical

Total for Section A: Qualitative Abnormalities in Reciprocal Social Interaction	<4	**AND**
Total of Section B - Non-Verbal: Qualitative Abnormalities in Communication	<4	**OR**
Total of Section B - Verbal: Qualitative Abnormalities in Communication	<4	**AND**
Total of Section C: Restricted, Repetitive, and Stereotyped Patterns of Behavior	<2	**AND**
Total of Section D = 0		

ADOS: Non-Spectrum Typical

	Module 1:	Module 2:	Module 3:	Module 4:	
Communication Total	<1	<2	<1	<1	**AND**
Social Interaction Total	<2	<2	<2	<2	**AND**
Communication + Social Total	<3	<3	<3	<3	

(IQ: Average and Higher than Average IQ>85

OR

Vineland Survey: Average and Higher than Average

Composite Domain Total Score	>85	**AND**
Communication Domain Total Score	>85	**AND**
Living skills Domain Total Score	>85	**AND**
Motor skills Domain Total Score	>85	**AND**
Socialization Domain Total Score	>85**)**	

Non-Spectrum Control: Neurological Disorder

ADI-R: Non-Spectrum Neurological

Total for Section A: Qualitative Abnormalities in Reciprocal Social Interaction	>4	**OR**
Total of Section B - Non-Verbal: Qualitative Abnormalities in Communication	>4	**OR**
Total of Section B - Verbal: Qualitative Abnormalities in Communication	>4	**OR**
Total of Section C: Restricted, Repetitive, and Stereotyped Patterns of Behavior	>2	**AND**
Total of Section D = 0		

ADOS: Non-Spectrum Typical or Mildly Affected

	Module 1:	Module 2:	Module 3:	Module 4:	
Communication Total	<4	<5	<3	<3	**AND**
Social Interaction Total	<4	<4	<4	<4	**AND**
Communication + Social Total	<7	<8	<7	<7	**AND**

(IQ: IQ = any

OR

Vineland Survey: Less than average

Composite domain total score	<85	**OR**
Communication domain total score	<85	**OR**
Living skills domain total score	<85	**OR**
Motor skills domain total score	<85	**OR**
Socialization domain total score	<85**)**	

Autism Spectrum Phenotype

For all remaining subjects/ages the Autism Disorder phenotype **and sub-phenotype rules are run** according to cut offs, for each Assessment (ADI-R, ADOS, IQ and Vineland Survey). Note that a minimum of three assessments - including ADI-R and ADOS – plus one other measure (Vineland or an IQ) is needed for categorization of an autism spectrum phenotype:

Sub-Phenotype: Severely Affected

ADI-R: Severely Affected

Total for Section A: Qualitative Abnormalities in Reciprocal Social Interaction	>10	**AND**
Total of Section B - Non-Verbal: Qualitative Abnormalities in Communication	>7	**OR**
Total of Section B - Verbal: Qualitative Abnormalities in Communication	>8	**AND**
Total of Section C: Restricted, Repetitive, and Stereotyped Patterns of Behavior	>3	**AND**
Total of Section D	≥1	

ADOS: Severely Affected

	Module 1:	Module 2:	Module 3:	Module 4:	
Communication Total	>4	>5	>3	>3	**AND**
Social Interaction Total	>7	>6	>6	>6	**AND**
Communication + Social Total	>12	>12	>10	>10	

AND at least one of these tests scores:

(IQ: Any

OR

Vineland Survey: Less than average

Composite domain total score	<85	**AND**
Communication domain total score	<85	**AND**
Living skills domain total score	<85	**AND**
Motor skills domain total score	<85	**AND**
Socialization domain total score	<85**)**	

Sub-Phenotype: Mildly Affected

The sub-phenotype of Mildly Affected is defined as remaining subjects not falling into the Severely Affected category who also meet the following criteria:

ADI-R: Mildly Affected

Total for Section A: Qualitative Abnormalities in Reciprocal Social Interaction	<4	**AND**
Total of Section B - Non-Verbal: Qualitative Abnormalities in Communication	<4	**AND**
Total of Section B - Verbal: Qualitative Abnormalities in Communication	<4	**AND**
Total of Section C: Restricted, Repetitive, and Stereotyped Patterns of Behavior	<2	**AND**
Total of Section D ≥1		

ADOS: Mildly Affected

	Module 1:	Module 2:	Module 3:	Module 4:	
Communication Total:	1 to 4	1 to 5	1 to 3	1 to 3	**AND**
Social Interaction Total:	1 to 4	2 to 4	1 to 4	1 to 4	**AND**
Communication + Social Total:	1 to 7	2 to 8	2 to 7	2 to 7	

(<u>IQ:</u> Average and Higher than Average IQ > 85

<u>OR</u>

<u>Vineland Survey:</u> Average and Higher than Average

Composite domain total score	> 85	**<u>AND</u>**
Communication domain total score	> 85	**<u>AND</u>**
Living skills domain total score	> 85	**<u>AND</u>**
Motor skills domain total score	> 85	**<u>AND</u>**
Socialization domain total score	> 85**)**	

Sub-Phenotype: Affected

The sub-phenotype of Affected is defined as subjects/ages remaining (i.e. not falling into the Severely Affected or Mildly Affected category) who also meet the following criteria:

<u>ADI-R</u>: Affected

Total for Section A: Qualitative Abnormalities in Reciprocal Social Interaction	>4	**<u>AND</u>**
Total of Section B - Non-Verbal: Qualitative Abnormalities in Communication	>4	**<u>OR</u>**
Total of Section B - Verbal: Qualitative Abnormalities in Communication	>4	**<u>AND</u>**
Total of Section C: Restricted, Repetitive, and Stereotyped Patterns of Behavior	>2	**<u>AND</u>**
Total of Section D ≥1		

<u>ADOS:</u> Affected

	<u>Module 1:</u>	<u>Module 2:</u>	<u>Module 3:</u>	<u>Module 4:</u>	
Communication Total	>4	>5	>3	>3	**<u>OR</u>**
Social Interaction Total	>7	>6	>6	>6	**<u>OR</u>**
Communication + Social Total	>12	>12	>10	>10	

(IQ: Average IQ 85 to 100

OR

Vineland Survey: Average

Composite domain total score	85 to 115	**OR**
Communication domain total score	85 to 115	**OR**
Living skills domain total score	85 to 115	**OR**
Motor skills domain total score	85 to 115	**OR**
Socialization domain total score	85 to 115**)**	

Precision of Definitions

After applying all aforementioned rules for the phenotype parameters definition, the precision for the definition of the **Autism Spectrum Phenotype and Sub-Phenotype** is defined as follows:

I. **Ideal Phenotype**

ADI+ADOS+nvIQ+vIQ+Vineland*

II. **Very Good Phenotype**

ADI+ADOS + (nvIQ or vIQ) +Vineland*

III. **Good Phenotype**

ADI+ADOS + (nvIQ or vIQ or Vineland)*

IV. **Clinical Diagnosis**

Clinical_diagnosis is provided and categorized in the Phenotype field in Browse Data. To ascertain the specific clinical diagnosis provided, one must query the clinical diagnosis field to see specific categorizations on clinical diagnosis.

IQ measures used for categorization are:

- Differential Ability Scales – Early Years
- Differential Ability Scales – School Age
- Raven's Coloured Progressive Matrices
- Stanford-Binet Intelligences Scales
- Leiter International Performance Scale - Revised
- Wechsler Intelligence Scale for Children
- Wechsler Abbreviated Scale of Intelligence

** nvIQ = non-verbal IQ and vIQ = verbal IQ*

Autism Sub-Types and the Minimally Verbal Categorization

To address the need to further define individuals with an autism spectrum diagnosis, many autism sub-types have been defined. As with the phenotype and sub-phenotype categories, the sub-type category can be expanded and enhanced by the autism research community through collaboration with the NDAR team.

For illustration, the minimally verbal represents the most complex sub-type currently defined by NDAR. To define this sub-type, rules were created and implemented based on scores from relevant clinical measures. The minimally verbal categorization follows in a similar manner as that of phenotype where first the ideal categorization was used, which includes subjects that had a minimally verbal designation from an ADOS, an ADI and at least one OTHER validation measure (i.e. Mullen, Vineland, MacArthur-Bates) that confirm the minimally verbal designation at a particular age. Subjects – at a particular age – are noted with an "Ideal" Minimally Verbal designation. Next, we checked the presence of minimally verbal in two out of the three groups (ADI/ADOS or ADI/OTHER or ADOS/OTHER) for a minimally verbal designation. Subjects that had a minimally verbal designation were then defined with a "Good" Minimally Verbal designation. Like phenotype observations ± 3 months were used for evaluation. The following rules were used for Minimally Verbal.

Assessment	Element	Value	Interpretation
ADI-R	Overall level of language	1; 2	2 (fewer than 5 words total or speech not used on daily basis); 1 (speech use on daily basis with min 5 words in the last month)
ADOS Module 1	Overall level of non-echoed language	2; 3; 8	8 (no words); 3 (at least one word but fewer than 5); 2 (single words only, must use min 5 during session)
ADOS Module 2	Overall level of non-echoed language	2; 3; 7	7 (all speech echoed); 3 (single words only or no spoken language); 2(mostly single words)
Mullen	Expressive language - names objects	0	Names 0
Mullen	Expressive language - oral vocabulary	0	Names less than 5
Vineland Survey	Expressive language - answers with word	0	Never
Vineland Survey	Expressive language - names at least 3 objects	0	Never
MacArthur-Bates Words & Gestures	Productive vocabulary measure	<6	Produces less than 6 words
MacArthur-Bates Words & Sentences	Productive vocabulary measure	<6	Produces less than 6 words

APPENDIX B

WAYNE STATE
UNIVERSITY

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CONCURRENCE OF EXEMPTION

To: Jessica Irwin
Psychology
298 Oxford St

From: for Dr. Deborah Ellis C. Zolondek / 2.2
Chairperson, Behavioral Institutional Review Board (B3)

Date: October 05, 2015

RE: IRB #: 103215B3X

Protocol Title: Child, Maternal, and Familial Predictors of Academic Achievement for Children with Autuism

Sponsor:

Protocol #: 1510014393

The above-referenced protocol has been reviewed and found to qualify for **Exemption** according to paragraph #4 of the Department of Health and Human Services Code of Federal Regulations [45 CFR 46.101(b)].

- Social/Behavioral/Education Exempt Protocol Summary Form (received in the IRB office 10/2/15)
- Research Protocol (received in the IRB office 10/02/15)

This proposal has not been evaluated for scientific merit, except to weigh the risk to the human subjects in relation to the potential benefits.

- Exempt protocols do not require annual review by the IRB.
- All changes or amendments to the above-referenced protocol require review and approval by the IRB **BEFORE** implementation.
- Adverse Reactions/Unexpected Events (AR/UE) must be submitted on the appropriate form within the timeframe specified in the IRB Administration Office Policy (http://irb.wayne.edu/policies-human-research.php).

NOTE: Forms should be downloaded from the IRB Administration Office website http://irb.wayne.edu at each use.

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ABSTRACT

IDENTIFYING SEX-SPECIFIC COGNITIVE AND DIAGNOSTIC PROFILES OF CHILDREN ON THE AUTISM SPECTRUM

by

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Although there has been great interest in identifying sex differences in diseases or disorders that differentially affect males versus females, relatively less effort has been devoted to research on the differences between males and females with autism spectrum disorder (ASD), despite the known male preponderance in ASD. The identification of separate male and female phenotypes within ASD would help parents, teachers, and clinicians better identify girls who may need ASD-related intervention services, inform the targets and goals of such interventions, and lead to the refinement of diagnostic criteria and instruments designed to diagnose ASD in children.

The current study sought to identify sex-specific cognitive and diagnostic profiles for children with ASD using a sample (N = 253, 213 males, 40 females; M_{age} = 10 years, Range = 4 - 16) of children from across the United States who are affected and severely affected by ASD (as defined by a complex algorithm developed by the National Database for Autism Research), and who are without intellectual disability or comorbid medical conditions. Well-validated, age-referenced, observational assessments were used to quantify cognitive ability and the clinical features of ASD. The Differential Ability Scales, Second Edition, School Age Battery was used to measure general conceptual ability, verbal ability, nonverbal reasoning ability, and spatial ability, and the Autism Diagnostic Observation Schedule, Second Edition was used to measure the clinical features of autism, including restricted or repetitive behaviors and interests, and deficits in reciprocal social interaction and communication. Results suggest that there are significant sex differences within ASD in the domains of nonverbal reasoning ability, spatial ability, the discrepancy between verbal and nonverbal reasoning abilities, and reciprocal social interaction, after controlling for age. Being affected versus severely affected by ASD also contributed to differences between males and females. Implications, limitations, and suggestions for future research are discussed.

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AUTOBIOGRAPHICAL STATEMENT

Jessica Irwin graduated from the University of Michigan, Ann Arbor, in 2010 with a Bachelor of Arts in psychology. In 2011, she became a doctoral student in the Cognitive, Developmental, and Social Psychology Area of the Department of Psychology at Wayne State University. In 2014, she earned her master's degree in developmental psychology, and has submitted this manuscript in partial fulfillment of the requirements for a doctoral degree in developmental psychology with a minor in quantitative methods. Upon graduation from Wayne State University, she will begin work as a postdoctoral fellow in the Department of Environmental Medicine at the University of Rochester in Rochester, New York, and will be working on the Seychelles Child Development Study. She will continue to engage in research of autism spectrum disorder, which has been her passion since she began her undergraduate work at the University of Michigan Autism and Communication Disorders Center. She will also continue to engage in her other passion: spending time with her dog, Sammy.