A Proposed Model of Intelligence and Its Implications for Children with Autism Spectrum Disorder

by

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Biographical Sketch

The author was born in Sleepy Hollow, New York, United States of America. She attended Harvard University and graduated with a Bachelor of Arts degree in psychology. She embarked on her career path by working as a therapeutic intervention specialist at Stony Lodge Hospital and a classroom aide at the Devereux Millwood Learning Center. She began doctoral studies in clinical psychology at the University of Rochester in 2010. She was awarded the Provost’s Fellowship in 2010. She earned a Master of Arts degree in clinical psychology in 2012. She pursued her research in the assessment and treatment of children with autism spectrum disorder and their families under the direction of Tristram Smith, Ph.D.

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Abstract

Although research indicates that IQ tests are reliable and valid measures of cognition when administered to individuals with autism spectrum disorder (ASD), it also reveals that such tests have unusual psychometric properties in this population, notably low intercorrelation among subtests, distinctive patterns of strengths and weaknesses, and overprediction of everyday functioning. A comprehensive explanation for these differences has yet to be offered. This study evaluates a new model of the structure of intelligence in the ASD population that, if confirmed, would help account for the differences. A three-domain model is proposed, consisting of language ability, perceptual ability, and social ability, with each ability further broken down into a fluid reasoning component and crystalized knowledge component. Fifty-three children with ASD, ages 6-12, with full scale IQ scores above 50, were assessed on a standardized IQ test (Stanford-Binet Intelligence Test, 5th Edition), a test of social skills (NEPSY-II), and parent-rated adaptive behavior (Vineland Adaptive Behavior Scales II), social skills (Social Skills Improvement System – Rating Scales), and executive functioning (BRIEF). Factor scores were estimated from 6 items (Verbal Knowledge, Verbal Fluid Reasoning, Nonverbal Knowledge, and Nonverbal Fluid Reasoning from the SB-5; Affect Recognition and Theory of Mind from the NEPSY-II), and a path analysis was conducted to test the fit of a model relating these factors to (1) constructs representing cognitive abilities and adaptive abilities, (2) constructs representing the components of the new model proposed in this study (language abilities, perceptual abilities, and social abilities), and (3) constructs representing the impact of executive functioning on the new model.
On the whole, results supported the use of the SB-5 with school-age children with ASD. The proposed model was partially supported with the inclusions of social skills and only 4 subtests of the SB-5 predicting adaptive behavior as well as the full IQ test. The inclusion of executive functioning in the model as an additional construct of cognition was not supported.
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Background and Introduction

The most recent prevalence study found that 1 out of every 68 children in the United States is diagnosed with an autism spectrum disorder (ASD) (Autism and Developmental Disabilities Monitoring, 2014). The defining characteristics of ASD include qualitative impairments in social interaction and communication, along with stereotyped and repetitive behaviors and restricted interests (American Psychiatric Association, 2013). In addition, individuals with ASD are at increased risk for co-occurring conditions including, epilepsy, tuberous sclerosis, macrocephaly, ADHD, Tourette syndrome and anxiety (Bolton, 2009; Simonoff et al., 2008).

One of the most important co-occurring conditions is intellectual disability. Approximately 31% of children with the diagnosis also have an IQ below 70, placing them into the range of intellectual disability (ADDM, 2014). This is a much greater percentage than would be expected from the overall prevalence of 0.71% of intellectual disability in the general population (Boyle, et al., 2008). There is limited understanding of why individuals with ASD have such varied intellectual skills. Therefore, the cognitive abilities of children with ASD and how they differ from those of the typically developing population are important to explore. A better understanding of the cognitive differences between individuals with ASD and typically developing individuals could open a window into the source of the social and behavioral difficulties of individuals with ASD by identifying how cognitive processing deficits could affect social and adaptive behaviors. This deeper understanding of their cognitive differences could then inform our education and intervention methods with this population by allowing more targeted skill building in their areas of deficits and strategies to help them use their strengths.
Beginning with Kanner’s (1943) original work identifying autism as a disorder, researchers and clinicians have remarked on the difficulty of estimating intelligence in children with ASD. Kanner (1943) asserted that although the cognitive abilities of these children may seem limited, “they are all unquestionably endowed with good cognitive potentialities…[though] Binet or similar testing could not be carried out because of limited accessibility” (Kanner, 1943, p. 247-248). This idea that children with ASD were too difficult to test persisted into the 1960s, with investigators citing various reasons including short attention span, lack of interpersonal motivation, language anomalies, and bizarre response patterns (Alpern, 1967). Fortunately, the desire to better understand the cognitive process inspired continued attempts to find ways to test children with autism. Alpern (1967) advised selecting cognitive tests based on an initial estimate of the child’s developmental level regardless of the child’s chronological age. Freeman (1976) contributed to this body of research by demonstrating how behavioral techniques (specifically the use of reinforcement) could be used to increase the motivation and maintain the attention of children with autism and thereby improve the accuracy of testing. Subsequent studies found that IQ scores were stable through childhood, children with ASD were able to obtain identified basals (performance levels establishing an individual’s ability to give valid responses on the IQ test) and ceilings (performance levels establishing the individual’s upper limit of ability), test scores correlated with concurrent parent-reported adaptive functioning, and test results predicted both academic achievement and adult occupational level (DeMeyer et al., 1974; Rutter, 1983).

It is now generally accepted that IQ measures are reliable and valid with the ASD population, and many incorporate these measures to characterize the cognitive abilities of individuals with ASD. Depending on the focus of the study, the purpose of IQ testing may be simply to characterize the sample (ADDM, 2014; Jones & Lord, 2013), evaluate outcomes of
interventions aimed at accelerating development (Lovaas, 1987; Eikeseth, Smith, Jahr & Eldevik, 2002; Grindle, et al., 2012), or profile the cognitive strengths and weaknesses of children on the spectrum (Munson et al., 2008; Oliveras-Rentas, Kenworthy, Roberson, Martin & Wallace, 2011; Goldstein et al., 2008). However, there continue to be concerns that IQ tests have unusual psychometric properties when given to children with ASD. Notably, researchers have observed lower intercorrelations between subtests than are seen in typically developing individuals (Mayes & Calhoun, 2003; Goldstein et al., 2008) and the tendency of IQ tests to over-predict academic and adaptive functioning (Carothers & Taylor, 2013; Kenworthy, Case, Harms, Martin, & Wallace, 2009). Researchers have also found distinctive patterns of ability such as strength in nonverbal reasoning skills and deficiencies in verbal comprehension ability (Carpentieri & Morgan, 2005; Coolican, Bryson, & Zwaigenbaum, 2007) that are often minimized by relying on overall IQ score alone. These findings have yet to be integrated into a conceptualization of the cognitive abilities of children with ASD and of the limitation of current measures to assess and represent those abilities. These concerns may indicate that cognitive assessments have limited construct validity as measures of intelligence in individuals with ASD. In other words, despite being reliable and useful predictors of current and future functioning, the results of IQ tests for children with ASD may need to be interpreted somewhat differently for children with ASD than for typically developing children. Thus, the current study aims to examine the construct of intelligence in ASD and determine the extent to which current cognitive assessments, adaptive behavior assessments, and social skills assessments capture the strengths and limitations of this population.
Intelligence and Cognitive Assessment of Typically Developing Children

Theories of the structure of intelligence. The first formalized and statistically supported theory of intelligence was developed by Charles Spearman in 1904. He analyzed measures of academic achievement, out-of-school judgment or “common sense,” sensory discrimination, and musical proficiency and found that each domain related to one common factor. He named this factor “g” as shorthand for “general intelligence” and equated it to overall intellectual functioning (Spearman, 1904). He credited the unexplained variance in each of the separate measures to differences in content that, while measuring distinct skills, were unimportant compared to overall ability. He theorized that any one task was too specific to truly capture “g” and emphasized the use of factor analysis of multiple tasks to understand overall intellectual functioning (Spearman, 1928).

Subsequent investigators disputed Spearman’s emphasis on g. On the basis of multiple factor analyses, Thurstone (1936) proposed that intelligence was more accurately split into different abilities and that an overall measure of cognitive ability was inaccurate. He recognized that for many people, cognitive abilities correlate highly with one another, but asserted that there were also many instances in which the correlations were relatively low. He contended that this finding demonstrated the need to distinguish multiple activities associated with intelligence rather than trying to reduce intelligence to one overall “g” factor. Thurstone (1936) identified seven primary mental abilities: number facility, word fluency, visualizing, memory, perceptual speed, induction, and verbal reasoning. Thurstone and Spearman debated their competing views over the next decade. Spearman criticized Thurstone for studying a biased sample and emphasized the reliability of “g” in predicting success in school, occupations and certain character traits (Spearman, 1939; Spearman, 1946) while Thurstone promoted a cognitive profile
approach that allowed us to understand more about individual skills and limitations (Thurstone, 1946).

During this period, Cattell began to use Thurstone’s statistical methods to investigate his own theories regarding cognition (Cattell, 1941). Cattell proposed that all cognitive abilities derived from two different intellectual factors. He defined fluid intelligence (Gf) as the ability to use inductive and deductive reasoning to solve novel problems. This often requires abstract and flexible thinking to apply reasoning skills in unfamiliar situations (McGrew, 2009). He also proposed that these abilities, while influenced by incidental learning from the environment, were primarily the results of biological and neurological factors. In contrast, he defined crystalized intelligence (Gc) as the acquired knowledge and abilities that were influenced by education and culture (Cattell, 1971). These abilities include declarative knowledge as well as procedural knowledge of how to perform concrete tasks (Horn, 1994). Together with Horn, Cattell investigated how these intelligences develop over the lifespan (Horn & Cattell, 1967). Their findings indicated that the distinction between fluid and crystalized intelligence is apparent in individuals of all ages, but tends to evolve in such a way that the comparative levels of these intelligences fluctuate with age. Fluid intelligence tends to decline with age while crystalized intelligence grows over the lifetime. They also examined how to measure fluid and crystalized intelligence (Horn & Cattell, 1967), noting that fluid intelligence was especially challenging to assess because of the difficulty of devising tasks that were equally unfamiliar to children from differing backgrounds and socioeconomic statuses (Cattell & Horn, 1978).

While collaborating with Cattell, Horn also introduced his own theory of intelligence to the field. He agreed with Cattell that fluid intelligence and crystalized intelligence were two aspects of cognition, but like Thurstone, he also believed there were many more factors that
should be included within a definition of intelligence. Horn theorized that these additional factors of intelligence included abilities in visual perception (Gv), short-term memory (Gm), long-term memory (Glr), processing speed (Gs), auditory processing (Ga), reaction time and decision speed (Gt), in addition to the previously mentioned crystalized intelligence (Gc) and fluid intelligence, Gf) (Horn & Stankov, 1982; Horn, 1991).

Because the different approaches to factor analysis taken by these psychologists supported both an overall intelligence factor theory and several multifactor theories, there was little agreement on a unified view of intelligence. Fortunately, Carroll’s (1993) survey of the available research on intelligence and his own analyses of previous findings offered a new perspective. He proposed a hierarchical theory of intelligence that was composed of three strata. This theory placed an overall intelligence factor, g, in Stratum III, broad factors akin to Horn’s G factors in Stratum II, and more narrow abilities in Stratum I. This hierarchical theory reconciled the conflicting theories of intelligence under an overarching framework that was corroborated in later studies (Carroll, 1997). This framework is commonly referred to as the Cattell-Horn-Carroll theory and is the foundation on which the most commonly used IQ tests are built (Aldonso, Flaagan, & Radwan, 2005).

**Development of current intelligence tests.** Two of the most common cognitive assessments used for school-aged children with or without ASD in research are the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003a) and the Stanford-Binet Intelligence Scales-Fifth Edition (SB-5; Roid, 2003a). Both of these assessments adhere to the hierarchical theory of intelligence by providing an overall Full Scale IQ score (FSIQ), a few factor scores, and several scores for more narrow abilities. Intelligence, as defined here and represented by g is an index of abilities that correlate positively but may underlie separate
cognitive factors. Thus $g$ is never measured directly, but by measuring the separate cognitive 
factors and understanding their relationship to each other we can create an estimate of $g$, the Full 
Scale IQ (Sattler, 2008). In the past, new editions of the Stanford-Binet Intelligence Scales and 
the Wechsler Intelligence Scales for Children have been directly compared to each other by their 
publishers as a measure of their similarity and concurrent validity. Both scales are well 
standardized and normed and are considered to measure the same construct of general 
intelligence in typically developing children (Urbina, 2004). However, these assessments also 
differ in the number of broader factors (2 on the SB-5, 4 on the WISC-IV), the division of these 
factors (5 subtests for each broader factor on the SB-5, 2-3 per factor on the WISC-IV) and in the 
primary factors that compose the broader concepts (Verbal and Nonverbal IQ on the SB-5; 
Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed on the 
WISC-IV. These differences affect the relationship between the assessments and the ability to 
directly compare their evaluation of cognitive abilities.

Unfortunately because they were published in the same year, the most recent editions 
could not be directly compared to each other by their creators before publication. A recent 
independent study compared WISC-IV and SB-5 scores in forty adolescents with ASD (Baum, 
Shear, Howe & Bishop, 2014). The investigators found that although full-scale IQ scores across 
the assessments correlated highly at 0.88, the majority of children (72.2%) scored higher on the 
SB-5 (mean FSIQ = 82.06) than the WISC-IV (mean FSIQ = 78.81) and 10% scored a full 
standard deviation higher (a statistically and clinically significant difference). Additionally, 
adolescents with ASD tended to score significantly higher on the WISC-IV Verbal 
Comprehension Index (VCI; mean = 83.49) than they did on the SB-5 Verbal IQ (VIQ; mean = 
79.59; Baum et al., 2014). Baum and colleagues (2014) propose that the discrepancy in FSIQ
may stem from the differences in how the tests assess working memory (verbally on the WISC-IV, verbally and nonverbally on the SB-5) and in the inclusion of processing speed on the WISC-IV but not the SB-5. However, the discrepancy also could be due to differences in the WISV-IV VCI (which is composed primarily verbal crystalized knowledge tasks and verbal reasoning tasks) and the SB-5 VIQ (which measures fluid reasoning, crystalized knowledge, quantitative reasoning, working memory and verbal reasoning about visual/spatial tasks). Thus, the Baum et al. study indicates that there may be important differences in how these two assessments measure skills and abilities of adolescents with ASD, though it cannot determine if those differences lie in the subtests used by each assessment or in how the index scores are created.

*Development of the Stanford-Binet Intelligence Scales.* Modern cognitive assessment of children originated with the Binet-Simon Scale of 1905 and was intended to identify and separate children with lower cognitive abilities compared to the general population in an effort to better serve them through targeted educational intervention (Binet & Simon, 1905). Binet and Simon sought to develop a measure that would allow children to demonstrate their abilities in comprehension, reasoning, judgment, and invention without bias toward what they might have learned through instruction. Due to the lessened attention span of these children, Binet and Simon also sought tasks that were quick and heterogeneous to give them an examination of individual skills and abilities without bias against those with attention problems (Binet & Simon, 1916). Since that time, the Binet-Simon scale went through substantial revisions as demands for cognitive testing changed and evolving theories of intelligence were integrated into testing instruments (Alfonso, Flanagan, & Radwan, 2005).

The most recent revision of the Binet-Simon Scale is the Stanford-Binet Scale of Intelligence-Fifth Edition (SB-5; Roid, 2003a). As mentioned previously, the SB-5 has a
hierarchical structure of intelligence in which an overall ability is broken down into broad factors that are created by more specific skills. The SB-5 breaks its Full Scale IQ (g) down into two IQ scores and five factor indexes with the 10 subtests going into each level differently, as summarized in Figure 1. That is, the secondary IQ scores of the model can be created by combining all of the nonverbal subtests and all of the verbal subtests to form a Nonverbal IQ and Verbal IQ respectively, or the nonverbal and verbal subtest of each factor can be collapsed to form the five factor indexes: Fluid Reasoning (Gf), Knowledge (Gk), Quantitative Reasoning (Gq), Visual/Spatial Processing (Gv), and Working Memory (Gm). Despite its multiple breakdown method, this structure maintains high correlations among all of the subtests and the Full Scale IQ (0.63-0.89) and high loadings of the subtests on g (0.70-0.83) (Roid, 2003b). This five-factor model allows intelligence to be looked at through two different organizational systems – one organized by the division between the factors and the other by the division between nonverbal and verbal abilities.

The SB-5 inclusion of five different factors (Fluid Reasoning, Knowledge, Quantitative Reasoning, Visual/Spatial Processing, Working Memory) and two different domains (Nonverbal IQ, Verbal IQ) has opened the assessment to investigations to confirm the theoretical structure of the assessment. Subsequent analyses by independent parties have presented some arguments against the current organization of factors and domains. Williams and colleagues (2010) found that the five-factor, two-domain model does not stand up to confirmatory factor analysis, but maps better onto a slightly different four-factor model. In their model, the nonverbal and verbal subtests load onto their factors and there is no domain split of nonverbal and verbal intelligence. Additionally, the Fluid Reasoning and Knowledge subtests all collapse onto one factor, taking the structure from five factors to four and creating a new latent factor that is represented by
knowledge and fluid reasoning skills jointly. This finding may indicate that these two factors are actually the same overall ability, or it may be an example of the problem Cattell and Horn (1978) described of the difficulty of finding subtests to differentiate between these two factors in children. These analyses may also be subject to sampling bias as only data from high-achieving students was used in these analyses (Williams et al., 2010). Indeed, DiStefano and Dombrowski’s (2006) findings suggest that the sample population used in analyses has a significant impact on the latent structure of intelligence. They found that the verbal/nonverbal domains were confirmed in a confirmatory factor analysis using the data of children under 10 years of age, but were not confirmed using the data of individuals over 10 years. This suggests that relationships between cognitive factors change through the course of development for even typically developing children.

**Comparing the WISC-IV to the SB-5.** To put the SB-5 in context, it is helpful to compare it to the other IQ test that has had the most influence on modern conceptualizations of the construct of intelligence, the Wechsler Intelligence Scale. Unlike the Stanford-Binet Intelligence Scales, the Wechsler Intelligence Scale for Children was derived from a cognitive assessment originally designed for adults. (Subsequently, an adaptation for children in preschool and early elementary school was also developed.) Wechsler developed the Wechsler-Bellevue Intelligence Test in 1939 as an alternative to the Stanford-Binet Intelligence Scales-Second Edition (Wechsler, 1939). Rather than use a heterogeneous approach, Wechsler sought subtests to characterize behavior as a whole. He believed in a g factor of overall cognitive abilities that reflected a person’s ability to “act purposefully, to think rationally, and to deal effectively with his environment” (Wechsler, 1944). Wechsler also developed the current standardization
practice of creating a cognitive assessment with a mean of one hundred and eliminating the use of an actual intelligence quotient.

The current edition of the Wechsler Intelligence Scale for Children, the WISC-IV, was developed through a rigorous standardization process and normed on a large sample of children that was representative of United States demographics (Wechsler, 2003b). Furthermore, the four-factor model presented in this edition has stood up to rigorous statistical analyses and demonstrated that this factor structure has a close model-data fit (Weiss, Keith, Zhu & Chen, 2013). In this factor structure, depicted in Figure 2, overall intelligence or \( g \) is composed of four factors represented by the four Composite Scores: Verbal Comprehension (Gc), Perceptual Reasoning (Gf), Working Memory (Gm), and Processing Speed (Gs). The subtests were calculated for their load onto \( g \) and are then grouped by how they related to each other, which suggest certain relationships between all of these constructs. Specifically, the high loadings of the Verbal Comprehension subtests onto \( g \) suggest that Verbal Comprehension skills have the greatest impact upon intelligence. These skills are also most highly correlated with the quality of the child’s education and their parents’ level of education, suggesting that many cognitive abilities learned by instruction have a large impact on the overall IQ score on a WISC-IV.

It is notable that even though both the SB-5 and WISC-IV were created to measure intelligence as theorized by the Cattell-Horn-Carroll theory, they do so in different ways. Both measure overall intelligence (\( g \)), and working memory (Gm) and define it in similar ways. In contrast to the WISC-IV, the SB-5 measures quantitative reasoning (Gq) while the WISC-IV

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1 While the current project was ongoing, a fifth edition (WISC-V) was published. The WISC-V retains a similar factor structure as the WISC-IV except that Perceptual Reasoning is replaced with two factors, Visual Spatial and Fluid Reasoning. Hence, the above comparison of the WISC-IV scales to the SB-5 in this section remains applicable to the newest edition.
assesses processing speed (Gs). Even more interestingly, the two tests define crystalized intelligence (Gc) and fluid reasoning (Gf) differently. The WISC-IV measures crystalized intelligence through the Verbal Comprehension Index that focuses on language knowledge and abilities while the Perceptual Reasoning Index measures fluid intelligence with primarily visual, nonverbal tasks. The SB-5 also measures crystalized intelligence and fluid reasoning, but measures each of these in both a verbal and nonverbal domain rather than relying heavily on one or the other. This elicits the question of which cognitive assessment better captures these abilities, the assessment that measures them through either verbal or nonverbal tasks, or the assessment that measures them across both verbal and nonverbal abilities? Additionally, if each assessment is measuring different factors of intelligence, are they still capturing overall intelligence in a comparable way? If certain individuals have varying abilities on crystalized knowledge tasks and fluid reasoning tasks in response to whether they are presented verbally or nonverbally, then those individual may receive different full-scale IQ scores on each of these assessments. In other words, the estimate of an individual’s overall ability is affected by how each test has defined and measured crystalized and fluid intelligence rather than by that individual’s actual ability. Although this concern is relevant to all test-takers, it is a particular limitation when standardized scores are derived from a normative sample and then applied to an atypical sample.

Across the WISC-IV and SB-5 we see limitations to cognitive assessment. We see that in the WISC-IV, the factor structure used best fits the data, but some subtests still do not load highly onto g. In the SB-5, subtests load more highly onto g, but its factor structure is not supported by independent analyses (Williams et al., 2010), which found a four factor structure (collapsing Fluid Reasoning and Knowledge into one factor) to be better supported in a sample
high scoring typically developing children. Interestingly, despite their differences, the WISC-IV and SB-5 appear to be measuring a similar overall g as the two tests’ Full Scales IQ correlate highly at 0.84 (Roid, 2003b). This suggests that although the tests measure differently defined cognitive abilities and structure their relationships in slightly different ways, they are still tapping into overall intelligence, or g. One study has compared the two cognitive assessments directly to explore how adolescents’ scores on the WISC-IV compared to their scores on the SB-5 (Wilson & Gilmore, 2012). They administered the WISC-IV and SB-5 in counterbalanced order to 30 typically developing children ages 12-14 years and found a significant difference between their Full Scales IQs on each test and between their Verbal IQ on the SB-5 and their Verbal Comprehension Composite on the WISC-IV. They also found the correlations between the tests to fall down to 0.58, much lower than otherwise reported. However, in their scoring of the tests, they used the Australian Edition of the WISC-IV that had specifically been re-normed on an Australian population, and used the standard edition of the SB-5, which had been normed on an American population. This creates the question of whether the difference in the scores is a valid difference in the assessments, or if it is an artifact of using norms based on different populations. Therefore, no conclusions can be drawn regarding the equivalency of the assessments. Overall, a deeper understanding of how these similar but divergent cognitive assessments compare to each other is still warranted, especially for special populations. If individuals with atypical cognitive development perform differently on these cognitive assessments those differences could indicate problematic assumptions made by one or both assessments.

**Intelligence and Cognitive Assessment of Children with ASD**

**Examining cognitive profiles.** Cognitive assessment of children with ASD has always relied on measures that have been designed for and normed on typically developing individuals,
i.e. the WISC-IV or SB-5 for school-age children. Once the validity and concurrent reliability of their use with children with ASD was established, researchers were able to look toward the predictive validity of these measures. Researchers found that although IQ measures did predict later achievement, the correlations between IQ and achievement were lower than those found in the typical population, indicating that there were other factors, not measured by the IQ tests, that impacted academic and occupational development in individuals with autism that did not necessarily impact typically developing individuals (DeMyer et. al., 1974; Rutter, 1983).

Researchers have also asked if these assessments are sensitive to possible differences in the cognition of children with ASD, such as a distinct cognitive profile characteristic of the disorder.

**Assessment with the WISC.** One way to examine how cognitive assessments capture the abilities of individuals with autism is to explore whether or not a certain pattern of abilities as measured by an assessment is common to individuals with the disorder. Siegel and colleagues (1996) used the Wechsler tests for children and adults to determine if individuals with ASD had a common profile of abilities. With their sample of children ages 6 through 16 with a full scale IQ score of 70 or above, they found support for previous findings that children on average obtained the highest scores on the Block Design subtest and lowest scores on the Comprehension subtest. However, they did not find support for a distinctive IQ profile that was unique to individuals with ASD and could be used as a diagnostic screen (Siegel, Minshew, & Goldstein, 1996).

A second study sought to clarify these findings by looking at another sample of high functioning children and adults with ASD (full scale IQ and verbal IQ greater than 70). Goldstein and colleagues (2008) replicated the overall finding that Block Design was the highest scoring subtest and Comprehension was the lowest. More importantly, they also looked at the
structure of the test itself in this population and found that subtest intercorrelations were generally lower in the ASD sample than in the published normative samples. The factor analysis of these intercorrelations revealed that although a three-factor model (collapsing processing speed and working memory into one factor) provided the best fit for both the ASD population and the typical population, the model fit for the ASD population was much less robust than that for the typical population. Unfortunately, none of their alternative models fit the data better, suggesting that although we know the WISC-IV factor structure does not line up as well to the cognitive structure of individuals with ASD as it does to typically developing individuals, we do not know where the mismatch lies.

Similarly, another study examined the relationship between high functioning autism (again defined as FSIQ and VIQ ≥ 70) and nonverbal learning disability (defined as Verbal IQ score 10 point or more than Performance IQ score and weakness in arithmetic and visuospatial skills) by again looking for a distinctive cognitive profile. The research showed that a prototypic IQ profile that distinguishes all individuals with autism does not match actual data (Williams, Goldstein, Kojkowski & Minshew, 2008). Again, this does not eliminate the possibility that the cognitive structure of individuals with ASD is different from typically developing individuals, it simply highlights the limitations of current assessments to evaluate that difference.

**Assessment with the SB-5.** Researchers have looked at the SB-5’s assessment of the cognitive abilities of children with ASD is a similar manner. Two such studies used the Stanford-Binet, Fourth Edition to evaluate children on the spectrum. The first study found that children with ASD (ages 3 through 7, average full scale IQ of 60.7) performed best on Pattern Analysis, a subtest measuring fluid reasoning, and worst on Absurdities, a subtest measuring verbal crystalized intelligence (Harris, Handleman, & Burton, 1991). Carpentieri & Morgan
(2005) compared patterns of abilities of children with ASD and intellectual disability (ages 4 through 12, average full scale IQ of 48) to children with an intellectual disability but not ASD (ages 4 through 12, average full scale IQ of 48). Similar to previous findings with the SB4 and the WISC, although a stable profile true of all children with ASD could not be found, as a group, children with ASD performed worst on Verbal Reasoning subtests and best on Quantitative Reasoning subtests. They also scored significantly lower on Verbal Reasoning than the group without ASD, for whom this was an area of strength relative to the other SB-5 domains.

Coolican and colleagues (2007) explored a possible cognitive profile for ASD as measured by the SB-5 in a higher functioning (average IQ of 82.29) sample of children (ages 3-16). They found that 40% of the children had significantly higher Nonverbal skills compared to Verbal skills. More interestingly, they found that although the Abbreviated IQ (ABIQ; composed of the Nonverbal Fluid Reasoning and Verbal Knowledge scales) correlated highly with the FSIQ (R² = 0.899), 23.8% of children had significantly higher ABIQ scores than FSIQ scores while 3.2% of children had significantly higher FSIQ scores than ABIQ scores. The scores differences for individual children ranged from 10 to 24 points. This incidence of significantly different ABIQ and FSIQ score differs from typically developing peers, for whom the Abbreviated IQ is more reflective of their FSIQ scores and for whom the test has been standardized to have a normal distribution (mean difference of zero and standard deviation of 15) in the split between FSIQ and ABIQ scores (Roid, 2003b). That is, in a random sampling of typically developing children only 9.2% should have ABIQ scores that are significantly higher than FSIQ and 9.2% should have ABIQ scores that are significantly lower than FSIQ. The children with ASD in the above sample deviated greatly from those expected ratios. This finding suggests that the factor loadings on g are different for children with ASD. That is, the two factors
(Nonverbal Fluid Reasoning and Verbal Knowledge) that normally correlate highly with more precise estimates of g no longer do so for the overall ASD population and result in an overestimate of ability for a significant minority of the population.

Assessment with other measures. In addition to examining how the structure of cognitive abilities is measured by individual cognitive assessments, researchers have also explored the cognition of individuals with ASD through the use of multiple assessments. Minshew and Goldstein’s (1998) study used a large battery of assessments to evaluate motor skills, memory abilities, language skills, and reasoning abilities in children with ASD who had an IQ greater than 70. They used different tests to capture what they described as “simple” and “complex” levels of each of these abilities. Simple tasks consisted of demonstrations of rote knowledge and memory (i.e., crystalized procedural knowledge) and complex tasks required demonstrations of comprehension and manipulation of information (i.e., use skills in novel ways). They found an overall profile for children with ASD that revealed deficits in complex tasks (concept formation, complex memory, complex language, and skilled motor activities) and strengths in simple tasks (attention, sensory perception, simple memory, simple language, and rule learning; Minshew & Goldstein, 1998). Overall, children with ASD perform comparably to typically functioning children on the simple tasks (crystalized procedural knowledge), but demonstrate deficits in the leap from simple tasks to more complex tasks that require novel use of skills.

A similar approach was used to examine the relationship between nonverbal reasoning skills and those skills assessed in traditional cognitive assessments. Dawson and colleagues (2007) used the WISC-III and Raven’s Progressive Matrices to examine how children (ages 7-16) with ASD performed on a concentrated measure of nonverbal fluid intelligence compared to
a measure that factored a variety of cognitive skills into an overall intelligence score. They found that overall, the scores of children with ASD fell in the average range of the Matrices and in the low average range of the WISC-III. Specifically, 33% of children with ASD scored in the range of an intellectual disability when tested with the WISC-III, but only 5% of children with ASD scored in that range on the Matrices (Dawson et al., 2007). Another study had similar findings with a group of verbal children with ASD ages 8-16 achieving Raven’s Progressive Matrices scores that were 11.54 points higher than their WISC-III Perceptual IQ score and 6.16 points higher than their Full Scale IQ score but no different from their Verbal IQ score (1.91 difference) (Bodner, Williams, Engelhardt & Minshew, 2014). These results suggest that by grouping the nonverbal fluid reasoning skills of individuals with ASD into an overall factor, much information is lost and their ability to think analytically is underestimated.

Similar to studies done exclusively with IQ tests (e.g. the SB-5), the split between nonverbal abilities and verbal abilities has also been investigated as a possible identifying profile of children with ASD through a wide variety of cognitive tasks and assessments. A recent study found that children with ASD (ages 4 through 17, average IQ of 90.3, range of 35-167) have a nonverbal IQ significantly higher than their verbal IQ more often than expected compared to population norms (Ankenman, Elgin, Sullivan, Vincent & Bernier, 2014). This effect was especially apparent in males with more significant autism symptomatology. However, age also predicted this cognitive split with the significant difference between nonverbal and verbal IQ scores found significantly more in younger children. The authors suggest that verbal abilities, as measured by current cognitive assessments, evolve over development and in response to intervention in this population, (Ankenman et al., 2014) but do not explain what this split could mean in terms of the structure of cognitive abilities in these children.
**Overall findings.** The literature suggests that although different cognitive assessments measure comparable and related constructs in typically developing individuals, this is not necessarily true for individuals with ASD. Correlations among different instruments and among subtests within an instrument tend to be lower for individuals with ASD than for typically developing individuals. Additionally, an unusual pattern of strengths and weaknesses is consistently found in children with ASD overall, summarized in Table 1. Strengths include nonverbal fluid reasoning tasks such as pattern analysis (Harris, Handleman & Burton, 1991), block design (Siegel, Minshew, Goldstein, 1996; Dawson et al., 2007) visuospatial tasks (Minshew & Goldstein, 1996; Coolican, Bryson & Zwaigenbaum, 2007), and quantitative reasoning tasks (Mayes & Calhoun, 2003; Carpentiere & Morgan, 2005; Dawson et al., 2007; Coolican, Bryson & Zwaigenbaum, 2007). In contrast, individuals with ASD tend to score lowest on verbal fluid reasoning tasks such as absurdities (Harris, Handleman & Burton, 1991; Carpentiere & Morgan, 2005), comprehension (Siegel, Minshew & Goldstein, 1996; Carpentiere & Morgan, 2005; Dawson et al., 2007), concept language and concept formation (Minshew & Goldstein, 1996) and Verbal Reasoning (Carpentiere & Morgan, 2005). This contrast indicates that overall fluid reasoning is neither a strength nor weakness since performance in this area varies based on whether or not tasks are presented verbally. Nor can individuals with ASD be described as having a weakness in all verbal tasks because children with ASD also perform well on concrete verbal tasks such as rule learning, simple memory tasks and simple language tasks (Minshew & Goldstein, 1998). Therefore, their pattern of strengths and weaknesses is not well explained by a verbal versus nonverbal profile or by a fluid reasoning versus crystalized knowledge profile. Thus, we still lack a comprehensive factor structure of the cognitive abilities of individuals with ASD. Recently, researchers have called on the field to use more nuanced
statistical techniques to understand how cognitive assessments relate on an individual level through latent variables (Schneider, 2013). An in-depth approach to these individual levels and latent variables may be needed to examine how skills measured in cognitive assessments relate to skills and abilities traditionally measured by other assessments.

**Examining the relationships between intelligence and other abilities**

**IQ and adaptive behaviors.** The American Association of Intellectual and Developmental Disabilities (AAIDD) defines adaptive behavior as a collection of practical, social, and conceptual skills that are performed in everyday living (AAIDD, 2010). The assessment of adaptive behavior is an essential part of diagnosing an intellectual or developmental disability, including ASD, because it provides evidence on whether low IQ scores are associated with difficulties meeting the demands of activities of daily living (APA, 2013). This assessment is used in conjunction with IQ scores to determine diagnosis, severity of symptoms and services provided by schools and other agencies. Assessment of adaptive behavior to inform school services is especially important. Research shows that even children and adolescents who have typical IQ but delayed adaptive functioning are more likely to struggle in school (Shelton et al., 1998; Vander Stoep, Weiss, McKnight, Beresford, & Cohen, 2002), indicating that adaptive skills influence academic performance independently of cognitive functioning.

The gold standard and most commonly used assessment of adaptive behaviors is the Vineland Adaptive Behavior Scales, Second Edition (Vineland-II, Sparrow, Cicchetti & Balla, 2005). The Vineland-II is organized to produce an Adaptive Behavior Composite from 4 domains which each consist of 2 or 3 subdomains, a hierarchical structure similar to that of the IQ tests previously discussed. The four domains assess communication skills (receptive
language, expressive language, writing skills), daily living skills (personal skills, domestic skills, and community skills), socialization skills (interpersonal relationships, play and leisure time, coping skills), and motor skills (fine and gross motor). For typically developing children, Full Scale IQ scores are commensurate with adaptive abilities as they are measured by the Vineland-II (Sparrow, Cicchetti & Balla, 2005). That is, usually children who fall in the average range of intellectual functioning fall in the average range of adaptive skills. In contrast, children with a variety of different developmental disabilities may not score in the same level of ability across measures of intellectual functioning and adaptive behavior. Over the years, the Vineland-II has become an essential tool used in conjunction with IQ testing to better understanding the everyday functioning and abilities of children with developmental disabilities. A new edition of the Vineland, the Vineland-3 was published in 2016, and has the same basic structure as the previous version and is likely to replace its predecessor in research and clinical practice (Sparrow, Cicchetti & Saulnier, 2016).

In 1988, Freeman and colleagues introduced the idea of a multimethod approach to better assess and predict the everyday deficits and abilities of children with autism through the combined use of Vineland Adaptive Behavior Scales (Sparrow et al., 1986) and the Wechsler Intelligence Scales for Children – Revised (WISC-R; Wechsler, 1974). He found that for children ages 6 through 15 with ASD the measure of adaptive skills and its sensitivity to social deficits and problem behaviors could predict functioning in a classroom over and above IQ alone. Researchers and clinicians continue to use the Vineland-II and cognitive assessments in this manner.

In a recent study, children with ASD had lower scores on the Vineland-II Adaptive Behavior Composite and in the Domain scores in relation to their IQ scores (Klin et al., 2007)
compared to typically developing children. Klin and colleagues found that children ages 7 through 18 with ASD whose Full Scale IQ (as measured by a variety of cognitive assessments) fell in the average range still had significant impairments in overall adaptive ability. Their socialization skills and daily living skills were the most discrepant from their IQ score. Scores on the communication domain typically fell one to two standard deviations below the full scale IQ while Socialization skills and Daily Living skills fell approximately one standard deviation below Communication scores. Such discrepancies between IQ score and Communication and Socialization skills may be partly expected since difficulty in social communication is a core deficit of ASD, but the impairment in Daily Living skills is not well explained. If the cognitive structure proposed in this study is confirmed, it will help to account for this discrepancy. Furthermore, the gap between cognitive ability and adaptive behaviors tends to increase with age with a significant difference in standard scores between younger (4-8) and older (9-17) children, indicating that gains made by children with ASD are not commensurate with development (Kanne et al., 2010). Other measures of adaptive behavior also demonstrate this achievement gap (Kenworthy, Case, Harms, Martin & Wallace, 2009) with adolescents (ages 12-20) with ASD performing 34 points lower on adaptive testing than their age- and IQ-matched, typically developing peers. Fortunately, targeted intervention focusing specifically on adaptive behavior may help to lessen the gap in younger children (Baghdadli et al., 2011).

The well-replicated finding that children and adolescents with ASD have higher Full Scale IQ scores than adaptive behavior scores (Klin et al., 2007; Baghdadli et al., 2011; Oakes, Harrison & Smith, in prep) indicate possible test bias for children with ASD. In other words, cognitive testing overestimates these children’s ability to use their cognitive skills in every day situations. The poor predictive relationship between typical IQ tests and adaptive skills is
distinctive to ASD since most children with developmental disabilities or cognitive deficits tend to demonstrate adaptive abilities commensurate with their intellectual abilities (Greer, Brown, Pai, Choudry & Klein, 1997). Compared to children with Specific Learning Disability, Emotional Disturbance, Developmental Language Disability, Intellectual Disability, Williams Syndrome, and Down Syndrome, children with ASD score significantly lower than their cognitive abilities and lower than age matched peers (Ditterline, Banner, Oakland & Beston, 2008; Liss et al., 2011; Rodrigue, Morgan & Geffkin, 1991). One reason for this testing bias may be the emphasis on perceptual reasoning used by most IQ tests. A recent study using several different tasks found that a flexible thinking factor but not a perceptual reasoning factor predicted adaptive abilities in children ages 8-13 with ASD (Williams, Mazefsky, Walker, Minshew, & Goldstein, 2014) while a later study explored how deficits in concept formation may explain the growing deficit in adaptive skills as individuals with ASD age (Williams, Minshew & Goldstein, 2015). However, a comprehensive explanation of why this happens is currently unavailable. This discrepancy may be due to a performance deficit or may be due to the difference in how each assessment measures areas of skill. The current study’s proposed structure of intelligence might provide a partial explanation (see Hypotheses and Aims). At present, investigators have largely skirted this issue by analyzing cognitive and adaptive behavior as separate constructs (e.g., Ankenmen et al., 2014), as illustrated in Figure 3.

For the purposes of our study, examining the relationships and correlations for the cognitive assessments (IQ and social abilities) with the Vineland-II composite and domain scores will yield information on how cognitive skills do or do not manifest themselves in everyday behavior. Specifically, it will be essential to look at how fluid intelligence and crystalized abilities (as measured by cognitive testing) predict adaptive behaviors that are either fluid,
adaptive responses to everyday situations or those that are simply examples of applied known skills. A pervasive difficulty with fluid reasoning could help to explain why individuals with ASD and high crystalized knowledge still show deficits in adaptive functioning that require more flexible thinking. Lastly, because adaptive skills are practiced at home, in school and in the community, they may be said to occur in social settings, making their relationship to cognitive social abilities important to evaluate.

**IQ and executive functioning.** Executive functioning refers to an individual’s ability to organize, plan and attend to tasks around them, initiate new tasks and shift between activities, as well as hold information in memory and inhibit other behaviors. Overall, these skills “allow an individual to perceive stimuli from his or her environment, respond adaptively, flexibly change direction, anticipate future goals, consider consequences, and respond in an integrated or common sense way” (Baron, 2004, p. 135). Executive functioning skills are theorized to be rooted in the prefrontal cortex, which develops over the first twenty years of life (Hill, 2004; Miyake et al., 2000). Consistent with this view, research has shown age effects in the development of concept formation, set shifting, inhibition, planning, and working memory throughout childhood (Hill, 2004; Archibald & Kerns, 1999). For example, two studies of typically developing children (ages 7-12 and 8-13) found positive associations between age and working memory, inhibition and set shifting (Archibald & Kerns, 1999; Lehto, Juujärvi, & Kooistra, 2003). In contrast, executive functioning skills are similar across age in adults and correlate strongly with scores on reasoning and perceptual speed tasks commonly measured in IQ tests (Salthouse, 2005).

Executive functioning skills are evaluated across (a) direct assessments of children in laboratory-based tasks such as the Executive Functioning Battery (Yerys, Hepburn, Pennington
& Rogers, 2006), the Cambridge Neuropsychological Test Automated Battery (CANTAB; Ozonoff et al., 2004), and Tests of Variables of Attention (TOVA; Kenworthy et al., 2005); (b) classroom observations of children (Kenworthy et al., 2013) and (c) parent- and teacher-ratings of children’s executive control (Kenworthy et al., 2005). Each of these tests of executive functioning either focuses on specific skills and abilities (e.g. windows tasks that test ability to inhibit responses, A-not-B that test ability to shift responses) or includes an entire battery meant to evaluate multiple aspects of executive control (e.g. CANTAB, TOVA). While laboratory assessments have been developed to have high internal reliability and validity, they measure executive control in a highly controlled environment during a one-to-one interaction that supports success on the tasks (Denckla, 2002). As such, they may yield results that differ from tests that were developed to capture everyday executive functioning, such as the Behavior Rating Inventory of Executive Functioning (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000). For example, one study of children with various neurological impairments (phenylketonuria, microcephaly, and frontal focal lesions) compared scores on the BRIEF to scores on lab-based tests (Contingency Naming Test (CNT), Rey Complex Figure (RCF), Tower of London (TOL), and Controlled Oral Word Association Test (COWAT)), and found little correlation amongst the BRIEF scales and the lab tests (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002). This suggests that the BRIEF and the lab tests may assess different constructs within the executive functioning domain.

Measures of everyday executive functioning skills may be especially useful because, much like adaptive skills, these skills are used constantly while living in the home, school, and community. In typically developing children the BRIEF has been found to reflect everyday dysfunction in executive functioning skills in these more social environments (Anderson et al.,
The BRIEF is also widely used in studies of children with ASD (Kenworthy, Yerys, Anthony & Wallace, 2008).

Executive function tasks have long been found to pose difficulty for individuals with ASD across development and ability (Gioia, Isquith, Kenworthy & Barton, 2002; Kenworthy, et al., 2005; Kenworthy et al., 2008), though different studies have found different strengths and limitations across different tasks at different ages. Research in this area is complex because of the large number of executive functioning tasks that can be used to assess different components of this complex amalgam of abilities. Overall, deficiencies in cognitive shifting or flexibility and difficulty organizing and planning are identified most often (Smithson et al., 2013; Rosenthal et al., 2013; Gioia et al., 2002) and negatively correlate with adaptive abilities (Kenworthy et al., 2005) in children with ASD while deficits in inhibition correlate negatively with theory of mind and social skills (Carlson, Moses & Claxton, 2004).

The BRIEF has also been evaluated in assessments of overall functioning, cognitive abilities, and adaptive abilities of children with ASD. Multiple studies show that executive functioning difficulties have an impact on cognitive assessment of children with autism, either by directly affecting these cognitive abilities, such as planning deficits that impact fluid reasoning, (Kalbfleisch & Loughan, 2011) or by limiting the individual’s ability to complete tasks that involve multiple processes at once, such as deficits in inhibition (Kenworthy et al., 2008). Unfortunately, most research on this topic has been correlational so that cognitive deficits and executive functioning deficits and the nature of their relationships cannot be teased apart (Kenworthy et al., 2008).

Adaptive behavior skills are also related to executive control, with deficits in initiation and working memory negatively correlating with better communication and socialization skills.
(Gilotty, Kenworthy, Sirian, Black & Wagner, 2002), but research has not yet examined whether this provides a full explanation for the discrepancy between cognitive abilities and everyday adaptive behaviors. Furthermore, the gap between cognitive abilities and other skills is also found in regards to executive functioning. Children and adolescents with ASD who score in the average range of IQ are found to have below-average executive functioning. Rosenthal and colleagues (2013) found that in a sample of children (ages 5-18) with high functioning ASD (mean FSIQ = 105) the mean scores on six of the BRIEF scales were in the clinically significant range. The number of clinically significant BRIEF scales also increased across the age range with children 5-7 years scoring in the clinically significant range on only one scale while adolescents 14-18 years scoring in the clinically significant range on 8 scales (Rosenthal et. al., 2013). Another study found that clinical significance across BRIEF scales ranged from 37-73% for participants (ages 12-22) with high functioning ASD (Kenworthy et al., 2009), though this executive functioning deficit is lessened for children with ASD that score in the gifted range of IQ (Kalbfleisch & Loughan, 2011). This consistent gap between cognitive abilities and other skills used in daily life (i.e. adaptive behaviors and executive functioning) is not explained by current research. Specifically, the repeated finding that cognitive shifting, flexibility, and planning are especially difficult for individuals with ASD may explain the limited value of cognitive assessments for predicting deficits in adaptive abilities and higher rates of disruptive behaviors in these children. A deeper understanding of how executive functioning skills mediates the relationship between cognitive abilities and adaptive skills in this population is warranted. A few preliminary studies have been conducted that evaluate intervention for executive functioning difficulties in ASD (Kenworthy et al., 2013; Fisher & Happé, 2005) with mixed results. For children ages 6-15, specific training sessions using an analogy about
“changing brain tools” that had children change tools on a truck when they had to practice cognitive flexibility in practice sessions did not improve scores on a modified card sort task or a trails task (Fisher & Happé, 2005). In contrast, Kenworthy and colleagues (2013) used the Unstuck and On Target (UOT) intervention, which includes self-regulatory scripts, guided/ faded practice, and visual/ verbal cueing, with children ages 7 through 11. They found positive effects on flexibility scores on the Challenge Task, WASI block design, and improvements on the Shift and Plan and Organize scales of the BRIEF. They compared this to a social skills intervention, which also showed improvements but at a smaller magnitude compared to the UOT group.

Overall, more extensive research needs to be done to examine whether the findings on UOT are replicable and whether improvements in executive functioning skills have a broader effect on adaptive abilities and social skills. Currently, these are usually analyzed as separate domains in ASD research (e.g. Kenworthy et al., 2008).

**IQ and social abilities.** Because deficits in social abilities are a defining feature of ASD, it is unsurprising that individuals with ASD often have more advanced cognitive abilities than social abilities (Baron-Cohen, 1989). However, a more fine-grained analysis of the association between these two domains may be useful in understanding the structure of intelligence in individuals with ASD. Importantly, social abilities can be split into two domains: social cognition and social skills. Social cognition typically refers to an individual’s ability to interpret verbal and nonverbal social and emotional cues, recognize central information pertaining to these cues, attribute mental and emotional states to others, recall different behavioral responses and the possible consequences of these responses, and respond appropriately in a variety of social situations (Cook & Oliver, 2011). In contrast, social skills are primarily learned behaviors that have been determined necessary by that individual’s culture (Cook & Oliver, 2011). These
include skills such as making eye contact to indicate that one is listening, saying “thank you” after receiving something, and shaking hands when meeting some one for the first time. This differentiation is similar to the difference between fluid intelligence and crystalized intelligence with social cognition reflecting an individual’s ability to react adaptively to novel situations (Taylor, 1990) while social skills require an individual to simply apply accumulated knowledge to social circumstances. As such, it coincides with research on the difficulties individuals with autism face with complex processing (Minshew & Goldstein, 1998) as well as the research that asserts that children with autism have a special deficit in processing social information (Baron-Cohen, 1989; Baron-Cohen, Leslie & Firth, 1985). Children with ASD struggle overall with complex and fluid processing, and social fluid processing is an area of specific deficit.

The split between social skill and social cognition can be especially apparent in individuals with ASD. Often children with ASD will learn appropriate social skills such as making eye contact, shaking hands, and saying “please” and “thank you,” but still struggle in social interactions. The difference is the necessity to adaptively respond to varied social situations rather than simply apply a constant rule. A recent study found this distinction in regards to how children with ASD make moral judgments. Compared to typically developing peers, children with ASD listed more concrete reasoning and specific rules condemning negative behaviors (Shulman, Guberman, Shiling, & Bauminger 2011). In other words, they relied on their crystalized knowledge of right and wrong and appropriate social behavior rather than a fluid understanding of what is morally acceptable. Unfortunately, many measures conflate social skills and social cognition by including questions that measure both aspects within the same scale of social ability. For example, the Vineland-II asks about saying please before requests (a social skill) in the same scale that it asks about noticing that some one needs help and offering
aid (a social cognitive ability). This results in a less detailed understanding of where individuals struggle in their abilities and of how to help those individuals.

Furthermore, the majority of cognitive testing is a standardized social situation – the individual interacts with a novel examiner for one to three hours. During those three hours the individual must attend to the examiner’s body position, gaze behavior, intonation, and pacing in order to perform well on tasks. This maintenance of co-orientation, or mutual awareness to tasks, makes standardized testing an interactional event (Marlaire & Maynard, 1990). The maintenance of attention on a single person for an extended period of time is a social cognitive skill that, if a weakness for an individual, can negatively bias testing results. Children with ASD have difficulty engaging with testing materials (Kanner, 1943; Freeman, 1976), joint attention deficits (Baron-Cohen, Leslie & Firth, 1985; Baron-Cohen, 1989; Klin, Jones, Schultz, Volkmar & Cohen, 2002), and reduced social attentiveness (Swettenham et al., 1998; Klin et al., 2002) – all of which could negatively impact testing. Fortunately, research has found that reinforcing on-task behavior and good test-taking skills improves the performance of children with ASD on standardized assessments (Freeman, 1976; Koegel, Koegel & Smith, 1997) to the extent that enhancing motivation without altering standardized administration is strongly advised for this population (Ozonoff, Goodlin-Jones & Solomon, 2005). While enhancing motivation may help with attention and on-task behavior, we still do not know how joint attention and theory of mind difficulties impact standardized testing. The confounding effect of social ability on cognitive testing results must be further examined. By measuring social skills directly and exploring how social skills and cognitive ability relate to adaptive behavior together, we can begin to understand their relationship to each other.
Additionally, a primary impairment in social cognition is just one theoretical model of ASD proposed to explain the social communication symptoms of ASD. While research continues to examine how these impairments in social attention and interaction vary across social and nonsocial circumstances, leaders in the field continue to call for research that integrates measures of social abilities and nonsocial abilities to improve overall understanding of ASD (Leekam, 2016).

In summary, our understanding of the cognitive abilities of individuals with ASD and how they manifest in everyday behavior is still incomplete. A satisfactory factor structure that explains the cognitive strengths and deficits of this population has not been identified. Nor has there been an explanation of why their adaptive behavior is not commensurate with their cognitive abilities. Although theories have been proposed that social or executive functioning deficits common to individuals with ASD are the driving force behind these inconsistencies, this has not been directly compared or tested. Therefore, an analysis of how different social abilities relate to cognitive skills and predict adaptive abilities is warranted.

A Proposed Structure of Intelligence in ASD

Based on findings reviewed in the preceding sections, I propose that cognitive assessment instruments currently used with children with ASD yield low inter-correlation among factors and have poor predictive ability for adaptive skills because the assessment assumes a structure of intelligence that is not a good fit for this population. In addition, I propose a different structure of intelligence that more accurately describes the skill profiles of children with ASD. If confirmed, my proposed structure of intelligence will produce factors that more closely fit the pattern of scores observed in the ASD population, thereby improving construct and predictive validity.
According to the hypothesis to be tested, the cognitive structure of children with ASD falls into a similar hierarchical structure, as proposed by previous theorists. Specifically, an overall level of cognitive ability, $g$, accounts for the relationships among three domains of more specific ability. These domains, which overlap with but differ from domains identified in studies of typically developing children, include a language ability domain, a perceptual ability domain, and a social ability domain. Furthermore, each of these domains contains crystalized and fluid skills. In other words, crystalized intelligence and fluid intelligence are not independent factors of intelligence, but skills used within each of these four domains. Figure 4 depicts the proposed model. If confirmed, the model would revise existing models in two ways: (1) the inclusion of a social ability domain, which is expected to help account for the discrepancy between IQ and everyday behavior reported in previous studies, and (2) the separation of crystalized and fluid intelligence within each domain, which is expected to help account for the low inter-correlation among tests and unusual pattern of strengths and weaknesses that prior investigators have highlighted. To explicate this restructuring, each ability domain as it is defined in the proposed model will be described separately:

**Language ability.** Language (or verbal) ability refers to the individual’s overall ability to use and understand language (Cattell, 1987). As reviewed above (pp. 6-12) and presented in Table 1, verbal abilities are generally divided into crystalized and fluid. Defining known words, using letters to write known ideas, and understanding simple directions are all examples of crystalized language ability because they all rely on information that the child has learned and can immediately respond with. Explaining similarities between words, demonstrating comprehension of common rules, and interpreting a problem in a story are all examples of fluid
language ability because they all rely on using information presented with language in a novel way.

**Perceptual ability.** Perceptual (or nonverbal) ability refers to an individual’s ability to take in information from their environment that is presented nonverbally or visually (Cattell, 1987). Similar to verbal ability, perceptual ability is also customarily regarded as falling into two types (crystalized and fluid) as explained in the previous literature review (pp. 6-13) and summarized in the Table 1. Identifying mistakes in pictures and recreating simple patterns are examples of crystalized perceptual ability because the child is simply responding to known information with rule-based answers. Fluid perceptual ability requires the individual to use visual or nonverbal information in a novel way and includes tasks like matrix reasoning and quantitative skills.

**Social ability.** As discussed previously in the section “IQ and Social Abilities,” social ability refers to an individual’s ability to acculturate to their social environment and adapt to the expectations of society (Taylor, 1990). Practicing domestic skills and appropriate safety rules are examples of crystalized social ability because such abilities simply replicate learned actions. Fluid social abilities include inhibiting behavior, interpersonal skills, and emotional control because they require learned social abilities to be used in novel ways and in novel situations.

Although the above three sets of abilities are commonly included in models of intelligence, the delineation of crystalized and fluid intelligence within each domain is unique to the model proposed here. Existing cognitive assessment instruments may fall short of capturing the cognitive abilities of children with ASD because they treat crystalized and fluid intelligence as independent domains but then combine them into a verbal factor (e.g. Verbal IQ of the SB-5) or a nonverbal factor (e.g. Nonverbal IQ of the SB-5). This combination compromises the utility
of the assessment of crystalized and fluid assessment because these different factors must be teased apart in order to see strengths and weaknesses within verbal and nonverbal ability. As seen in previous studies, children with ASD do quite well on rote, crystalized tasks but struggle to take on more complex, fluid tasks (Minshew & Goldstein, 1998). When crystalized and fluid abilities are combined onto one factor, we lose information about the individual’s strengths and limitations. This has not appeared to be a problem for typically developing children, possibly because these skills are highly correlated for them. However, it is hypothesized that this is not the case for children with ASD due to their greater variation in abilities across tasks.

This proposed structure of intelligence is intended to elucidate the struggle children with ASD have with fluid abilities in general, but especially those in the language and social domain. Since every cognitive assessment with the most commonly used instruments is a social event and almost all adaptive or executive functioning tasks occur in social settings, the social ability limitations of children with ASD could influence the measurement of all other domains. The proposed model includes social ability in order to better model how social ability relates to these other domains. Specifically, this study will examine whether there is evidence for a division between social fluid reasoning and crystalized social reasoning, and whether such a division is associated with fluid and crystalized intelligence as measured by cognitive testing and as demonstrated in adaptive skills.

**Hypotheses and Aims**

**Hypothesis 1: Children with ASD demonstrate low inter-correlation among tests and low internal consistency of factors.**

**Aim 1a.** Replicate previous findings of low inter-correlation among subtests on the Stanford-Binet Intelligence Scales, 5th Edition (SB-5: Roid, 2003; Goldstein et al., 2008).
Correlational analyses will be conducted to evaluate the relationships among the subtests and domains of the SB-5. These correlations are expected to be lower than those found in the sample norms (0.63-0.89).

**Aim 1b.** Replicate previous findings of a relative strength in nonverbal fluid reasoning compared to verbal fluid reasoning for children with ASD as measured by the SB-5 (Coolican et al., 2007). Paired t-tests will be used confirm a statistical difference in these subtest scaled scores for the overall sample.

**Hypothesis 2:** Three domains, each with a crystalized knowledge and fluid reasoning component, best represent the cognitive abilities of children with ASD: Verbal Ability, Perceptual Ability, Social Ability.

**Aim 2.** Perform a confirmatory factor analysis of the proposed model of three ability domains (Verbal, Nonverbal & Social), each with a fluid reasoning component and crystalized knowledge component. Figure 5 depicts the analysis. This will provide factor scores for the Verbal Ability, Perceptual Ability, and Social Ability domains. This model should be confirmed since it reflects the split in verbal abilities and nonverbal abilities common to individuals with ASD (Coolican, Bryson & Zwaigenbaum, 2007). However, there is a possibility that a two-factor model defined by fluid reasoning and crystalized knowledge will be found instead. If this occurs, these factors will be used in the new model.

**Hypothesis 3.** The proposed three-domain model accounts for more of the variance in adaptive ability than does the conventional model, which groups nonverbal and verbal skills into a Fluid Reasoning Domain and Knowledge Domain.

**Aim 3a.** A conventional model based on the current approach to cognitive testing and its relationship to adaptive abilities will be tested. The conventional model is depicted in Figure 6.
This model will fit the data because it uses only manifest variables and all paths will be estimated.

**Aim 3b.** The proposed model that uses the verbal ability, perceptual ability and social ability to predict adaptive skills will be tested. The verbal, perceptual and social factors from previous analyses will be used. The proposed model is depicted in Figure 7. This model will fit the data because it uses only manifest variables and all paths will be estimated.

**Aim 3c.** The proposed model will more closely fit the data than the conventional model. Model fit indices will be used to directly compare the ability of the proposed model to account for the variance in the data. If the proposed model does not demonstrate a closer fit than the conventional model, a simplified model analysis will be conducted. The fit of the Fluid Reasoning domain and Knowledge domain of the SB-5 will be compared to that of the Nonverbal IQ and Verbal IQ of the SB-5 to evaluate which more parsimonious version of the model more accurately describes the data.

**Hypothesis 4.** Executive functioning acts as a mediator in the relationships among verbal ability, nonverbal ability, and social ability and adaptive abilities.

**Aim 4.** Executive functioning as defined by the BRIEF Global Executive Composite (GEC) will be found to mediate the relationship among the three cognitive domains of the proposed model and adaptive abilities. This mediated model is depicted in Figure 8. The use of the GEC was a change from the original analysis plan for the current study. The plan had been to use the Shift and Inhibit scales in the model due to their previously identified correlation with adaptive abilities (Shift) and social abilities (Inhibit). However, a recent study found that neither the two-indices factor structure of the published BRIEF nor the newly proposed nine-factor model of the BRIEF (Granader et al., 2014) fit the data from children with ASD. Therefore, the
GEC was used as the most reliable scale of overall executive functioning deficit. This change was made after the initial proposal of the study but before any analyses had been conducted.

Methods

This study aimed to collect prospective data on 60 children with ASD. Study visits were conducted in a quiet room at the University of Rochester’s Saunders Research Building. The study was supervised by Tristram Smith, Ph.D. The entire study was carried out under approval from the Research Subjects Review Board (RSRB) of the University of Rochester.

Participants

Participants were recruited from Monroe County, New York and surrounding areas through a research subject database, University of Rochester’s ASD clinic (the Andrew J. Kirch Developmental Services Center), and regular contact and advertising with the following types of agencies: (a) public school districts, (b) pediatricians, (c) regional autism societies and other parent groups, (d) patients already seen at our institutions, (e) web sites maintained by our institutions, and (f) local media. Recruitment involved sending informational materials about the study to appropriate agency staff members followed by a phone call to answer any questions. The author made presentations to parent groups, special education groups and clinicians (e.g., local mental health centers). The Neurodevelopmental and Behavioral Pediatrics research division has a close relationship with community providers and parent groups (e.g., faculty serve on boards of community agencies, have numerous contracts to provide consultation to such agencies, conduct community-partnered research, and include community members in all divisional committees). Its research study database included 511 individuals with ASD whose parents or guardians expressed an interest in research and the Kirch Center saw approximately
1,500 patients with ASD in 2014-2015. Because of this large recruitment base, enrollment of 60 participants for this project was considered quite feasible.

Participants met the following inclusion criteria: (a) age 6-12 years (school-age) to capture the time period in which IQ is relatively stabilized but adaptive skills, social skills, and executive functioning skills are being developed, (b) diagnosis of ASD based on the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Lecouter, 1994) or the Autism Diagnostic Observation Scale-2 (ADOS-2, Lord et al., 2012), (c) Full Scale IQ ≥ 50 to avoid floor effects (d) absence of any comorbid diagnosis that would prevent standard administration of study procedures. These diagnoses included but were not limited to (a) genetic disorders such as Fragile X and Down syndrome, (b) sensory disabilities such as deafness or blindness, (c) motor disabilities such as cerebral palsy (d) disruptive behaviors. An effort was made to recruit participants whose sex distribution was representative of the ASD population (approximately 4 or 5 males for every female) and whose racial and ethnic distribution was representative of the county where the study would take place (approximately 80% Caucasian). Table 1 presents the target enrollment by sex and race/ethnicity.

Procedures

Phone screens that inquired about a participant’s verbal abilities and cognitive abilities were conducted for each participant before they were scheduled for a study visit. Participants then completed an assessment of cognition, adaptive behavior, social skills, executive functioning and ASD symptoms during 1-2 study visits lasting a total of 2½ - 3½ hours. Parental permission was obtained for each participant and child assent was obtained for applicable participants. Two participants had completed the diagnostic assessment at the Kirch Center in the past 12 months. Their parent signed a release to share a copy of the ADOS-2 protocol so that the
assessment would not need to be repeated. All participants completed the assessment in one study visit with the exception of one participant who could only schedule a two hours session initially. This participant returned the next day to complete the last assessment. The author or a trained research technician explained all of the parent surveys and then administered all of the child assessments. The author and research technician had weekly supervision to monitor and maintain standardized administration of the assessments. IRB-approved assessment reports were available for all participants at their request.

Measures

Participants completed one cognitive assessment and a diagnostic assessment if diagnosis had not been confirmed over the past year. Caregivers also completed measures regarding their child’s adaptive behaviors, executive functioning skills, and social skills. These measures allowed an analysis of the relationships among different cognitive skills and the relationships among cognitive abilities and adaptive behavior and social abilities.

Cognitive Assessments. Cognitive skills were represented by domain scores and full-scale scores from the SB-5. The SB-5 provides ten subtests that factor into 5 domain scores, which are combined to create a nonverbal IQ, verbal IQ and a full-scale score.

Stanford-Binet Intelligence Scales – Fifth Edition (SB-5; Roid, 2003a). The SB-5 is a standardized, direct observation of a person’s (age 2-89 years) cognitive skills as measured by testlets administered by a trained examiner. Testlets fit into subtests, which construct Factor Scores and a Full Scale IQ score. Five Factor Scores are calculated through the subtests: Fluid Reasoning, Knowledge, Quantitative Reasoning, Visual-Spatial Processing, and Working Memory. Nonverbal and Verbal IQ scores are also provided. All IQ and Factor scores also provide percentile ranks and confidence intervals. The Stanford-Binet was originally developed
as an assessment to determine a child’s educability (Binet, 1905); major revisions have come over the years to expand the assessment to capture the abilities across the spectrum of intelligence. The most recent revisions indicate exceptional internal consistency reliability for the subtests (0.84-0.89), Factor Indexes (0.90-0.92), the Nonverbal IQ (0.95), Verbal IQ (0.96) and Full Scale IQ (0.98).

The SB-5 was standardized on a sample of 4,800 individuals (2,400 individuals in the age group of interest), also stratified across age, sex, ethnicity, geographical region, and parental education to create a mean of 100 and standard deviation of 15 for the Factor and IQ scores. Children with an Autism diagnosis (N = 83) were included in special group studies, which found a lower overall average IQ (M = 70.4) and greater variation across scores (SD=21.2) (Roid, 2003b). Due to its ability to attain a Nonverbal Score and its wide age range, the SB-5 is commonly used in early intervention and longitudinal studies of children with and without ASD.

The Full Scale IQ of the SB-5 can be broken down into a Nonverbal and Verbal IQ scores and into five Factor Scores. For the analyses of this study, only the Factor Scores and Full Scale IQ score will be examined. Each of the five Factor Scores: Fluid Reasoning, Knowledge, Quantitative Reasoning, Visual-Spatial Processing, and Working Memory are comprised of Nonverbal and Verbal subtests and each of these subtests are comprised of testlets. Fluid Reasoning measures the ability of an individual to use new information to solve problems through inductive and deductive reasoning and is comprised of the Object Series/ Matrices, Early Reasoning, Verbal Absurdities, and Verbal analogies testlets. Knowledge measures crystalized knowledge and comprehension and is composed of the Procedural Knowledge, Picture Absurdities, and Vocabulary testlets. Quantitative Reasoning assesses the individual’s abilities to use numbers and understand mathematical concepts. It is informed by the nonverbal and
verbal Quantitative Reasoning testlets. Visual-Spatial Processing measures visual processing and perceptual reasoning through the Form Board, Form Patterns, and the Position and Direction testlets. Lastly, Working Memory assesses short-term memory and ability to manipulate new information with the Delayed Response, Block Span, Memory for Sentences, and Last Word testlets. The administration of testlets vary by age and ability, so not all individuals are given all testlets; therefore, analyses will not be done at the level of subtests.

The SB-5 subtest division of Nonverbal Fluid Reasoning, Verbal Fluid Reasoning, Nonverbal Knowledge, and Verbal Knowledge and their standard scores make the SB-5 an appropriate existing measure for evaluating how these four separate skills load onto the constructs theorized in the proposed model of cognition. This division of fluid and crystalized skills within verbal and nonverbal abilities differs from the structure in other IQ tests, such as the WISC-IV, which combines fluid and crystalized skills within one subtest (e.g. Similarities). The division in the SB-5 provides subtests that can be used specifically to test the proposed structure of intelligence in ASD (Figure 4) and contribute to factors in the confirmatory factor analysis to be conducted (Figure 5).

**Adaptive Skill Assessment.** Adaptive skills were represented by domain scores from the Vineland Adaptive Behavior Scales-II, Caregiver Rating Form (Vineland-II, Sparrow, Cicchetti & Balla, 2005). Data on adaptive skills provided information on how cognitive abilities may manifest in everyday situations so that we could measure associations between cognitive skills and adaptive abilities.

**Vineland Adaptive Behavior Scales II (Vineland-II; Sparrow, Cicchetti & Balla, 2005).** The Vineland-II assess adaptive functioning through caregiver ratings of an individual across several domains: Communication, Daily Living Skills, Socialization, and Motor Activities and
includes an Adaptive Behavior Composite. The VABS was originally developed to better understand the everyday skills of individuals with developmental disorders by gathering information from their caretakers. The current edition of the Vineland-II has evidence of good internal consistency with high split-half reliability estimates for the domains (0.80-0.95) and for the Adaptive Behavior Composite (0.95-0.98) across the age range (Sparrow, et. al., 2005). Test-retest reliability is also high (0.86-0.96) for the domains and composites across age groups and the coefficient alpha for the Adaptive Behavior Composite is 0.97 (Sparrow, et al., 2005).

The Vineland-II was standardized using a normative sample of 3,687 individuals from birth to 90 years old. The participants were recruited from across the country and stratified across race/ethnicity, community size, socioeconomic status and special education placement. The test developers also included clinical populations in their studies and created score profiles for children with ASD. The Adaptive Behavior Composite and domain scores are presented as standard scores with a mean of 100 and standard deviation of 15. Subdomain scales are presented at V-scale scores with a mean of 15 and standard deviation of 3.

The Adaptive Behavior Composite represents the sum of four domain scales for children birth through 6 years and the sum of three domain scales for individuals 7-90 years old. The Motor Skills domain is omitted from the composite for individuals older than 6 years. The Communication Domain splits into Receptive communication, Expressive communication and Written communication subdomains. Daily Living Skills is composed of Personal skills, Domestic skills, and Community skills subdomains. The Socialization Domain combines the Interpersonal Relationships, Play and Leisure Time, and Coping Skills domain. Finally, the Motor Skills domain includes Gross motor skills and Fine motor skills domains.
The Vineland-II is considered a gold standard measure of adaptive behaviors and is used across clinical and educational settings to determine strengths and deficiencies in everyday skills. It is the most widely used measure in the assessment of the adaptive skills of individuals with ASD (Ozonoff, Goodlin-Jones & Solomon, 2005). Multiple studies have confirmed its ability to assess the social and adaptive deficits of this population (Klin et al., 2007; Kenworthy et al., 2009) and it is often used in determining classroom and treatment interventions for this population. As such, it is important to evaluate the relationship between this measure of adaptive skills and the proposed model of cognition. Because the Vineland-II measures a combination of fluid and crystallized adaptive skills, the inclusion of this measure allows for a test of the hypothesis that the proposed model and its division of abilities will better predict the adaptive behaviors assessed by the Vineland-II (Hypothesis 3).

**Social Skills Assessments.** Social skills were represented by domain and composite scores from the Social Skills Improvement System - Rating Scales (SSIS-RS; Gresham & Elliot, 2008) and by scale scores from the Social Perception Domain of the NEPSY-II (Korkman, Kirk & Kemp, 2007a). The SSIS-RS provided a parent-rated measure of the child’s crystallized knowledge and use of social skills while the NEPSY-II provided a measure of crystallized knowledge and of how the child applied his or her social knowledge to understanding and responding to social events. These measures of crystallized social knowledge and fluid social reasoning were used to create the social ability factor in the proposed model (Figures 5 and 6).

**Social Skills Improvement System – Rating Scales (SSIS-RS; Gresham & Elliot, 2008).** The SSIS-RS assesses social abilities through parent ratings, teacher ratings, or self-ratings of an individual across several domains: Communication, Cooperation, Assertion, Responsibility, Empathy, Engagement, and Self-Control. For the purpose of this study, the parent rating form
will be used. The current edition of the SSIS Rating Scales demonstrates good internal consistency with median scale reliabilities of the Social Skills scales in the mid- to upper .90s for the parent form. Test-retest indices for Total Social Skills were 0.84 for the parent form and in the 0.80s for the Social Skills subtests and coefficient alphas ranged from 0.81-0.97 for the school age group (Gresham & Elliot, 2008; Gresham, Elliot, Vance & Cook, 2011).

The SSIS-RS was standardized using a normative sample of 2,800 individuals from 3- to 18-years old. The participants were recruited from across the country and stratified across race, region, and socioeconomic status. Additionally, the SSIS-RS has three validity scales including an F index to assess artificially negative endorsement, Response Pattern to assess the respondent’s attention to the measure, and Response Consistency to assess the consistency with which the respondent endorsed similar items (Gresham & Elliot, 2008).

The SSIS-RS social skills standard score provides an overall estimate of social skills ability based on age norms. It is created through the compilation of the prosocial behaviors evaluated in each of its domains. The Communication scale measures the individual’s use of verbal social communication (saying please and thank you) and nonverbal social communication (making eye contact). The Cooperation scale evaluates behaviors such as sharing and helping others while the Assertion scale consists of items meant to reflect how the individual initiates and responds to social situations. The Responsibility scale measures how an individual regards his own work and the property of others. The Empathy scale evaluates how an individual demonstrates concern for others while the Engagement scale measures how an individual connects to peers. Lastly, the Self-Control scale has items pertaining to how an individual manages conflict and other social situations (Gresham & Elliot, 2008).

The SSIS-RS and its predecessor, the Social Skills Rating Scale (SSRS), are two of the
most commonly used assessments of social skills for typically developing children and for children with developmental disabilities (Matson & Wilkins, 2009; Cook & Oliver, 2011; Crowe, Beauchamp, Catroppa & Anderson, 2011). The SSIS-RS and SSRS have also been used as outcome measures for social skills intervention research for children with ASD (Ozonoff & Miller, 1995; Webb et al., 2004; White, Koenig, Scanhill, 2007). Furthermore, its domains of Communication, Cooperation, Assertion, Responsibility, Empathy, Engagement, and Self-Control capture the crystalized social skills postulated in this model.

**NEPSY-II: Social Perception domain (Korkman, Kirk & Kemp, 2007a).** The NEPSY-II is a comprehensive assessment of neuropsychological functioning through a standardized, direct observation of a person’s (age 3-16) responses to subtests administered by a trained examiner. It is composed of 6 domains (Attention and Executive Functioning, Language, Memory and Learning, Sensorimotor, Social Perception, and Visuospatial Processing) that contain two to thirteen subtests. The NEPSY-II was created with the flexibility to administer only subtests of interest to evaluate for different disabilities and clinical issues.

The Social Perception domain contains two subtests that evaluate skills used in social interactions. Affect Recognition evaluates a child’s ability to recognize affect from photographs of children’s faces. Theory of Mind assesses a child’s ability to understand that other people have their own thoughts, feelings, and ideas. It examines a child’s ability to take another person’s perspective, interpret intention, and understand deception. The two scales of the Social Perception domain have reliable coefficients from 0.75-0.87 across the age range for their normative sample and from 0.85-0.90 for the special groups, indicating good reliability.

The NEPSY-II was standardized on a sample of 1,200 children ages 3-16 and stratified across age, sex, ethnicity, geographical region, and parental education to create a mean of 10 and
a standard deviation of 15 for all of the subtests. Children with Autistic Disorder (N = 23) and children with Asperger’s Disorder (N = 19) were included in special group studies on the Affect Recognition subtest, which found a lower mean score of 7.6 for children with Autistic Disorder and 8.8 for children with Asperger’s Disorder and slightly less variation across scores (SD = 2.7 and 2.5, respectively). Compared to matched control groups, children with Autistic Disorder had a statistically significant mean score but children with Asperger’s Disorder did not (Korkman, Kirk & Kemp, 2007b). Because the Theory of Mind subtest provides percentage ranges rather than scale scores for children over the age of six despite norms for children up to age 16, a regression analysis was run with age regressed onto Theory of Mind total. Age accounted for 10% of the variance in Theory of Mind scores, $r = 0.316$, $F(1, 51) = 5.65$, $p = 0.02)$. The residuals from this regression analysis were used in all analyses with Theory of Mind in order to statistically control for age.

The Social Perception domain and its subtests are based on the theory that how people process social information affects how they initiate and respond in social interactions. For example, the ability to attend to faces and interpret facial expressions provides important information to guide social behaviors (Korkman, Kirk & Kemp, 2007b). This corresponds to the social domain, crystalized knowledge and fluid reasoning aspect of the proposed model of cognition.

**Executive Functioning Assessment.** Executive functioning abilities were assessed through the Behavior Rating Inventory of Executive Function, Parent Form (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000). The BRIEF allowed us to analyze whether executive functioning is a mediator in the relationship between cognitive abilities and adaptive skills in the proposed model.
Behavior Rating Inventory of Executive Function (BRIEF; Gioia, et. al., 2000). The BRIEF is a standardized assessment of executive functioning at home for individuals aged 5-18 years that is completed by their parent. It is designed to be high in ecological validity and sensitive to developmental changes (Gioia, Isquith, Guy & Kenworth, 2000). The BRIEF provides a Global Executive Composite that is composed of a Meta-Cognition Index and Behavioral Regulation Index. The Meta-Cognition Index reflects the Monitor, Organization of Materials, Plan/Organize, Working Memory, and Initiate scales. The Behavioral Regulation Index is comprised of the Emotional Control, Shift, and Inhibit Scales. All scales, indexes, and the composite provide T scores, percentiles, and confidence intervals to compare results against a normative sample. Higher scores on the BRIEF indicate greater impairment with a score of 65 and above considered clinically significant.

The BRIEF has strong psychometrics as demonstrated by its high internal consistency ($\alpha = 0.80-0.98$) and high test-retest reliability ($r_s = 0.082$).

The BRIEF was standardized and normed based on child ratings from 1,419 parents. This group was representative of urban, suburban, and rural areas and stratified across gender, ethnicity, and socioeconomic status. The clinical sample of 852 included children with developmental disorders (high functioning autism, reading disorder, ADHD) and acquired neurological disorders (traumatic brain injury) (Gioia, Isquith, Guy & Kenworth, 2000). These studies found that children with ASD scored higher than controls on all scales of the BRIEF. Due to its excellent psychometrics and broad assessment of many executive functioning abilities, the BRIEF is an appropriate instrument to obtain an overall estimate of executive functioning deficits.
The BRIEF includes subscales of Plan/ Organize, Initiate, and Shift, three weakness of executive functioning common to children with ASD (Smithson et al., 2013; Rosenthal et al., 2013; Gioia et al., 2002). Its Global Executive Composite score has also been found to be a valid representation of overall executive functioning difficulties in children with ASD (Granader et al., 2014) and makes it an appropriate measure to elucidate the mediating relationship of executive functioning deficits the ability of children with ASD to use their cognitive abilities in everyday situations.

Data Analysis

Before generating a path model, data screening was conducted to evaluate for collinearity and multivariate outliers within the sample. Psychometric properties of the measure used for the proposed study have been presented above, but sample reliability was also reported (Vacha-Haase, Ness, Nilsson, & Reetz, 1999), because the proposed population sample differed from the sample norms. The proposed analyses included a correlational and a path model designed to address each specific aim for the present study.

Analysis 1. Correlational Analysis – Cognitive, Adaptive, and Social Skills

(Hypothesis 1, Aim 1a). Correlational analyses were conducted to evaluate the relationships among the cognitive assessment tasks, composite and factor scores, and Full Scale IQ scores. The relationships between cognitive abilities and the Vineland-II domains and composite score and the SSIS-Rating Scales subscales and composite scores were also explored. All of the observed abilities were entered into a single correlational matrix and compared to expected correlations in the literature. Although this analysis did not impact how the remaining analyses were conducted, it was important because it was used to characterize how similar or different children with ASD were compared to the typical population.
Analysis 2. Comparison of Verbal Fluid Reasoning and Nonverbal Fluid Reasoning (Hypothesis 1, Aim 1b). Paired t-tests were used to test the difference in Verbal Fluid Reasoning scores and Nonverbal Fluid Reasoning scores. Nonverbal Fluid Reasoning scores were expected to be significantly higher than Verbal Fluid Reasoning scores.

Analysis 3. Confirmatory Factor Analysis (Hypothesis 2, Aim 2). A confirmatory factor analysis of the three domains: Verbal Ability, Nonverbal Ability, and Social Ability was conducted. This confirmatory factor analysis also provided factor scores for each of these domains. These factor scores were used in all subsequent analyses.

Analysis 4. Path Analysis of the Conventional Model (Hypothesis 3, Aim 3a). A path analysis of the conventional model was conducted in order to establish indices of fit to compare to the proposed model. This model used the SB-5 Full Scale IQ to predict the Vineland-II ABC.

Analysis 5. Path Analysis of the Proposed Model (Hypothesis 3, Aim 3b). A path analysis of the proposed model was conducted in order to establish indices of fit to compare to the proposed model. This model used the factor scores of Verbal Ability, Nonverbal Ability, and Social Ability calculated in the previous analyses to predict Vineland-II ABC.

Analysis 6. Comparison of Fit (Hypothesis 3, Aim 3c). The AIC of the conventional model was compared to the AIC of the proposed model to determine which of the two models more closely fit the data.

Analysis 7. Evaluate Executive Functioning as a Mediator (Hypothesis 4, Aim 4). The BRIEF Global Executive Composite was evaluated as a potential mediator of relationships among the cognitive abilities and the Vineland-II ABC. Mediation and moderation analyses are conducted similarly in SEM with the distinction that mediation analyses use longitudinal data to draw conclusions regarding causal effect. Longitudinal data is outside the scope of this study,
but executive functioning was theorized to act as a mediator between cognitive ability and everyday skills (Hypothesis 4, pp. 36-37) and was tested as such.

**Sample Size Justification**

This study used SPSS Version 20.0 (IBM, 2011), to create factor scores to be incorporated in a path analysis. Factor scores were estimated from 6 items (Verbal Knowledge, Verbal Fluid Reasoning, Nonverbal Knowledge, and Nonverbal Fluid Reasoning from the SB-5; Affect Reasoning and Theory of Mind from the NEPSY-II) obtained from the sample of 60 participants. This 1:10 item to participant ratio provides satisfactory power to confirm factor scores and avoid error (Costello & Osborne, 2005). Using those factors, a total of 10 parameters, including the six factor scores and four manifest variables (i.e., the four components of intelligence in the proposed model) were estimated in the final path analysis. An accepted rule of thumb for estimating minimum sample size in tests of model fit is 5-10 participants for each parameter estimate with more leniency for models that do not include latent variables (Kline, 2011).

**Results**

**Sample**

Over seven months of recruitment (July, 2014 – February, 2015), I contacted 108 caretakers of 111 children with ASD through recruitment calls and callbacks to inquiries regarding the study. Twenty-six individuals did not respond to initial contacts, 5 were unable to schedule, 5 declined participation, and 5 failed the phone screen. A total of 70 individuals were scheduled for a study visit. Of those individuals, 11 canceled due to inclement weather or sickness and were unable to reschedule, and 6 individuals did not meet inclusion criteria. The remaining 53 individuals (44 males, 9 females)
completed all study procedures and met inclusion criteria. The mean age of these participants was 9.6 (SD = 1.9; range: 6-12). See Figure 9. The majority of the sample described themselves as Caucasian (87%), lived in a parental home (92.2%) and had an annual household income greater than $60,000 (66.6%). Full demographic information can be found in Table 2. All participants scored above criteria for an autism spectrum disorder on the ADOS-2 (mean = 14.1; SD = 3.2; range: 8-22).

Overall, the participants represented a wide range of cognitive functioning with Full Scale IQ scores ranging from 51 to 126 with an average Full Scale IQ of 92.49 (SD = 19.46). Mean Nonverbal IQ (94.6, SD = 18.2) and Verbal IQ (91.4, SD = 20.5) were comparable. As expected and in contrast to their average Full Scale IQ, overall participants demonstrated a deficit in their adaptive skills with a mean Vineland-II Adaptive Behavior Composite score of 74.72 (SD = 9.98, range 59-107). Only 8 of the 53 participants scored within the average range of functioning in adaptive behavior. Scores on the SSIS-RS Social Skills fell in a similar pattern with a mean score of 76.34 (SD = 11.51) and 12 of 53 participants scoring in the average range. Participants also demonstrated deficits on the NEPSY-II Theory of Mind Task with 60.4 percent falling in the lower 25th percentile or below compared to their peers and an additional 22 percent falling in the low average range. In total only 9 participants scored in the high average or above range. Similarly, participants scored in the clinically significant range in regards to the BRIEF Global Executive Composite with a mean T-score of 71.96 (SD = 7.58) and only 9 of 53 participants scoring below the clinically significant range. NEPSY-II Affect Recognition scored differed somewhat from this pattern with participants attaining a mean scaled score of 9 (SD = 2.7), which is within the average range of ability. Table 3 includes descriptive statistics for all
assessments completed. See Figure 10 through Figure 14 for the distribution of these assessment results.

Tests of Proposed Model of Cognition in ASD

Data screening indicated that collinearity was not a concern, and no multivariate outliers were identified.

Analysis 1. Correlational Analysis – Cognitive, Adaptive, and Social Skills

(Hypothesis 1: Children with ASD demonstrate low inter-correlation among tests and low internal consistency factors; Aim 1a: Replicate previous findings of low inter-correlation among subtests on the SB-5). The tasks of the SB-5 correlated strongly with each other overall. The relationship between Nonverbal Fluid Reasoning and Nonverbal Knowledge $r(51) = 0.49$, $p<0.001$ was the weakest while the relationship between Verbal Fluid Reasoning and Verbal Knowledge $r(51) = 0.79$, $p<0.001$ was the strongest. This finding offers some preliminary support for examining nonverbal fluid reasoning and crystalized knowledge separately for the ASD population. The subtests also correlated highly with the Full Scale IQ score, ranging from $r(51) = 0.73 – 0.89$. The domain scores correlated even more highly with Full Scale IQ with a range of $r(51) = 0.88 – 0.92$. The full correlation tables are available at Table 4 and 5. These high correlations are similar to those in the overall normative sample used for standardizing the SB-5 and higher than those of the ASD subgroup within that sample, which had lower correlations between subtests and domains (Roid, 2003b).

Some associations were found between cognitive abilities and the Vineland-II domains and composite score and the SSIS-Rating Scale and NEPSY-II. The Vineland-II Adaptive Behavior Composite (ABC) positively correlated with FSIQ at $r(51) = 0.33$, $p = 0.02$. Of the domain scores, the communication domain correlated most strongly with FSIQ $r(51) = 0.46$, $p =$
0.001 and the socialization domain correlated most weakly $r(51) = 0.13, p = 0.36$ (ns). The SSIS-RS social skills scale only correlated significantly with the SB-5 Verbal IQ score $r(51) = -0.27 (p = 0.05)$ in an unexpected direction with higher verbal skills being associated with fewer social skills. In contrast, the NEPSY-II Affect Recognition scale and Theory of Mind residual score both correlated significantly with FSIQ. All correlations can be found in Table 7.

**Analysis 2. Comparison of Verbal Fluid Reasoning and Nonverbal Fluid Reasoning**

(Hypothesis 1: Children with ASD demonstrate low inter-correlation among tests and low internal consistency factors; Aim 1b: Replicate previous findings of a relative strength in nonverbal fluid reasoning compared to verbal fluid reasoning for children with ASD as measured by the SB-5). Nonverbal Fluid Reasoning scores were not significantly different from Verbal Fluid Reasoning scores in this sample $t(52) = 0.843, p = 0.40$, (ns). This finding suggests that, for this sample, difference in nonverbal and verbal fluid reasoning scores was evenly distributed. See Figure 15.

**Analysis 3. Confirmatory Factor Analysis** (Hypothesis 2: Three domains, each with a crystalized knowledge and fluid reasoning component, best represent the cognitive abilities of children with ASD: Verbal Ability, Perceptual Ability, Social Ability; Aim 2: Perform a confirmatory factor analysis of the proposed model of three ability domains, each with a fluid reasoning component and crystalized knowledge component). A confirmatory factor analysis was conducted using the Bartlett Method. This method was chosen because it creates univocal and unbiased factors scores (Thomson, 2006). *Univocal* means that variables load onto only one variable (simplifying structure) and that repeated sampling will result in consistent statistics (protecting against error). An Oblimin rotation was also used; this factor-analytic method is employed when factors are not predicted to be orthogonal to one another (Cohen, Cohen, West &
Aiken, 2003). Visual examination of the scree plot indicated three factors: a reasoning factor on which all four SB-5 subtests and the NEPSY-II Theory of Mind subtest loaded, a social skill factor, on which the SSIS-RS social skills score loaded, and a social reasoning factor, on which the NEPSY-II Affect Reasoning scale loaded. The full structure matrix can be found in Table 8. Variables discriminated well between components, with loadings greater than 0.5 on their identified components; however, the third component had an eigenvalue of less than one, and the second and third components were each defined by only one variable. Additionally, the SSIS-RS social skills scale had negative correlations with the other factors in this analysis, so it was dropped from further analyses. Overall, the Bartlett CFA provided mixed support for a three-factor model. It found strong discrimination among components. However, only one factor had an eigenvalue above 1, and, even for this factor, the eigenvalue was only slightly above 1, indicating that it accounted for a small portion of the variance in the data. Additionally, although two other factors were identified, they each contained only one variable, indicating that the factor analysis had limited benefit for reducing variables. The most likely reason for this was the high correlation between the individual subscales which increased cross-factor loading, making the overall factor structure unstable (i.e., strongly influenced by how the computer rounds off calculations) and therefore, questionable (DiStefano, Zhu & Mîndrilă, 2009).

Due to the mixed and possibly unstable results of the Bartlett method for confirmatory factor analysis, a confirmatory factor analysis model (Figure 16) using the full-information maximum likelihood (FIML) method through AMOS 7.0 statistical software (Arbuckle & Wothke, 1999) was conducted. This method of confirmatory factor analysis is theory-driven, requiring the researcher to specify how she hypothesizes the variables to be related so that analyses then determine whether or not the actual intercorrelations among the subtests are
consistent with the hypothesized relationships. It also allows for the modeling of error, which is especially important when using different types of measures (i.e. direct observation, parent report, etc.). The fit of the model was evaluated based on (a) the comparative fit index (CFI) statistic with values between 0.95 and 1.00 indicating acceptable fit (Bentler, 1990) and (b) the root mean square error of approximation (RMSEA) with values of 0.08 or less reflecting adequate fit (Browne & Cudeck, 1993).

This model fit the data well, $\chi^2 (6) = 1.166, p = 0.979$, CFI = 1.00, RMSEA = 0.000. Each subtest loaded significantly onto its theorized factor. Nonverbal fluid reasoning and nonverbal knowledge significantly loaded onto the perceptual factor $\beta = 0.66$, $p < 0.001$ and $\beta = 0.74$, $p < 0.001$, respectively. Verbal fluid reasoning and verbal knowledge loaded significantly onto the verbal factor, $\beta = 0.85$, $p < 0.001$ and $\beta = 0.93$, $p < 0.001$. The NEPSY-II Affect recognition subscale and Theory of Mind subscale loaded onto the social factor, $\beta = 0.45$, $p = 0.002$, $\beta = 0.82$, $p < 0.001$. Each factor then significantly loaded onto a higher order latent factor of cognitive ability: perceptual ability $\beta = 0.97$, $p < 0.001$, verbal ability $\beta = 1.05$, $p < 0.001$, and social ability $\beta = 0.89$, $p < 0.001$. These results indicate that this factor structure was an acceptable fit to the data so perceptual, verbal, and social factor scores were created based on the variables. These factors were derived by creating z-scores for each of the loading variables and then using the average z-score of these variables. This factor structure was then used in further analyses.

**Analysis 4. Path Analysis of the Conventional Model** (Hypothesis 3: The proposed three-domain model accounts for more of the variance in adaptive ability than does the conventional model; Aim 3a: A conventional model based on the current approach to cognitive testing and its relationship to adaptive abilities is tested). A path analysis of the conventional
model was conducted in order to establish indices of fit to compare to the proposed model. This model used the SB-5 Full Scale IQ to predict the Vineland-II ABC. Full Scale IQ significantly predicted Vineland-II ABC, $\beta = 0.33, p = 0.002$. This model produced an AIC fit index score of 6.00 and a BIC fit index score of 11.91. These fit indices were subsequently compared to those of the proposed models.

**Analysis 5. Path Analysis of the Proposed Model** (Hypothesis 3: The proposed three-domain model accounts for more of the variance in adaptive ability than does the conventional model; Aim 3b: The proposed model that uses the verbal ability, perceptual ability and social ability to predict adaptive skills is tested). A path analysis of the proposed model was conducted in order to establish indices of fit to compare to the conventional model. This model used the Verbal Ability, Perceptual Ability, and Social Ability factors established in the previous analyses to predict Vineland-II Adaptive Behavior Composite through the latent variable of cognitive ability (Figure 17). This model fit the data moderately well, $\chi^2(2) = 2.911, p = 0.233$, $\text{CFI} = 0.989$, $\text{RMSEA} = 0.094$, $\text{AIC} = 18.911$, $\text{BIC} = 34.67$. Perceptual ability loaded significantly onto cognitive ability, $\beta = 0.80, p < 0.001$, as did verbal ability, $\beta = 0.96, p < 0.001$, and social ability, $\beta = 0.72, p < 0.001$. The latent variable, cognitive ability then predicted VABS ABC significantly, $\beta = 0.42, p = 0.002$.

**Analysis 6. Comparison of Fit** (Hypothesis 3: The proposed three-domain model accounts for more of the variance in adaptive ability than does the conventional model; Aim 3c: The proposed model will more closely fit the data than the conventional model). The AIC of the conventional model was compared to the AIC of the proposed model to determine which of the two models more closely fits the data. The AIC of the conventional model (6.0) was less than
the AIC of the proposed model (18.911), indicating that the conventional model more closely fits the data in the study.

**Analysis 7. Evaluate Executive Functioning as a Mediator** (Hypothesis 4: Executive functioning acts as a mediator in the relationships among verbal ability, nonverbal ability, and social ability and adaptive abilities; Aim 4: Executive functioning as defined by the BRIEF Global Executive Composite will be found to mediate the relationship among the three cognitive domains of the proposed model and adaptive abilities). The BRIEF Global Executive Composite was evaluated as a potential mediator among in relationships among the cognitive abilities and the Vineland-II ABC.

The BRIEF Global Executive Composite (GEC) score was added to the proposed model as an additional indirect path between cognitive ability and the Vineland-II ABC (see Figure 18). The original analysis plan was to evaluate executive functioning as a potential mediator of the association between intelligence and everyday skills of children with ASD (i.e. a continuous variable with ongoing effects) as this is consistent with how executive functioning is conceptualized in the literature (Kenworthy et al., 2005; Blijd-Hoogewys, Bezemer & van Geert, 2014). Unfortunately, due to limitations with sample size and power, the BRIEF GEC was instead added to the model as an additional measure of cognitive ability that also has a direct relationship with adaptive functioning as measured by the Vineland-II ABC. This was chosen due to previous research findings regarding the correlation between executive functioning and adaptive skills (Kenworthy et al., 2005) and between executive functioning and reasoning skills (Salthouse, 2005). The BRIEF GEC loaded significantly onto cognitive ability, $\beta = 0.12, p < 0.05$ and was significantly associated with Vineland-II ABC, $\beta = -0.29, p = 0.019$. The path between cognitive ability and Vineland-II ABC also increased slightly (from 0.42 to 0.44, both $p$
< 0.05) with the addition of the BRIEF GEC. Although the model fit the data, $\chi^2(5) = 3.983, p = 0.553, \text{CFI} = 1.00, \text{RMSEA} = 0.000, \text{AIC} = 23.983, \text{BIC} = 43.686$, adding the BRIEF GEC to the model did not create a better fitting model than the proposed model nor the conventional model.

**Post-hoc Analyses.** In order to understand how all of the assessments fit together overall, zero-order correlations between pertinent variables were also conducted. The relationships amongst the social abilities were examined to understand how different measures of social abilities related to each other. As expected, the Vineland-II Socialization domain correlated positively with NEPSY-II Affect Recognition scale $r(51) = 0.41, p = 0.003$ and SSIS-RS social skills scale $r(51) = 0.50, p < 0.001$; however, it did not correlate significantly with the NEPSY-II Theory of Mind residual score $r(51) = 0.22, p = 0.12, ns$. Also as expected from the literature, the NEPSY-II Theory of Mind task was significantly related to SB-5 FSIQ $r(51) = 0.67, p < 0.001$ and the ADOS-2 severity scores $r(51) = -0.50, p < 0.001$.

The relationships amongst executive functioning skills and the other skill domains were also explored (see Table 9). The BRIEF GEC did not correlate significantly with SB-5 FSIQ $r(51) = 0.14, p = 0.33$ nor was the relationship with the Vineland-II ABC maintained outside of the proposed model $r(51) = -0.25, p = 0.07$ though the latter was marginally significant. Relationships between the BRIEF GEC and the ADOS-2 severity score, NEPSY-II Affect Recognition scale, and NEPSY-II Theory of Mind scale were also nonsignificant.

**Achieved Statistical Power**

In structural equation modeling, power is examined by calculating the probability that an analysis will reject a model that is not a good fit to the data (Kline, 2011). G*Power (Faul, Erdfelder, Lang & Buchner, 2007) was used to evaluate the power for each of the models run in the analyses. The confirmatory factor analysis (analysis 3) had $\text{CMIN} = 12.992, \text{df} = 11$ with
power = 0.116. The path analysis of the proposed model (analysis 5) had a CMIN = 2.911, df = 2 with power = 0.125. Analyses were underpowered due to the small sample size of this study, a special clinical population. Although analyses and findings should be regarded as preliminary, these models still provide promising data regarding the proposed theory that should be tested further.

**Discussion**

The current study tested a proposed structure of cognition in children with autism spectrum disorder (ASD). These children present with a unique distribution of cognitive abilities that may impact the accuracy of their assessment and efficacy of interventions designed to teach them. This population has an increased prevalence of intellectual disability compared to the typical population, but the range of cognitive abilities across individuals ranges from the severely impaired to the superior range. Similarly, the language ability of children with ASD also ranges from minimally verbal to fluent in spoken language (ADDM, 2014). As a result, assessment and intervention tools must also be able to address this wide range in ability.

Although this study included only children with ASD who were fluent in spoken language, the sample still exhibited a wide range of cognitive abilities, replicating previous findings (ADDM, 2014; Carothers & Taylor, 2013; Coolican, Bryson & Zwaigenbaum, 2007). The mean IQ of the sample (92.5) was comparable to that in other studies with similar inclusion and exclusion criteria (Ankenman et al., 2014) though some limited the lower end of the range to 70 or above (Goldstein et al., 2008) or specifically looked at children with ASD and average or gifted intelligence (Kalbfleisch & Loughan, 2011). Nevertheless, the study was only partially successful in replicating other findings on IQ in children with ASD, and it provided mixed evidence on the utility of the proposed structure of intelligence in these children. The findings on
each hypothesis are discussed below, followed by a discussion of study limitations and implications of the findings for research and clinical practice.

**Hypothesis 1: Children with ASD demonstrate low inter-correlation among tests and low internal consistency of factors.**

**Aim 1a.** Replicate previous findings of low inter-correlation among subtests on the Stanford-Binet Intelligence Scales, 5th Edition (SB-5: Roid, 2003; Goldstein et al., 2008).

Contrary to prediction, this sample of children differed from previous samples in regards to the correlation among subtests and FSIQ. Whereas previous studies reported weaker correlations between subtests and FSIQ in ASD samples than in the norming sample (Mayes & Calhoun, 2003; Goldstein et al., 2008), correlations in the ASD sample in the current study were comparable to that of the norming sample, indicating that the participants in this study tested more similarly to the typical population than did previous groups of children with ASD. Our sample did have a wider range of ability than did Goldstein and colleagues (2008) but was similar to the Mayes and Calhoun (2003) study, which also recruited a wide range of ability. In contrast to Mayes and Calhoun (2003), who recruited young children (3-7 years old) our sample was older (6-12 years). In addition to sampling differences, other possible reasons for the unexpectedly high correlation among IQ subtests could include lower symptom severity of this sample or unusual sample demographics, but these seem not to be the case with this sample. The average ADOS-2 severity score of 8.1 indicates a highly affected sample (severity range for an ADOS-2 that yields an ASD classification is 5-10). Unfortunately, the small sample size of this study could have limited the variability of scores and the ability to identify lower intercorrelations. The finding of high intercorrelations does not support the study hypothesis but
does support previous reports that the SB-5 is a reliable measure with this population (Coolican, Bryson & Zwaigenbaum, 2007; Roid, 2003b).

**Aim 1b.** Replicate previous findings of a relative strength in nonverbal fluid reasoning compared to verbal fluid reasoning for children with ASD as measured by the SB-5 (Coolican et al., 2007).

Previous research on the cognitive abilities of children with ASD has identified a unique profile of strengths and weakness. Consistent with previous studies, overall, participants in the current study scored highest on nonverbal reasoning tasks and lowest on verbal tasks. However, the difference in these scores was not statistically significant and children performed similarly on crystalized verbal tasks and fluid reasoning verbal tasks. Thus, the hypothesis was not supported. This finding may be due to the difference in the age of our sample (school age versus preschool age) in prior studies reviewed in the Introduction and may reflect age-related improvements in language skill (Turner, Stone, Pozdol & Coonrod, 2006; Cantwell & Baker, 1989). Together, the findings for Aims 1a and 1b indicate that the test scores of children with ASD can be interpreted as recommended by the technical manual for the SB-5 without concern for the internal consistency of the test or the appropriateness of analyzing strengths and weaknesses from subtest scores.

**Hypothesis 2: Three domains, each with a crystalized knowledge and fluid reasoning component, best represent the cognitive abilities of children with ASD:** Verbal Ability, Perceptual Ability, Social Ability

**Aim 2.** Perform a confirmatory factor analysis of the proposed model of three ability domains (Verbal, Nonverbal & Social), each with a fluid reasoning component and crystalized knowledge component.
In testing the proposed theory of intelligence, the Bartlett method confirmatory factor analysis did not pull out the predicted three-factor solution. Rather, it yielded one factor. This was likely due to the unexpectedly high intercorrelations among SB-5 subscales in our sample. Although it does not support the proposed theory of intelligence, the one-factor solution is further evidence that findings from IQ tests given to children with ASD can be interpreted in much the same way as findings from IQ tests given to typically developing children because it replicates the high loadings onto a common factor \((g)\) built into these assessments. The confirmatory factor analysis might have been more successful if items from different tests (e.g. Raven’s Matrices, PPVT, etc.) were used rather than subtests from one combined measure because, although they also correlate across individuals, they are not designed to load onto the same overall factor (Minshew & Goldstein, 1998; Narzisi et al., 2013).

Additionally, the good fit of the confirmatory factor analysis run through a structural equation model supports adding measures of social skills into overall models of cognitive abilities for children with ASD. This finding is consistent with the proposed theory of intelligence. Social skill ability loaded well onto a latent measure of cognitive ability, suggesting that those skills are related to aspects of intelligence traditionally measured by cognitive assessments that leave those skills out of their model of intelligence. Future studies will have to be conducted to determine if the loading of social ability onto general cognitive ability is unique to the ASD population or also found in the typically developing population. Overall, the CFA and SEM yielded mixed evidence on the proposed structure of intelligence. Analyses did not yield the three theorized factors, but did indicate that assessments of cognitive ability should include measures of social reasoning and knowledge for children with ASD.
Hypothesis 3: The proposed three-domain model accounts for more of the variance in adaptive ability than does the conventional model, which groups nonverbal and verbal skills into a Fluid Reasoning Domain and Knowledge Domain.

Aim 3a. A conventional model based on the current approach to cognitive testing and its relationship to adaptive abilities will be tested.

The conventional model of intelligence and ability used in research and clinical practice uses the FSIQ score of a child to roughly predict that child’s adaptive skill. In our sample, the SB-5 FSIQ predicted 11% of the variance in Vineland-II ABC (r = 0.33, p = 0.02). This finding is consistent with previous studies that had similar sample demographics (Klin et al., 2006; Kenworthy et al., 2009). In this way, our sample was representative of previous studies.

Aim 3b. The proposed model that uses the verbal ability, perceptual ability and social ability to predict adaptive skills will be tested.

The proposed model that uses the theoretical factor structure to predict adaptive behaviors predicted a greater amount of the variance in Vineland-II ABC scores with 18% (r = 0.42, p < 0.05). Although this relationship is not significantly different from the relationship between traditional measures of intelligence and adaptive skills, it does indicate that including social skills reasoning and knowledge into our conception of intelligence may improve prediction of how well a child with ASD will apply their cognitive skills in their daily life. Specifically, the proposed model uses only four of the ten SB-5 subtests in combination with the social skills abilities to predict adaptive functioning at least as well as the full SB-5. Therefore, inclusion of the full SB-5 and the social skills abilities may provide significantly more information compared to the conventional model. On a different note, using fewer subtests significantly cuts down on administration time even when adding the time to administer the
NEPSY-II scales, suggesting that the proposed model of estimating adaptive skills is more time effective and at least as accurate as using a full IQ test.

**Aim 3c.** The proposed model will more closely fit the data than the conventional model. Model fit indices will be used to directly compare the ability of the proposed model to account for the variance in the data.

Although the theoretical model met indices of good fit of the data overall, it did not fit the data better than the conventional model, as assessed by SEM measures of model fit. This may have been affected by the low sample size and use of multiple latent variables in the theoretical model. Once again, this provides evidence for interpreting IQ tests the same way for children with ASD as we do for typically developing children while still leaving open further research regarding how social cognition relates to cognitive skills and feeds into adaptive behavior.

**Hypothesis 4: Executive functioning acts as a mediator in the relationships among verbal ability, nonverbal ability, and social ability and adaptive abilities.**

**Aim 4.** Executive functioning as defined by the BRIEF GEC scale will be found to mediate the relationship among the three cognitive domains of the proposed model and adaptive abilities.

As explained earlier the intended mediation analysis could not be conducted due to sample size and power constraints. An alternative analysis was pursued instead to evaluate executive functioning as an additional measure of cognitive ability that also had a direct relationship with adaptive skills. This addition of a parent measure of executive functioning did not have robust support. The correlation between cognitive ability and executive functioning was not significant, suggesting that executive functioning does not significantly add to the model regarding the relationship between cognitive ability and adaptive skills. Previous studies have
found inconsistent results when analyzing the relationship between executive functioning and adaptive skills (Ozonoff et al., 2004; Kenworthy et al., 2005) and executive functioning with intelligence (Blijd-Hooegewys, Bezemer & van Geert, 2014; Rosenthal et al., 2013) and this study is the first to explore executive functioning as a manifest variable for latent cognitive ability.

Post-hoc Analyses

Overall, the pattern of correlations between the measures indicate that a comprehensive assessment of a school age child with ASD must include measures of cognitive abilities, social skills, adaptive skills and executive functioning as all of these assessments provide unique information that can contribute to education and intervention planning. Specifically, while social ability measures may have some overlap, those that measure Theory of Mind contribute novel information not captured by other scales. Similarly, the independence of the BRIEF scores from measures of intelligence and adaptive skills despite significant deficits emphasizes the importance of measuring these deficits in order to gain a clearer picture of the whole child. Lastly, while the significant inverse relationship between Theory of Mind and ADOS-2 severity is an expected finding, it is an important finding regarding the relationship between the NEPSY-II and the updated ADOS-2 that has not yet been reported in previous literature.

Summary of conclusions

On the whole, results indicate that the SB-5 can be used as a valid assessment of the cognitive abilities of school-age children with ASD. The model fit indices of the proposed theory of intelligence provide support for inclusion of social abilities as a dimension of overall cognitive abilities. Whether the usefulness of including social abilities into a cognitive model is unique to children with ASD or common to all children is still unknown. If it were unique to children with ASD, it would highlight the need to model the impact of social demands across
evaluations to measure their impact in assessment of skills and abilities of this population. This could then be used to understand the gap between potential abilities and actual performance of skills so often seen in children and adolescents with ASD. Furthermore, interventions could then strive to improve the social cognition deficits that may be impeding the ability of children with ASD to apply their skills and abilities in everyday settings.

In further regard to the proposed model, the division of verbal abilities and perceptual abilities into fluid reasoning and crystalized knowledge domains was not supported. This aspect of the model was meant to reflect the profile of skills and weaknesses found in children with ASD that were not well modeled by theories of strength in concrete skills nor strength in nonverbal abilities. By not finding support for this breakdown, an explanation for the diverse spread of skills in this population is still lacking, but may indicate that as children are identified earlier and exposed to more efficacious interventions, the classic cognitive profile of ASD is diminishing.

Although the proposed model did not predict adaptive scores more accurately than the current model, it does predict as accurately with fewer subtests and less assessment time. Further research will examine the additive effect of social skills when combined with a full IQ test (rather than just four subscales) in regards to both a cognitive model and its ability to predict adaptive functioning. Clinicians and school officials may also choose to administer abbreviated tests to save time and lesson demands on children while still gathering as much information as they did previously.

Lastly, executive functioning deficits were found to be unrelated to both cognitive abilities and adaptive skills despite their high prevalence in the sample. Thus, the high intercorrelations among subtests and domains for the SB-5 and the lack of statistically significant
improvement in prediction with the proposed model confirm the utility of the SB-5 with this population but also highlight the need for more research on how social skills and executive functioning deficits relate to the application of cognitive abilities in everyday life and growth of adaptive skills. One possible factor in this was that the cognitive and social skills assessments were direct child observations while the executive functioning and adaptive skills assessments were parent-rating forms. In small samples such as this one, these assessment modalities may impact how the relationships among skills are modeled due to measurement error (Kline, 2011). That is, each measurement modality (parent measure, direct observation, etc.) comes with its own measurement error or noise. With a larger sample size, the errors from the same measurement modalities can be correlated to each other and reduced in the overall model. This smaller sample did not provide enough data to support doing so.

Overall, this study confirms that IQ scores of children with ASD may be used similarly to the IQ scores of typically developing children, but more targeted assessments of other domains is necessary to understand the challenges they face in everyday life.

Limitations

This study explored the relationship of social ability to cognitive skills indirectly by examining social ability, as measured by parent report and direct child observation, relative to both cognitive and adaptive abilities. A limitation is that the study did not fully separate effects of social ability from the cognitive testing due to the social nature of the cognitive assessment itself, without a non-social assessment as a comparison. That is, the SB-5 takes place in the context of a social interaction between the examiner and child. Ideally, future studies will use cognitive tasks that require little to no social interaction with an examiner in order to better control for the effect of social skills on intelligence assessment performance. We also relied
solely on parent report for measures of adaptive behavior and executive functioning. Unfortunately, it was not feasible to add additional sources of information due to such factors as (1) absence of well-established behavior observations (for adaptive skills), (2) need for a greater number of observations to measure a comparable number of skills (for executive functioning) and (3) need to consent additional informants and have support personnel (to obtain teacher reports). Including both parent-report and child observations of performance-based assessment could have provided more information about these deficits and how that manifest across different environments (Anderson et al., 2002).

A related concern is that the model may oversimplify the structure of intelligence in individuals with ASD. For example, attention and working memory tasks might form a separate factor. Examples of crystalized tasks in this domain include searching for symbols or codes or repeating back strings of numbers in the same order heard. Fluid attention and working memory ability captures the ability of the individual to attend to and manipulate new information. Such tasks include letter-number sequencing and monitoring work. One study (Minshew, Goldstein & Siegel, 1997) suggests that individuals with ASD may have a particular strength in this area. The current study focuses on the three factors that are judged to be most consistent with the literature on individuals with ASD and will not provide information on attention and memory, as discussed in the introduction. Since the addition of social skills was supported, a direction for future studies would be to test whether additional factors such as working memory and attention should be incorporated in a more complete model of IQ by testing the combinations of the full IQ test with the social ability additions. It is predicted that this model would increase the ability of the model to predict adaptive behavior.
This study did not use a measure of ASD symptom severity to characterize its participants and control effects of severity in the proposed model of cognition. The functioning level of individuals with ASD is usually estimated based on cognitive ability, language skills, adaptive abilities, and social skills. All of these abilities are being measured and represented in the analyses completed for the path model. Another measure of ASD symptom severity, such as the Social Responsiveness Scale - Second Edition (Constantino, 2012) could create redundancy in the symptoms it measures while leaving out other important factors of symptom severity (e.g. IQ, adaptive skills) in this population. Additionally, although the ADOS-2 provides a severity score, it is a new feature of this measure that has not yet been studied in relationship to cognitive abilities and adaptive skills, so although this data has been gathered, it was not used in the path model analyses. It may be possible in the future to use the ADOS-2 severity score to control for ASD symptom severity in the future. It was not used in this study as the number of controls and variables that could be used in analyses was already limited by the small sample size.

Lastly, as in much clinical research, there was limited power due to a small sample size and great heterogeneity within the sample. This was an especially limiting factor when it came to testing the factor structure and fit of the models, which would ideally include a sample closer to 400 participants. Although the models had a high level of fit in SEM analyses, there may not have been enough power to detect a false positive. Therefore, these analyses must be treated as preliminary findings to be replicated with a larger sample of children with ASD, and ideally, a control group of typically developing children. Additionally, measures of the individual aspects of intelligence (i.e. nonverbal fluid reasoning, nonverbal knowledge, verbal knowledge, etc.) would ideally come from different sources so that the factor structure could not be attributed to
the features of a particular intelligence test (e.g., the SB-5) (Minshew, Goldstein & Siegel, 1997; Minshew & Goldstein, 1998).

**Research Implications**

This study provides robust support for the use of the SB-5 in measuring the cognitive skills of children with ASD. Test makers use high intercorrelations between their subtests in order to evaluate strengths and weakness in individuals (Clark & Watson, 1995). The high intercorrelations found in this study indicate that, although individual children with ASD may have large scatter in abilities, this scatter does not affect the utility of the SB-5 for measuring these varied strengths and weaknesses.

In contrast to their similarity to the typical population in cognitive abilities, our ASD sample still had significantly lower adaptive skills. The sample’s mean adaptive behavior composite score was almost two standard deviations below average and 17.8 points lower than the sample’s mean IQ, indicating that even children in the study with above average IQ tended to have significant deficits in their adaptive skills, in accordance with previous studies (Klin et al., 2007; Kanne et al., 2010). We found a significant (albeit small) correlation between cognitive ability and adaptive skills, indicating that higher cognitive scores are related to higher adaptive scores, but we still lack an explanation for the discrepancy between cognitive and adaptive skills. Future research should continue to delve into the discrepancy between cognitive functioning and adaptive functioning in order to better understand how cognitive abilities are applied in everyday situations and to develop interventions that are better at targeting that misapplication.

Similarly, our sample scored significantly below average in social skills measures and had clinically significant difficulties with executive functioning. Preliminary analyses that involved solely zero order correlations revealed a significant positive relationship between
measures of theory of mind and cognitive skills. This is an expected finding as the ability to reason and use previous knowledge are involved in the specialized process of making inferences about others’ mental states (i.e., theory of mind). Unexpectedly, however, verbal cognitive abilities and parent rated social skills were negatively correlated. Although counterintuitive, this finding has a number of possible explanations. First, parents of higher functioning children have higher expectations for their children, which may lead them to make more critical judgments of their child’s ability than do parents of children with lower functioning ASD (Knott, Dunlop & Mackay, 2006). Additionally, children with ASD and high verbal abilities may find themselves in complex social situations more often (e.g., placement in general education settings at school; Eaves & Ho, 1997; Aljunied & Frederickson, 2011), in effect giving them more opportunity to reveal their deficits. Research examining this performance deficit in social skills across environments and raters could help to illuminate this finding.

Lastly, by adding in the social abilities component to intelligence while taking out six out of ten SB-5 subtests, the proposed model predicted adaptive skills at least as well as a full IQ test. Further research can test whether the predictive value of social ability combined with an abbreviated assessment of IQ is unique to the ASD population or also found in the typically developing population. Furthermore, the social ability factor can also be examined alongside a full IQ test to determine its additive effect of predicting skills over and above typical cognitive testing.

Clinical Implications

Although the proposed model of intelligence did not provide statistically more information that did the conventional model, the additional information it did provide has substantial clinical value. First, the confirmation of the applicability of a gold standard IQ test
being used in this population is helpful across clinical and academic settings. Additionally (as presented in the discussion regarding hypotheses 3 and 4), we found that adding measures of social skills and executive functioning when attempting to create treatment plans for children with ASD in and out of the classroom, may lead to better predictions of how they are able to use their skills in their daily environment and what deficits may present themselves. These additional assessments are important to include because they provide unique information not provided by conventional IQ tests. Increased understanding of how social abilities and deficits impact the expression of cognitive abilities in children with ASD could also inspire new interventions to target these specifics deficits and guide curriculum development in finding less socially demanding ways to educate and assess these children.

Although including executive functioning in the theorized model of intelligence did not improve upon the model, the finding that nearly all children in this sample have clinically significant difficulties with executive functioning that are unrelated to cognitive abilities and adaptive skills is notable. Traditional academic assessments include intelligence tests, adaptive skill assessments, language evaluations, and achievement tests to guide recommendations on children’s classroom placement and goals. Executive functioning assessments are rarely included despite the fact that executive functioning deficits significantly impact children’s functioning in the classroom. Because cognitive and adaptive measures do not predict executive functioning ability, the deficits in executive functioning demonstrated by children with ASD are not being considered when predicting their success in classrooms and formulating their goals. The high rate of clinically significant difficulty in executive functioning in this sample speaks to the importance of including evaluations of executive functioning in treatment planning for this population, specifically because it is not measured by any of the more commonly used
assessments and is not significantly correlated with IQ nor adaptive skills. It also highlights the need for executive functioning interventions, such as the UOT intervention that showed improvement in fluid reasoning and flexibility, set shifting and organization (Kenworthy et al., 2013) as an educational priority for children with ASD from a young age.

**Future Directions and Concluding Comments**

Overall, this study provided robust evidence for the efficacious use of the SB-5 to assess the intelligence and strengths and weakness of children with ASD. It also provided initial support for the addition of social reasoning and knowledge factors as domains of cognitive ability in order to improve our ability to predict every day functioning in this population. It replicates previous findings that children with ASD and average intelligence have significant deficits in their adaptive behavior (Klin et al., 2007) and that the difference between verbal and nonverbal abilities decrease with age (Joseph, Tager-Flusberg, & Lord, 2002; Sigman & McGovern, 2005). Lastly, findings regarding executive functioning deficits and its distinction from other abilities highlight the necessity for comprehensive evaluations for children with ASD. In accordance with current reviews of school age children with ASD (Bouminger-Zviely, 2014), this study finds that only by creating a full profile of their strengths and challenges can we understand and meet the needs of children with ASD. Doing so will help them reach their fullest potential, as social and adaptive deficits predict classroom achievement where IQ fails to do so (Estes, Rivera, Bryan, Cali & Dawson, 2011; Freeman et al., 1988; White, Scahill, Klin, Koenig & Volkmar, 2006).

Future research can extend these findings in a number of directions. As previously mentioned, one avenue should be to examine how the addition of the social factors impacts the cognitive profile of typically developing children to determine if this feature is unique to ASD
and therefore needs special consideration. Another avenue would be to explore the proposed model in a younger age group (preschool age) and older age group (high school age and adult) to investigate how much the relationships amongst these variables vary with developmental progression. This would contribute to the literature regarding the development of cognitive abilities in children with ASD and may provide information on times when certain strengths or weaknesses are more pronounced. If promising results continue to be found, future research must also include an attempt to develop a fully computerized IQ test measuring the same constructs for children so that the social component of IQ testing can be fully controlled and evaluated. A study that tests typically developing children and children with ASD with a conventional IQ test and this computerized test in counterbalanced order would greatly elucidate and quantify the social impact of in-person testing. Of course, this would lead to theoretical debate regarding the external validity of such testing. Assuming a computerized IQ test leads to higher IQ scores for children with ASD due to decreased social demands, what does this imply regarding the predictive validity of the test when used to predict later achievements that are impacted by social demands? Is a pure measure of “g” more important than an enhanced prediction of everyday functioning? How could these divergent scores be integrated in order to both characterize cognitive abilities and academic achievement? In regards to both theoretical debate and practical implications for research and clinical work, these future research aims could ultimately benefit children with ASD by inspiring improved assessment and more targeted interventions.
References


Executive Function. Odessa, Fl: Psychological Assessment Resources


### Tables

Table 1

*Strengths and Weaknesses as evaluated by the literature*

<table>
<thead>
<tr>
<th>Cognitive Abilities</th>
<th>Strengths</th>
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<tr>
<td><strong>Nonverbal fluid reasoning tasks</strong></td>
<td>Pattern Analysis (SB4)&lt;sup&gt;1&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>Block Design (WISC-R, WISC-III)&lt;sup&gt;2, 6&lt;/sup&gt;</td>
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<td></td>
<td>Visuospatial areas&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>Nonverbal IQ (SB4)&lt;sup&gt;4&lt;/sup&gt;</td>
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<td>Quantitative Reasoning (SB4)&lt;sup&gt;4, 5&lt;/sup&gt;</td>
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<td>Arithmetic (WISC-III)&lt;sup&gt;6&lt;/sup&gt;</td>
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<td>Fluid Reasoning (SB-5)&lt;sup&gt;7&lt;/sup&gt;</td>
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<td>Quantitative Reasoning (SB-5)&lt;sup&gt;7&lt;/sup&gt;</td>
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<td>Visual Spatial Processing (SB-5)&lt;sup&gt;7&lt;/sup&gt;</td>
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<td><strong>Verbal crystalized knowledge tasks</strong></td>
<td>Simple memory&lt;sup&gt;3&lt;/sup&gt;</td>
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<td>Simple language&lt;sup&gt;3&lt;/sup&gt;</td>
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<td></td>
<td>Rule learning&lt;sup&gt;3&lt;/sup&gt;</td>
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<sup>1</sup> (Harris, Handleman & Burton 1991)
<sup>2</sup> (Siegel, Minshew, Goldstein, 1996)
<sup>3</sup> (Minshew & Goldstein, 1998)
<sup>4</sup> (Mayes & Calhoun, 2003)
<sup>5</sup> (Carpentiere & Morgan, 2005)
<sup>6</sup> (Dawson, Soulières, Gernsbacher & Mottron, 2007)
<sup>7</sup> (Coolican, Bryson, Zwaigenbaum, 2007)
**Table 2**

*Participant and family characteristics*

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<th>% of sample</th>
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Assessment Results

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<th>Maximum</th>
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<td>4.1</td>
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<tr>
<td>Inhibit (T score)</td>
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<td>88</td>
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<td>NEPSY-II</td>
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<td>Affect Reasoning (scale score)</td>
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<td>2</td>
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Table 4

Subtest correlations of the SB-5

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<tr>
<th></th>
<th>NV-FR</th>
<th>NV-Kn</th>
<th>NV-QR</th>
<th>NV-VSR</th>
<th>NV-WM</th>
<th>V-FR</th>
<th>V-Kn</th>
<th>V-QR</th>
<th>V-VSR</th>
<th>V-WM</th>
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<td>0.71</td>
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<tr>
<td>NV-VSR</td>
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<td>0.50</td>
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<tr>
<td>NV-WM</td>
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<td>0.63</td>
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<tr>
<td>V-FR</td>
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<td>0.64</td>
<td>0.70</td>
<td>0.57</td>
<td>0.64</td>
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<tr>
<td>V-Kn</td>
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<td>0.70</td>
<td>0.69</td>
<td>0.60</td>
<td>0.73</td>
<td>0.79</td>
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<tr>
<td>V-QR</td>
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<td>0.69</td>
<td>0.68</td>
<td>0.55</td>
<td>0.73</td>
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<td>0.68</td>
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<tr>
<td>V-VSR</td>
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<td>0.55</td>
<td>0.56</td>
<td>0.63</td>
<td>0.74</td>
<td>0.78</td>
<td>0.63</td>
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<tr>
<td>V-WM</td>
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<td>0.61</td>
<td>0.72</td>
<td>0.50</td>
<td>0.70</td>
<td>0.65</td>
<td>0.72</td>
<td>0.53</td>
<td>0.59</td>
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<tr>
<td>FSIQ</td>
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<td>0.81</td>
<td>0.84</td>
<td>0.73</td>
<td>0.84</td>
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<td>0.89</td>
<td>0.81</td>
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<td>0.82</td>
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</table>

n = 53
All correlations significant at p<0.01

NV-FR – Nonverbal Fluid Reasoning
NV-Kn – Nonverbal Knowledge
NV-QR – Nonverbal Quantitative Reasoning
NV-VSR – Nonverbal Visual/Spatial Reasoning
NV-WM – Nonverbal Working Memory
V-FR – Verbal Fluid Reasoning
V-Kn – Verbal Knowledge
V-QR – Verbal Quantitative Reasoning
V-VSR – Verbal Visual/Spatial Reasoning
V-WM – Verbal Working Memory
FSIQ – Full Scale IQ
Table 5

*Domain correlations of the SB-5*

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<tr>
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<th>VIQ</th>
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<th>Kn</th>
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<th>VSR</th>
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<td>Kn</td>
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<td>0.80</td>
<td>0.77</td>
<td>0.70</td>
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n = 53
All correlations significant at p<0.01

FSIQ – Full Scale IQ
NVIQ – Nonverbal IQ
VIQ – Verbal IQ
FR – Fluid Reasoning
Kn – Knowledge
QR – Quantitative Reasoning
VSR – Visual/Spatial Reasoning
WM – Working Memory
### Table 6

**Correlations between SB-5 and Vineland-II**

<table>
<thead>
<tr>
<th>SB-5 - FSIQ</th>
<th>SB-5 - NVIQ</th>
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<th>SB-5 - FR</th>
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<td>Vineland-II ABC</td>
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n = 53

* Correlation is significant at p<0.05
** Correlation is significant at p<0.01

FSIQ – Full Scale IQ
NVIQ – Nonverbal IQ
VIQ – Verbal IQ
FR – Fluid Reasoning Index
Kn – Knowledge Index
ABC – Adaptive Behavior Composite
DLS – Daily Living Skills
Table 7

**Correlations between SB-5, SSIS-RS and NEPSY-II**

<table>
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<tr>
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<th>SB-5 - NVIQ</th>
<th>SB-5 - VIQ</th>
<th>SB-5 - FR</th>
<th>SB-5 - Kn</th>
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<tr>
<td>NEPSY AR</td>
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<td>0.40**</td>
<td>0.44**</td>
<td>0.40**</td>
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<tr>
<td>NEPSY TOM</td>
<td>0.67**</td>
<td>0.63**</td>
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<td>0.66**</td>
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n = 53

* Correlation is significant at p<0.05
** Correlation is significant at p<0.01

FSIQ – Full Scale IQ
NVIQ – Nonverbal IQ
FR – Fluid Reasoning Index
Kn – Knowledge Index
SSIS-RS – Social Skills Improvement System-Rating Scale
NEPSY AR - NEPSY-II Affect Recognition
NEPSY TOM – NEPSY-II Theory of Mind
Table 8

*Bartlett factor analysis results*

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<td>NEPSY-II Affect Recognition</td>
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NV-FR – Nonverbal Fluid Reasoning
NV-Kn – Nonverbal Knowledge
V-FR – Verbal Fluid Reasoning
V-Kn – Verbal Knowledge
SSIS-RS – Social Skills Improvement System-Rating Scale
Table 9

*Correlations between BRIEF GEC and other measures*

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</tr>
<tr>
<td>Vineland-II ABC</td>
<td>-0.25</td>
<td>0.07</td>
</tr>
<tr>
<td>ADOS-2 severity score</td>
<td>-0.01</td>
<td>0.97</td>
</tr>
<tr>
<td>NEPSY-II Affect Recognition</td>
<td>-0.27</td>
<td>0.06</td>
</tr>
<tr>
<td>NEPSY-II Theory of Mind</td>
<td>0.16</td>
<td>0.25</td>
</tr>
</tbody>
</table>

GEC – Global Executive Composite  
SB-5 – Stanford-Binet, 5th Edition  
FSIQ – Full Scale IQ  
ABC – Adaptive Behavior Composite
Figure 1. Structure of the Stanford-Binet Intelligence Scales, Fifth Edition
Figure 2. Structure of the Wechsler Intelligence Scales for Children, Fourth Edition
Figure 3. Current model of intelligence and adaptive skills

*Factor present only on the SB-5
+Factor present only on the WISC-IV

Key:
Gc – Crystalized knowledge
Gf – Fluid reasoning
Gm – Working memory
Gq – Quantitative reasoning
Gs – Processing Speed
Figure 4. Proposed structure of intelligence

Key:
Gc – Crystalized knowledge
Gf – Fluid reasoning
Figure 5. Confirmatory factor analysis for the domains of the proposed model

Key:
SB-5 – Stanford-Binet, 5th Edition
V-Kn – Verbal Knowledge
V-FR – Verbal Fluid Reasoning
NV-Kn – Nonverbal Knowledge
NV-FR – Nonverbal Fluid Reasoning
SSIS-RS – Social Skills Improvement System-Rating Scale
Figure 6. Conventional model of Stanford-Binet, 5th Edition Full Scale IQ score (FSIQ) predicting the Vineland Adaptive Behavior Scales, 2nd Edition Adaptive Behavior Composite (ABC)
Figure 7. Proposed model of the Verbal Factor, Perceptual Factor, and Social Factor predicting the Vineland Adaptive Behavior Scales, 2nd Edition Adaptive Behavior Composite (ABC)
Figure 8. Proposed model with the BRIEF Global Executive Composite (GEC) mediating the relationship between the cognitive factors and adaptive abilities (ABC)
Figure 9. Age of participants
Figure 10. Stanford-Binet Full Scale IQ score distribution
Figure 11. Vineland-II Adaptive Behavior Composite score distribution
Figure 12. Autism Diagnostic Observation Schedule-2\textsuperscript{nd} Edition severity score distribution
Figure 13. Social Skills Improvement System-Rating Scales social skills score distribution
Figure 14. BRIEF Global Executive Composite score distribution
Figure 15. Graph of Fluid Reasoning subscale difference scores
Figure 16. Confirmatory factor analysis of proposed model

*p < 0.05
Figure 17. Model of proposed theory of intelligence predicting adaptive skills

*p < 0.05
*p < 0.05

Figure 18. Model with executive functioning as a mediator