Predictors of Basic Reading Skills
in High-Functioning Children with Autism Spectrum Disorder:
The Role of Cognitive Flexibility

by

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Dedication

To Jonathan, Jeremy, and Jessica

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Abstract

      The number of high-functioning children identified with Autism Spectrum Disorder (ASD) has greatly increased in recent years. The academic skills of these children show considerable variation, and some children struggle with basic reading. It is important to update and expand our understanding of factors contributing to the development of word reading skills in this population because revised diagnostic criteria, small samples, large age and ability ranges, a narrow selection of variables, and varying outcome measures limit the generalizability of older results.

      The purpose of this study was to document systematically the literacy, cognitive, language, and executive function skills of high-functioning children with ASD in the early grades, and to identify predictors of basic reading skills. Although restrictive behaviors and communication and social deficits define ASD, cognitive inflexibility is also a life-long challenge. Since cognitive flexibility may facilitate the acquisition of reading, measures of this skill were included as possible additional predictors.

      Assessments were conducted with a diverse sample of 63 children with ASD, ages 6 through 9. All participants had nonverbal ability above 80, were enrolled in grades 1 - 4, and participated in the general curriculum. Group performance on all measures was reviewed to determine patterns of strength or weakness. A series of regression analyses was conducted to identify predictors of basic reading and to determine whether cognitive flexibility explained additional variance.

      Basic reading skills varied greatly, with many children, especially first-graders, exhibiting above-average skills. Verbal, nonverbal, language, phonemic awareness, and word reading skills were average, but weaknesses were found in cognitive flexibility, working memory, visual processing speed, listening comprehension, and retrieval fluency. As is the case for typically developing children, measures of nonverbal ability, language, and phonemic awareness had strong relationships with the basic reading

measures, and were able to predict 55 percent of the variance, but cognitive flexibility did not contribute significantly after controlling for these factors.

Results support the importance of specialized instruction and accommodations for children with ASD, even those with above-average ability, in order to address deficits in language and executive functions.

CHAPTER 1

Introduction

The number of children identified with Autism Spectrum Disorder (ASD) has increased dramatically in recent years (Centers for Disease Control and Prevention, 2012; Newschaffer et al., 2007; Yeargin-Allsopp et al., 2003). Whether this is due primarily to increased awareness amongst educators, psychologists, and medical professionals, broadened diagnostic criteria, or a true increase in the percentage of children affected is a matter of debate and research (Shattuck, 2006). The result, however, is a sharp increase in the number of high-functioning children with ASD receiving special education services in schools throughout the United States (National Center for Education Statistics, 2007), and our knowledge of their academic needs is inadequate.

Early intervention is extremely important in the prognosis of children with ASD. Since the primary areas of atypical development in young children are social, communicative, and behavioral, the provision of early learning experiences to increase social attention, imitation and flexibility can help develop language and the ability to learn from others, to cascade toward a more normal trajectory of cognitive development (Karmiloff-Smith, 1998). Considerable international attention has therefore been given to research, development, and education in the area of early intervention.

Students in grade school, however, are past the scope of early interventions. High-functioning students with cognitive, language, and behavioral abilities sufficient for inclusion into regular classrooms are often given little specialized support to help them develop academic and other skills necessary for independence in adulthood (Griffin, Griffin, Fitch, Albera, & Gingras, 2006). They are often placed in general education classrooms with teachers who have minimal knowledge of ASD, supported by paraprofessionals with little training, and on the caseloads of social workers or teacher consultants who have little specialized training in autism (Lanter & Watson, 2008). The educational community is actively working to improve services

for students with ASD through increased education and training for educators and parents. Although information about supports such as visual schedules, sensory breaks and behavior plans has been widely disseminated, there is less discussion about academic achievement and intervention. Schools may provide support to improve classroom behavior, but offer less specialized intervention towards improving decoding, comprehension, writing or math skills (Newman et al., 2007).

Teachers and other professionals working with students with autism are challenged to provide optimal interventions, not because they cannot understand the basics of ASDs or of learning, but because students present differently and are challenged by different skill areas at different ages. It is said, "If you know one person with autism, you know one person with autism." Although children with ASD by definition present with deficits in social skills, language and behavior, other abilities vary greatly due to the interactional effects of intelligence, environment, intervention and development on current functioning. In addition to the great diversity *among* children, there are developmental changes *within* children, exhibited in dramatically different skills and abilities at different ages. Because ASD is a complex developmental disorder, one way to better understand it is to focus research on specific age groups, developmental stages, ability levels or skill complexities.

Research and interventions usually focus on improving the main deficit areas in ASD. However, independence in adulthood requires more than social and communication skills; reading and other academic skills are also necessary for success (Internation Reading Association & NAEYC, 1998). There is a rich history of research into social and cognitive abilities in ASD, but less attention has been paid to the acquisition and achievement of academic skills such as reading, and even less to effective methods for remediation (Chiang & Lin, 2007; Mayes & Calhoun, 2006; Whitby & Mancil, 2009). In addition, much of the research about reading and ASD dates back to a time when diagnostic criteria were stricter and the average participant had more severe autistic and cognitive impairment; those results may not apply to many mildly impaired students currently identified.

The most important period for literacy development is early childhood (IRA & NAEYC, 1998). Although there is some recent research into literacy skills in students with ASD (Mayes & Calhoun, 2006; Nation, Clarke, Wright, & Williams, 2006; Smith Gabig, 2010), it is often restricted by extremely small samples or a vast range of cognitive ability and age amongst

participants, which could confound or diffuse results. The reading challenges of a six-year-old with ASD and average intelligence are different from those of a twelve-year-old because of the increasing complexity of both verbal ability and literacy expectations; while six-year-olds are learning to recognize and decode words, twelve-year-olds should be learning to comprehend more complex material and connect it to background knowledge. It is developmentally appropriate, therefore, to focus an investigation of the attainment of word reading skills on the early elementary years.

To understand reading skills it is important to consider factors that contribute to reading development. Correlates of basic reading skills in typically developing children include cognitive and language factors such as general intelligence, oral language, and phonemic awareness (Hammill, 2004; Mayes, Calhoun, Bixler & Zimmerman, 2008; Speece, Ritchey, Cooper, Roth & Schatschneider, 2003). It is not known if all these factors are important in the prediction of basic reading skills in high-functioning children with ASD, nor how these factors interrelate. It is also not known whether other factors may also play a role.

There are indications that weaknesses in executive functions, particularly those relating to divergent thinking constructs (Guilford, 1967) such as cognitive flexibility and fluency, are related to autistic symptoms (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Lopez, Lincoln, Ozonoff, & Lai, 2005; Turner, 1999). Although executive functions have been defined in different ways, facets commonly discussed are planning, flexibility (set-shifting), fluency (generativity), inhibition/impulsivity, attention, initiation, organization and self-monitoring. It is clear that these functions affect learning (Meltzer, 2007). It is also clear that difficulties or delays in the development of executive functions, particularly cognitive flexibility, are common in ASD (Gioia, Isquith, Kenworthy, & Barton, 2002; Hill, 2004; McEvoy, Rogers, & Pennington, 1993; Ozonoff, South, & Provencal, 2007).

Cognitive flexibility is the ability to disengage and shift attention, consider more than one characteristic of something, and think divergently; deficits in cognitive flexibility are seen in children with ASD (Ozonoff, 1997; Verte, Geurts, Roeyers, Oosterlaan & Sergeant, 2006). Measures of cognitive flexibility have also been found to relate to the ability of typically developing children to learn to read words (Berninger & Nagy, 2008; Cartwright, 2008; Gaskins, 2008; Homer & Hayward, 2008). Learning to decode requires flexibility to think simultaneously about word meanings and word sounds, accept font variations in the appearance of letters,

synthesize a whole from parts, and accept and learn a non-linear system of phonics, where a sound can be represented by different letters or letter combinations, and some letters represent more than one sound (Cartwright, 2008). Because of the noted weakness in cognitive flexibility, learning to read should hypothetically be difficult for cognitively rigid children with ASD; yet research indicates that word-reading ability in the ASD population varies widely: while it is often commensurate with IQ (Whitby & Mancil, 2009), it is sometimes better than expected by cognitive ability (Frith & Snowling, 1983; Mayes & Calhoun, 2003a, 2003b), and sometimes worse (Åsberg, Dahlgren, & Sandberg, 2008; Jones et al., 2009; Nation et al., 2006; Spector, 2009). It is not clear whether children with ASD of normal intelligence learn to read words at a typical age because most research into reading and ASD has included a large range of participant age and ability. It is clear, however, that achievement varies, leading to some interesting questions: if most children with ASD exhibit deficits in cognitive flexibility, why are some able to read words easily while others struggle? Are they using phonological strategies to decode words or primarily relying on visual strengths to memorize whole words? Do many high-functioning children in the early grades have difficulty reading words? Do predictors of basic reading skills for typically developing children such as vocabulary and phonemic awareness similarly correlate with basic reading skills for children with ASD? Does cognitive flexibility add to the predictive power of IQ and language on reading skills?

This study was designed to address these questions. A sample of high-functioning children with ASD in the early elementary years was recruited in order to examine cognitive, language, and word reading performance; determine correlates of basic reading skills; and investigate relationships with cognitive flexibility.

CHAPTER 2

Review of Literature

This chapter begins with an overview of Autism Spectrum Disorder (ASD) and developmental effects on language and cognition. Executive functions are then reviewed, with a focus on cognitive flexibility, including deficits in ASD and possible effects on development. The last section discusses reading, from a brief review of models to a detailed examination of recent research into the reading skills of children with ASD.

Autism Spectrum Disorder and Development

Autism is a pervasive developmental disorder characterized by impairments in social reciprocity, communication, and imagination (Frith, 1991; Happé & Frith, 1995; Mitchell, 1997) as well as repetitive behaviors or interests (Lord & Risi, 2000). It is pervasive in that it affects functioning in all environments throughout the life course, and developmental in that characteristics of the disorder change as children interact with their environment and develop from infancy to adulthood (Wetherby, Prizant, & Schuler, 2000). The term Autism Spectrum Disorder encompasses the previously distinguished diagnoses of Autism, Asperger's Disorder and Pervasive Developmental Disorder - Not Otherwise Specified (Macintosh & Dissanayake, 2004; Wetherby & Prizant, 2000).

Abnormal brain development is assumed to underlie autism's effects on social and cognitive development (Akshoomoff, Pierce, & Courchesne, 2002). Some children exhibit smaller head circumference at birth but brain overgrowth during infancy (Courchesne, Carper, & Akshoomoff, 2003; Klin et al., 2004). There is also evidence of abnormally slowed brain growth in later childhood (Courchesne et al., 2001). While there may be an increased capacity for the storage of information, fewer connections are made, which inhibits higher-level learning. It is possible that the underdevelopment of neurons in the frontal cortex during the preschool years

causes problems with the integration of information with the rest of the brain, leading to other abnormalities and autistic traits (Courchesne, Redcay & Kennedy, 2004). Neuroconstructivists theorize that early abnormalities affect interaction with the environment and people in a cascading effect that leads to further brain differences due to the plasticity of the brain during early development (Karmiloff-Smith, 1998).

An early neurologically-based deficit of social attention in the child affects interactions with others and leads to a deviant trajectory in social and cognitive development (Mundy & Stella, 2000; Trevarthen & Aitken, 2001). Before cognition regulates behavior, a neuroaffective motivation system primes typically developing infants to focus on humans and give precedence to social information. Impairment of this early social attention (as in the case of children with ASD) severely affects nonverbal interactions between caregiver and child, with the ensuing implications for what the child is able to learn from them. Such interactions typically lay the groundwork for later development in language, cognition and socialization (Adamson, McArthur, Markov, Dunbar, & Bakeman, 2001).

Attention, Shifting Attention, and Imitation. Deficits in attention affect the development of language and cognition, and difficulties shifting attention are related to cognitive rigidity. Children with ASD often exhibit unusual patterns of attention: hyperfocusing on minute objects in the environment such as dust particles in the air or lint on the floor, while underattending to other stimuli, especially social stimuli (Dawson et al., 2004; Mayes, Calhoun, Mayes & Molitoris, 2012; Roeyers, Van Oost, & Bothuyne, 1998). An early sign of autism, even during the first year of life, is a diminished response to a parent's voice or the child's name (Baranek, 1999; Ceponiene et al., 2003; Dawson et al., 2004 Osterling, Dawson, & Munson, 2002). Compared to typically developing and developmentally disabled or delayed children, children with ASD attend more to objects than to people and shift attention between two objects more often than between two people or between a person and an object (Charman et al., 1997, 2000; Dawson et al., 2004; Maestro et al., 2002; Swettenham et al., 1998). Attention deficits in autism include difficulties in disengaging, widening the attentional spotlight, reorienting to a new focus, and shifting between visual and auditory stimuli (Allen & Courchesne, 2001; Courchesne et al., 1994; Harris, Courchesne, Townsend, Carper, & Lord, 1999; Landry & Bryson, 2004; Renner, Klinger, & Klinger, 2006).

Attention shared with another person (intersubjectivity, joint attention, or social referencing) is essential to normal cognitive, social and language development (Gauvain, 2001). Children with autism have difficulty sharing attention with others and directing attention to others (Adamson et al., 2001; Brown & Whiten, 2000; Carpenter & Tomasello, 2000; Mundy & Stella, 2000; Stahl & Pry, 2002; Wimpory, Hobson, & Williams, 2000). Infants and toddlers with ASD pay less attention to caregivers, make less eye contact, show less interest in sharing experiences, and are less likely to use nonverbal referential communication, such as pointing to objects of interest (Baranek, 1999; Lord & Risi, 2000; Maestro et al., 2002; Trevarthen & Aitken, 2001; Young, Brewer, & Pattison, 2003). Children with ASD appear to follow a different developmental trajectory than typically developing children, developing joint attention skills only after imitative learning and referential language have been attained (Carpenter, Pennington, & Rogers, 2002). This delay in the development of shared attention is thought to contribute to the language delays and awkward social skills of even high-functioning children with ASD (Weatherby & Prizant, 2000).

Impairments in attention shifting, a precursor of cognitive rigidity, may also contribute to problems with imitation, which in turn affect the development of language and cognition (Brown & Whiten, 2000). Most children with ASD show an impaired ability to imitate (Dawson et al., 2002; Hobson & Lee, 1999; Rogers & Bennetto, 2000); however, intensive intervention has been shown to improve both imitation and communication skills in preschoolers with ASD, suggesting a specific delay, rather than a deficit, in the ability to imitate (Ben-Itzchak & Zachor, 2007).

In summary, deficits or delays in the ability to shift attention between objects, people, and modes contribute to the social and language impairments seen in children with ASD. Shifting attention is an early facet of cognitive flexibility.

Language Development. Impairment in the ability to shift attention directly contributes to deficits in language, while the language deficits further affect development in cognition and reading. In a typically developing infant, the preference for humans over objects, the ability to direct attention, and the ability to imitate are essential for optimal language development (Trevarthen & Aitken, 2001). When a child's ability to engage in intersubjective interactions is impaired, the child misses scaffolded learning opportunities with caregivers, which may lead to

delays in social, language and cognitive development (Weatherby & Prizant, 2000). Difficulty shifting attention between stimuli and a reduced interest in people can impede social referencing and referential learning (Adamson et al., 2001). This can affect language development, especially lexical development, as diminished joint attention in the toddler years reduces the accuracy of lexical mapping and affects growth in vocabulary and concepts (Ben-Itzchak & Zachor, 2007).

Language development is dependent upon both the environment and more innate factors such as orientation to humans, phonological sensitivity, associative memory and a rule-learning system. When an infant has a significant deficit in any of these areas, it will affect language development, regardless of the richness of the language environment. Research has indicated that syntactic development is highly heritable and facilitated by innate language acquisition mechanisms (which may be damaged or overly rigid in autism), but lexical development is more dependent upon cognitive ability, social skills, memory and the environment (Ganger, 2000; Hoff, 2001). Thus, while basic language skills may be directly impaired in autism, vocabulary development may be affected at a secondary level due to social and cognitive deficits.

Many children with classical or severe autism do not develop language at all, and those who do may exhibit echolalia, abnormal prosody, or difficulty in the use of pronouns (American Psychiatric Association, 2000; Klinger, Dawson, & Renner, 2003; Roberts, 1989). Pragmatic impairments affected by cognitive rigidity (e.g., problems with conversation reciprocity, inappropriate topic shifts, an inability to integrate words with gestures, and difficulty considering the listener's needs and knowledge) are common in children with mild autism (Tager-Flusberg, 2001). There may also be semantic impairments, such as an underuse of vocabulary, difficulty with word retrieval, and difficulty understanding humor, irony or implied meaning (APA, 2000; Klinger et al., 2003).

Language development has been an important focus in research on ASD, both as a predictor and as an outcome variable. Longitudinal studies suggest that nonverbal ability at age two facilitates development in verbal and nonverbal communication, which then supports development in language (Anderson et al., 2007; Ben-Itzchak & Zachor, 2007;Thurm, Lord, Lee, & Newschaffer, 2007). Compared to children with other disorders, children with ASD need a higher level of nonverbal ability in order to develop language at all (Lord, Risi, & Pickles, 2004).

This difference could be due to difficulties related to cognitive flexibility, such as shifting attention and attending to or imitating others.

Cognitive Development and High-Functioning Autism. Cognitive deficits or delays can also affect the acquisition of basic reading skills. Although the IQs of children with ASD range from below to above normal, most children experience some delay in cognitive development, especially verbal intelligence (Grigorenko et al., 2002). A developmental lag appears in formal evaluations of individual ability; on average, fullscale IQ scores gradually increase through the preschool and early elementary years until around 8 to 10 years, when verbal ability catches up to nonverbal ability (Mayes & Calhoun, 2003a, 2003b). In other words, the delayed language development of children with ASD may depress measures of verbal intelligence (VIQ) and fullscale intelligence (FSIQ) in high-functioning children until the early elementary years (Joseph, Tager-Flusberg, & Lord, 2002). Since traditional measures of verbal intelligence presuppose that children can consider and manipulate words on several levels, it is possible that cognitive rigidity in children with ASD further depresses estimates of VIQ.

The delayed or depressed assessments of cognitive abilities, especially verbal intelligence, in children with ASD make it difficult to match subjects for comparison groups in research relating to cognitive flexibility (Russo et al., 2007), language (Tager-Flusberg, 2004), or reading (Smith Gabig 2010). Varying selection methods for comparison groups contribute to inconsistent results.

Although many children with ASD experience delays in cognitive development, some meet criteria for cognitive impairment, defined as an IQ of 70 or below (Yeargin-Allsopp et al., 2003). "Classic" autism is a combination of deficits in social development, imitation, and language along with cognitive impairment. Much of the research into reading and autism has focused on, or included, children with cognitive impairment. However, the current broader criteria for ASD include children with normal or above normal intelligence, children who did not experience a significant delay in language development, and those with subtler indications of rigid behaviors or interests. Higher ability in any area can lessen the impact of ASD on development and overall functioning compared to classic autism.

The population of children identified with an Autism Spectrum Disorder continues to grow and change. In 1996 autism was estimated to affect 3.4 children per thousand, and 68%

also had a cognitive impairment, defined as an IQ of 70 or below (Yeargin-Allsopp et al., 2003). In 2008 the prevalence of Autism Spectrum Disorder was estimated at 11.3 per 1000, or one in 88 children, with only 38% classified with cognitive impairment (Centers for Disease Control and Prevention, 2012). Cognitive ability in the average to above-average range can mitigate the effects of ASD on development; however, even high-functioning children with ASD have often been reported to exhibit learning disabilities in math or reading (Frith & Hill, 2004; Jones et al., 2009; Mayes & Calhoun, 2006).

The inclusion of children with both cognitive impairment and autism in research makes it difficult to discern the impact of each disability on basic reading skills. Changing diagnostic criteria also make it difficult to generalize findings from older research conducted with lower-functioning students to today's higher-functioning population. There is a need to investigate cognitive, language, and reading skills in the current population of higher-functioning children with ASD to learn more about their academic achievement and outcomes.

Executive Functions and Autism Spectrum Disorder

This section begins with brief descriptions of executive functions, development, and selected measures of executive function. The following discussion on executive functions and Autism Spectrum Disorder focuses on cognitive flexibility, fluency, working memory, and processing speed.

Executive functions are the cognitive processes responsible for intentional, goal-directed behaviors in response to novel situations. These abilities directly impact learning and development. Unlike habitual or autonomous responses or simple associative learning, the complex demands of higher-level learning or problem-solving require activation of the executive functions of representation, planning, execution and evaluation (Zelazo, Carter, Reznick, & Frye, 1997).

Although theoretical models of executive function vary, separate skills in planning, selective attention, impulse control, concept reasoning, cognitive flexibility (set shifting), cognitive fluency and working memory are usually differentiated (Anderson, 2008; Ozonoff et al., 2007; Pennington & Ozonoff, 1996). Early conceptions considered executive function to be superordinate to other cognitive processes, performing a top-down role of supervision and control (Gioia et al., 2002). Most current models place executive functions into more interactive

and basic positions in overall cognitive functioning (Denckla, 2007), which may make deficits or delays both more difficult to isolate and more pervasive in their effect on development. One model separates executive functions into 6 facets: planning and goal setting; organizing; prioritizing; memorizing, or accessing information; shifting flexibly; and self-monitoring (Meltzer & Krishnan, 2007). These processes are not envisioned as linear, but as interactive and reciprocal, making real-life and academic tasks challenging for students with weaknesses in any one component.

Anderson (2008) conceptualized an executive control system consisting of four distinct domains, each with integral components: attentional control (consisting of selective attention, self-regulation, self-monitoring and inhibition); goal setting (initiative, conceptual reasoning, planning, and organization); information processing (fluency, efficiency, speed); and cognitive flexibility (divided attention, working memory, conceptual transfer, and feedback utilization). These abilities are sometimes considered "cold" executive function skills, in contrast to "hot" skills that combine affect with purposeful behavior, such as empathy, theory of mind, emotional regulation, and affective decision-making (Jacques & Zelazo, 2005a; Zelazo, Qu, & Müller, 2005).

Cognitive flexibility is one facet of executive function, and one of the most-studied executive functions (Friedman et al., 2008). It is usually conceived as Set Shifting, or the ability to inhibit perseveration and change strategy to achieve a goal. Set Shift is closely related to divided attention and attention shift. Flexibility is the ability to *consider multiple representations* of an object, idea or situation; a necessary precursor to flexibility is attention shift, the ability to *disengage attention from one object and shift attention to another*. Divided attention, the ability to *respond simultaneously to more than one object*, is another prerequisite to cognitive flexibility. At a higher level, set shift is the ability to *change a behavior or perception flexibly* in response to an environmental change or failure of a scheme. The abilities to shift between sets, learn from mistakes, devise alternative strategies, divide attention, and process multiple sources of information form the foundation of the cognitive flexibility domain (Anderson, 2008).

Child Development and Executive Functions. Executive functions begin to emerge in infancy and continue to develop through early adulthood (Eslinger & Biddle, 2008; Homer &

Hayward, 2008). As with language development, the most dramatic growth occurs in the preschool years; however, executive functions continue to improve in the elementary years, with more improvement in the early years and slowed development in later elementary years (Altemeier, Abbott, & Berninger, 2008). Another spurt of development in most executive functions occurs in preadolescence; interestingly, Piaget's theorized transitions between cognitive stages matches these observed growth spurts in executive function (Anderson, Anderson, Jacobs, & Smith, 2008).

Cognitive flexibility begins with an infant's ability to shift attention between two or more objects, or the ability to shift attention between auditory and visual stimuli. A strong connection has been found between executive functions, particularly cognitive flexibility, and performance on theory of mind tasks in typically developing preschoolers (Hughes, 1998; Hughes & Ensor, 2007; Jacques & Zelazo, 2005b); cognitive flexibility appears to be necessary for the development of theory of mind (Homer & Hayward, 2008). Flexibility develops earlier than other executive functions, with most children attaining a functional level by the early elementary years; however, it continues to mature throughout adolescence and young adulthood (Altemeier et al., 2008; Anderson et al., 2008; De Luca & Leventer, 2008; Wang, Chen, & Zhong, 2009). Adolescents may develop the flexibility needed to perceive a variety of choices, but they struggle to develop the analytical maturity necessary to make good decisions. It has been suggested that a qualitative change in the development of cognitive flexibility occurs around the age of 6; while younger children can increase their *accuracy* on set shift tasks with practice, adolescents improve their *response time* (Davidson, Amso, Anderson, & Diamond, 2006).

Cognitive flexibility is related to language, cognitive, and social development (Jacques & Zelazo, 2005b; Pellicano, 2010b). It correlates modestly (.3) with general ability (FSIQ) in children (Arffa, 2007), but the relationship has been found to be weaker in young adults (Friedman et al., 2006) and insignificant in adult psychiatric patients (Kunce, Blount & Tamkin, 1987); it is distinct from, but makes a unique contribution to, problem-solving ability (Corder & Corder, 1974).

Cognitive flexibility is considered a "cold" executive function, but positive emotions can improve flexibility. For example, typically developing children perform set-shift tasks better when cards feature variations of happy faces instead of symbols (Qu & Zelazo, 2007). It has been suggested that increased dopamine levels triggered by positive emotions facilitate cognitive

flexibility. If this is true, the documented diminished release of dopamine in children with ASD (Neuhaus, Beauchaine, & Bernier, 2010) could hinder the development of cognitive flexibility, which may then affect development and learning.

Measures of Executive Function. There is no single task that can assess all facets of executive function. Although tasks are used as measures of global executive function or its various components, there is still debate about what they actually measure; the field remains challenged by differing theories and construct fuzziness (Kenworthy, Yerys, Anthony, & Wallace, 2008; Meltzer & Krishnan, 2007). However, the standard assessment for executive dysfunction in ASD has long been the Wisconsin Card Sorting Test, developed by Berg in 1948 (Ozonoff & Schetter, 2007).

The Wisconsin Card Sorting Test (WCST) is a measure of executive abilities and frontal lobe functioning (Axelrod, Goldman, Heaton, & Curtiss, 1996; Heaton, 1981; Heaton, Chelune, Talley, Kay, & Curtiss, 1993). It clearly taps cognitive flexibility, but it also involves inhibition, attention, working memory and self-regulation (Hill, 2004; Meltzer & Krishnan, 2007; Ozonoff, 1995). Three intercorrelated but separable functions have been determined from response variation analyses: inhibiting, updating (working memory) and shifting (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

Performance on the WCST differs between normal controls and subjects with neurological problems such as brain lesions, schizophrenia, AD/HD or autism, even when participants have normal IQs (Braff, Heaton, Kuck, & Cullum, 1991; Ozonoff, 1997). It is the traditional test most likely to reveal executive function deficits in children with ASD (Geurts, Corbett, & Solomon, 2009; Shu, Lung, Tien, & Chen, 2001; Van Eylen et al., 2011). Although inhibition and working memory are involved in the task, its unique demand is on cognitive flexibility. Other tasks attempting to measure cognitive flexibility have had mixed results differentiating between children with ASD and other populations because the cognitive load is insufficiently challenging or explicit directions are provided. The WCST may be more ecologically valid than these other assessments, since their explicit directions provide unrealistic scaffolding to the participant or student and thus increase success (Geurts et al., 2009; Van Eylen et al., 2011). Variance in the performance of children with ASD on the WCST is greater than the variance in typically developing children; this is a likely cause of weak results when children

with ASD are treated as a single group. Variation in the population provides a reason to investigate the *differences* among performance levels of children with ASD (Landa & Goldberg, 2005; Van Eylen et al., 2011)

Various scores from the WCST have been used in research, but the score for perseverative responses is the most sensitive to brain dysfunction (Heaton, 1981) and may best reveal differences between ASD and other diagnostic groups (Ozonoff, Pennington, & Rogers, 1991). Differences in perseverative responses are seen even after controlling for IQ (Ozonoff, 1995).

The original WCST is challenging to administer, requiring complex recording of participant responses at the same time the examiner is interacting with the task and participant (Artiola i Fortuny & Heaton, 1996). Computerized versions have been developed to increase scoring accuracy and reliability (Tien et al., 1996). Although performance discrepancies between teens and young adults with and without ASD have been found to be smaller on the computerized WCST than on the traditional test (Ozonoff, 1995), the computerized version still reveals significant perseveration and set-break differences between typically developing and ASD groups and may be more accurate and reliable due to automatic scoring (Artiola i Fortuny & Heaton, 1996; Kaland, Smith, & Mortensen, 2008). Since the performance of typically developing children begins to look like adult performance around the age of 10, computerized versions remain sensitive to performance differences in children under the age of 11 (Chelune & Baer, 1986). Three small studies checking the reliability and validity of the WCST with autistic populations found highly reliable (test-retest .90) and slightly better (though not significant) performance on the computerized version, suggesting that social impairments may contribute to performance deficits during traditional face-to-face administrations. The task requirements of categorization and shifting are challenging for young children , but it is appropriate for typically developing children ages 6 and up, as they should be developmentally able to switch flexibly between rules (Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Overall, the computerized WCST reveals fewer significant differences between typically developing and neurologically impaired participants, yet remains a discriminating task for children under 11.

Another computerized instrument that attempts to measure cognitive flexibility is the Intradimensional-Extradimensional Shift Task from the Cambridge Neuropsychological Test Automated Battery (Robbins et al., 1998). However, because the instructions are more explicit it

appears less challenging than the WCST, and fewer significant differences have been found for children with ASD (Goldberg et al., 2005; Happé, Booth, Charlton, & Hughes, 2006; Kenworthy et al., 2008; Ozonoff et al., 2004).

It has been recommended that researchers use both a measure of cognitive flexibility in everyday functioning and a clinical task to assess performance (Bernstein & Waber, 2007; Heaton & Pendleton, 1981; Hill & Bird, 2006; Kenworthy et al., 2008; Meltzer & Krishnan, 2007). One of the most commonly used assessments of executive function in daily life is the Behavior Rating Inventory of Executive Function (Gioia, Isquith, Guy & Kenworthy, 2000). It consists of an 86-item questionnaire completed by a parent or teacher that measures inhibition, cognitive flexibility, organization, planning, metacognition, self-control and initiation. The Behavior Rating Inventory of Executive Function (BRIEF) has been shown to discriminate between typically developing children and those with ASD (Chan et al., 2009; Gillet et al., 2008; Gioia et al., 2002) used in combination with a task like the WCST, it can provide a more ecologically valid assessment of cognitive flexibility.

Executive Functions and Autism Spectrum Disorder. Deficits or delays in the development of executive functions have been associated with various disorders, including Attention Deficit/Hyperactivity Disorder, Learning Disabilities, and ASD (Meltzer, 2007) . While problems of self-regulation, inhibition, working memory and attention are typical for children with AD/HD (Barkley, 1997; Happé et al., 2006; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), a different profile of executive function deficits –cognitive flexibility, planning, and, to a lesser extent, fluency, inhibition and working memory - are seen in ASD (Bramham et al., 2009; Christ, Holt, White, & Green, 2007; Geurts et al., 2004; Goldstein et al., 2001; Kenworthy, Black, Harrison, della Rosa, & Wallace, 2009; Lopez et al., 2005; Mackinlay, Charman, & Karmiloff-Smith, 2006; Ozonoff & Jensen, 1999; Pellicano, 2007, 2010a; Sanders, Johnson, Garavan, Gill, & Gallagher, 2008; Sergeant et al., 2002; Shu et al., 2001; Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2005; Williams, Goldstein, Carpenter, & Minshew, 2005).

Connections between executive function deficits and ASD have been explored for over 30 years (Kenworthy et al., 2008; Ozonoff & Schetter, 2007; Ozonoff et al., 2007; Russell, 1997; Russo et al., 2007). Deficits are generally seen across the autism spectrum (Ozonoff, Rogers, & Pennington, 1991; Verté et al., 2006). Relatives of children with ASD have also been shown to

have weaknesses in executive functions, especially set shift, fluency, and planning, suggesting a central role of executive dysfunction in the broader autistic phenotype (Hughes, Leboyer, & Bouvard, 1997; Hughes, Plumet, & Leboyer, 1999; Ozonoff, Rogers, Farnham, & Pennington, 1993; Sumiyoshi, Kawakubo, Suga, Sumiyoshi, & Kasai, 2011; Wong, Maybery, Bishop, Maley, & Hallmayer, 2006).

It has been theorized that impairments in executive functions cause autism, or the main deficits in autism, such as repetitive behaviors (Boyd, McBee, Holtzclaw, Baranek, & Bodfish, 2009; Lopez et al., 2005; South, Ozonoff, & McMahon, 2007; Turner, 1997; Turner, 1999; Zandt, Prior, & Kyrios, 2009), lack of creative play (Jarrold, 1997), and delayed social and language development (Hill & Bird, 2006; Kenworthy et al., 2009). There is modest support for this theory (Gilotty, Kenworthy, Sirian, Black, & Wagner, 2002; Kenworthy et al., 2009). Although a deficit in theory of mind (the awareness that self and others have minds, and the ability to attribute separate mental states to them) has been postulated to cause the characteristics of ASD, cold executive function abilities may be more important and have a more direct impact on development. Early researchers found executive function deficits to be more specific to children with ASD than deficits in theory of mind (Ozonoff et al., 1991), and subsequent research has indicated that executive function ability precedes and mediates the development of theory of mind in children with and without ASD (Hughes & Ensor, 2007; Pellicano, 2007, 2010b; Tager-Flusberg & Joseph, 2005). Executive functions appear to be necessary, but not sufficient for the development of theory of mind; verbal ability remains the strongest predictor (Pellicano, 2010a).

It is also possible that executive functions relate more to the varied *outcomes* for children with ASD than to its cause. For example, there are indications that adult savants have fewer executive function impairments than IQ-matched non-savants with ASD (Crane, Pring, Ryder, & Hermelin, 2011). In addition, children with a wide range of verbal and nonverbal ability (yet an average mean) have been found to exhibit varying deficits in executive function (Kenworthy et al., 2009). It is possible that executive function abilities mediate the outcome of ASD, so that children with more intact executive functions are better able to accommodate the neurological disorder. Relationships between executive functions and severity of ASD behaviors are evident only when looking at *differences among* children with ASD instead of comparing group performance to typically developing children. Due to variations in abilities and outcomes,

researchers have begun to focus more attention on investigating heterogeneity in ASD (Kenworthy et al., 2009; Pellicano, 2010a; Tager-Flusberg, 2004; Smith Gabig, 2010).

*Cognitive Flexibility***.** The executive function most consistently impaired in children with ASD is cognitive flexibility (Ozonoff, 1997; Pennington & Ozonoff, 1996; Sergeant et al., 2002), and ASD is the disorder most specific to a deficit in cognitive flexibility, although rigid thinking is also seen in learning and attention disabilities, Obsessive-Compulsive Disorder, and schizophrenia (Gu et al., 2008; Kleinhans, Akshoomoff, & Delis, 2005; Meltzer, 2007; Ozonoff & Jensen, 1999; Ozonoff et al., 2007; Sinzig, Bruning, Morsch, & Lehmkuhl, 2008; Willcutt et al., 2005). Parents of children with ASD rate them higher on problems with cognitive flexibility (shifting) than other executive function problems (Gilotty et al, 2002; Rosenthal et al., 2013), and children with ASD are rated higher on shifting problems than children with other developmental disorders (Gioia et al., 2002). Children and young adults with ASD have been found to perseverate and make more errors on the WCST than clinical controls with learning and attention problems (Ozonoff et al., 1991), AD/HD, or conduct disorders (Szatmari, Tuff, Finlayson, & Bartolucci, 1990). Deficits in cognitive flexibility (set shifting) and planning are seen in the task performance of children with ASD compared to typically developing children and those with developmental delays or specific learning disabilities (Hughes et al., 1994; McEvoy et al., 1993), and the deficits are stable over time (Ozonoff & McEvoy, 1994).

As stated earlier, cognitive flexibility is related to, but distinguishable from, general intelligence. Depending upon measures and subject age, correlations between cognitive flexibility and IQ in children with ASD have ranged from insignificant (Joseph & Tager-Flusberg, 2004; Landa & Goldberg, 2005) to as high as .45-.5 (Liss et al., 2001; Pellicano, 2010b). Performance on the WCST has been found to be a stronger correlate of long-term adaptive outcome than FSIQ; the strongest predictor was nonverbal ability (Rumsey, 1985; Szatmari, Bartolucci, Bremner, & Bond, 1989).

Cognitive flexibility is related to repetitive behavior (South et al., 2007), predicts social improvement in young adults with autism, and may be more critical to development than abilities in central coherence, or the ability to process information globally and "see the big picture," (Berger, Aerts, van Spaendonck, Cools, & Teunisse, 2003). Yet both central coherence and executive functions appear to impact development independently in ASD (Pellicano, 2010b).

Research has not consistently found significant deficits in cognitive flexibility for all children with ASD; for example, results with preschoolers have been mixed (Griffith, Pennington, Wehner, & Rogers, 1999; Yerys, Hepburn, Pennington, & Rogers, 2007). Some tasks developed for preschool children may not tap early elements of flexibility, such as orientation of visual attention or shifting attention between auditory and visual modalities (Courchesne et al., 1994; Harris et al., 1999; Keehn, Lincoln, Muller, & Townsend, 2010).

It is also likely that the relationship between executive functions and language ability (Tager-Flusberg & Joseph, 2005) confounds findings since delayed development in ASD makes it difficult to select a comparison group; if matched by VIQ or vocabulary, a chronologically older ASD group may have higher nonverbal ability, more mature flexibility, or compensatory strategies; yet if matched by nonverbal ability, the ASD subjects may be younger and more challenged than a control group with developmental delays (Russo et al., 2007). For example, when WCST performance of children with ASD and FSIQ-matched children with developmental language disorders was compared, significant differences in perseverative errors were found (Liss et al., 2001); however, when VIQ was controlled the relationship was no longer significant. The authors hypothesized that task performance was mediated through VIQ, yet they could not rule out the possibility that deficits in cognitive flexibility impact the development of language, and therefore, VIQ. Similarly, a study that matched ASD and typically developing children on age, FSIQ and vocabulary found higher perseverative errors in the ASD group that did not reach statistical significance (Robinson, Goddard, Dritschel, Wisley, & Howlin, 2009); if cognitive flexibility affects language development, differences may attenuate when comparison groups are matched on vocabulary.

Certain executive function tasks appear to be less challenging for adolescents and adults with ASD who have average or above-average IQs, suggesting that their development is delayed rather than deficient (Bebko & Ricciuti, 2000; Shu et al., 2001). One research team that used a computerized version of the WCST reported lower performance for 13 very high functioning (IQs from 94-125) adolescents and young adults with ASD compared to matched typically developing youth, but this difference was not statistically significant (Kaland et al., 2008). The lack of statistical significance may have been caused by the small group sizes, but it is also possible that the computerized WCST was simply not challenging enough for young adults with above-average cognitive ability. Similarly, executive function deficits have been found in

younger, but not older, children with ASD when using the Cambridge Neuropsychological Test Automated Battery (Happé et al., 2006). Although children with ASD with normal IQs may perform adequately on simple tasks of flexibility, they still struggle with complex, open-ended, or rigidly controlled tasks (Bebko & Ricciuti, 2000; Kenworthy et al., 2008; Van Eylen et al., 2011; Whitby & Mancil, 2009; White, Burgess & Hill, 2009; Zandt et al., 2009).

      Fluency, Working Memory, and Processing Speed. There is also evidence that people with ASD exhibit deficits or delays in three other interrelated executive functions: fluency, working memory, and processing speed. Though not studied as much as cognitive flexibility, cognitive fluency has been investigated in connection with autism; deficits in fluency have even been hypothesized to cause the repetitive behaviors and restricted interests of the disorder (Kenworthy et al., 2009; Lopez et al., 2005; Turner, 1997; Turner, 1999). Retrieval fluency tasks measure the ease of recall of information stored in memory. For example, children and adults with ASD exhibit deficits in the ability to generate words in categories compared to typically developing children and those with other disorders (Bramham et al., 2009; Geurts et al., 2004; Zandt et al., 2009). They also exhibit deficits in the ability to think of creative ways to play with a toy (Lewis & Boucher, 1995). Performance on semantic fluency tasks has been found to correlate with communication ability even after controlling for vocabulary (Kenworthy et al., 2009).

      Another executive function researched in autism spectrum disorders is working memory, particularly auditory and visuo-spatial span abilities (Russo et al., 2007). On parent ratings of executive problems in their children with ASD, working memory is the second most common area of concern after cognitive flexibility (Gioia, 2002; Rosenthal et al., 2013). Deficits in working memory are seen in children with ASD (Russell, Jarrold & Henry, 1996), and it has been found to correlate significantly with adaptive behavior (Gilotty et al., 2002). Two tests considered to tap short-term or working memory are the Numbers Reversed task from the Woodcock Johnson-III (Woodcock et al., 2001) and the Digit Span test from the Wechsler Intelligence Scale for Children IV (Wechsler, 2003). Samples of children with ASD with mean IQs in the average range have been found to perform significantly lower than average on Digit Span (Kaland, Smith & Mortensen, 2007; Mayes & Calhoun, 2007, 2008; Nyden, Billstedt, Hjelmquist & Gillberg, 2001), and savants with ASD have been found to perform significantly

better on Digit Span than nonsavants (Bolte & Poustka, 2004). Interpretation of these results is somewhat difficult, however, since the Digit Span test has two parts: Digits Forward, which taps short-term auditory memory, and Digits Backward, which additionally requires the mental manipulation of information and the concept of reversibility. Reversing numbers adds to the cognitive demands of the task and may tap cognitive flexibility since reversing order is a form of shifting (Hale, Hoeppner & Fiorello, 2002). When results are calculated separately for forward and backward span tasks, significant impairments are seen in children with ASD on the more challenging backward tasks, but not the simpler forward spans (Joseph, McGrath & Tager-Flusberg, 2005). This suggests that reversed tasks measure more than short-term memory and may also require flexibility.

Timed tasks requiring perceptual discrimination such as symbol searches or visual matching are used to estimate information processing speed, although the requirement to make decisions also taps working memory. Children with ASD are more likely to have problems with visual processing speed than typically developing children or children with AD/HD (Mayes & Calhoun, 2007, 2008).

Summary of Executive Functions and Autism Spectrum Disorder. More than 30 years of research has revealed executive function deficits in ASD, most notably cognitive flexibility, yet evidence has been insufficient to conclude that executive function deficits are the primary cause of autism (Kenworthy et al., 2008; Ozonoff & Schetter, 2007). For example, significant differences are difficult to find at every developmental stage because different abilities develop at different rates. Recent studies have found weaker relationships between new measures of cognitive flexibility and ASD when tasks are simplified and directions are provided more explicitly in an attempt to isolate flexibility from other executive functions (Happé et al., 2006; Kenworthy et al., 2008). Comorbidity with other executive function disorders such as AD/HD and Obsessive-Compulsive Disorder makes it difficult to select subjects for comparison groups to clarify the specific cognitive flexibility deficits of ASD (Christ, Kanne, & Reiersen, 2010; Geurts et al., 2009; Kenworthy et al., 2008; Sinzig et al., 2008). The higher IQ of participants in recent studies (such as the Kaland 2008 study of adolescents and young adults with FSIQs ranging from 94 to 125) also makes differences less perceptible (Hill, 2004). The relationship between ASD and cognitive flexibility is complex, yet the test that started it all – the

WCST – remains a good instrument for assessing differences among subjects. A deficit or delay in cognitive flexibility may impede the ability of children with ASD to learn, and thus contribute to delays and deficits in development. A specific question is whether cognitive rigidity affects the acquisition of basic reading skills in the early grades.

Reading and Autism Spectrum Disorder

This section begins with constructs and models of reading. Common correlates of reading for typically developing children are discussed. Relationships between reading and executive functions, particularly cognitive flexibility, are followed with an overview of reading skills in children with ASD. Twelve studies focusing on reading skills in children with ASD are highlighted. I conclude with a brief discussion of the intersection of reading, cognitive flexibility, and ASD, and an outline of the current study.

The objective of reading is to comprehend the meaning of connected text. The fluent reading of words is necessary for successful comprehension since the cognitive demands of decoding unfamiliar words leaves less attention and memory capability for the construction of meaning (Perfetti, 1986; Samuels, 1994). Reading incorporates a complex set of skills and knowledge used to construct meaning from printed words, including phonemic awareness, phonics, fluency, vocabulary and text comprehension (Adams, 1990; National Reading Panel & NICHHD, 2000). Whereas early models of reading were linear and hierarchical, current models note that competent readers coordinate cognitive processing at several levels at once, from the recognition of letters and simple association with phonemes to self-monitoring and the interactive evaluation of new information with background knowledge (Lipson & Wixson, 2003).

In the early elementary years, children learn to decode unknown words, recognize sight words, read connected text with some fluency, and comprehend simple or familiar text. In the later elementary years, they must become more strategic readers, expanding vocabularies and concepts and developing metacognitive comprehension skills (Slavin, Lake, Chambers, Cheung, & Davis, 2009). Children who struggle with reading in later grades may have exhibited difficulty with initial reading skills or may not have had problems until comprehension challenges increased (Adlof, Catts, & Lee, 2010). Although mature readers do not utilize

decoding strategies to read most words, both listening comprehension and decoding are necessary for good reading comprehension (Hoover & Gough, 1990).

Readers may read words in several ways: they may recognize memorized words instantly through the so-called lexical route (i.e., sight word identification), or they may decode them using a variety of nonlexical processes, such as recognition of common spelling patterns, use of analogy, use of context, and phonological processing (Adams, 1990; Ehri, 1997; Ehri & Snowling, 2004; Shaywitz et al., 2000; Smith Gabig, 2010;). According to one major model of reading development, most beginning readers pass through four phases in the development of sight word reading (Ehri, 1994; Ehri, 2005a, 2005b; Ehri & Snowling, 2004). In the pre-alphabetic or logographic phase, children use distinguishing visual cues or characteristics to identify words, such as the M in McDonalds or the two "eyes" in "look." A modest sight word vocabulary may be acquired utilizing paired associative learning. Children are usually in this phase before they have received formal instruction in reading. During the first year of reading instruction most children become more phonemically aware and learn some letter names and corresponding phonemes. They begin to use a partial alphabetic strategy to read words, attending primarily to the first and final letters of words and guessing them through context. In the second or third year of instruction, children often reach the full alphabetic phase, known as grapheme-phoneme or phonological recoding. With this skill, children are able to relate all letters in a word to the corresponding phonemes. In the final phase, called consolidated alphabetic, readers are able to utilize knowledge of orthography, spelling patterns and word units to recognize rimes, syllables, morphemes, suffixes, and root words. As readers mature they find a greater need to use this knowledge in order to decode less common and more complex words efficiently (Ehri, 2005a).

The construction of meaning from identified words incorporates an understanding of context and semantic knowledge (Adams, 1990). Although sight recognition of a word may permit fairly direct links to meaning, the process of phonological recoding adds to cognitive demands as the reader must view and identify letters, decode them to "hear" a word, connect that to lexical-semantic memories, and filter through context and syntax to discern the intended meaning.

Difficulty reading words can occur with orthographic, phonological, or lexical-semantic processing. In dyslexia, the most common deficit occurs in the phonological process, a

dysfunction of the cognitive system that segments words into phonological parts (Brady, 1997; Fletcher et al., 1997; Fletcher et al., 1994; Muter & Snowling, 2009; Shaywitz et al., 2000). There are several components of phonological processing, including phonological awareness, verbal memory, and naming: a deficit in the first is usually noted in people with dyslexia, while the latter two are often, but not always involved (Blachman, 2000; Fletcher et al., 1997; Jiménez, Siegel, O'Shanahan, & Ford, 2009). The ability to precisely perceive individual speech sounds appears to be related both to development and genetics; there is lower activation of language-processing parts of the brain in dyslexic children and adults (Shaywitz et al., 2000), though recent research indicates it may be improved or mediated by intense intervention (Shaywitz et al., 2004). Low phonological awareness may affect the quality of word representations in working memory and also be connected to problems of accurate or quick word retrieval from long-term memory. There are indications that visual memory, or the ability to visualize word orthography, may also affect phonological perception (Adams, 1990; Blachman, 2000).

Predictors of Basic Reading Skills in Typically Developing Children. Cognition and reading influence each other in a reciprocal relationship during development (Ferrer et al., 2007). It is therefore not surprising that correlates of basic reading skills include cognitive and language factors such as IQ (Mayes, Calhoun, Bixler & Zimmerman, 2008), nonverbal ability (Pammer & Kevin, 2007), oral language (Speece, Ritchey, Cooper, Roth & Schatschneider, 2003), rapid naming (Fletcher et al., 2011; Swanson et al., 2003), phonemic awareness (Hammill, 2004; Speece et al.,2004), working memory, and processing speed (Christopher et al., 2012; Floyd, Keith, Taub & McGrew, 2007).

Intelligence correlates modestly with basic reading skill across a range of ages (Hammill, 2004), and the relationship is stronger for children at-risk for reading problems (Cardoso-Martins & Pennington, 2004) or in elementary school (Ferrer et al., 2007; Mayes, Calhoun, Bixler & Zimmerman, 2009). The correlation between IQ and word identification in a meta-analysis with a broad range of ages was .42 (Swanson, Trainin, Necoechea & Hammill 2003); in a study of first graders it was .52 (MacDonald, Sullivan & Watkins, 2013). Relationships between IQ and nonword decoding were stronger in both studies: .63 for all ages in the meta-analysis, and .55 for the first graders. The relative contributions of nonverbal and verbal ability to reading skills are less clear; some studies have found weak to moderate relationships between nonverbal ability

and word reading (Speece et al., 2004), but others have found a stronger relationship between reading and nonverbal than verbal ability, especially in the early grades (Ferrer et al., 2007).

Phonological awareness has also been found to correlate strongly with word reading skills (Fletcher et. al., 2011; MacDonald et al., 2013; Swanson et al., 2003). One study found strong correlations ($r = .73 - .77$) between phonological awareness, word identification and nonword decoding for first through third graders (Speece et al., 2004); others have found correlations between .55 and .66 (MacDonald et al., 2013). Phonemic awareness develops during early reading instruction, as the emphasis on speech sounds leads to more sensitive perception in a reciprocal process essential for the learning of the letter-sound relationships of phonics (Blachman, 2000; Ehri, 2005a; Ehri & Soffer, 1999; Farrar & Ashwell, 2008). Children with delays or deficits in phonemic awareness struggle with beginning reading tasks, and without intervention they may rely on inefficient strategies for word identification even after phonological sensitivity has improved (Greaney, Tunmer, & Chapman, 1997). Awareness of syllables and of onset-rimes precedes the ability to perceive phonemes, and generally occurs between the ages of 4 and 6 (Goswami, 2000). The ability to count and segment phonemes is followed by an ability to segment and blend, and, eventually, by the ability to manipulate phonemes, such as deletions and reversals (Adams, 1990; Blachman, 2000). Children who struggle with reading in the early grades tend to be challenged by onset-rime and phonological memory tasks, but this relationship weakens once the interrelationship with lexical development (vocabulary knowledge), also typically delayed in struggling readers, is considered (Goswami, 2000). Considering the importance of phonological sensitivity and vocabulary for the development of reading, it is not surprising that over half of the children with delayed language development exhibit reading difficulties at the age of eight (Law, Boyle, Harris, Harkness, & Nye, 1998; Miniscalco & Dahlgren Sandberg, 2010).

Rapid Automated Naming has been found to correlate moderately with word recognition ($r = .43$) and nonword decoding ($r = .52$; Swanson et al., 2003). However, other researchers have suggested that the relationship between rapid naming and basic reading skills has been overstated (Christopher et al., 2012; MacDonald et al., 2013; Mayes, Calhoun, Bixler & Zimmerman, 2009). When the Rapid Automated Naming task involves letters and numbers, the relationship holds for most children, but when the task involves colors or object names, there appears to be no significant relationship (Cardoso-Martins & Pennington, 2004; Christopher et

al., 2012). Nevertheless, as a measure of cognitive fluency (retrieval) and processing speed, Rapid Automated Naming has been investigated in both reading and ASD research and is worthy of consideration in research involving both fields.

Cognitive abilities such as working memory and processing speed have also been found to correlate significantly with word reading skills. A meta-analysis found that correlations between word reading measures and working memory (span tasks) ranged from .31 to .54 (Swanson et al., 2003). Another study of 483 youth from 8-16 years of age found that both working memory (span tasks) and visual processing speed (perceptual discrimination) uniquely predicted word reading (Christopher et al., 2012). A third study found that digit span (working memory) was a significant predictor of word reading in elementary students and added to the variance in word reading after controlling for IQ (Mayes et al., 2009).

Reading ability in typically developing children appears indirectly related to general ability, mediated by auditory processing, verbal knowledge, short-term memory, long-term storage/retrieval and processing speed (Floyd et al., 2007). It is important to consider all of these factors when investigating correlates of reading.

It is not clear if reading skills in high-functioning children with ASD are related to abilities like IQ, phonemic awareness and memory to the same extent as found in typically developing children; this is the crux of this study and is discussed further in the section on reading and ASD.

Reading and Executive Functions in Typically Developing Children. Reading ability parallels cognitive development in general but may also be affected by the development of specific executive functions such as cognitive flexibility, self-regulation, and working memory (Cartwright, 2008). For example, cognitive flexibility has been associated with reading (Yeniad, Malda, Mesman, van Ijzendoorn & Pieper, 2012), and children with reading problems have been found to have deficits in executive functions (Booth, Boyle & Kelly, 2010).

The need for readers, especially early readers, to simultaneously process orthographic, phonological, morphological and syntactic information suggests that cognitive flexibility plays a role in the development of basic reading skills (Altemeier, Abbot & Berninger, 2008; Cartwright, Marshall, Dandy, & Isaac, 2010). Preschool children are limited in their ability to perceive multiple representations of objects or situations (Piaget & Inhelder, 1969), and that ability is

necessary in order to perceive words on multiple levels (phonological, orthographic, semantic) and learn to read (Bialystok & Niccols, 1989; Farrar & Ashwell, 2008; Homer & Hayward, 2008).

Researchers have hypothesized a reciprocal relationship between cognitive flexibility and literacy, with flexibility needed in the development of beginning reading skills, and literacy growth facilitating further development of cognitive flexibility through such factors as increased metalinguistic awareness or improvements in working memory (Gaskins, 2008; Homer & Hayward, 2008; Tachibana et al., 2013). For example, representational and executive function abilities precede and mediate the development of theory of mind in children with and without ASD (Hughes & Ensor, 2007; Pellicano, 2007, 2010b; Tager-Flusberg & Joseph, 2005), and theory of mind and vocabulary predict the ability to rhyme (Farrar & Ashwell, 2008). The ability to rhyme – which requires executive functions to inhibit the semantics of words, focus on their sounds, hold them in working memory and shift flexibly between the representations in order to manipulate sounds – has been found to predict beginning reading skills (Farrar & Ashwell, 2008; Goswami, 1999). In turn, increased literacy opportunities assist in the maturation of executive functions (Tachibana et al., 2013). There is evidence that the ability to perceive multiple representations and think flexibly is important in the development of reading skills (Altemeier et al., 2008; Berninger & Nagy, 2008; Cartwright, Hodgkiss, & Isaac, 2008; Gaskins, 2008).

Some researchers have reported relationships between cognitive flexibility and word reading skills in typically developing children. Cartwright (2002) found a strong correlation for elementary school children ($r = .48$) between decoding skill and the ability to shift between categories in a multiple classification sorting task. The ability to shift (cognitive flexibility) was also found to account for some variation in word reading skills in 9-12 year-old children after controlling for rapid naming ability (van der Sluis, de Jong, & van der Leij, 2007). Altemeier et al. (2008) asserted that inhibition and shifting explained as much as .55 of the variance in word reading skills in typically developing children in elementary grades, and contributed significantly to reading and writing achievement. A weakness of these studies is that they did not address possible interactions between cognitive flexibility performance and overall ability; in contrast, a recent correlational study involving typically developing children in elementary school found that cognitive flexibility did not add to the prediction of word reading skills after IQ and other

factors had been entered into a regression model (Mayes, Calhoun, Bixler & Zimmerman, 2009). This suggests that relationships between basic reading skills and cognitive flexibility in typically developing children have not been fully explored.

Investigations of executive function deficits in children with dyslexia have indicated impairments in working memory (backward digit span), inhibition, and semantic fluency (Reiter, Tucha, & Lange, 2005). Although executive functions are impaired in children with reading problems (Booth et al., 2010), relationships between executive functions and reading skills are weaker than in typically developing readers (Altemeier et al., 2008). Some studies have found no executive function deficits after controlling for phonological functioning (Locascio et al., 2010; Schuchardt, Maehler, & Hasselhorn, 2008), suggesting that executive function deficits equally, or primarily, affect phonological skills.

In addition to common cognitive and language correlates of word reading ability, it is important to consider executive functions such as cognitive flexibility in the exploration of factors contributing to basic reading achievement.

Reading Skills in Children with Autism Spectrum Disorder. Reading abilities in children with ASD vary greatly (Åsberg et al., 2008; Asberg & Dalgren Sandberg, 2012; Griswold, Barnhill, Smith Myles, Hagiwara & Simpson, 2002; Jones et al., 2009; Spector, 2009; White et al. 2006), but poor performance on tests of reading comprehension is fairly common (Ferrer et al., 2007; Minshew, Goldstein, Taylor, & Siegel, 1994; Nation et al., 2006; O'Connor & Klein, 2004). Comprehension problems may result from weaknesses in decoding or in oral language ability (Hoover & Gough, 1990). Children with dyslexia generally struggle more with decoding, and children with ASD struggle more with language (Frith & Snowling, 1983; Nation & Norbury, 2005); however, comprehension problems in some children with ASD appear to be caused by decoding weaknesses (Asberg et al., 2008; Brown, Oram-Cardy & Johnson, 2013; Ricketts, Jones, Happe & Charman, 2013). The large age range in most studies of children with ASD makes it difficult to determine if reading skills develop in a typical sequence or when problems arise.

Some children with ASD are able to read words, though not comprehend, at advanced levels compared to their language ability, a pattern typically called hyperlexia (Aram, 1997; Frith & Snowling, 1983; Nation, 1999; Snowling & Frith, 1986). There are varying definitions of

hyperlexia. Some researchers have considered children who read spontaneously before the age of six with exceptional word recognition and poor comprehension to be hyperlexic (Newman et al., 2007). Others have studied children with exceptional reading abilities and few comprehension problems (O'Connor & Hermelin, 1994), or children who simply read well despite ASD or impairments in language or cognition (Burd, Ivey, Barth, & Kerbeshian, 1998; Nation, 1999; Saldaña, Carreiras, & Frith, 2009; Snowling & Frith, 1986). Although not exclusive to children with ASD, an ability to read connected text unexpectedly well compared to VIQ appears to be more prevalent in ASD than in typically developing children (Grigorenko et al., 2002; Grigorenko, Klin, & Volkmar, 2003). It has been estimated that 7% to 21% of children with ASD or pervasive developmental disorders read words extremely well compared to their language and cognitive abilities (Burd, Kerbeshian, & Fisher, 1985; Jones et al., 2009; Grigorenko et al., 2002).

Varying definitions of hyperlexia have complicated the interpretation of findings. Since the basic construct is good word reading and poor comprehension, it is possible that children who are strong in basic reading skills but weak in comprehension are part of the normal variation in reading ability (Nation, 1999). There also appears to be a developmental effect on comprehension for children with ASD; a discrepancy between word reading ability and comprehension widens with age as interpretive demands increase (Goldstein, Minshew, & Siegel, 1994; O'Connor & Hermelin, 1994; Sparks, 2004).   Some adolescents have adequate basic reading skills with contextual comprehension weaknesses that should not be confused with the exceptional word-calling strengths of young children with "traditional" hyperlexia. Older students with ASD may have learned all the components necessary for good reading comprehension but have difficulty applying them when needed (Chiang & Lin, 2007; Snowling & Frith, 1986) because weaknesses in cognitive flexibility impair the higher-level multitasking requirements of reading.

Although the reading comprehension struggles of children with ASD are well-known, there is also great variation in basic reading skills, and some high-functioning children experience difficulty learning to read (Miniscalco & Dahlgren Sandberg, 2010; Nation et al., 2006; Spector, 2009; White et al., 2006). An analysis of data from the Early Childhood Longitudinal Study found that between 28% and 41% of children with ASD scored below the 25th percentile on reading ability from kindergarten to grade 5 (Spector, 2009). Mean reading

scores were average for children with ASD, but individual performance varied more than in the general population. According to teacher report, the children with ASD in kindergarten were seven times more likely to have trouble producing rhyming words and three times more likely to struggle with decoding strategies. Compared to the general population, children with ASD in first grade were three times as likely to have difficulty reading words.

The percentage of children with word reading difficulties has varied greatly amongst studies. Some researchers have found infrequent word reading disabilities in children with ASD (Mayes & Calhoun, 2007) but others have found high percentages with basic reading problems, such as 33% (Asberg & Dahlgren Sandberg, 2012), 37% (Åsberg et al., 2008), 45% (Ricketts et al., 2013), or 51% (Nation et al., 2006).

If a large number of children with ASD have difficulty reading words, an examination of correlates may suggest factors contributing to the problem. Cognitive and language abilities known to correlate with basic reading skills in typically developing children may not relate as strongly with reading for children with ASD. For example, IQ has been found to be the strongest predictor of word reading for typically developing children (Mayes et al., 2009), but IQ has not related significantly to reading ability in some investigations of hyperlexic or ASD children (Jones et al., 2009; Newman et al., 2007). Relationships between basic reading and nonverbal ability have also varied in the literature; although strong correlations for younger children with ASD were reported on one study (Mayes & Calhoun, 2008), another reported a correlation of .45 for typically developing children, but -.15 for the age-matched high-functioning children with ASD (Smith Gabig, 2010). Reading comprehension relates strongly to language development in the typically developing population (Nation et al., 2006), but relationships with decoding have been less clear, sometimes correlating with language (Norbury & Nation, 2010) and sometimes linking more strongly to nonverbal intelligence .

Rote learning, which can use perceptual representation or semantic representation, is a relative strength for high-functioning children with ASD (Ben Shalom, 2003; Bölte & Poustka, 2004; Williams, Goldstein, & Minshew, 2006). Some children appear to use this strength to facilitate the recognition of whole words, leading to strong reading achievement in early grades (Mayes & Calhoun, 2006) that diminishes over time because this strategy is less useful as text vocabularies increase and comprehension demands become more complex. One indication that

some children with ASD over-rely on strengths of instant word recognition is the difficulty they are reported to have reading nonwords.

There are many accounts of a relative weakness for nonword reading in ASD. Results of recent studies have been inconclusive, with some observing a high incidence of difficulty reading nonwords (Asberg & Dahlgren Sandberg, 2012; Nation et al., 2006; Smith Gabig, 2010; Tager-Flusberg & Joseph, 2003) and others seeing no significant difference from typical controls (Frith & Snowling, 1983; Newman et al., 2007; Sparks, 2004). Relatedly, some researchers have found that children with ASD have intact phonological abilities (Frith & Snowling, 1983; Newman et al., 2006) and others, deficits (Smith Gabig, 2010; Sparks, 2001, 2004; Tager-Flusberg & Joseph, 2003).

In order to learn more about word reading skills and predictors for children with ASD, a literature review was conducted of studies from the last decade with an investigative focus on the topic. Because the number of children diagnosed with ASD has grown in the past twenty years and the percentage of children with cognitive impairments has declined (Centers for Disease Control and Prevention, 2012), narrowing the search to papers published within the last ten years increased the relevance of results to the population of children enrolled in schools today.

Recent Research into Reading Skills and Predictors for Children with Autism Spectrum Disorder. In the following detailed review of 12 studies, it should be noted that sample sizes are generally very small; only two studies included more than 41 children with ASD. Comparisons and conclusions are difficult due to the large age and ability range of participants; the varying criteria for hyperlexia or reading difficulty; and varying measures of reading and ability. Some studies defined basic reading skills as the ability to read lists of words or nonwords, while others used simple connected text, or sentences, as a measure of basic functional reading. Some studies considered a child to have a reading problem if skills were below average for typically developing children the same age, while others defined a reading difficulty as performance discrepant with a child's verbal or general ability. Although it is difficult to discern a clear pattern in the findings, a review of recent literature was necessary in order to lay a foundation pertinent to this investigation. These studies offer a wealth of information relating to reading skills in children with ASD, but the varied findings also build a

case for more research with larger samples, narrower ranges of age and overall ability, and broader assessments of possible correlates and mediating factors.

Some of the research that follows focused on children with ASD with (and without) hyperlexia to learn more about related strengths and weaknesses. Results regarding phonological and cognitive skills varied, perhaps due to selection criteria or extremely small sample sizes.

Sparks (2004) assessed three ten-year-old children with autistic behaviors, nonverbal IQs ranging from 52 to 111, and hyperlexia (defined as spontaneous reading by age five, impaired listening comprehension, and a large discrepancy between word reading and comprehension). Performance on word recognition and nonword decoding was similar. Sparks found *orthographic skills typical for age and consistent with word recognition skills, but low oral language and phonological abilities*. Specifically, performance on phonological tasks requiring the mental manipulation of phonemes was difficult, even for the child with an above-average IQ. Sparks suggested that children with hyperlexia utilize spelling patterns rather than phonological skills to read words.

Another study found phonological skills in children with hyperlexia stronger than in children with ASD without hyperlexia, but typical for word reading ability. Newman et al. (2007) compared the literacy and cognitive abilities of 40 children and young adults with ASD, some with hyperlexia, to typically developing children matched on word reading ability. Children were placed in the hyperlexia group based on documented reports of early, exceptional word reading ability compared to comprehension or cognition. While the hyperlexic group (with a mean IQ of 89) ranged from age 3 to 20, the non-hyperlexic children (mean IQ of 99) were 8 to 19, and the typically developing children 7 to 19, making comparisons difficult. Performance on word recognition and nonword decoding tasks was similar within each group. The *hyperlexic children were superior to the typically developing children on word recognition and nonword decoding, comparable on vocabulary and phonological tasks, and weaker on visual memory. The children with ASD without hyperlexia were significantly weaker on word reading, vocabulary, visual memory, and phonological tasks compared to the other two groups.* Both ASD groups performed well on rapid naming. Seventy-three percent of the variance in comprehension could be predicted by the ability to decode plus group membership, suggesting that many children with ASD have poor comprehension due to basic reading skills, while others comprehend poorly for other reasons.

A similar study, but with contrasting results, was conducted in Brazil. Six children with hyperlexia and ASD, selected for precocious word reading, discrepancy with IQ, and poor comprehension, were matched on word reading skills to 6 children with ASD without hyperlexia and 6 younger typically developing children (Cardoso-Martins & da Silva, 2010). Many of these children were not high-functioning; the group with hyperlexia had a mean NVIQ of 66, and the ASD group without hyperlexia had a NVIQ of 75. Both groups with ASD had lower average performance on nonword decoding than word recognition. The group with hyperlexia performed significantly lower (standard score of 60) on a measure of receptive vocabulary compared to the non-hyperlexic and control groups and *was weaker on tasks measuring phonological awareness and letter sounds. In contrast, they showed superiority, even compared to the typically developing children, on rapid naming of letters and digits*. Results were supportive of the hypothesis that children with hyperlexia learn to read words through rote memorization and the analysis of orthographic patterns rather than phonological skills.

The next three studies focused on the variation of reading ability within the ASD population and related factors. All found a considerable percentage of children with ASD to have difficulty with basic reading skills.

Nation, Clarke, et al. (2006) examined the reading profiles of 41 verbal children with ASD between ages 6 and 15 in a clinical sample and found variable, but overall poor reading skills. Many children with cognitive impairment were included in this sample, as the average NVIQ was 84. *Twenty-two percent of the children could not read any words, and 51% performed at least one standard deviation (SD) below age-appropriate levels on word reading (yet the group mean for those who could read was average, indicating that other children performed well above average for age). Many children struggled to decode nonsense words; of those able to read at all, 42% were at least one SD below population norms on this measure*. The correlation between word and nonword reading was lower in this sample of children with ASD ($r = .69$) than in studies of typically developing children, suggesting that *children with ASD struggle more with phonological analysis and rely more heavily on word memorization*.

Another study assessed cognitive and literacy skills in 100 adolescents with ASD and examined subgroups of participants with discrepancies between ability and achievement (Jones et al., 2009). Fourteen percent of the total sample had below average IQ (74) but average word reading ability (95); this group showed no significant difference between nonverbal and verbal

ability. *Ten percent of the sample had low word reading skills (67) with average nonverbal but lower verbal IQ; this group seemed similar to children with a language impairment (but not ASD) who also struggle with reading.* The authors emphasized a need to study subgroups of children with ASD relative to academic achievement discrepancies and suggested similar research with younger participants.

Fifteen 10-15 year olds with ASD were assessed for reading, language, and cognitive abilities to investigate correlates of basic reading (Asberg & Dalhlgren Sandberg, 2012). Although mean word reading performance for all fifteen children did not differ significantly from a comparison group of typically developing children, one-third of the children with ASD were poor word readers, scoring below the 10th percentile. Phonemic awareness task performance was lower for the children with ASD than for the typically developing children, and the subgroup with word reading problems was significantly lower than the other children with ASD on phonemic awareness, receptive vocabulary and rapid naming of digits.

Many researchers attempt to compare reading skills and correlates in children with ASD to those of children with other disabilities and to typically developing children. Some of these also estimate the number of children with ASD who struggle with basic reading skills.

A team of Swedish researchers (Åsberg et al., 2008) compared the reading and memory performance of 37 children with ASD, 19 typically developing children, and 21 children with deficits in attention, motor coordination and perception. Children ranged in age from 7 to 15 and had FSIQs greater than 75; groups were roughly matched by mental age. The *group with ASD performed significantly lower than the other groups on word reading and a memory task. Thirty-seven percent of the children with ASD struggled with basic word reading; they were younger, with slightly lower verbal ability, than the children with ASD who were proficient readers, and they struggled more with short-term memory tasks.* The results of this study suggested a *developmental delay in decoding skills for many children with ASD*, since the poor word readers were younger and had slightly lower verbal ability, which generally increases in the early elementary years. Word recognition and sentence comprehension skills were strongly correlated (.86) in children with ASD, contrasting with other studies, which found weak connections.

High-functioning girls with ASD between the ages of 8 and 17 were the focus of the next study. The 20 girls with ASD in this sample had weaker literacy skills than the 54 typically

developing girls (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010), but the difference did not reach statistical significance, possibly due to the small group size or large age range of the ASD group. *However, 21% of the girls with ASD exhibited a disability in word reading* (defined conservatively as a standardized score below 75, or the 5th percentile).

Another Swedish study found that *children with ASD had significant deficits in single word reading and phonological skills compared to other children with language delays* (Miniscalco & Dahlgren Sandberg, 2010). Twenty-one children from a community-representative sample of language-delayed children participated in follow-up studies at ages 6 and 8. They were placed in three diagnostic groups; those with ASD (N = 5), those with AD/HD (N = 8), and children with no diagnosis other than language delay (N = 8). *The children with ASD were very low on decoding skills and had significant delays in syntax/grammar, phoneme identification and morphological awareness* compared to others; however, they also had the lowest mean IQ (74). Word retrieval was also below average, but not rapid picture naming.

Fourteen Spanish adolescents with ASD who could read words better than comprehend were *not found to differ from typically developing children (matched on age and word reading ability) on tasks measuring semantic, orthographic, or phonological word representations* (Saldaña et al., 2009). However, when the teens with ASD were divided into two groups, those who read words commensurate with VIQ ($X = 99$) and those who read surprisingly well compared to VIQ ($X = 73$), the latter was found to have superior phonological and orthographic skills. No differences between the groups with ASD were found on rapid picture naming, digit naming, or backward digit span (working memory). The authors emphasized the need to create subgroups in analyses of children with ASD in order to better understand reading development.

A large study of 384 verbal, high-functioning children with ASD entering a commercial tutoring program found near-normal word reading skills (Huemer & Mann, 2010); however, only children with some reading skill were assessed. The sample included 171 children with parent-reported diagnoses of autism, 94 with Asperger's Disorder, and 119 with Pervasive Developmental Disorder - Not Otherwise Specified (PDD-NOS). The children with autism or PDD-NOS had vocabulary and phonological skills significantly below average, but all three ASD groups exhibited deficits in verbal comprehension and following oral directions. *Despite these weaknesses, word recognition was good (ranging from 89 for children with PDD-NOS to*

95 for the Asperger's group), and nonword reading even higher (from 93 for the PDD-NOS group to 100 for the Asperger's group).

Smith Gabig (2010) explored predictors of reading ability by measuring reading and phonological awareness in 14 5-8 year old children with ASD and 10 typically developing children. All children were enrolled in special education and had functional speech, a diagnosis of ASD, and NVIQ between 83 and 109 (12 participants were above 90). Although NVIQ was typical for both groups (96 and 106), the children with ASD scored considerably lower on vocabulary (88 SS versus 103). *No relationship was found between NVIQ and decoding for the children with ASD*, but positive relationships were found between NVIQ, nonword reading and word analysis for typically developing children. Surprisingly, *no significant differences were found in word or nonword reading skills between the age-matched groups, but the children with ASD were weaker in phonemic awareness, and it did not correlate with decoding skill*. The *children with ASD were also weaker reading nonwords than real words*. The small sample size made it difficult to find significant differences between groups, but the lack of a relationship between phonemic awareness and decoding skill in children with ASD is corroborated in some other studies (Cardoso-Martins & da Silva, 2010; Miniscalco & Dahlgren Sandberg, 2010).

The researchers in these 12 studies approached word reading performance and correlates in children with ASD in different ways. Some were interested in mean performance compared to other diagnostic groups or typically developing children. Some determined rates of word reading problems in their samples of children with ASD; others selected subgroups within ASD such as precocious readers, strong word readers, or poor comprehenders to tease apart differences. A few studies reported findings that differed from others. All of this makes it difficult to find consensus and reiterates the need for more studies with larger samples and smaller age ranges.

Three studies found weaker nonword decoding than word recognition skill in children with ASD (Cardoso-Martins & da Silva, 2010; Nation et al., 2006; Smith Gabig, 2010), but three other studies found similar abilities on both tasks (Sparks, 2004; Newman et al., 2007; Huemer & Mann, 2010). This continues, therefore, to be an interesting question for additional research.

Estimated rates of reading difficulty in samples of children with ASD ranged from 10% (Jones et al., 2009) to 51% (Nation et al., 2006). Clearly this is also an important question that has not been definitively determined.

And finally, there are conflicting results regarding phonological skills in readers with ASD, whether they are typical for word reading ability, and whether they correlate with word reading ability. Some children with ASD may be delayed in their development of phonemic awareness and therefore use other strengths, like whole word memorization, when first learning how to read. Although 57% of the children with ASD in Smith Gabig's study could blend sounds at age-appropriate levels, only 29% could use word analysis to decode. The author suggested that future research include more measures of word analysis skills to better understand the decoding abilities of children with ASD. Smith Gabig (2010) also wrote:

> The ability to engage in phonological analysis at the level of onset-rimes with syllables *requires the ability to shift from the whole of the stimulus word to focus on one or more parts of the word*, an ability linked to the concept of decentering, a metacognitive achievement associated with the Piagetian stage of concrete operations that begins between 5 and 7 years of age. Future research should focus on the relationship between cognitive development and developmental changes in phonological awareness and achievement in children with autism to better understand the relationship between these critical areas of development (pp. 77-78, emphasis added).

Cognitive Flexibility, Autism Spectrum Disorder and Reading. The ability to think flexibly to concurrently consider multiple representations of letters and words is necessary in order to learn to decode using the phonetic code (Cartwright, 2008). Cognitive flexibility may be impaired in children with dyslexia (Reiter et al., 2005), and there is considerable research suggesting cognitive flexibility deficits or delays in children with ASD. If flexibility is important for the development of word reading skills, it would be logical to conclude that children with ASD would have difficulty learning to read. However, assessments of reading skills indicate that for some children with ASD the ability to read words develops surprisingly early and becomes a strength (Newman et al., 2007), while many learn to read commensurate with ability, and some struggle. Thus, we clearly have much to learn about the relationship of cognitive flexibility to reading development in this population.

Recent research has investigated relationships between cognitive flexibility and beginning reading skills in typically developing children (Altemeier et al., 2008; Cartwright et al., 2010), between ASD and cognitive flexibility (Geurts et al., 2004; Ozonoff et al., 2007;

Rosenthal et al., 2013), and between ASD and reading (Asberg et al., 2010; Cardoso-Martins & da Silva, 2010; Miniscalco & Dahlgren Sandberg, 2010; Nation et al., 2006; Smith Gabig, 2010;). However, sample sizes in studies investigating reading and ASD are typically very small. Only 2 of the 12 reviewed studies from the past decade had more than 41 participants, and even the Mayes and Calhoun research, frequently used as a reference for the field, assessed only 63 children between the ages of 6 and 15. No studies focusing on children in elementary school, when reading skills are primarily developed, had more than 14 participants. In order to learn more about the basic reading skills of high-functioning children with ASD and the predictors of those skills, it is important to include enough children in the early elementary grades for statistical power. It is also important to consider the role of executive functions, especially cognitive flexibility, in addition to typical predictors of word reading. An examination of relationships between word reading and cognitive and language measures can increase our understanding of the development of basic reading skills in high-functioning children with ASD.

Summary and Research Questions

The population of children identified with Autism Spectrum Disorder (ASD) has increased dramatically in recent years (Centers for Disease Control and Prevention, 2012; Newschaffer et al., 2007; Yeargin-Allsopp et al., 2003). As the number of children identified with milder impairments has grown, the percentage of children with ASD and cognitive impairment has declined from 68 to 38 percent, resulting in a growing number of high-functioning children in general education and resource programs.

Although cognitive, language, and literacy abilities of children with ASD have been investigated for decades, the inclusion of children with cognitive impairment in many earlier studies means that the results may not apply to the population of children currently enrolled in elementary schools. Updated performance results for a broad range of measures can improve our understanding of areas of strength and weakness in high-functioning children with ASD and inform educational planning.

Reading is critical to academic success and independence in adulthood. Studies focused on the development of reading in children with ASD have often been restricted by extremely small samples or large ranges of participant age and ability. Due to these restrictions, estimates

of the percentage of children with deficits in word reading skills have ranged from 3% (Mayes & Calhoun, 2006) to 51% (Nation et al., 2006). The percentage of high-functioning children in early elementary school struggling with age-appropriate reading skills is unclear.

A primary goal of reading research is to improve our understanding of factors related to good and poor achievement in order to improve instruction and intervention. It is important, therefore, to consider a broad range of cognitive, language, and background factors when investigating correlates and predictors of reading achievement in special populations. Executive functions are also important to consider as they are known to relate to cognitive development and achievement. Research into correlates and predictors of basic reading skills in children with ASD has produced conflicting results; some studies have found typical relationships with cognitive, language, and phonemic awareness measures, and others have not.

We know from the literature that most children with ASD exhibit deficits in executive functions such as cognitive flexibility and fluency, though there is variability within the population. Research has suggested that cognitive flexibility is important for the development of literacy. There is also considerable evidence of variation in the basic reading skills of children with ASD, yet no research has investigated relationships between cognitive flexibility, phonemic awareness, and basic reading skills in children with ASD.

The theoretical framework for this investigation was based on theories about reading words (Ehri, 2005a); theories of executive function in cognitive development (Anderson, Jacobs, & Anderson, 2008); theories about reading and cognitive flexibility (Cartwright, 2008) and theories about ASD taken from cognitive, developmental and neuropsychological scholars. I hypothesized that deficits in executive functions such as cognitive flexibility, fluency, working memory and processing speed would be seen in a sample of high-functioning children with ASD, and that a considerable minority would exhibit difficulty with word reading measures. I also hypothesized that children with ASD would perform better on a word recognition task than on a nonword decoding task, which might indicate a reliance on rote learning and associative memory over the use of phonological or orthographic strategies. This hypothesis relates to Ehri's phases of sight word reading and research in ASD and cognitive flexibility; if children struggle with phonological analysis due to delays in the development of cognitive flexibility, they may rely more upon rote learning to read sight words.

And finally, I hypothesized that deficits in cognitive flexibility would affect the development of phonemic awareness and basic reading skills in the early elementary grades because flexibility is initially required to deal with multiple representations such as the phonological, semantic, morphological and orthographic aspects of words; variation in fonts; complicated phonetic rules in a language that is not orthographically transparent (lacking specific and exclusive letter-sound correspondence) and the semantic illogic of homonyms, homographs, homophones, and rimes.

Most research in this field compares children with ASD to children with another disability or typically developing children. However, it is clear that the abilities to read words, decode and comprehend vary considerably amongst children with ASD. There are many theories about differences in performance, but thus far no clear answers are available. Since ASD is a developmental disorder, an important criterion for interpretable research should be to narrow the range of age and educational experience in study design. It is developmentally appropriate for children between the ages of five and nine to learn to read words; therefore, research investigating basic reading skills should focus on children in that age range. It is important to see how basic reading skills relate to typical correlates of beginning reading skills such as phonemic awareness, language, and intelligence. It is also important to learn more about the skills children with ASD use to read words, whether and why they may struggle with nonwords, and whether they use phonological recoding, orthographic patterns, or whole word memorization to read words. It has been recommended that studies of language in autism examine differences among children with ASD instead of comparing them to other groups of children (Tager-Flusberg, 2004); for "by directly investigating heterogeneity we can identify more homogenous subtypes within the population (page 78)."

For these reasons, this study focused on performance on, and relationships among, reading, language, and cognitive measures in a moderately sized diverse sample of high-functioning children with ASD enrolled in the primary grades. It was hypothesized that basic reading skills would relate positively to cognitive and language measures and to the ability to shift set or act flexibly; it was also hypothesized that children with ASD would have weaker nonword than word reading skills since decoding would tap cognitive flexibility more than sight word recognition. The research questions were:

1. How will a sample of high-functioning children with ASD enrolled in early elementary grades and participating in general curriculum instruction perform on basic reading tasks and related cognitive, language, and phonemic awareness measures?

2. Will high-functioning children with ASD perform better on a word recognition task than a nonword decoding task?

3. To what extent do typical correlates of beginning reading skills such as phonemic awareness, nonverbal cognitive ability and oral language predict basic reading skills in high-functioning children with ASD?

4. Does cognitive flexibility significantly correlate with basic reading skills for children with ASD, and does it contribute to the variance in basic reading skills after controlling for other factors such as language and phonemic awareness?

CHAPTER 3

Methods

This study assessed literacy, cognitive, and language abilities in high-functioning children with Autism Spectrum Disorder (ASD) enrolled in early elementary grades in order to determine performance levels and investigate relationships among measures. Sixty-three children aged 6 through 9 completed a battery of cognitive, language, and literacy tests as well as a test of cognitive flexibility, while a parent completed questionnaires and checklists to assess behaviors and executive functions in the home.

Participants

Participants were recruited by advertising through autism centers, associations, conferences, parent groups, disability organizations, clinics, newspapers, magazines, universities and schools in Michigan. Brochures, flyers, and a web site were produced in order to provide a summary of the study along with contact information for the primary investigator. Since the investigation focused on predictors of basic reading skills, an emphasis was placed on recruiting both children who read words well and children experiencing problems learning to read. At a minimum, participants had to be able to recognize ten letters; however, no children were rejected because of failure to meet this requirement.

Selection criteria. Table 3.1 lists all study requirements. Seventy-six children with ASD were assessed for possible participation in the study. Three children did not meet age or grade restrictions, 3 could not complete the assessments, and 7 had nonverbal scores below the cut-off. Thus, assessment results for 63 children with ASD living in or near Michigan were analyzed to answer the research questions.

Table 3.1. Selection Criteria for Participants

Age	6 years, 4 months through 9 years, 11 months
Grade	Enrolled in grades 1-4
Grade Retention	0-1 times
Educational Environment	Full access to/participation in general education curriculum [a]
Reading skill	Ability to identify at least 10 letters
Medical diagnosis and/or Eligibility	Autism, Asperger's, PDD-NOS, ASD
Comorbidity	No moderate or severe vision, hearing or physical disability
Cognitive Ability	NVIQ above 80
Language	Monolingual: English in home and school
ASD Interventions	No highly intense (more than six) or unusual educational or medical interventions [b]

[a] All children received literacy instruction in the general curriculum. Twelve children (19%) had received additional general education literacy support, and three (5%) had received some special education support for reading.
[b] Additional information about interventions is presented under Background Factors, below.

Diagnosis. Participants came from the population of high-functioning children enrolled in general and/or special education programs in Midwestern schools. All had a written letter of diagnosis on the Autism spectrum (Autism, Asperger's Disorder, PDD-NOS or ASD) from a psychologist or medical doctor (e.g., psychiatrist, developmental pediatrician, pediatric neurologist) and/or had received a multidisciplinary evaluation through a Michigan school district and been found eligible for special education using *Individuals with Disabilities Education Act* (IDEA) ASD criteria. Parents provided documentation of both for 62% of the participants. Psychologists and/or medical specialists were involved in the identification of all participants since a psychologist or psychiatrist is a required member of the multidisciplinary evaluation team that initially recommends eligibility for special education in Michigan.

Language. The study was restricted to children who spoke English at home. According to parent report, three children had some exposure to a second language, but the primary language at home, and the one used to communicate with the children, was English.

Age. Children ages six through nine were recruited. The tight age range of participants was a strength of this design, and a rare restriction in ASD research. There were three reasons for the small range. First, larger age ranges incorporate a greater variety of developmental levels and academic expectations, which may complicate or weaken findings. Second, there is evidence that cognitive profiles change over time for many children with ASD, with verbal

intelligence (VIQ) considerably lower than nonverbal intelligence (NVIQ) when children are young but becoming less disproportionate in late childhood, especially for children with language delays or lower overall full scale intelligence (FSIQ). Third, unusual literacy achievement patterns, such as hyperlexia, become less salient by the age of 10 as other children's word reading skills catch up. Therefore, to explore differences in basic reading skills it was important to assess children in the first few years of school, when those skills are most disparate.

Education. Children enrolled in first through fourth grade were included in the study; at a minimum, they had received reading instruction for a full year of kindergarten. Children were receiving instruction and support in a variety of settings, but all had access to, and participated in, the general education curriculum. Seventy-nine percent of the participants were enrolled in general education classrooms; half of these (40 % of the total sample) also received some support in a resource program, often for writing or work completion. An additional ten children (16 %) were placed in a general education classroom for part of the day and a special education classroom for the remainder, and three children (5%) were in special education classrooms all day. Although this means that 60% of the sample received some special education support in resource programs or self-contained classrooms, it is unlikely that remedial reading instruction was provided, as research has indicated that very few children with ASD (8%-11%) have IEP goals relating to academic achievement (Kurth & Mastergeorge, 2010).

Seventy-six percent of the parents reported that their child had never received any formal reading instruction outside of regular education; in fact, thirty percent of the children were noted to be reading simple books before the age of five. Twenty percent of the children had received some form of literacy instruction (including comprehension or writing) in general education programs such as summer school, a response-to-intervention program, or tutoring. Only five percent were reported to have received special education support through a teacher consultant or resource teacher for basic reading instruction.

Grade Retention. Seven of the participants spent two years in kindergarten, usually at parent request; typically the first year was in a special education class, and the second year was in a general education kindergarten. One of these children later skipped a grade to catch up with her age peers. One child repeated first grade at parent request; there were no other grade retentions.

Comorbidity. There were no participants with moderate to severe vision, hearing, or physical impairments.

Cognitive Ability. Seven children with nonverbal ability (NVIQ) below the 10th percentile (at or below 80), as measured by the Woodcock-Johnson III Thinking Ability-Standard Scale (WJ-III: Woodcock, McGrew, & Mather, 2001), were excluded from analyses. Full scale IQs for these excluded children ranged from 47 to 75. This restriction of the sample was intended to reduce the possible confounding of cognitive impairment with performance on executive function assessments. Nonverbal ability was considered a more accurate measure of overall ability than full scale IQ because verbal skills are often depressed in early elementary children, catching up to nonverbal ability around the age of 8-10.

ASD Interventions. Background information was used to create a scale reflecting the number of current and past medical and educational interventions each child had received. This scale was used to ensure that children receiving highly intense or unusual therapies who were also outliers on dependent or independent variables would be excluded from analyses. Specific information about the coding of this scale is presented below. None of the children, however, who met all other selection criteria for inclusion in the study group had a high score on this intervention scale.

Sample

The 63 participants meeting selection criteria for the study ranged from 6 years 4 months to 9 years 11 months in age. There were 55 males (87%) and 8 females (13%). The racial/ethnic distribution was 87 percent (55) white; 3 percent (2) Black; 5 percent (3) Asian; and five percent (3) Hispanic. Thirty-three percent (21) of the children were enrolled in first grade; 27% (17) in second grade; 22% (14) in third grade; and 16% (10) in fourth. Thirty-seven percent of the children had also been identified with an attention deficit.

Measures

A variety of instruments was utilized to screen participants for inclusion in the study and to assess cognitive and language ability, cognitive flexibility, phonemic awareness and other abilities that may be related to the acquisition of word reading skills.

Cognitive. Subtests from the Woodcock-Johnson III Tests of Cognitive Abilities were used to obtain estimates of cognitive cluster abilities (Figure 3.1). These included General

Intellectual Ability (FSIQ), Verbal Ability-Extended Scale (VIQ), Thinking Ability-Standard Scale (NVIQ), and Cognitive Efficiency-Standard (Visual Matching and Numbers Reversed). Individual test scores were also examined, including Retrieval Fluency and Rapid Picture Naming as measures of cognitive fluency. These tests and indices were then explored as possible predictors of reading, as they have been found to relate to decoding in typically developing early elementary students (Christopher et al., 2012; Fletcher et al., 2011; Floyd et al., 2007; Mayes et al., 2008; Pammer & Kevin, 2007). Cognitive measures were also used to control for overall ability while investigating the contribution of cognitive flexibility to basic reading skills.

The WJ-III was selected as it was designed to assess the full range of cognitive abilities according to the Cattell-Horn-Carroll theory (McGrew, 2005). It attempts to assess narrow abilities individually, and was normed on the same sample as the WJ-III Achievement tests, permitting the direct comparison and combination of ability and achievement measures (Mather & Schrank, 2001). Additionally, there is value in utilizing the WJ-III to assess cognitive and achievement abilities in high-functioning children with ASD as it is frequently available in the field, yet few studies have examined this population's cognitive performance on this instrument.

General Intellectual Ability, used to measure FSIQ, estimates g, a global predictor of school and lifetime achievement related to overall cognitive ability. The Standard Scale combines results from Verbal Ability (Verbal Comprehension), Nonverbal Ability (Visual-Auditory Learning, Spatial Relations, Sound Blending, and Concept Formation), and Cognitive Efficiency (Visual Matching and Numbers Reversed). It has a median reliability of .98 for children between age 5 and 19 (all reported WJ-III reliabilities are for ages 5-19).

The Verbal Comprehension measure from the standard battery includes picture vocabulary, synonym, antonym and verbal analogy subtests to measure verbal ability. Its use alone might underestimate VIQ in children with ASD since the latter three tasks involve the mental manipulation of multiple representations of words, a skill known to be difficult for some children with ASD (Huemer & Mann, 2010; Sparks, 2004) and one that taps cognitive flexibility. The Verbal Ability- Extended Scale adds to this basic set of tasks a test of applied contextual knowledge (General Information), and it was therefore used as a broader measure of functional verbal ability (Sparks, 2004). The median reliability is .94.

Nonverbal ability (NVIQ) was assessed with the WJ-III Thinking Ability-Standard Scale, which includes one test from each of the four thinking abilities – long-term retrieval (Visual-Auditory Learning), visual-spatial thinking (Spatial Relations), auditory processing (Sound Blending), and fluid reasoning (Concept Formation). The Thinking Ability scale has median reliabilities of .94.

Visual-Auditory Learning is primarily a test of associative memory. Respondents are asked to quickly learn and recall meanings for rebuses in order to "read" sentences. It has a median reliability of .86.

Spatial Relations asks subjects to identify, from five choices, two or three puzzle pieces that, when rotated and combined, would replicate a target shape. It has a median reliability of .81.

In Sound Blending the subject listens to a series of syllables or phonemes and blends them into a word; it has a median reliability of .86. Sound Blending is an important test in the WJ-III, as it is used as a measure of phonemic awareness/synthesis in addition to being the auditory processing component of nonverbal ability. Its role in these two clusters is one reason that scores from individual tests (rather than cluster indices) were used in the final regression models for predicting reading.

In Concept Formation the subject is presented with sets of visual stimuli that vary in color, shape, size, and number. For each set the subject needs to determine a rule of class membership (e.g., which shape is the most different and why). Immediate feedback is given about the rule, so subjects can learn and improve. This task is primarily a measure of fluid reasoning, but it has similarities with the WCST and also taps cognitive flexibility; therefore, it was also sometimes used as a measure of flexibility. To address its dual role as a component of the Nonverbal cluster and as a measure of cognitive flexibility, the components of nonverbal ability, rather than the index, were individually entered into the final regression models that predicted reading.

The Cognitive Efficiency cluster includes Numbers Reversed and Visual Matching. Numbers Reversed is a measure of working memory with a median reliability of .86. The subject listens to a set of numbers (beginning with two) and is asked to repeat them in reverse. Visual Matching is a task of perceptual discrimination in which the subject locates and circles two matching numbers in each set of six. It is a timed test with a median reliability of .89.

Figure 3.1. Measures of Cognitive Abilities [a]

General Intellectual Ability-Standard Scale[b] (FSIQ)

      Verbal Ability-Extended Scale (VIQ)
          Verbal Comprehension
          General Information

      Thinking (Nonverbal) Ability-Standard Scale (NVIQ)
          Visual-Auditory Learning
          Spatial Relations
          Sound Blending
          Concept Formation

      Cognitive Efficiency-Standard Scale
          Visual Matching
          Numbers Reversed

      Cognitive Fluency
          Retrieval Fluency
          Rapid Picture Naming

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[a] Woodcock-Johnson III Tests of Cognitive Ability and Tests of Achievement (Woodcock et al., 2001)
[b] Verbal Comprehension, Visual-Auditory Learning, Spatial Relations, Sound Blending, Concept Formation, Visual Matching, and Numbers Reversed

      Cognitive Fluency was measured with two individual tests: Retrieval Fluency and Rapid Picture Naming. In Rapid Picture Naming the subject names pictures of common items as quickly as possible; its median reliability is .97. In the Retrieval Fluency task each subject is given one minute to name as many items from a category (food/drink, names, and animals) as possible. It is a test of ideational fluency or generation and has a median reliability of .83.

      Language. Language, Phonemic Awareness, and Reading measures are shown in Figure 3.2.

      The Oral Language Extended Skills Cluster of the WJ-III was used as the measure of language ability. It is a composite of four subtests: Story Recall and Picture Vocabulary (Oral Expression cluster), and Understanding Directions and Oral Comprehension (Listening Comprehension cluster).

      The Story Recall task asks the respondent to echo a short story or state all recalled details of a story; it taps short-term auditory memory. The test begins with items containing two short sentences, and ends with items containing five complex sentences. Participants are scored on the

number of pertinent details recalled. Story Recall has a median reliability of .87 in the age range of 5 to 19.

Picture Vocabulary assesses language development, vocabulary, and word retrieval by asking the respondent to name items in pictures. It has a median reliability of .77 in the 5 to 19 age range.

Understanding Directions is a test of language comprehension. Participants are presented with a picture and asked to follow increasingly complicated oral instructions to point to various objects. Six pictures and sets of directions are included in the task; the starting point is based on an estimate of the respondent's listening comprehension. It has a median reliability of .77 in the 5 to 19 age range.

The Oral Comprehension task is an oral cloze procedure requiring the respondent to complete a sentence or passage with a logical word. It taps listening comprehension, reasoning, and vocabulary, and has a median reliability of .80 in the 5- to 19-year age range.

Phonemic Awareness. Strong correlates of beginning reading skills in typically developing children include phonemic awareness (Fletcher et al., 2011; Hammill, 2004). Three phonemic awareness measures from the WJ-III battery as well as a cluster index were used to investigate interrelationships with cognitive flexibility and reading: Sound Blending (discussed above), Incomplete Words, Sound Awareness (phonological awareness, the ability to mentally manipulate phonemes), and their index, Phonemic Awareness.

Incomplete Words measures auditory analysis and closure by asking a respondent to identify words with one or more missing phonemes; its reliability is .77.

Although Sound Blending and Incomplete Words require shallow phonological sensitivity (Stanovich, 1992), Sound Awareness requires deep phonological sensitivity. The test requires participants to mentally manipulate speech sounds to retrieve words that rhyme with a stimulus, and to delete, substitute, or reverse speech sounds to create another word. The rhyming task proceeds from pointing at a picture to recalling a word that rhymes with the stimulus. In Deletion, the subject is asked to remove a phoneme from a word to create a new word. In Substitution, syllables or phonemes are substituted to create new words, and in Reversal, syllables or phonemes must be mentally reversed to identify new words. Sound Awareness has a median reliability of .81.

Figure 3.2. Measures of Language, Phonemic Awareness, and Basic Reading Skills[a]

Oral Language-Extended Scale
        Oral Expression Cluster
                Story Recall
                Picture Vocabulary

        Listening Comprehension Cluster
                Understanding Directions
                Oral Comprehension

Phonemic Awareness (Factor Cluster)
                Sound Blending [b]
                Incomplete Words
                Sound Awareness

Reading Skills
        Basic Reading Skills Cluster
                Letter-Word Identification (Word Identification)
                Word Attack (Nonword Decoding)

[a] Woodcock-Johnson III Tests of Cognitive Ability and Tests of Achievement (Woodcock et al., 2001)
[b] Also in Thinking Ability Scale

Reading. The Basic Reading Skills Cluster from the Woodcock-Johnson III Tests of Achievement (Woodcock et al., 2001) was used as the measure of word reading. This combination of Letter-Word Identification and Word Attack is considered an index of decoding skill (Floyd et al., 2007; Locascio et al., 2010). Letter-Word Identification, shortened to Word Identification in this paper, assesses the ability to read common sight words, while Word Attack assesses the ability to decode nonwords. Word Attack is referenced as Nonword Decoding in this paper.

Cognitive Flexibility. Measures of cognitive flexibility are listed in Figure 3.3. There were four measures; three from performance tasks and one from a parent rating scale.

The first two measures of cognitive flexibility were taken from each child's performance on a computerized version of the Wisconsin Card Sorting Test (WCST: Heaton et al., 1993). The WCST uses a simulated deck of cards with four possible numbers of four possible shapes in four possible colors. Four stimulus cards are depicted on the computer screen representing four different categories. The participant is asked to match each card from the response deck to one of the stimulus cards and is told whether each choice is right or wrong. The cards can be matched

Figure 3.3. Measures of Cognitive Flexibility

Performance

       Wisconsin Card Sorting Test
              Total Errors
              Perseverative Responses

       Woodcock-Johnson III[a]
              Concept Formation[b]

Natural Environment

       Parent Ratings (Behavior Rating Inventory of Executive Function)
              Shift (Cognitive Flexibility)

[a] Woodcock-Johnson III Tests of Cognitive Ability and Tests of Achievement (Woodcock et al., 2001)
[b] Also in Thinking Ability Scale

on color, shape, or number. After the child has made a specified number of "correct" responses on any of the three criteria, the examiner changes the criterion without any explicit signal and says "wrong" to each incorrect response until the respondent guesses the new rule and uses it. The task is theorized to be a measure of set shift, or cognitive flexibility. Scoring includes the total number of correct responses and the number of errors, refined further into the number of categories completed, perseverative errors (nonrandom errors based on previous/incorrect rules), perseverative responses (consistent with previous rule but possibly correct), nonperseverative (random) errors, and set breaks. Numerous studies have found that people with ASD tend to make an above-average number of errors and perseverative responses (Kaland et al., 2008; Ozonoff & Jensen, 1999; Rumsey, 1985); therefore, the WCST total errors score and number of perseverative responses were examined for this study. The traditional WCST was normed on children ages 6 and up, while the computer version is normed for 6.5 and up (Chelune & Baer, 1986; Heaton et al., 1993). A reliability study with ASD participants found test-retest coefficients of .93 on perseverative errors and .94 on total errors (Ozonoff, 1995).

       The third measure of cognitive flexibility is the Concept Formation test on the WJ-III, described in the Cognitive Measures section; it is primarily a measure of fluid reasoning.

       The fourth measure of cognitive flexibility was taken from the Shift scale on the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). The BRIEF is an 86-item parent questionnaire developed to assess a child's executive functioning in daily life. It

attempts to measure executive function in a natural, as opposed to experimental, setting. Responses are made using a three-point scale for the frequency of each behavior (never, sometimes, or often). Results are calculated for eight subscales: Initiate, Working Memory, Plan/Organize, Organization of Materials, Monitor, Inhibit, Shift, and Emotional Control. Each subscale is reported as a T-score with a mean of 50 and standard deviation (SD) of 10; T-scores over 64 indicate possible clinical significance. The BRIEF was normed on 1419 control children and 852 children from clinical referrals. Mean internal consistency ranged from .80 to .98 and test-retest reliability from .76 to .88. Preliminary studies indicated sensitivity to executive function deficits in a variety of disorders, and construct validity was evidenced through convergent and discriminant analyses with respected measures of emotion, behavior and attention (Gioia et al., 2002). Children with ASD have been found to score higher on all scales, but especially the Shift scale, than typically developing children or children with AD/HD, RD or Traumatic Brain Injury (TBI). This paper presents descriptive data from the BRIEF regarding all parent ratings of executive problems, but only the Shift scale was used in analyses.

The Shift scale assesses the ability to make transitions, tolerate change, switch attention, problem-solve flexibly, and change mindsets or topics (Gioia et al., 2000). Because children with ASD often struggle to generalize and apply skills, the Shift scale of the BRIEF is designed to assess how much the child applies cognitive flexibility in daily functioning. This measure was hypothesized to relate more strongly to basic reading skill achievement than the WCST because it was based on daily behavior in the natural environment.

Background Factors. Parents completed two short questionnaires (Appendix B) providing participant background information such as date of birth, grade, current and past educational placements, medical problems, major developmental milestones, parent education and occupation, and past and current interventions for ASD. Many of these questions were open-ended. Responses were reviewed to ensure that no participants needed to be removed from analyses due to medical comorbidities, multiple grade retentions or any other exclusion criterion. Responses from the questionnaires then were coded to create categorical and dummy variables for race (minority), sex (maleness), age at administration, grade, grade retention, medical diagnosis, IEP, age child could read a beginning book, and whether the child had received any tutoring or special support in reading.

A checklist of possible psychological, educational, therapeutic and biomedical therapies for autism was included in the parent questionnaire, and any checked item provided a follow-up question asking for length of time and other pertinent information. This information was used to create a measure for ASD Interventions, with 0 assigned for no educational or medical interventions; 1 for one through four typical interventions (e.g., occupational therapy, physical therapy, speech and language therapy, applied behavioral analysis, sign language, sensory integration, or play-based therapy); 2 for five to six therapies, and 3 for unusual or intense (seven or more) therapies. No children meeting selection criteria for inclusion in the study group were coded 3.

A rough indicator of socio-economic status (SES) was created from parent education and occupation information; each parent or partner was coded 0-2 for educational attainment (high school=0, some college=1, graduate/professional school=2) and 0-2 for occupation (unskilled=0, skilled=1, professional=2). Families were given an additional point if they declined the gift card offered (see Assessment Procedures below); this resulted in an ordinal variable ranging from one to seven.

The background variables are listed in Figure 3.4. Relationships among these background variables, cognitive ability, and literacy achievement were reviewed to see if there were any possible confounding factors influencing results, such as comorbidities, interventions, or SES.

The Social Communication Questionnaire – Lifetime (Rutter, Bailey, & Lord, 2003) is a parent checklist of 40 communication and social skills designed as a preliminary screening instrument for the identification of children needing further evaluation for ASD (Berument, Rutter, Lord, Pickles, & Bailey, 1999); it is listed in Figure 3.4. Some questions refer to current behaviors, and others to behaviors when the child was four years old. The instrument is internally consistent (.93) with a high test - retest reliability (.81). It has been found to be both sensitive (.85) and specific (.75) as a measure of ASD (Norris & Lecavalier, 2010; Skuse, Mandy, & Scourfield, 2005).

In this study, use of the Social Communication Questionnaire (SCQ) had initially been intended to corroborate each child's ASD diagnosis. However, there were compelling reasons to

Figure 3.4. Background Measures

Participant Information[a]
        Sex
        Race (White, Black, Hispanic, Asian)
        Grade
        Age at Test Administration Grade
        Grade Retention
        SES (Parent education/occupation scale, 0-7)
        ASD Interventions (0-3)
        Attention Deficit/Hyperactivity Disorder

Autism Screening: Social Communication Questionnaire – Lifetime

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[a] Parent Questionnaires

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believe that this criterion was inappropriate in the current sample. Ten percent of the parents did not identify a sufficient number of classic characteristics of autism in their child to meet the ASD cutoff score of 15; this group included all of the non-white parents. Determining cutoff scores is always a balancing act between sensitivity and specificity, and a recent validation study reported that 17 percent of locally diagnosed children failed to meet the ASD cutoff on the SCQ (Chandler et al., 2007). The investigator's clinical impressions of autistic-like behaviors observed during assessment had only a modest relationship with parent ratings, and there were also no significant relationships between SCQ scores and most variables, including FSIQ. The parent rating did correlate positively ($r = .34$, p $<.01$) with ASD Interventions, as children perceived by parents to exhibit more autistic behaviors were more likely to have received interventions through special education or private clinics. The only other significant correlations were with parent ratings on the BRIEF, indicating that parents who rated their children with numerous symptoms of autism also noted numerous problems with executive functions. This correspondence could be due to the actual severity of autism or to parental bias on both questionnaires. Given these factors, it was determined that the SCQ cutoff score for the referral of unidentified children could not be used to confirm diagnosis in high-functioning children who had long been receiving interventions to target such behaviors. As a result, the score was included in analyses but not used to eliminate children from the study.

Assessment Procedures

Assessment sites were arranged at the University of Michigan School of Education, the Eastern Michigan University Autism Collaborative Center, and regional school district offices across the state. Individual arrangements were also made upon request to utilize conference rooms in public libraries, school districts, and other universities for the assessment.

Several documents, including a description of the study, consent form, and participant information form were provided to parents who expressed interest in the study in response to flyers, newsletters, brochures, advertisements or the web site. Assessment appointments were scheduled for a location and time convenient for the family. At the beginning of the appointment, the assessments were described, questions were answered, and signed consent was received. Each child was asked for and granted assent. The WJ-III Cognitive Assessment, language and literacy subtests from the WJ-III Tests of Achievement were administered in standard order. The computerized WCST was the final task. A visual checklist was used to help the child predict and manage the testing sequence, and small items such as pencils, erasers and toys were offered at the completion of the cognitive battery and at the completion of all tasks.

All assessments are standardized instruments, and established procedures for administration and scoring were followed. Standard accommodations provided included the reduction of environmental distractions, verbal encouragement, and a brisk pace to maintain the child's engagement. Because transitions between tasks, formats, and modes are generally difficult for children with ASD, the stimuli for Sound Blending, Incomplete Words, Story Recall, Understanding Directions, Oral Comprehension, and Sound Awareness were presented orally, an accommodation acceptable under certain circumstances according to the publisher. This eliminated the loss of time and participant engagement that resulted from shifting from an oral to a recorded stimulus mid-task. Since all assessments were conducted by the principal investigator, administration and accommodation protocols were provided consistently across participants. It is possible that mean scores for some tasks were mildly inflated from the accommodation, but differences between children and relationships among measures would remain.

While children were being assessed, a parent completed the developmental questionnaire, BRIEF and SCQ. A $25 gift card was offered to families upon the completion of testing and receipt of all paperwork. Families were mailed a summary report of their child's assessment results and offered a telephone conference to discuss the results in more detail.

Scoring Procedures

All assessments were scored according to publisher procedures. Standardized scores calculated by age were used for most measures, including the WCST and the cognitive and achievement tests, while T-scores were used for the BRIEF. Age-based standardized scores were considered appropriate for most analyses since a few children had been retained one grade. However, standardized scores by grade were used to analyze differences between nonword decoding and sight word identification skills since classroom instruction was assumed to impact these skills. Background and developmental items were coded into dummy, categorical, or ordinal variables, such as the measure for ASD Interventions.

Research Design

Descriptive statistics were calculated to review the performance of participants on cognitive, language, literacy, and cognitive flexibility measures; these data served to address the first research question. Since the standard scores were based on large national samples, it was possible to determine whether participant performance was typical for age.

Another analysis compared standard scores calculated by grade level for the two components of the basic reading skill index (Letter-Word Identification, labeled Word Identification, and Word Attack, labeled Nonword Decoding). A one-sample t-test was calculated to answer the second research question: whether children with ASD performed better on word recognition tasks than decoding tasks.

A series of correlation and multiple regression analyses was then conducted to investigate relationships among the measures. The combination of variables that best predicted basic reading skill was identified by systematically removing predictor variables according to a theory-driven model. Results answered the research question of whether typical correlates of beginning reading skills such as phonemic awareness, NVIQ and oral language would predict basic reading skills in children with ASD. Correlations and regressions were also used to determine whether measures of cognitive flexibility correlated significantly with basic reading skill, and whether they added to the prediction of basic reading skills after controlling for language, NVIQ and phonemic awareness.

Cognitive and language ability, cognitive flexibility, literacy-related skills and reading measures were predicted to correlate positively. However, research suggested that they might

not correlate or predict basic reading skills as strongly in an ASD sample as in typically developing children. Correlations from the Woodcock-Johnson III Normative Update Technical Manual (McGrew, Schrank, and Woodcock, 2007) and data from the literature were used for comparison. It was expected that cognitive flexibility would make a unique contribution to the prediction of basic reading skill.

CHAPTER 4

Results

This chapter is a report of the results of analyses conducted to check for interactions with background factors, summarize assessment results, and answer research questions. It begins with a review of background measures to address concerns about confounding of results, then describes results from the parent checklists. Participant performance on cognitive, language, phonemic awareness, reading, and cognitive flexibility measures are reviewed to answer the first research question. The data are examined in more detail to determine whether children with ASD can decode nonwords as well as they can recognize sight words. The last two research questions are then addressed: whether typical correlates of reading skills predict a significant amount of the variance for children with ASD, and whether cognitive flexibility adds to a prediction model that includes nonverbal, language, and phonemic awareness measures.

A correlation matrix including all dependent and independent variables is presented in Appendix C.

Cognitive, Language, Reading, Executive Function and Background Measures

Background Variables. Descriptive and/or frequency data for all variables were examined to ensure correct coding. Cross tabulations and a correlation matrix were generated to check background variables such as race, sex, socio-economic status (SES), Autism Spectrum Disorder (ASD) interventions, and comorbid Attention Deficit/Hyperactivity Disorder (AD/HD) to see if any factors correlated strongly with dependent or independent variables in a manner that might confound results. Table 4.1 presents the correlations among these background, predictor, and outcome variables.

Table 4.1. Correlations for Background, Literacy, and Cognitive Flexibility Measures

	Basic Reading	Word Identification	Nonword Decoding	BRIEF Shift	WCST Total Errors	WCST Perseveration	Phonemic Awareness[a]	Sound Awareness
Sex (Male)	-.10	-.13	-.07	-.01	-.14	-.15	.09	-.14
Age	-.25*	-.32**	-.17	-.02	.07	-.05	-.04	-.09
Grade	-.18	-.26*	-.10	.07	.08	-.04	-.05	.00
Retained	-.22	-.12	-.31**	-.22	.07	.06	-.06	-.11
Non-white	.26*	.31**	.18	.01	-.13	-.13	.04	-.06
Interventions	.05	.08	.01	.02	-.14	-.08	-.22	-.27*
SES	.16	.20	.11	-.17	.10	.08	.14	.07
AD/HD	-.13	-.16	-.08	.18	-.14	-.08	-.11	-.04

[a] Sound Blending and Incomplete Words
* Correlation is significant at the .05 level (two-tailed).
 ** Correlation is significant at the .01 level (two-tailed).

Sex. This variable was coded 1=male, 0=female; thus, negative correlations indicate that girls performed slightly better on measures. There were no significant correlations with any of the dependent variables.

Age. There were significant relationships between age and both the Basic Reading cluster ($r = -.25$, $p < .05$) and Word Identification ($r = .-32$, $p < .05$); younger children tended to receive higher standardized scores on word recognition which also affected the cluster score.

Grade. There was a small but significant negative relationship between grade and Word Identification ($r = -.26$, $p < .05$); first graders tended to score higher when standardized by age.

Grade Retention. Repeating one grade had a negative correlation with Nonword Decoding ($r = -.31$, $p < .01$) when normed on age, but not when normed on grade ($r = -.16$).

Race. Non-white participants tended to be younger than the average participant; half (4) were in first grade, 2 were in second grade, 2 in third, and none in fourth. Since first graders tended to have higher standard scores on the reading tasks, nonwhite students as a group performed somewhat better than the average participant on Word Identification ($r = .31$, $p < .05$), and Basic Reading Skills ($r = .26$, $p < .05$). There were no other significant correlations.

ASD Interventions. The Intervention scale created from parent responses to the background questionnaire was negatively correlated with the Woodcock-Johnson III (WJ-III: Woodcock, McGrew et al. 2001) Sound Awareness score ($r = -.27$, $p < .05$), suggesting that children with more severe characteristics had more trouble with the phonological tasks.

Socioeconomic Status (SES). Parent education ranged from completion of eighth grade through professional degrees and doctorates. There were no significant correlations with any literacy or cognitive flexibility measures.

Attention Deficit/Hyperactivity Disorder. A dual-diagnosis of AD/HD had no significant relationship with any dependent measures.

Overall, though there were some relationships among background, literacy, and cognitive flexibility variables, the magnitude of correlations was small and did not suggest unusual confounding of results.

Parent Ratings. Parent ratings from the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000) and the Social Communication Questionnaire are shown in

Table 4.2 below. As a group, parents reported that their children exhibited many more executive function problems than is typical for same-age children; T-scores for the various scales (standardized to a mean of 50 on a national sample) ranged from 36 to 99.9. Consistent with the literature (Gioia et al., 2002), the highest ratings were for Shift (cognitive flexibility), Working Memory, and Planning; all were nearly two standard deviations (SD) above the standardized scale mean. Although a high rate of executive function problems in children with ASD has consistently been reported in the literature, some parents in this study did not appear to discriminate among items, but instead selected the same response for all or most items. This "straight line" response bias, with high parent ratings on many items, may help explain why none of the BRIEF measures correlated significantly with cognitive or achievement variables. The construct of interest, Shift, correlated significantly with only one variable besides other BRIEF scales: the SCQ parent checklist ($r = .37$, p < .01). This correlation between parent ratings could be due to consistent response bias across instruments or due to the severity of a child's ASD resulting in higher ratings on both instruments. However, the latter explanation is not supported by other results since neither Shift nor SCQ correlated significantly with any cognitive or achievement variables.

Scores for the SCQ ranged from 6 to 34, and the mean was 19.4. Although 14 children were rated below the recommended cutoff score of 15, other recent studies have also found false negatives on the SCQ and have recommended that lower cutoffs be used to avoid missing children who would meet diagnostic criteria for ASD (Brooks & Benson, 2013; Corsello et al., 2007). One recent study utilizing a clinical sample of children diagnosed with ASD found variability in ratings similar to those in the current study and a mean of only 14.4, indicating that many of the children with ASD had received scores below the cutoff of 15 (Ghazuiddin, Welch, Mohiuddin, Lagrou, & Ghaziuddin, 2010).

Figure 4.1 shows the distribution for the Shift Scale of the Behavior Rating Inventory of Executive Function, a measure of problems with cognitive flexibility. It is slightly skewed to the left (-.12, standard error .30). As the scores represent T-scores normed on a typical population (with a normative mean of 50), it can be seen that only five parents in the sample scored their child below the normed average. As stated previously, the average rating for study participants was nearly two standard deviations above the mean. Clearly, most parents of study participants observed numerous difficulties with cognitive flexibility in the daily lives of their children.

Table 4.2. Descriptive Statistics for Parent Ratings of Child Behaviors

Behavior Rating Inventory of Executive Function	Mean	Standard Deviation	Min	Max
Inhibit	61.3	12.14	37	87
Shift	68.1	11.21	43	91
Emotional Control	61.4	13.16	36	85
Behavioral Regulation Index	64.9	11.03	41	88
Initiate	64.8	11.79	42	95
Working Memory	68.6	9.66	49	85
Plan/Organize	67.6	12.47	39	100
Organization of Materials	58.8	9.42	36	72
Monitor	65.0	9.67	44	82
Metacognition Index	67.8	9.80	44	87
Global Executive Composite	67.9	9.67	43	88
Social Communication Questionnaire (Raw Score)[a]	19.4	6.32	6	34

Note. BRIEF items are measured as T-scores, with a normal mean of 50; means above 50 indicate above-average problems. A difference of 10 from the mean indicates a difference of one standard deviation. The N for all variables was 63.

[a] The recommended cutoff for further evaluation of ASD in an undiagnosed child is 15.

Figure 4.1. Shift Scale Scores from the Behavior Rating Inventory of Executive Function
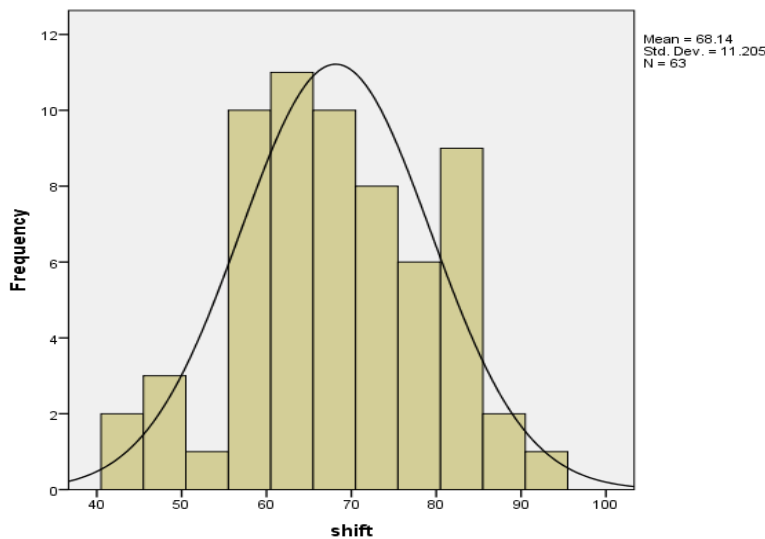
Note: Scores are T-scores with a mean of 50.

Cognitive, Language, and Reading Measures. The first research question addressed the performance of a sample of high-functioning children with ASD enrolled in early elementary grades and participating in general curriculum instruction on basic reading tasks and related cognitive, language, and phonemic awareness measures. The assessment results summarized in this section are usually reported as standardized scores or T-scores normed by age, which makes it simple to discern whether performance, on average, varied from that of typically-developing children. Independent t-tests were also calculated to determine whether differences were significantly discrepant from national norms.

As can be seen in Table 4.3, the children's mean standard score on the measure of General Intellectual Ability (FSIQ) reflects average performance. The verbal and nonverbal scales and their individual components were all average or slightly above average for age, while Cognitive Efficiency, Visual Matching, Numbers Reversed, Retrieval Fluency, and Rapid Picture Naming were below. In general, means that varied more than about 6 points from 100 reached significance ($p < .05$) on independent t-tests. Since the sample excluded children with nonverbal IQ of 80 or below, statistical means slightly above 100 would not be unexpected. Group means that are slightly above average should therefore be viewed with caution and not necessarily considered important. Means below average, however, are notable and likely to indicate areas of weakness for high-functioning children with ASD; this would especially be relevant for Cognitive Efficiency, Visual Matching, Numbers Reversed and Retrieval Fluency.

Although mean performance was within the range of average for most cognitive measures, the range of performance was considerable, especially for Visual Matching (85). Some children had great difficulty circling the two matching numbers on each line in this simple task, suggesting problems with symbol discrimination and processing speed. Another test with large performance variability (a range of 78 points) was Retrieval Fluency, a test of long-term retrieval, categorization, and ideational fluency. In contrast, Spatial Relations had a relatively narrow range of performance (48), suggesting that the ability to visually discriminate between and mentally rotate shapes is intact in most high-functioning children with ASD.

Table 4.3. Descriptive Statistics for Cognitive Measures

	Mean	Standard Deviation	Min	Max
General Intellectual Ability[a] (FSIQ)	99.0	12.51	69	129
Verbal Ability (VIQ)	104.6	14.10	66	134
Verbal Comprehension	104.8	12.42	72	130
General Information	104.8	15.54	58	137
Thinking (Nonverbal) Ability (NVIQ)	104.7	11.23	81	135
Visual-Auditory Learning	100.5	15.06	69	144
Spatial Relations	100.3	10.13	70	118
Sound Blending	106.1	12.08	68	132
Concept Formation	105.0	12.41	62	131
Cognitive Efficiency Cluster	86.4*	14.89	41	111
Visual Matching	82.4*	19.65	33	118
Numbers Reversed	91.0*	15.69	50	120
Cognitive Fluency				
Retrieval Fluency	87.9*	18.78	50	128
Rapid Picture Naming	94.4	14.47	59	128

Note. The N for all variables is 63.
[a]Verbal Comprehension, Visual-Auditory Learning, Spatial Relations, Sound Blending, Concept Formation, Visual Matching, and Numbers Reversed
*Significantly below the normative mean (independent t-test) at $p < .05$.

The areas of weakness, Cognitive Efficiency and Cognitive Fluency, were examined more closely. The Cognitive Efficiency cluster included the Visual Matching and Numbers Reversed tasks. The mean score for Visual Matching ($X = 82$) was the lowest of all the cognitive tests; its distribution is shown in Figure 4.2. Although a few children scored at or above average on the Visual Matching Task, half (31) exhibited significant deficits in perceptual speed by scoring at least 1 SD below average (the 16th percentile). Numbers Reversed ($X = 91$), which taps working memory and cognitive flexibility (Hale et al., 2008), was also a challenging task for many children, with 22 (35%) performing at least 1 SD below average (Figure 4.3). Clearly this

Figure 4.2. Distribution of Scores for Visual Matching

Mean = 82.43
Std. Dev. = 19.65
N = 63
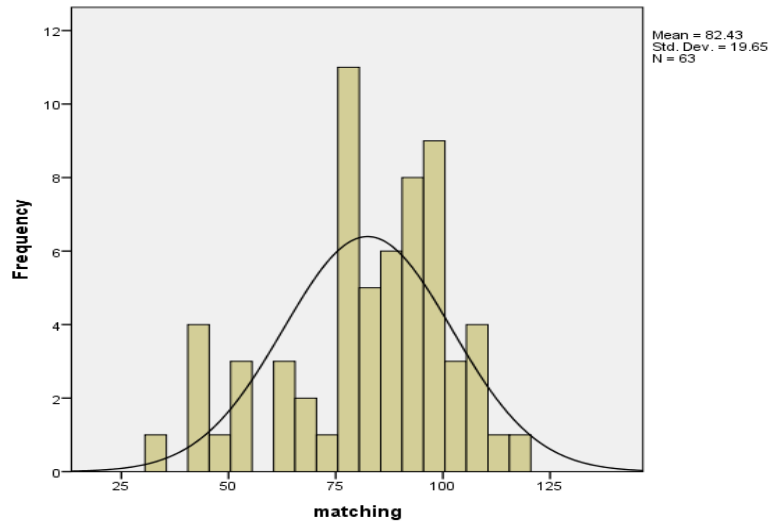
Note: Skew(X) = -.70

Figure 4.3. Distribution of Scores for Numbers Reversed

Mean = 90.95
Std. Dev. = 15.694
N = 63
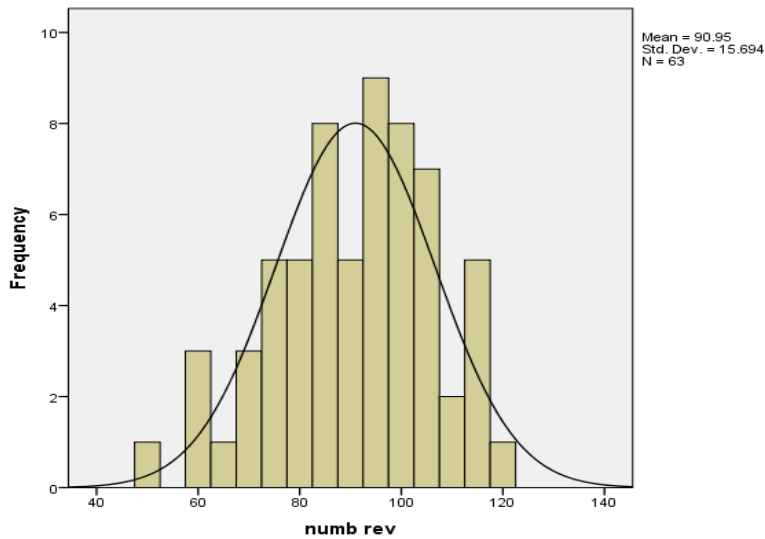
Note: Skew(X) = -.46

sample of children, as a group, exhibited significant problems with cognitive efficiency, visual processing speed, and working memory.

Most participants also performed below average on the Cognitive Fluency tasks; those distributions are shown in Figures 4.4 and 4.5. Forty-one percent of the participants scored at least 1 SD below average on Retrieval Fluency, and 29% performed below the 1st standard deviation on Rapid Picture Naming.

Language and literacy test results are shown in Table 4.4. The Basic Reading Skills index and the components Word Identification and Nonword Decoding were all slightly, but not significantly, above average. Two of the three phonemic awareness measures (Sound Awareness and Sound Blending) and the cluster index were also slightly above average for age. Incomplete Words, the third phonemic awareness measure, requires the retrieval of rhyming words from memory, so below-average group performance on this task may have been affected by retrieval weaknesses in some children.

Oral Language was average for age; the Oral Expression cluster (106) was slightly above average, and the Listening Comprehension cluster (97) slightly below. Oral Expression included two tests: Story Recall (echoing sentences and paragraphs), which was a relative strength for many children, and Picture Vocabulary, which also was slightly above average. In contrast, the Listening Comprehension test Understanding Directions, which requires the storage and processing of complex oral instructions, was relatively difficult for the group. The distribution of scores for Understanding Directions is shown in Figure 4.6; the mean was significantly below average compared to typically developing children. One-third of the children (20) performed more than one SD below average on this task.

In reviewing the cognitive and language results together it becomes apparent that participants exhibited slight, though not statically significant, strengths in vocabulary (Verbal Comprehension, General Information, Picture Vocabulary), and short-term auditory memory (Story Recall). Weaknesses were seen for many children on the timed cognitive tests that tapped processing speed and/or long-term retrieval (Visual Matching, Retrieval Fluency, and Rapid Picture Naming). Working memory (Numbers Reversed and Understanding Directions) was also difficult for the group on average. During administration it was clear that many participants had difficulty attempting the Visual Matching, Numbers Reversed, and Retrieval Fluency tasks despite non-distracting test environments and verbal encouragement from the examiner.

Figure 4.4. Distribution of Scores for Retrieval Fluency
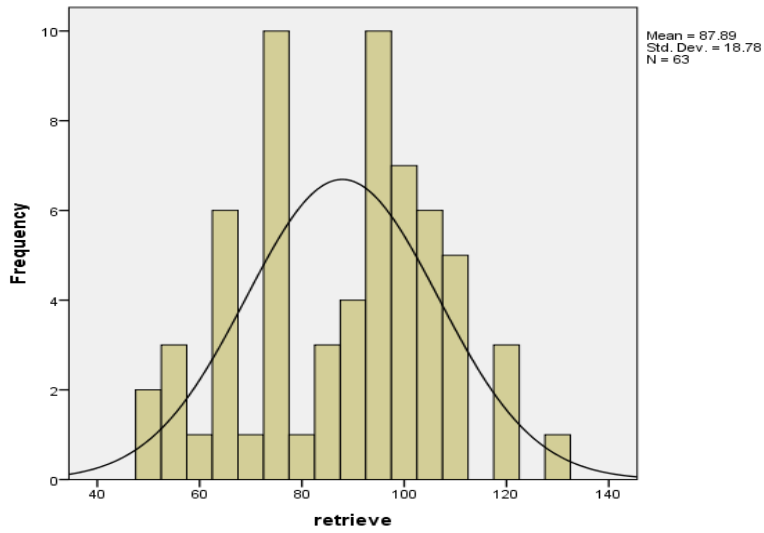
Note: Skew(X) = -.17

Figure 4.5. Distribution of Scores for Rapid Picture Naming
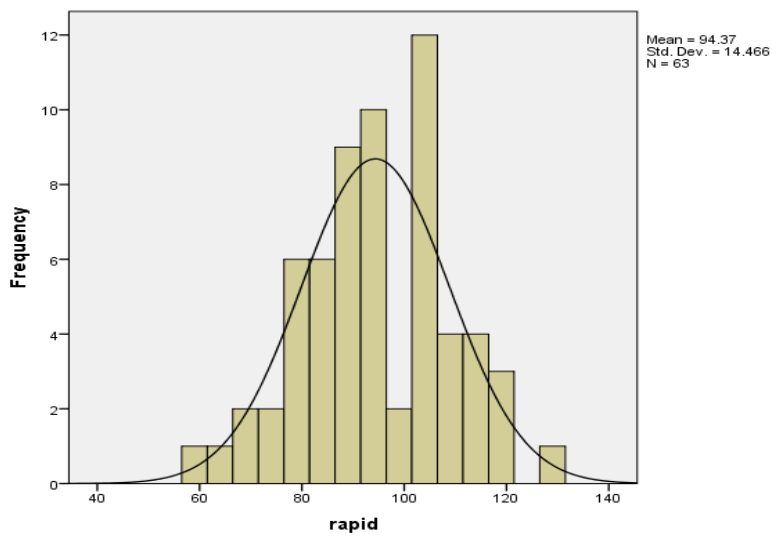
Note: Skew(X) = -.04

Table 4.4. Descriptive Statistics for Language, Phonemic Awareness, and Reading Measures

	Mean	Standard Deviation	Min	Max
Oral Language Cluster	101.5	14.16	67	130
Oral Expression Cluster	105.6	13.50	79	133
Story Recall	106.4	13.32	65	141
Picture Vocabulary	103.7	12.17	81	129
Listening Comprehension Cluster	97.3	14.71	55	121
Understanding Directions	93.0*	15.01	54	120
Oral Comprehension	100.7	12.27	72	124
Phonemic Awareness Cluster	106.3	18.44	50	149
Sound Blending	106.1	12.08	68	132
Incomplete Words	94.7	17.39	44	129
Sound Awareness	108.8	22.85	41	164
Basic Reading Skills Cluster	105.2	13.74	76	136
Letter-Word Identification	105.7	14.12	75	140
Word Attack (Nonword Decoding)	104.1	12.67	73	133

Note. From the Woodcock-Johnson III NU Tests of Achievement and Tests of Cognitive Abilities. The N for all variables is 63 except Listening Comprehension, Oral Comprehension, Phonemic Awareness, and Sound Awareness (all with N=62)
* Significantly below the normative mean (independent t-test) at $p < .05$.

Figure 4.6. Distribution of Scores for Understanding Directions
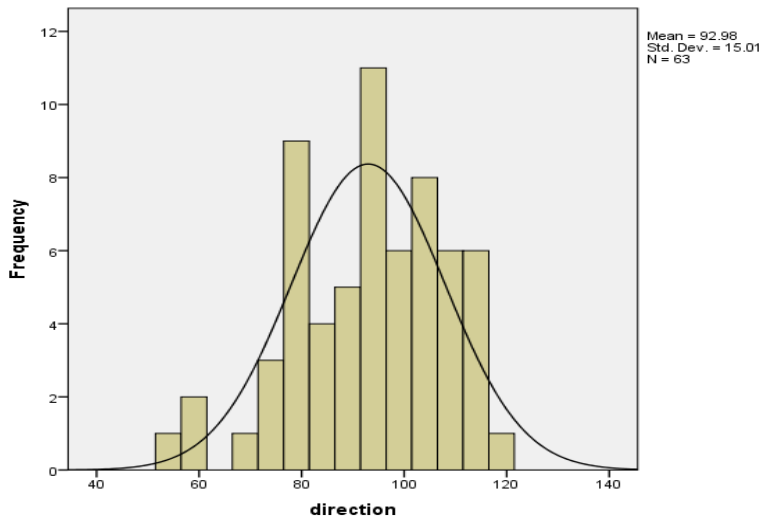
Standard score distributions for the reading measures are presented in the next few figures. The Basic Reading Skills cluster scores are shown in Figure 4.7. As noted earlier, the group mean was above average for age, and there were many strong performers; 44% of the participants scored between 104 and 119. Only 4 (6%) children scored one standard deviation below average, while 17 (27%) scored one SD above average. A higher proportion of poor word readers had been expected from the literature, but only 10 children (16%) in this sample scored below the 25th percentile, a common cutoff in literacy research (Siegel, 2003). Basic Reading Skills has a mode of 113, Kurtosis of -.50, and skewness of .01.

The histogram for Word Identification is shown in Figure 4.8. This measure of sight word recognition, related to memorization skills, is more symmetrically distributed.

A histogram for the measure of Nonword Decoding is presented in Figure 4.9. Five children performed one SD below average for age, while 13 performed one SD above average. Although the mean is above average, the mode is 97 and skewness is -.12.

To summarize, very few children in this sample of high-functioning children with ASD exhibited difficulty or disability in their word-reading skills. The high proportion of children with word reading problems found in other studies was not observed in this sample. Further examination of the results focused on differences between word recognition and nonword decoding skills and possible interactions with age.

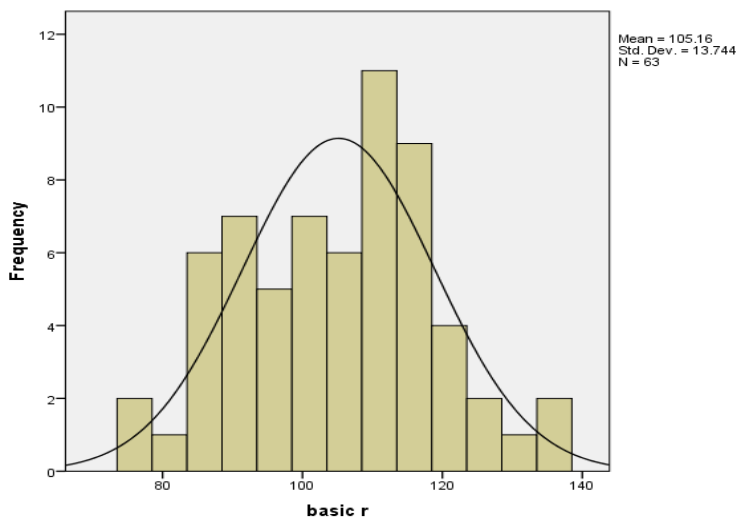Figure 4.7. Distribution of Scores for Basic Reading Skills

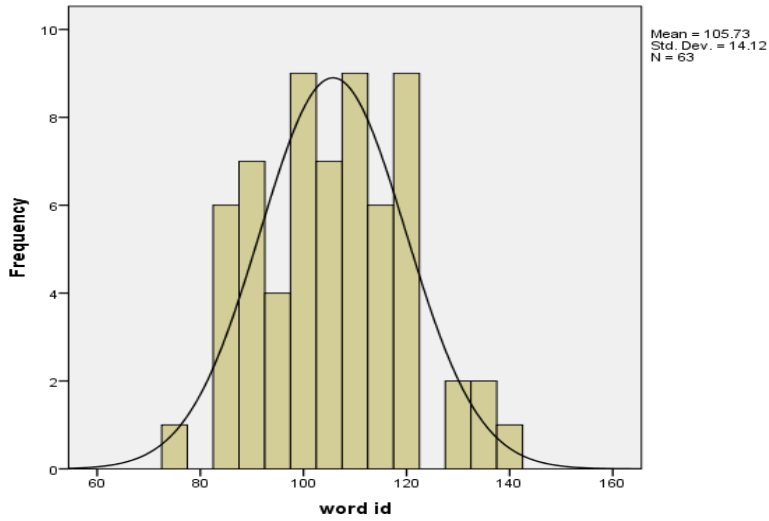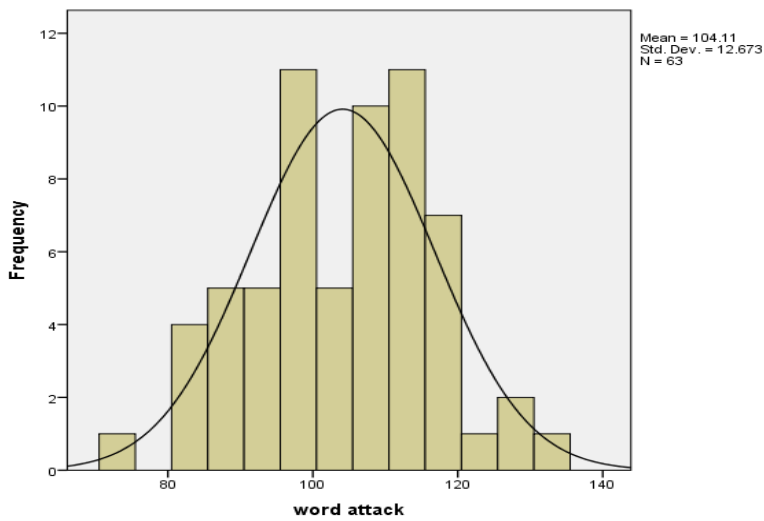Figure 4.8. Distribution of Scores for Word Identification

Figure 4.9. Distribution of Scores for Nonword Decoding

Word Reading Skills

The second research question sought clarification about sight word reading and decoding skills in high-functioning children with ASD. As noted in the literature review, there is general

consensus that rote memorization, or associative memory, is an area of strength for many children with ASD. Studies have often shown evidence of an early facility in word recognition that is better than predicted by FSIQ but not always matched by nonword decoding ability. Some studies have indicated that children with ASD have considerable difficulty reading nonwords.

The Basic Reading Skills cluster is composed of two tests: Word Identification and Nonword Decoding. These tests represent different skills: the recognition of memorized sight words contrasted with the ability to apply phoneme/grapheme knowledge to analyze and verbalize nonwords. Surprisingly, considering the discrepancy between these skills reported in some studies of children with ASD, scores on Word Identification and Nonword Decoding in the current sample correlated highly ($r = .86$, p $< .01$).

In order to investigate whether the children performed better on a word recognition task than a nonword decoding task, standardized scores for each child were recalculated based on norms by grade, not age, to account for the reading instruction that had been received. Descriptive statistics are shown in Table 4.5; since a few children had been retained once, reading performance normed on grade was slightly higher than when normed by age.

The difference in means between Word Identification and Nonword Decoding was fairly small but in the expected direction. To determine whether the difference reached significance, means for the two components were compared using a paired-samples t-test. The children performed slightly better on word recognition than on nonword decoding tasks ($t = 2.24$, p $< .018$), which is consistent with the literature. However, the effect size was small (Cohen's $d = .28$).

A relationship between Word Identification and grade had previously been noted when reviewing background factors; a negative correlation ($r = -.26$) suggested that first graders were receiving higher standardized scores. In order to examine this interaction, the means for Basic Reading, Word Identification, and Nonword Decoding were calculated by grade, and an analysis of variance was conducted to determine the strength and significance of relationships. As seen in Table 4.6, the relationship between Word Identification and grade was significant (p $< .01$), and the difference was between first graders and children in the other grades. The mean performance score on Word Identification for first graders was 117. First graders also performed slightly better on Nonword Decoding ($X = 112$) than children enrolled in other grades, but this difference

Table 4.5. Descriptive Statistics for Basic Reading Measures[a]

	Mean	N	Std. Deviation	Std. Error Mean
Basic Reading Skills	108.5	63	15.21	1.91
Word Identification	109.2	63	14.48	1.83
Nonword Decoding	107.0	63	14.08	1.77

Note: N = 63
[a] Standardized by Grade

Table 4.6. Mean Performance on Basic Reading Measures by Grade[a]

Grade	N	Basic Reading Skills	Word Identification	Nonword Decoding
1	21	116.3*	117.3*	112.3*
2	18	105.8	106.2	104.9
3	14	104.3	106.1	103.1
4	10	102.9	102.1	104.8
Total	63	108.5	109.2	107.0
F		*3.12*	*4.00*	*1.63*
Significance		*.033*	*.012*	*.192*

[a] Participant scores were standardized by Grade.
* Significantly above the normative mean (independent t-test) $p < .01$.

did not reach statistical significance

The remarkably strong performance of the first graders on the basic reading tasks required a closer examination of the data. Since five of the first graders had been retained in kindergarten once (and were therefore a year older) they were removed from the following histograms of scores on the two reading tasks. As seen in Figure 4.10, four of the remaining 16 children performed right at grade level, while half (8) were able to read words more than one SD above grade level (above the 85th percentile). Only one child scored slightly below grade level. This represents remarkable strength in word recognition skills for the first graders.

The Nonword Decoding scores for the 16 first graders who had not been retained are shown in Figure 4.11. While the group's performance is still significantly higher than average, the scores are distributed more evenly.

Figure 4.10. Word Identification Scores for First Graders Who Were Not Retained

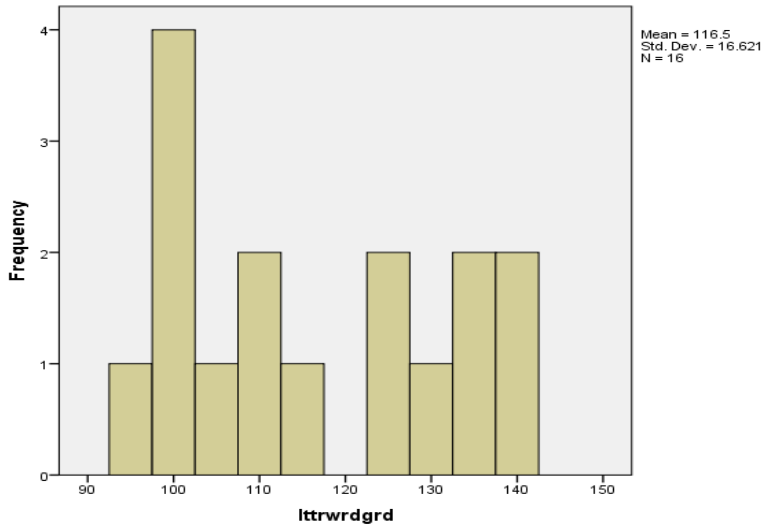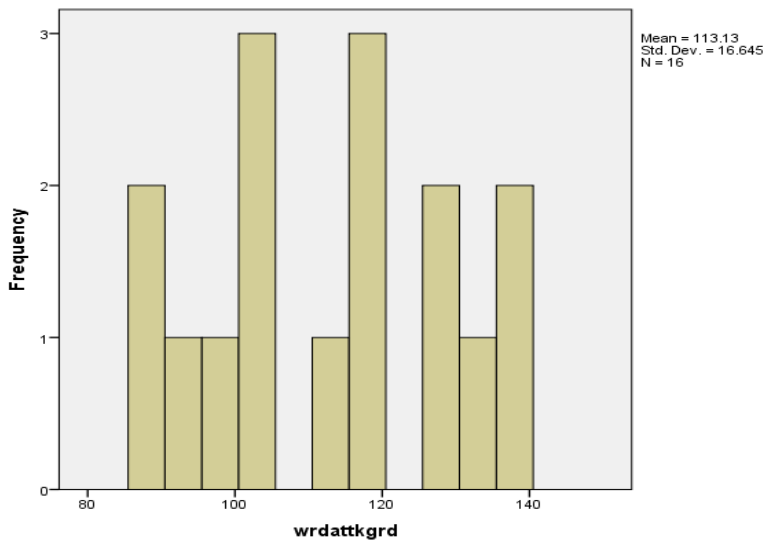Figure 4.11. Nonword Decoding Scores for First Graders Who Were Not Retained

In summary, the high-functioning children in this sample performed better on the word recognition task than on the nonword decoding task. However, it was not due to deficits in decoding skills but due to exceptional strength in sight word recognition for most of the children. This was especially true for the children enrolled in first grade.

Cognitive and Language Predictors of Basic Reading Skills

The third research question was whether typical correlates of basic reading skills such as phonemic awareness, nonverbal ability, and oral language predicted reading skills in children with ASD, as they do for children without ASD. A correlation matrix was generated and a series of regression analyses conducted to answer this question.

Pearson correlations were calculated in order to examine the relationships among the cognitive, phonemic awareness, language, and basic reading measures. A full correlation matrix is presented in Appendix C; targeted tables are presented in this chapter.

Table 4.7 shows the correlations among the category cluster scales (Verbal Ability, Nonverbal Ability, Cognitive Efficiency, Oral Language, and Phonemic Awareness) and the individual test scores that were used to represent Processing Speed (Visual Matching), Working Memory (Numbers Reversed), Cognitive Fluency (Retrieval Fluency and Rapid Picture Naming), and Phonemic Awareness (Incomplete Words and Sound Awareness). Because the hypothesis predicted positive relationships among all variables, statistical significance was calculated using a one-tailed test. Intercorrelations ranged from negligible to very strong. Predictors of basic reading skills frequently noted in the literature, such as Verbal Ability, Nonverbal Ability, and Phonemic Awareness had strong relationships with the basic reading measures. The strongest predictors were Phonemic Awareness, Nonverbal Ability and Sound Awareness. Moderate relationships were found with Verbal Ability, Oral Language, and Numbers Reversed. Rapid Picture Naming, which has been found to predict reading skills in some studies, had only negligible or weak relationships with reading. Relationships among Visual Matching, Retrieval Fluency, and the reading measures were also weak or negligible.

Basic Reading Skills correlated .64 with the Phonemic Awareness cluster index due to strong relationships between reading and the phonemic awareness cluster components Sound Awareness ($r = .59$, $p < .01$) and Sound Blending ($r = .52$, $p < .01$). There was a weaker relationship between Basic Reading and the phonemic awareness component Incomplete Words ($r = .28$, $p < .05$), which required the retrieval of rhyming words from long-term memory. The Phonemic Awareness cluster correlated .61 with Word Identification and .62 with Nonword Decoding.

Table 4.7. Correlations Among Cognitive, Language, and Reading Clusters and Tests

	GIA[a]	1	2	3	4	5	6	7	8	9	10	11	11	12
1. Verbal Ability	.78**													
2. Nonverbal	.91**	.69**												
3. Cognitive Efficiency	.80**	.42**	.58**											
4. Visual Matching	.52**	.31**	.41**	.62**										
5. Numbers Reversed	.69**	.34**	.48**	.88**	.17									
6. Retrieval Fluency	.54**	.35**	.37**	.63**	.62**	.40**								
7. Rapid Picture Naming	.43**	.28*	.30**	.55**	.61**	.32**	.60**							
8. Oral Language	.79**	.91**	.71**	.46**	.32**	.38**	.42**	.39**						
9. Incomplete Words	.50**	.46**	.38**	.43**	.27*	.38**	.23*	.20	.43**					
10. Sound Awareness	.69**	.66**	.70**	.37**	.20	.35**	.15	.20	.65**	.40**				
11. Phonemic Awareness	.73**	.68**	.76**	.42**	.22*	.40**	.17	.22*	.65**	.58**	.93**			
11. Basic Reading	**.54****	**.43****	**.61****	**.36****	**.18**	**.36****	**.06**	**.09**	**.39****	**.28***	**.59****	**.64****		
12. Word Identification	**.51****	**.44****	**.59****	**.29****	**.11**	**.32****	**-.02**	**.00**	**.40****	**.25***	**.56****	**.61****	**.97****	
13. Nonword Decoding	**.52****	**.35****	**.57****	**.40****	**.23**	**.38****	**.12**	**.18**	**.32****	**.28***	**.56****	**.62****	**.96****	**.86****

[a] General Intellectual Ability
* Pearson correlation is significant at the .05 level (one-tailed).
** Correlation is significant at the .01 level (one-tailed).

Clearly, typical predictors of reading, such as Verbal Ability, Nonverbal Ability, and Phonemic Awareness correlated strongly with Basic Reading Skills in this sample of high-functioning children with ASD. To examine these relationships in perspective and determine whether they are similar to those found in the broader population of early elementary children, results from a nationally representative sample of 6-8 year old children for the normative update for the Woodcock-Johnson III were used for comparison. The cluster score intercorrelations and test score intercorrelations from the Woodcock-Johnson III Normative Update Technical Manual (McGrew, Schrank, and Woodcock, 2007) are presented in Tables 4.8 and 4.10 along with results from this study.

All correlations were similar across the two samples. Differences between comparable correlations were compared using the Fisher z-transformation, and only the difference on Cognitive Efficiency reached statistical significance ($z = $ -1.6, $p < .05$); for children with ASD in the current sample, Cognitive Efficiency had a weaker relationship with Basic Reading Skills. Nonverbal Ability and Phonemic Awareness had slightly, but not significantly, stronger correlations with reading for the children with ASD compared to the national sample, while General Intellectual Ability, Verbal Ability and Oral Language had slightly weaker relationships with Basic Reading.

As noted previously, Nonverbal IQ had a slightly stronger relationship with Basic Reading than Verbal Ability for the children with ASD. The correlation ($r = .61$) is consistent with research involving typically developing populations (Ferrer et al, 2007) as well as children with and without dyslexia (Pammer & Kevan, 2007).

This comparison indicates that relationships between cluster scores in this study of children with ASD were similar to those found in studies of typically developing children; Phonemic Awareness, Nonverbal Ability, and General Intellectual Ability were all strong predictors of Basic Reading Skills, while Verbal Ability, Cognitive Efficiency and Oral Language had modest relationships. In order to investigate these relationships in more depth and avoid possible confounding due to the inclusion of both a phonemic awareness test (Sound Blending) and a cognitive flexibility test (Concept Formation) in the Nonverbal and GIA clusters, relationships between individual cognitive and language tests and basic reading were examined.

Table 4.8. Correlations Between the Basic Reading Cluster Score and Other Cluster Scores for the ASD Sample and the Woodcock-Johnson III Normative Update Sample

	General Intellectual Ability	Verbal Ability	Nonverbal Ability	Cognitive Efficiency	Oral Language	Phonemic Awareness
Current ASD Sample	.54**	.43**	.61**	.36**	.39**	.64**
WJ-III NU[b]	.65	.57	.56	.53[c]	.54	.58

Note. N = 62 or 63 for the current ASD sample.
[a]McGrew, Schrank, and Woodcock, 2007
[b] Ns range from 1020 to 199
[c] Difference between correlations (Fisher z) significant at p < .05, one-tailed).
** Correlation is significant at the .01 level (one-tailed).

Table 4.9 presents the Pearson correlations between the individual tests included in the Verbal Ability, Nonverbal Ability, and Oral Language clusters and the basic reading measures. One-tailed tests were again used for significance testing since all relationships were predicted to be positive. The strongest relationships for all the reading variables were with the Visual-Auditory Learning Test. Correlations with Sound Blending were also strong, as were those with Picture Vocabulary and General Information (also a measure of vocabulary knowledge). Relationships with Oral Comprehension and Concept Formation are modest, and Story Recall had insignificant correlations with the reading measures.

The Woodcock-Johnson III Normative Update sample was again used as a comparison group for many of these correlations. Although correlations between individual tests and cluster indices are not available for the WJ-III normative sample, relationships between individual tests and the components of Basic Reading Skills could be compared with results from the current study. Correlations between verbal, nonverbal, language, phonemic awareness, and word reading test scores are shown in Table 4.10 for the ASD sample and for 6-8 year old children in the WJ-III normative update. The correlations were again comparable, yet it is notable that the children with ASD tended to exhibit slightly *stronger* linear relationships between reading measures and all nonverbal tests except Concept Formation (a test of fluid reasoning that also taps cognitive flexibility) and *weaker* relationships between reading and all Oral Language tests except Picture Vocabulary. However, the only differences between comparable correlations that

Table 4.9. Correlations Among Verbal, Nonverbal and Language Tests and Basic Reading Measures

	Verbal Ability		Nonverbal Ability				Oral Language				Reading	
	1	2	3	4	5	6	7	8	9	10	11	12
1. Verbal Comprehension												
2. General Information	.77**											
3. Visual Auditory Learning	.36**	.38**										
4. Spatial Relations	.33**	.34**	.33**									
5. Concept Formation	.65**	.58**	.31**	.38**								
6. Sound Blending	.32**	.35**	.33**	.13	.19							
7. Story Recall	.67**	.63**	.40**	.24*	.51**	.22*						
8. Understand Directions	.75**	.75**	.39**	.48**	.68**	.34**	.65**					
9. Picture Vocabulary	.74**	.73**	.45**	.26*	.38**	.32**	.58**	.54**				
10. Oral Comprehension	.72**	.73**	.36**	.17	.62**	.17	.73**	.71**	.53**			
11. Basic Reading	**.38****	**.41****	**.56****	**.34****	**.28***	**.52****	**.13**	**.29***	**.45****	**.30****		
12. Word Identification	**.39****	**.43****	**.56****	**.30****	**.27***	**.53****	**.15**	**.27***	**.49****	**.31****	**.97****	
13. Nonword Decoding	**.31****	**.34****	**.51****	**.35****	**.25***	**.47****	**.08**	**.27***	**.36****	**.25***	**.96****	**.86****

* Pearson correlation is significant at the .05 level (one-tailed).
** Correlation is significant at the .01 level (one-tailed).

Table 4.10. Correlations Between Verbal, Nonverbal, Language, and Reading Tests for the ASD Sample and the Woodcock-Johnson III Normative Update Sample[a]

	Verbal Ability			Nonverbal Ability				Oral Language			PA
	Verbal Comp	General Info	Visual-Auditory Learn	Spatial Relation	Sound Blending	Concept Form	Story Recall	Under-stand Direct.	Picture Vocab.	Oral Comp.	Sound Aware-ness
Word Identification											
ASD Sample	.39**	.43**	.56**	.30*	.53**	.27*	.15	.27*	.49**	.31*	.55**
WJ-III NU[a]	.54	.45	.50	.20	.37	.43	.36 [b]	.49 [b]	.36	.42	.55
Nonword Decoding											
ASD Sample	.31**	.34**	.51**	.35**	.47**	.25*	.08	.27*	.36**	.25*	.56**
WJ-III NU[a]	.51 [b]	.41	.46	.23	.41	.40	.33[b]	.46 [b]	.34	.38	.53

[a] N=1064
[b] Difference between correlations (Fisher z) significant at $p < .05$, one-tailed).
* Pearson correlation is significant at the .05 level (two-tailed).
** Correlation is significant at the .01 level (two-tailed).

reached statistical significance were between reading measures and Story Recall, Understanding Directions, and Verbal Comprehension (one-tailed *Fisher z* significant at p < .05). These tests were less predictive of basic reading skills in this sample of high-functioning children with ASD.

The individual test scores used to represent processing speed (Visual Matching), working memory (Numbers Reversed), and cognitive fluency (Retrieval Fluency and Rapid Picture Naming) were also compared to the word reading measures in the normative sample from the WJ-III (Table 4.11). The fluency and processing speed measures, which indicated below average performance by the children with ASD, did not relate as strongly to word reading in the ASD sample as in the normative sample; differences in correlations with Word Identification were significantly weaker (p < .05). However, although the children with ASD also performed poorly as a group on Numbers Reversed, it did correlate significantly with word reading, similar to the normative group.

The correlation analyses from the current study indicated that the four tests with the strongest relationships to Basic Reading Skills for children with high-functioning ASD were Sound Awareness (*r* = .59), Visual-Auditory Learning (*r* = .56), Sound Blending (*r* = .52), and Picture Vocabulary (*r* = .45); all were significant at p < .01. Sound Awareness has already been discussed briefly; as a measure of deep phonological sensitivity, it taps the ability to mentally manipulate speech sounds to construct new words.

Table 4.11. Correlations Between Cognitive Fluency and Efficiency and Basic Reading Tests for the ASD Sample and the Woodcock-Johnson III Normative Update Sample

	Visual Matching	Numbers Reversed	Retrieval Fluency	Rapid Picture Naming
Word Identification				
Current ASD Sample	.11	.32**	-02	.00
WJ-III NU[a]	.47 [b]	.43	.34 [b]	.23 [b]
Nonword Decoding				
Current ASD Sample	.23	.38**	.12	.18
WJ-III NU[a]	.40	.40	.28	.20

[a] N=1064
[b] Difference between correlations (Fisher z) significant at p < .05, one-tailed).
* Pearson correlation is significant at the .05 level (two-tailed).
** Correlation is significant at the .01 level (two-tailed).

Of the nonverbal tests, Visual-Auditory Learning had the strongest relationships with the reading measures. This test requires that participants quickly learn meanings associated with symbols, or rebuses, so they can "read" a story. Many of the rebuses are drawn to suggest their associated meaning, so children who notice the nonverbal logic of the symbols have an easier time memorizing the meanings. This task taps the ability of children to attend, associate meaning with a symbol, memorize the association, and retrieve it to comprehend a message. It therefore relates strongly to a child's ability to recognize a letter, learn a sound associated with it, and retrieve that knowledge to sound out a word; however, the logic implicit in many of the symbols included in Visual-Auditory Learning makes it an easier task (if participants notice and utilize the clues).

The strength of the relationship between Basic Reading and Visual-Auditory Learning, and the strong relationship with Sound Blending, helps explain why Nonverbal Ability, which includes both components, had such a strong relationship with Basic Reading ($r = .61$). Other measures of nonverbal ability commonly used in research do not include tests relating to phonemic awareness.

Regression Analyses: A Model to Predict Basic Reading Skills. Because many abilities have been found to correlate significantly with basic reading skills in typically developing children, multivariate models are useful for accounting for interactions among measures (MacDonald, 2013). A series of regressions was conducted to determine which cognitive and language measures would best predict basic reading skills in high-functioning children with ASD.

To begin, category cluster scores for Verbal Ability, Nonverbal Ability, Cognitive Efficiency, and Oral Language were used as predictors for Basic Reading Skills. They were entered as a block, with the weakest predictors removed in backwards steps; a summary of models is shown in Table 4.12, and the statistics for each model are in Table 4.13.

When all four cluster scores (Verbal Ability, Nonverbal Ability, Cognitive Efficiency, and Oral Language) were entered into a backward regression, only Nonverbal Ability remained as a predictor in the final model; with a correlation of .61, it was able to predict 36% of the variance. Verbal Ability and Oral Language were highly intercorrelated ($r = .91$) and Oral Language was the last cluster to be removed. Since language delays are a central deficit in

Table 4.12. Regression Models Using Cognitive and Language Clusters to Predict Basic Reading Skills

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.620a	.384	.342	11.151
2	.619b	.384	.352	11.061
3	.610c	.373	.352	11.066
4	.607d	.369	.358	11.009

Note. Measures from the Woodcock-Johnson III NU. Predictors were entered in a block and removed backwards.

a Predictors: (Constant), Oral Language, Cognitive Efficiency, Nonverbal, Verbal

b Predictors: (Constant), Oral Language, Nonverbal, Verbal

c Predictors: (Constant), Oral Lang, Nonverbal

d Predictors: (Constant), Nonverbal

Table 4.13. Coefficient Statistics for Regression Models Using Cognitive and Language Clusters to Predict Basic Reading Skills

Model Number and Predictors	Unstandardized Coefficients		Standarized Coefficients		
	B	Std. Error	Beta	T	Sig.
1. (Constant)	26.126	13.448		1.943	.057
Verbal	.257	.248	.263	1.034	.306
Nonverbal	.772	.199	.631	3.869	0
Cognitive Efficiency	.027	.118	.03	.232	.817
Oral Language	-.305	.254	-.314	-1.201	.235
2. (Constant)	26.291	13.321		1.974	.053
Verbal	.252	.245	.259	1.027	.309
Nonverbal	.791	.18	.646	4.396	0
Oral Language	-.298	.25	-.308	-1.192	.238
3. (Constant)	28.052	13.216		2.123	.038
Nonverbal	.82	.178	.67	4.612	0
Oral Language	-.086	.141	-.089	-.61	.544
4. (Constant)	27.384	13.103		2.09	.041
Nonverbal	.743	.124	.607	5.97	0

autism, and children with language delays often have difficulty learning to read (Law et al.,1998; Miniscalco et al, 2010), it was decided to continue consideration of Oral Language in the prediction of basic reading skills in subsequent regressions. Abilities such as processing speed, fluency, and phonemic awareness have been found to predict word reading skills in typically developing children; therefore, individual test scores to represent processing speed (Visual Matching), working memory (Numbers Reversed), cognitive fluency (Rapid Picture Naming), and phonemic awareness (Incomplete Words and Sound Awareness) were added to Nonverbal Ability and Oral Language in the second set of regression analyses. The Phonemic Awareness cluster included a test already represented in the Nonverbal Ability cluster, so only the non-overlapping individual phonemic awareness components were included in the regression analyses. As seen in the last section, the weakest, and only insignificant, correlates of Basic Reading Skills were Retrieval Fluency ($r = .06$), Rapid Picture Naming ($r = .09$), and Visual Matching ($r = .18$). Because the relationship between Retrieval Fluency and Basic Reading Skills was negligible, and because Retrieval correlated highly with Rapid Picture Naming and Visual Matching, it was excluded from analyses to reduce the number of predictors.

For the regression analysis, all predictors were again entered as a block, with the weakest predictors removed in backwards steps; a summary of models is shown in Table 4.14, and the statistics for each model are in Table 4.15. Visual Matching and Incomplete Words made the smallest independent contributions to the model and were removed first; Rapid Naming and Numbers Reversed followed. The strongest predictive model, with a correlation of .66 and an adjusted R^2 of .41 included Sound Awareness and Nonverbal Ability. To reiterate, due to conceptual arguments and statistical significance in earlier models, Oral Language was retained as a strong possible predictor for the next set of regressions.

The third series of regression analyses utilized individual WJ-III test scores for Nonverbal Ability and Oral Language rather than the cluster scales to see which components were most predictive. The regression models are summarized in Tables 4.16 and 4.17. Regression analyses were also run with the Verbal Ability test Verbal Comprehension and General Information added, but the final model did not differ. Visual-Auditory Learning, Picture Vocabulary, Sound Awareness, Sound Blending, and Story Recall correlated .77 with Basic Reading Skills and predicted 55 percent of the variance. In this sample of children with ASD, associative memory, phonological skills, and vocabulary were able to strongly predict basic

Table 4.14. Regression Models Using Cognitive and Language Cluster Scores and Component Tests to Predict Basic Reading Skills

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.677a	.458	.388	1.838
2	.677b	.458	.399	1.739
3	.677c	.458	.410	1.645
4	.672d	.451	.413	1.616
5	.665e	.443	.414	1.609
6	.655f	.429	.410	1.646

Note. Measures from the Woodcock-Johnson III NU. Predictors were entered in a block and removed backwards.
a Predictors: (Constant),Sound Awareness, Visual Matching, Numbers Reversed, Incomplete Words, Rapid Naming, Oral Language, Nonverbal
b Predictors: (Constant), Sound Awareness, Numbers Reversed, Incomplete Words, Rapid Naming, Oral Language, Nonverbal
c Predictors: (Constant), Sound Awareness, Numbers Reversed, Rapid Naming, Oral Language, Nonverbal
d Predictors: (Constant), Sound Awareness, Numbers Reversed, Oral Language, Nonverbal
e Predictors: (Constant), Sound Awareness, Oral Language, Nonverbal
f Predictors: (Constant), Sound Awareness, Nonverbal

reading skills.

The first set of regression analyses showed that Nonverbal Ability had such power to predict Basic Reading Skills that Oral Language and Verbal Ability added nothing to a model. For the second analyses, measures of processing speed (Visual Matching), working memory (Numbers Reversed), cognitive fluency (Rapid Picture Naming), and phonemic awareness (Incomplete Words and Sound Awareness) were added to Nonverbal Ability and Oral Language. Only Sound Awareness was able to add power to the model containing Nonverbal Ability. In the third set of regressions the components of Nonverbal Ability (Visual-Auditory Learning, Spatial Relations, Sound Blending, and Concept Formation) and Oral Language (Story Recall, Understanding Directions, Oral Comprehension, and Picture Vocabulary), were entered into a regression model along with Sound Awareness to predict Basic Reading Skills. In the final model, five measures of memorization, vocabulary, and phonological ability were able to predict 55 percent of the variance.

Table 4.15. Coefficient Statistics for Regression Models Using Cognitive and Language Clusters and Tests to Predict Basic Reading Skills

Model Number and Predictors	Unstandardized Coefficients		Standarized Coefficients		
	B	Std. Error	Beta	T	Sig.
1. (Constant)	35.356	15.976		2.213	.031
Nonverbal	.567	.222	.451	2.558	.013
Oral Language	-.142	.158	-.141	-.898	.373
Visual Matching	.001	.098	.002	.013	.99
Numbers Reversed	.11	.109	.122	1.009	.317
Rapid Picture Naming	-.088	.131	-.092	-.670	.506
Incomplete Words	.012	.094	.015	.131	.897
Sound Awareness	.20	.093	.329	2.146	.036
2. (Constant)	35.297	15.157		2.329	.024
Nonverbal	.568	.202	.452	2.807	.007
Oral Language	-.142	.156	-.141	-.912	.366
Numbers Reversed	.11	.106	.121	1.037	.304
Rapid Picture Naming	-.087	.105	-.091	-.825	.413
Incomplete Words	.013	.091	.016	.137	.891
Sound Awareness	.199	.091	.329	2.199	.032
3. (Constant)	35.672	14.777		2.414	.019
Nonverbal	.567	.2	.452	2.829	.006
Oral Language	-.138	.152	-.137	-.91	.367
Numbers Reversed	.113	.102	.125	1.108	.273
Rapid Picture Naming	-.087	.104	-.091	-.833	.408
Sound Awareness	.201	.089	.332	2.262	.028
4. (Constant)	32.013	14.072		2.275	.027
Nonverbal	.566	.2	.451	2.834	.006
Oral Language	-.174	.145	-.173	-1.204	.233
Numbers Reversed	.096	.1	.106	.959	.342
Sound Awareness	.209	.088	.344	2.364	.022
5. (Constant)	34.599	13.802		2.507	.015
Nonverbal	.619	.192	.493	3.226	.002
Oral Language	-.172	.145	-.17	-1.187	.240
Sound Awareness	.212	.088	.35	2.404	.019
6. (Constant)	31.175	13.544		2.302	.025
Nonverbal	.52	.173	.414	2.999	.004
Sound Awareness	.178	.084	.294	2.128	.038

Table 4.16. Regression Models Using Individual Cognitive, Language, and Phonemic Awareness Tests to Predict Basic Reading Skills

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.799a	.639	.576	9.02
2	.799b	.639	.584	8.94
3	.788c	.621	.571	9.07
4	.778d	.606	.563	9.16
5	.767e	.588	.551	9.28

Note. Measures from the Woodcock-Johnson III NU. Predictors were entered in a block and removed backwards.
a Predictors: (Constant), Sound Awareness, Spatial Relations, Sound Blending, Story Recall, Visual-Auditory Learning, Picture Vocabulary, Concept Formation, Oral Communication, Understanding Directions
b Predictors: (Constant), Sound Awareness, Spatial Relations, Sound Blending, Story Recall, Visual-Auditory Learning, Picture Vocabulary, Oral Communication, Understanding Directions
c Predictors: (Constant), Sound Awareness, Spatial Relations, Sound Blending, Story Recall, Visual-Auditory Learning, Picture Vocabulary, Understanding Directions
d Predictors: (Constant), Sound Awareness, Spatial Relations, Sound Blending, Story Recall, Visual-Auditory Learning, Picture Vocabulary
e Predictors: (Constant), Sound Awareness, Sound Blending, Story Recall, Visual-Auditory Learning, Picture Vocabulary

Visual-Auditory Learning, Picture Vocabulary, Sound Awareness, and Sound Blending contributed to the prediction of reading in the expected positive direction. Story Recall, however, had an unexpected negative relationship with basic reading once the other factors were entered. Possible reasons for this are discussed in the final chapter.

In summary, for this sample of high-functioning children with ASD, "typical" predictors of word reading skill such as nonverbal ability (Visual-Auditory Learning), vocabulary (Picture Vocabulary), and phonological awareness (Sound Awareness and Sound Blending) were able to predict basic reading skills in a manner similar to that of typically developing children.

Relationships between Cognitive Flexibility Measures and Reading

The fourth research question was whether measures of cognitive flexibility would relate significantly to basic reading skills and contribute to the variance after controlling for other

Table 4.17. Coefficient Statistics for Regression Models Using Individual Cognitive, Language, and Phonemic Awareness Tests to Predict Basic Reading Skills

Model Number and Predictors	Unstandardized Coefficients		Standarized Coefficients		
	B	Std. Error	Beta	T	Sig.
1. (Constant)	-7.306	2.362		-.359	.721
Visual-Auditory Learn	.275	.095	.295	2.908	.005
Spatial Relations	.329	.140	.241	2.35	.023
Sound Blending	.367	.117	.312	3.143	.003
Concept Formation	.015	.138	.014	.109	.914
Story Recall	-.343	.151	-.305	-2.274	.027
Understanding Direct.	-.280	.145	-.303	-1.93	.059
Picture Vocabulary	.272	.128	.238	2.121	.039
Oral Comprehension	.263	.168	.233	1.563	.124
Sound Awareness	.175	.078	.289	2.253	.029
2. (Constant)	-6.704	19.418		-.345	.731
Visual-Auditory Learn	.274	.094	.295	2.934	.005
Spatial Relations	.331	.137	.243	2.416	.019
Sound Blending	.366	.115	.311	3.179	.002
Story Recall	-.342	.149	-.304	-2.293	.026
Understanding Direct.	-.275	.138	-.298	-1.999	.051
Picture Vocabulary	.271	.126	.237	2.142	.037
Oral Comprehension	.266	.164	.235	1.622	.111
Sound Awareness	.177	.074	.292	2.399	.020
3. (Constant)	4.943	18.312		.27	.788
Visual-Auditory Learn	.281	.095	.302	2.96	.005
Spatial Relations	.277	.135	.203	2.052	.045
Sound Blending	.332	.115	.282	2.891	.006
Story Recall	-.249	.140	-.221	-1.781	.081
Understanding Direct.	-.184	.128	-.20	-1.444	.154
Picture Vocabulary	.284	.128	.248	2.221	.031
Sound Awareness	.211	.072	.348	2.935	.005
4. (Constant)	13.312	17.541		.759	.451
Visual-Auditory Learn	.293	.095	.314	3.067	.003
Spatial Relations	.195	.123	.143	1.575	.121
Sound Blending	.307	.115	.261	2.677	.010
Story Recall	-.350	.122	-.312	-2.882	.006
Picture Vocabulary	.268	.129	.234	2.08	.042
Sound Awareness	.182	.070	.301	2.612	.012
5. (Constant)	27.389	15.293		1.791	.079
Visual-Auditory Learn	.323	.095	.347	3.416	.001
Sound Blending	.300	.116	.255	2.587	.012
Story Recall	-.344	.123	-.306	-2.792	.007
Picture Vocabulary	.280	.130	.245	2.153	.036
Sound Awareness	.192	.070	.316	2.722	.009

factors such as language and phonemic awareness. Descriptive results from the Wisconsin Card Sorting Test (WCST) are presented below, as the other measures – the Shift Score from the BRIEF and Concept Formation from the WJ-III – were already described. Relationships among the cognitive flexibility measures and the Basic Reading measures follow. In the final set of regression analyses, the cognitive flexibility measures are individually entered into the regression model containing nonverbal and language factors to predict Basic Reading Skills.

Cognitive Flexibility Performance. Descriptive statistics for the Wisconsin Card Sorting Test are shown in Table 4.18; scores for two children were removed from analyses due to problems during administration. The data represent standardized scores normed by age, so a score above 100 indicates above-average performance on the test. Although study participants performed well on many measures in the WJ-III test battery relative to the broader population, with a group mean of 99 on General Intellectual Ability and 105 on Nonverbal Ability, their mean performance on the WCST was below average for age. Independent t-tests comparing mean performance for this sample to the normed referential group resulted in significant findings for both Total Errors and Perseverative Responses. These results are consistent with previous reports of problems on the WCST for people with ASD.

Frequency distributions for the Total Errors and Perseverative Responses measures are shown in Figures 4.12 and 4.13. Total Errors is skewed to the right (.72); mean performance was two-thirds of a standard deviation below the norm, but three children performed well above average for age. Perseverative Responses is slightly skewed to the left (-.23).

Table 4.18. Descriptive Statistics for Wisconsin Card Sorting Test

	Mean	Standard Deviation	Min	Max
Total Errors	91.4**	10.52	73	122
Perseverative Responses	94.9*	10.05	70	116

Note: Scores were standardized by age. The N for all variables is 61.
* Significantly below the normative mean (independent t-test) at p < .05.
** Significantly below the normative mean (independent t-test) at p < .01 level.

Figure 4.12. Distribution of Scores for Wisconsin Card Sorting Test: Total Errors
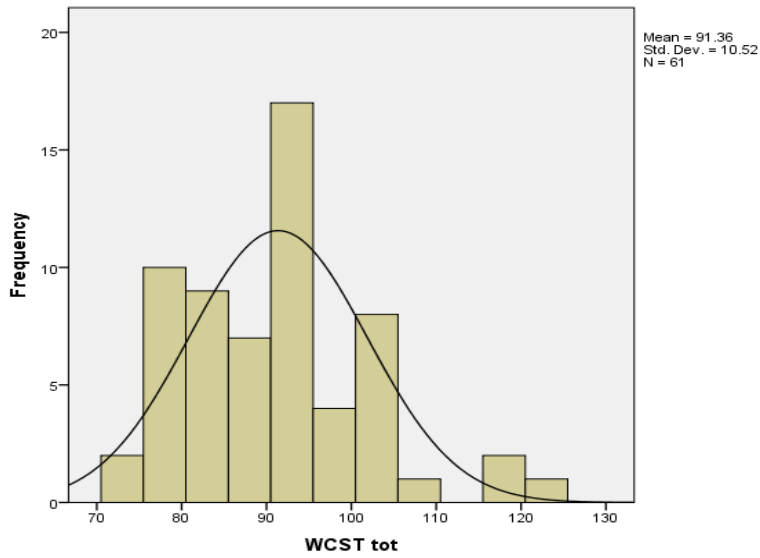
Note: Raw scores were standardized by age based on performance.

Figure 4.13. Distribution of Scores for Wisconsin Card Sorting Test: Perseverative Responses
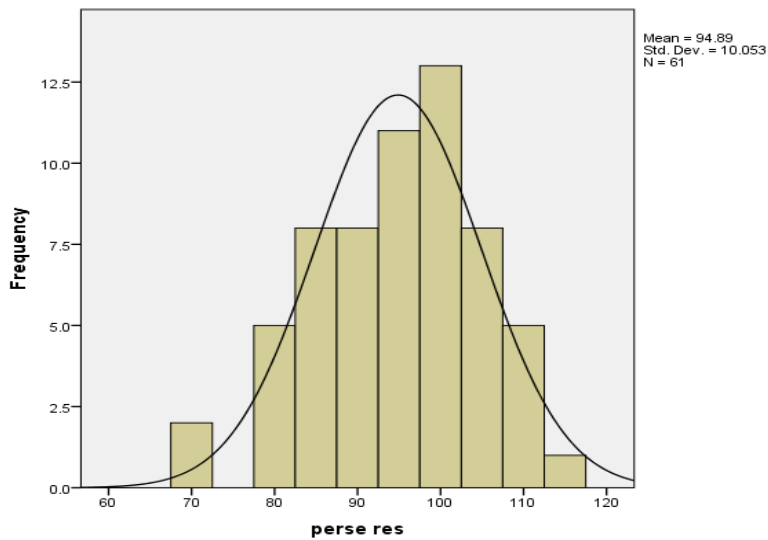
Note: Raw scores were standardized by age based on performance.

Relationships Among Cognitive Flexibility and Basic Reading Measures.

Correlations among the three measures of cognitive flexibility plus Concept Formation, the WJ-III test of fluid reasoning that also taps cognitive flexibility, are shown in Table 4.19. The two WCST measures, taken from participant performance data, are highly intercorrelated, but there is a surprising insignificant relationship between the WCST and the Shift parent rating from the BRIEF. Correlations between the WCST measures and the Concept Formation test are strong and range from .43 to .53, significant at $p < .01$. Also shown in the table are correlations between the cognitive flexibility measures and the WJ-III General Intellectual Ability score. Its relationships with the WCST measures are moderately strong, while the relationship with the Shift scale is negligible.

Correlations between the cognitive flexibility measures and the reading measures are shown in Table 4.20. The performance measures of cognitive flexibility (WCST and Concept Formation) correlated significantly, though weakly, with the basic reading measures; participants who did well on the WCST tended to have better word reading skills. Both the WCST Total Errors Standardized Score and Perseverative Responses correlated .22 with Basic Reading Skills ($p < .05$). Nonword Decoding was significantly correlated with the WCST Total Errors ($r = .23$, $p < .05$), and Word Identification was significant with Perseverative Responses ($r = .22$, $p < .05$). Relationships between the reading variables and Concept Formation were slightly stronger. Again, one-tailed tests were used to calculate significance since all measures had been expected to correlate positively.

Table 4.19. Correlations Among Measures of Cognitive Flexibility and General Ability

	WCST Total Errors	WCST Persev. Response	BRIEF Shift Scale	WJ-III Concept Formation
WCST Perseverative Response	.69**			
BRIEF: Shift Scale	-.11	-.03		
WJ-III Concept Formation	.53**	.43**	.10	
General Intellectual Ability	.44**	.42**	.09	.79**

Note. Ns range from 61 to 63.
** Correlation is significant at the .01 level (two-tailed).

Table 4.20. Correlations Between Measures of Cognitive Flexibility and Reading

	Basic Reading Skills	Word Identification	Nonword Decoding
Wisconsin Card Sorting Test			
Total Errors	.22*	.20	.23*
Perseverative Responses	.22*	.22*	.20
BRIEF[a] Shift Scale	-.04	-.04	-.05
WJ-III[b] Concept Formation	.28*	.27*	.25*

 Note. Ns range from 61 to 63.
[a] Behavior Rating Inventory of Executive Function
[b] Woodcock Johnson III NU
* Correlation is significant at the .05 level (one-tailed).
** Correlation is significant at the .01 level (one-tailed).

In contrast to the positive correlations for performance measures of cognitive flexibility, parent ratings of their child's inflexibility in the natural environment (the Shift scale on the BRIEF) had negligible correlations with the reading measures. A review of Appendix C, which contains intercorrelations for all study measures, indicates that this parent rating did not correlate significantly with any variable except the other parent rating, the SCQ.

A series of regression analyses was performed to assess the ability of cognitive flexibility measures to predict Basic Reading Skills (Table 4.21). Since most cognitive flexibility variables were strongly interrelated, each was entered individually into a regression to predict Basic Reading. Concept Formation predicted six percent of the variance, significant at $p < .03$. Each of the two WCST measures individually predicted three percent of the variance, but did not meet significance at $p < .05$.

Although the three performance measures of cognitive flexibility correlated weakly with the reading variables, the WCST measures reached significance only when using one-tailed criteria. Separate regression analyses revealed that only Concept Formation was independently able to predict word reading at a significant level. The next analysis step was to determine whether any of the cognitive flexibility measures contributed to a predictive model that also included nonverbal, phonological, and vocabulary measures.

Table 4.21. Summary of Regression Analyses Using Individual Cognitive Flexibility Measures to Predict Basic Reading Skills

	Model Summary			Coefficient		
		Adjusted	Std. Error of			
	R	R Square	the Estimate	Beta	t	Signif.
With WCST Total Errors	.22	.03	13.30	.22	1.71	.09
With Perseverative Response	.22	.03	13.30	.22	1.70	.09
With Shift (BRIEF)	.04	-.02	13.85	-.04	-.32	.75
With Concept Formation	.31	.06	13.31	.28	2.27	.03

The Contribution of Cognitive Flexibility to the Predictive Model. Additional regression analyses were conducted to address the fourth research question; whether any measures of cognitive flexibility would contribute to the variance in basic reading skills after controlling for other factors. The four measures of cognitive flexibility were entered separately into regression models with the five cognitive and language variables (Visual-Auditory Learning, Picture Vocabulary, Sound Awareness, Sound Blending, and Story Recall) that, in combination, predicted 55 percent of the variance. The results are shown in Table 4.22. As might be expected from the weak correlations reported earlier, none of the cognitive flexibility measures was able to add power to a model predicting Basic Reading Skills that already included nonverbal, language, and phonemic awareness measures.

Summary

The first research question assessed the performance of a sample of high-functioning children with ASD enrolled in early elementary grades and participating in general curriculum instruction on basic reading tasks and related cognitive, language, and phonemic awareness measures. Overall, results indicated intact performance on nonverbal and verbal measures, strong performance on basic reading skills, and weak performance on measures tapping cognitive fluency, processing speed, working memory, and cognitive flexibility. Mean standard scores for the group were average or slightly above for General Intellectual Ability, Nonverbal Ability, and Verbal Ability, while Cognitive Efficiency (Visual Matching and Numbers Reversed), Retrieval Fluency, and Understanding Directions were all significantly below average

Table 4.22. Summary of Regression Analyses Adding Individual Cognitive Flexibility Measures to Nonverbal, Phonemic Awareness and Language Measures to Predict Basic Reading Skills

| | Model Summary | | | Coefficient | | |
	R	Adjusted R Square	Std. Error of the Estimate	Beta	t	Signif.
Basic Model [a]	.767	.551	9.28			
With WCST Total Errors	.761	.531	9.31	.09	.93	.36
With Perseverative Response	.757	.525	9.31	.04	.37	.71
With Shift (BRIEF)	.787	.551	9.28	-.09	-1.00	.32
With Concept Formation	.767	.544	9.358	.03	.26	.79

a Visual-Auditory Learning, Sound Blending, Sound Awareness, Picture Vocabulary, Story Recall

compared to typically developing children. Despite common problems with fluency, flexibility, and working memory, the children's mean performance on word reading measures was strong, especially for first graders, and many children scored in the superior range.

The second research question examined whether early elementary children with ASD performed better on word recognition than nonword decoding tasks. These two tasks correlated more strongly than expected, but participants performed slightly better on the Word Identification task; a paired samples t-test was significant. However, a weakness in nonword decoding that was predicted from a review of the literature was not the reason for this discrepancy; rather, it was due to superior performance by many children on the word recognition measure. First graders as a group scored better on both reading tasks than children in higher grades, but this was statistically significant only for Word Identification.

The third research question asked if typical correlates of basic reading skills such as phonemic awareness, NVIQ and oral language predicted reading skills in high-functioning children with ASD. The result was positive; a regression model including five measures (Visual-Auditory Learning, Sound Blending, Sound Awareness, Picture Vocabulary, and Story Recall) correlated .77 with Basic Reading Skills and predicted 55 percent of the variance. Although research has been unclear about whether children with ASD learn to read words commensurate with IQ, these results indicated that typical predictors of reading such as nonverbal ability,

vocabulary, and phonological skills can strongly predict word reading skills in high-functioning children with ASD in the early elementary grades.

The fourth research question asked if measures of cognitive flexibility would add to the predictive power of a model already containing phonemic awareness, language, and nonverbal ability predictors. Performance measures of cognitive flexibility correlated significantly, but weakly, with basic reading skills; however, none was able to add significantly to the predictive power of the model that included measures of nonverbal reasoning, language, and phonological skills. A discussion of the implications of the results follows in the next chapter.

CHAPTER 5

Discussion

The primary aims of this study were to examine basic reading skills and related cognitive and language skills in a moderately sized sample of high-functioning elementary students with Autism Spectrum Disorder (ASD); to determine predictors of basic reading skills; and to investigate possible relationships between basic reading skills and executive functions, especially cognitive flexibility,. To test the hypotheses, 63 children with ASD enrolled in grades 1-4 were assessed with cognitive, achievement, and executive function tests, and descriptive, correlation and regression analyses were conducted.

This chapter begins with an examination of participant performance on the measures and how these results compare to those from earlier studies of children with ASD; a comparison of word recognition and decoding analysis skills follows. The next two sections discuss predictors of basic reading, and the relationship with cognitive flexibility. The chapter concludes with a discussion of the limitations of the study, and suggestions for further study based on the results.

Performance of High-Functioning Children with ASD on Cognitive, Language, and Reading Measures

Although cognitive, language, and reading abilities of children with ASD have been investigated for decades, the results from many earlier studies may not apply to the population of higher-functioning children currently enrolled in elementary schools. Descriptive results from the current study improve our understanding of areas of strength and weakness for children with ASD in the early grades and inform educational planning.

Group performance on many measures of basic reading, cognitive, and language skills was slightly higher than average, but means slightly above average would not be unexpected since children with nonverbal IQs of 80 or below were excluded from analyses. Means below

average, however, suggested common areas of weakness for high-functioning children with ASD in elementary school.

Cognitive and Language Measures. There were no indications of global problems with nonverbal or verbal tasks for the children in this sample. Although performance varied, score distributions were comparable to those of typically developing children.

Significant delays or deficits in Cognitive Efficiency and/or Cognitive Fluency were evident, however, for many children in the sample, confirming hypotheses based on the literature. Performance on Visual Matching ($X = 82$) was the poorest of all of the tests, and half of the children scored at least one SD below average. This supports results from other research indicating that perceptual discrimination, or visual processing speed, is a weakness for many children with ASD (Mayes & Calhoun, 2007; 2008). This weakness may affect academic tasks that require the precise and efficient discrimination of visual symbols, such as reading, spelling, math and writing, even when children are high-functioning and have general verbal and nonverbal abilities in the normal range.

Numbers Reversed ($X = 91$) also challenged many children, with 35% performing at least 1 SD below average; a recent study of high-functioning children with ASD ages 6-14 reported a similar group mean (Mayes & Calhoun, 2008). Although Numbers Reversed is primarily considered a task of short-term memory, participants were observed to have difficulty reversing the order, not recalling the numbers. In contrast, most participants performed very well on Story Recall ($X = 106$), which also tests short-term memory but does not require the mental manipulation of information. Other researchers have also found intact auditory short-term memory in children with ASD but impaired working memory on more challenging tasks (Joseph et al., 2005; Russell et al., 1996). In addition to working memory, the task of reversing numbers taps cognitive flexibility (Hale et al. 2002; Williams, Weiss & Rolfus, 2003). A reversal of direction can be difficult for children with ASD; for example, changes in the sequence of routines or schedules are known to cause difficulty for many (Gioia et al., 2002). It is interesting to note that children with AD/HD, which is highly comorbid with ASD, also perform significantly lower ($X = 94$, p < .01) on the Numbers Reversed task than children without AD/HD (Ford, Floyd, Keith, Fields & Shrank, 2003; Mayes & Calhoun, 2007). Since children with only AD/HD also have problems with cognitive flexibility (Gioia et al., 2002), it is possible that demands on flexibility contributed to the poor performance on this task. To ensure that

comorbidity with AD/HD did not cause the low mean on Numbers Reversed for the children with ASD in the current sample, an ad-hoc analysis was performed excluding children who were dually diagnosed; significant underperformance (X = 93) was still found.

The assertion that Numbers Reversed may challenge children with ASD due to demands on cognitive flexibility is supported by an observation. In developing the test protocol for this study, it was decided to exclude the other WJ-III working memory test (Auditory Working Memory Task), which was not needed for the global ability assessment, because it caused considerable frustration in some young children with ASD. The Auditory Working Memory task requires short-term storage of a few numbers and objects provided orally with the requirement to mentally separate them and repeat them by category in order. The task certainly taps working memory, but it also requires cognitive flexibility to shift between the two categories. Although it would have been difficult to include this task considering the other testing demands , in a future study it would be interesting to use it with high-functioning children with ASD as another indicator of the ability to shift set.

Cognitive fluency is another area of interest in research, and other studies have reported fluency deficits in children with ASD (Geurts et al., 2004; Kleinhans et al., 2005; White et al., 2006; Zandt, 2009), though a recent study of high-functioning children did not find group performance significantly below average (Kenworthy et al., 2009). Cognitive Fluency was a significant weakness for many participants in this study, with most performing below average on the tasks. Forty-one percent of the children scored at least one SD below average on Retrieval Fluency. Even when asked to list as many animals as possible within one minute, a simple task for most children in elementary school, most of the children in this highly verbal sample could name only a few. Many children were unable to use any strategy, such as subcategories, to assist in the recall of pertinent information.

Group performance on Rapid Picture Naming was stronger, as this only required the retrieval of common object names prompted by visual cues; yet even here, 29% performed below the first standard deviation. Other studies of children with ASD have reported inconsistent results on rapid naming tasks, from mild deficits to intact performance (Newman et al., 2007; White et al., 2006). Although retrieval fluency is clearly an area of weakness for many of the children in the sample, retrieving words relating to ideas or categories (ideational generation) appeared to be more difficult than simple word retrieval. Difficulty with fluency

probably contributes to the deficits in oral expression and writing that are commonly seen in children with ASD, and indicates the importance of special education instruction and support in communication and organization strategies for these children.

Performance on oral language measures was surprisingly good considering the prevalence of language delays or deficits seen in children with ASD (Joseph et al., 2005; Kjelgaard & Tager-Flusberg, 2001; Wetherby et al., 2000). Listening Comprehension, which has been found to be lower in children with ASD (Griswold, Barnhill, Smith Myles, Hagiwara & Simpson, 2002) was lower than other cognitive and language measures, but only the Understanding Directions task had a group mean significantly below average ($X = 93$). One third of the participants performed more than one SD below average on this task, which involved increasingly complex instructions to point to specific objects in pictures. Other research has also found significant deficits in listening comprehension, especially of complex language, in children with ASD (Griswold et al., 2002; Huemer & Mann, 2010; Ricketts et al., 2013).These results suggest that even for high-functioning children it is important to provide classroom accommodations such as written directions, repeated directions, and comprehension monitoring to assure that children attend to information and understand expectations.

Phonemic Awareness was strong for the group as a whole, though there was a vast range of performance on Incomplete Words, which required the retrieval of rhyming words from memory, and Sound Awareness, which required the mental manipulation of phonemes to create new words. Kindergarten teachers have reported that children with ASD are seven times more likely to have difficulty thinking of rhyming words and three times more likely to struggle with decoding strategies (Spector, 2009). Other studies have also found deficits in phonological abilities in ASD (Smith Gabig, 2010; Schmidt et al., 2008; Tager-Flusberg & Joseph, 2003). However, although individuals in this sample of high-functioning children displayed phonological weaknesses, especially with rhyming tasks, global deficits were not seen.

An interesting but rough comparison to the results from this sample can be made using data from a clinical sample of 101 children and adolescents diagnosed with ASD in the Woodcock-Johnson III Normative Update Technical Manual (McGrew et al., 2007). That group performed slightly less well overall, with a median GIA of 95, and Verbal Ability and Visual-Auditory Learning of 97. As in the current study, the strongest results were for Spatial Relations (99) and Sound Blending (100), with average performance on Concept Formation and Numbers

Reversed (94), and poor results on Processing Speed (Visual Matching: X =86). The age and ability span of this sample was much greater than the current study, but the areas of strength and weakness are comparable. The cognitive and language performance results of this study are supported by other research (Mayes & Calhoun, 2006, 2007, 2008; Mayes et al., 2009); verbal and nonverbal abilities are generally intact in high-functioning children, but weaknesses are evident in the processing of complex language and in executive functions such as cognitive fluency, working memory, and visual processing speed.

Reading Measures. Research into the basic reading skills of children with ASD has produced varied results, likely due to selection criteria, small samples, large ranges of participant age and ability, varying outcome measures, and interest in unusual abilities such as hyperlexia. Some studies have indicated a high rate of word reading disability in children with ASD (Åsberg et al., 2008; Asberg et al., 2010; Brown et al., 2012; Jones et al., 2009; Nation et al., 2006; Ricketts et al., 2013; Spector, 2009), but others have shown a fairly normal distribution of reading ability (Huemer & Mann, 2010; Mayes & Calhoun, 2008; Smith Gabig, 2010).

Based upon the literature review, a greater percentage of children performing poorly on the reading measures had been expected. However, participants in this study had slightly better than average Basic Reading Skills. Sixty-three percent scored at or above an age-normed standard score of 100, while 37% scored below. Although other research has indicated that 37 to 51 percent of children with ASD experience difficulty with word reading skills (Åsberg et al., 2008; Miniscalco & Dahlgren Sandberg, 2010; Nation et al., 2006), only 6% of the participants in the current study had Basic Reading scores one standard deviation below average, and only 16% scored low enough (below the 25th percentile) to be considered poor word readers.

A strong possibility for these discrepant results is the young age range of participants in the current study. Teenagers were included in nine of the twelve reviewed studies, and only two (Smith Gabig, 2010; Miniscalco & Dahlgren Sandberg, 2010) were restricted to children under the age of ten. Strong word reading skills similar to those found in the current study were seen in the Smith Gabig study, but not the latter one. Recent research has suggested that word reading skills in children with ASD decline with age relative to typically developing peers (Norbury & Nation, 2011; Wei, Blackorby & Schiller, 2011) so research focusing on children in the primary grades might find above-average performance.

Another factor that may have influenced findings is sample size. In the twelve studies that were closely reviewed (see Chapter 2), only two (Huemer & Mann, 2010; Jones et al., 2009) had larger sample sizes than the current study. Both of these had results comparable to those in the current study.

A third possibility for the difference in results is the overall ability of participants, as several researchers reporting higher proportions of word reading disability worked with clinical samples that included more low-functioning children. For example, half of the children studied by Nation et al. (2006) performed at least one standard deviation below word reading norms. The sample had a mean nonverbal ability at the 16th percentile, which is considerably lower than the mean for the current study (63rd percentile). Miniscalco & Dahlgren Sandberg (2010) reported poor decoding skills in five children whose average nonverbal IQ was even lower (the fifth percentile). Since the current study excluded children with nonverbal ability of 80 or below, sample differences in cognitive ability may explain the differences in results. In support of this contention, the children in the current study with Basic Reading Scores one standard deviation below the mean had IQs ranging from 69 to 87. Asberg, Dahlgren et al. (2008) also recruited from a clinical population, but limited selection to children with FSIQ above 75; however, the mean nonverbal IQ for their sample was still lower than that of the current study (93.5 compared to a mean of 105). It is possible that the higher percentage of children with low or borderline cognitive ability in these three studies partially explains the higher proportion of poor readers.

On the other hand, a clear relationship between cognitive ability and basic reading has not been established for children with ASD. Although word reading ability is generally commensurate with IQ, interest in hyperlexia means that much of the research has compared good readers with low IQs to other children with ASD (Cardoso-Martins et al., 2010; Jones et al., 2009; Newman et al., 2007; Saldana et al., 2009). In some studies this could be due to study design and participant selection, but the superior word reading ability of some children with ASD clearly complicates results for other studies. So while basic reading skills vary among children, and between studies, mean skill levels are probably affected by the populations studied. Clinical samples include more children with lower overall ability than community samples drawn from the general population of children with ASD. Studies that include high-functioning

children or that exclude nonreaders or children with cognitive impairments result in higher reading averages, sometimes reaching above-average levels.

This does not mean, however, that learning disabilities (areas of discrepant weakness) or splinter skills (areas of learning strength) are rare for children with ASD; rather, it simply suggests that the mean cognitive ability of groups will affect mean academic performance. It is clear from the current study and other research that some children with ASD learn to recognize words, or decode phonetically, quite easily. Earlier research has estimated that 7% to 21% of children with pervasive developmental disorders read words extremely well compared to overall ability (Burd et al., 1985; Jones et al., 2009; Grigorenko et al., 2002). The children in the current study had an average mean IQ, but 27% scored at least one standard deviation above average for age on Basic Reading Skills when less than 15% would have been expected.

In support of earlier research indicating that many children with ASD are able to read words prior to formal schooling (Aram, 1997; Church, Alisanski & Amanullah, 2000; Frith & Snowling, 1983; Nation, 1999; Newman et al., 2007), nearly one third of the parents in this study reported that their children were able to read some words and beginner books before the age of five. Specifically, 3 percent of the children were reported to read words and beginner books at age two, an additional 8 percent at age three, and an additional 19 percent at age four. Although this was based on parent report, in reference, the National Center for Education Statistics reported that in 2000 only two percent of children entering kindergarten (average age 5 ½) were able to read simple sight words, and only one percent were able to read sentences (NCES, 2001).

Although some children exhibited strength in basic reading, it was an area of weakness, or even disability, for others. Standard scores ranged from the 5th through the 99th percentile, and 16% met a criterion for poor word reading defined as below a standard score of 90, or the 25th percentile. Autistic traits such as obsessive interests (Aram & Healy, 1998; O'Connor & Hermlin, 1991), strong rote memorization ability (Boucher, 2007; Mayes & Calhoun, 2003b; O'Connor & Hermelin, 1989), and a weak central coherence/focus on details (Frith, 1991; Frith, Happe & Sidons 1994; Nation, 1999) may help some children with ASD learn to read words precociously, but they do not result in strong word reading skills for all.

In summary, the current study found a wide range of reading ability in high-functioning children with ASD, with participants as a group performing slightly better than average for age on the measure of Basic Reading Skills and its components, Word Identification and Nonword

Decoding. These above-average means may have been influenced somewhat by the exclusion of children with nonverbal ability below the tenth percentile, but the basic finding of strong word reading scores attained by many children in the group holds nonetheless.

Development of Word Reading Skills

There is a long history of research into basic reading strengths and problems for children with ASD. One thread has focused on early or unexpected reading ability (hyperlexia), while another examined differences between word identification skills and decoding ability. Hyperlexia was discussed previously in the section on reading; here I discuss results for the research question regarding sight words vs. nonwords.

Children with ASD are known for strong associative memory skills and attention to details, which may help them recognize words more easily than age peers, especially in the early grades (Mayes & Calhoun, 2003a, 2006). A relative weakness decoding nonwords has been reported by some researchers (Nation et al., 2006; Smith Gabig, 2010; Tager-Flusberg & Joseph, 2003), while others have found no difference between sight word and decoding skills (Cardoso-Martins & Silva, 2010; Frith &Snowling, 1983; Minshew et al., 1994; Sparks, 2004; White et al., 2006). Since past studies often utilized small samples or included participants with a wide range of ages and abilities, the current study selected high functioning children within a narrow age range to better compare age-appropriate sight word and decoding abilities.

Although other studies of children with ASD have not found word identification and nonword decoding skills to correlate as strongly as in typically developing children (Nation et al., 2006), participants in the current study tended to do well on both tests, and the measures were highly correlated ($r = .86$). This is similar to correlations found in the typically developing population (Nation & Snowling, 1997; Vellutino, Tunmer, Jaccard & Chen, 2007) and to those from a recent study of youth with ASD (Asberg & Dahlgren Sandberg, 2012).

The average participant scored higher on the sight word recognition task than the nonword decoding task, but this was due to above-average sight word recognition and not to below-average decoding. The phenomenon was strongest for children in first grade, and may have been due to precocious reading ability for some children, especially the third of participants reported to be reading words prior to kindergarten entrance. Both Word Identification and Nonword Decoding were highest for first graders compared to national norms Overall, the high-

functioning children in this sample exhibited grade-appropriate lexical access and phonological decoding skills, with above-average performance observed in many first graders.

There are several other possibilities, besides the precocious development of word reading skills, for the exceptional performance of first graders on the basic reading measures. Strong word recognition and nonword decoding skills could be the result of an increased emphasis on literacy skill instruction in preschool and kindergarten. It is also possible that the first graders in this sample were more likely to attend schools with strong academic programs, or come from families with higher socio-economic status. A post-hoc analysis revealed a weak but significant correlation ($r = -.27$, $p < .05$) between the SES index and grade, indicating that younger children tended to come from families with higher SES. Further analysis would be necessary to discern whether this trend could account for the grade level performance differences in basic reading skills.

Phonemic Awareness skills were intact in this sample of high-functioning children, and phonemic awareness performance correlated strongly with nonword decoding ($r = .62$). The impaired or disconnected phonemic awareness skills seen in other studies (Cardoso-Martins & da Silva, 2010; Miniscalco & Dahlgren Sandberg , 2010; Smith Gabig, 2010; Sparks, 2004) were not seen here. Instead, performance on two of the three phonemic awareness tests (Sound Blending and Sound Awareness) was slightly above average, and only Incomplete Words, a cloze task requiring the retrieval of rhyming words from memory, had a below-average group mean ($X = 95$). Retrieval of words from memory, as seen in the Retrieval Fluency measure, was an area of relative weakness for participants as a group.

Consideration was given to possible reasons that the results of this study differed from those in Smith Gabig (2010), which found nonword decoding weaknesses in elementary children with ASD. The 14 children in that study, slightly younger (5-8) than those in the current study, were also high-functioning and had above-average group means for Word Identification (115) and Nonword Decoding (104). However, they performed significantly below average for age on sound blending (8 on a standardized scale of 10, $p < .05$) and sound deletion tasks (6, $p < .01$), and these phonological measures did not correlate significantly with word or nonword reading ability. The main difference between the samples is that the children in the Smith Gabig study had a much lower group mean on receptive vocabulary (77), which correlated strongly ($r = .62$) with phonological ability. Therefore, although the children in the two studies had comparable

NVIQs, lower vocabulary skills in the Smith Gabig sample may have delayed the development of phonemic awareness (Metsala, 1999; Rvachew, 2006) and nonword decoding skills.

To summarize, no deficit in nonword decoding skills was found in the current sample of early elementary high-functioning children with ASD, while strength was found in sight word recognition, especially for first graders. Individual results varied greatly, but memorization skills appeared to serve many children with ASD well as they began to interact with the printed word.

Cognitive and Language Predictors of Basic Reading Skills

A primary goal of reading research is to improve our understanding of factors related to achievement in order to improve instruction and intervention. Correlates and predictors of word reading skills in children with ASD have been studied previously, but results have been inconclusive; although some researchers have found typical relationships with cognitive, language, and phonemic awareness measures, others have not. An objective of the current study was to investigate relationships among a broader range of cognitive, language, and phonological skills than are typically assessed in a single study to control for interactions and focus on younger high-functioning children with ASD who are presumably still developing word reading skills.

Overall, correlates of basic reading skills evident in the typically developing population, such as nonverbal ability, phonemic awareness, and vocabulary, were relevant for children with ASD. However, several cognitive and executive function abilities often found to be weak or impaired in children with ASD, such as verbal ability, oral language, processing speed, and fluency, had weaker relationships with word reading skills in this sample than in typically developing children.

Consistent with research focused on typically developing children in the early grades (Cardoso-Martins et al, 2004; Fletcher et. al., 2011; Speece et al, 2004), Phonemic Awareness was the strongest correlate of Basic Reading Skills and its components. These correlations ($r =$ .61 to 64) were only slightly weaker than those found between phonemic awareness, Word Identification, and Nonword Decoding in a study of typically developing first through third graders ($r = .73$ to .77: Speece et al., 2004) and in a recent study assessing children with ASD ($r = .65$ and .67: White et al., 2006). The strong relationships found in the current study are important, as some studies with smaller samples, larger age ranges, or a focus on children with

hyperlexia have not found significant relationships between phonemic awareness and basic reading skills (Cardoso-Martins & da Silva, 2010; Smith Gabig 2010; Tager-Flusberg & Joseph 2003; Sparks 2001, 2004). Some of these studies used phonological tasks that are challenging for children with cognitive impairments, and results may have been confounded by difficulty following directions or the bi-modal challenge of representing speech sounds with physical objects (Heumer & Mann, 2009; Sparks, 2004). The sound awareness task used in the current study would be nearly as challenging, but no participants had nonverbal ability below 80. The difference, therefore, may lie in the stronger NVIQ and language skills in the current study sample. The results of the current study suggest that phonemic awareness is intact in high-functioning children with ASD in the primary grades and contributes to the development of basic reading skills in a typical manner.

Although measurements of cognitive ability have not always been reliable predictors of reading for children with ASD (Asberg et al., 2010; Asberg & Dahlgren Sandberg, 2012; Newman et al. 2007; Smith Gabig, 2012), this study found a strong relationship between General Intellectual Ability and Basic Reading Skills ($r = .54$, p < .01). This correlation between overall ability and word reading is comparable to those reported for high-functioning children with autism ($r = .64$; Mayes & Calhoun, 2008) and for typically developing children ($r = .59$: Mayes et al., 2009; $r = .65$: McGrew et al., 2007). Thus, the relationship between cognitive ability and word reading in high-functioning children with ASD in the early grades appears to be similar to the relationship in typically developing children.

As noted earlier, Nonverbal IQ had a slightly stronger relationship with Basic Reading than Verbal Ability. This could be due to the inclusion of the phonemic awareness test Sound Blending in the Woodcock-Johnson NVIQ cluster, as other measures of nonverbal ability used in research do not include a phonemic awareness task. However, the correlation ($r = .61$) is consistent with research involving typically developing populations (Ferrer et al, 2007; McGrew et al., 2007), and children with dyslexia (Pammer & Kevan, 2007). A similar correlation has been found between achievement and NVIQ in younger (6-7), but not older high-functioning children with ASD, suggesting that NVIQ is more important for academic success in the early elementary years (Mayes & Calhoun, 2008).

The impact of language and vocabulary on word reading is less clear. Picture Vocabulary was strongly related to Word Identification ($r = .49$) and Basic Reading Skills ($r =$

.45), and contributed uniquely and significantly to the prediction model. As vocabulary has been found to correlate strongly with IQ in children with ASD (Kjelgaard & Tager-Flusberg, 2001) it is important to note that in the current study vocabulary continued to relate significantly to word reading after controlling for nonverbal and phonological abilities. Positive relationships between vocabulary, phonological skills, and word reading in children with ASD have been apparent in other studies (Asberg et al., 2012; Newman at al., 2007). Vocabulary has been theorized to affect the development of phonological awareness in typically developing children (Metsala, 1999), and this may explain the relationship between vocabulary and reading in the current sample. Picture Vocabulary correlated strongly with two of the three phonemic awareness measures. Considering general language weaknesses in children with ASD, vocabulary development may be even more important for the development of phonemic awareness and therefore, word reading, than in typically developing children. Although it is difficult to determine the importance of vocabulary on word reading skills in this correlational study, the subject is clearly worthy of additional research.

Performance on the listening comprehension task Understanding Directions was significantly below average for the group; however, the scores correlated weakly ($r = 29$) with Basic Reading Skills; and did not contribute significantly to the prediction model. It appears that comprehension difficulties with complex language do not negatively affect the development of word reading skills for children with ASD in the early grades. A receptive language deficit could impact the ability to benefit from instruction in decoding strategies, but it might not affect word reading performance for many children with ASD if they can memorize words and teach themselves decoding through orthographic analysis.

Mean scores for Visual Matching (perceptual processing speed), Retrieval Fluency (semantic fluency), and Rapid Picture Naming were also below average for the children in this sample, but they did not correlate significantly with word reading. These abilities have been associated with basic reading skills in typically developing children, but it is not clear whether they significantly impact word reading development, as results for both Rapid Picture Naming and processing speed have been inconsistent (Christopher et al., 2012; Mayes & Calhoun, 2008; MacDonald et al., 2013). Regardless, the impairments in fluency and perceptual processing that affected many children in this sample did not impact word reading skills in a linear relationship. Difficulties with fluency and processing speed may have a greater effect on reading fluency and

comprehension than on word reading skills, and a timed reading task would be helpful for investigating this possibility.

Participants also performed significantly below average on the working memory task Numbers Reversed, yet this variable did have moderate relationships with Word Identification (r = .32), and Nonword Decoding (r = .32), similar to typically developing children. The ability to hold information in short-term memory and mentally manipulate it appears to be more closely related to processes necessary for phonological decoding than processing speed and fluency.

In summary, several typical predictors of basic reading skills correlated strongly for children with ASD and were able to predict a significant amount of the variance, while some areas of weakness for children with ASD did not appear to affect word reading skills. Although there were some interesting differences compared to a normative sample of typically developing children, only the weak correlation between Story Recall and basic reading – and the negative contribution to the predictive model – were noteworthy. However, some cognitive and executive function abilities often found to be weak or impaired in children with ASD, such as verbal ability, oral language, processing speed, and fluency, had *weaker* relationships with word reading skills in this sample than in typically developing children. Correlation in the general population does not necessarily imply a direct relationship, and either these abilities are less important than assumed in the development of word reading skills, or some children with ASD are able to use other strengths to compensate.

Story Recall had an unexpected negative relationship with basic reading once the other factors were entered into the regression analysis. Story Recall is a task of short-term auditory memory in which participants listen to short narratives (two or more sentences) and repeat them to the examiner. Auditory memory has been found to be unimpaired in children with ASD (Russell & Jarrold, 1996), and during administrations it was observed that many children with notable ASD characteristics did surprisingly well on this task. Echolalia, the repetition of the language of others, is a common trait in children with ASD, with an inverse relationship to comprehension (Roberts, 1989). It appears that a strong ability to echo sentences and stories in some of the children with more severe ASD had an inverse relationship with word reading skill so that the measure added a negative predictive power to Basic Reading Skills after controlling for the stronger correlates of nonverbal ability and language. While interesting, a negative additive power would not be useful in the prediction of basic reading problems in the field.

However, this does suggest that Picture Vocabulary alone may be a more useful measure of functional expressive language ability for children with ASD than the WJ-III cluster score, which includes Story Recall.

The remaining four tasks in the WJ-III test battery – Visual-Auditory Learning, Sound Blending, Sound Awareness, and Picture Vocabulary - appear to have useful predictive value for basic reading skills in high-functioning children with ASD. Although the expected proportion of children with reading problems was not seen in this sample of young children, tests measuring phonological skills, vocabulary, and the ability to memorize meaningful symbols would be useful for the discovery of skill weaknesses and the development of targeted educational interventions.

The Relationship between Cognitive Flexibility and Reading

Cognitive flexibility has been hypothesized to affect the development of phonemic awareness and basic reading skills in the early elementary grades because flexibility is initially required to deal with multiple representations of words. Because prior research has indicated flexibility weaknesses in children with ASD, it is intriguing that word reading skills in the early grades are often similar or superior to those of typically developing children.

One objective of this study was to investigate the relationship between Cognitive Flexibility and Basic Reading Skills. Specifically, the question was whether cognitive flexibility contributed to the variance in basic reading skills after controlling for common predictors of reading such as nonverbal ability, language, and phonemic awareness. Following recommendations provided in the literature, both performance-based measures and parental ratings of executive functioning were used to assess cognitive flexibility. Performance measures correlated significantly, though weakly, with reading achievement measures, but the parent rating did not.

Performance measures of cognitive flexibility included standardized scores from the computerized Wisconsin Card Sorting Test (Total Errors and Perseverative Responses). Group performance on the WCST was significantly below average for age, consistent with prior research that has found mild or moderate deficits on this task for people with ASD (Kenworthy et al 2008; Liss et al, 2001). Positive relationships were found between each of the WCST

performance scales and the Basic Reading measures, ranging from .20 to .23; most of these associations were significant at the .05 level (one-tailed).

The WCST measures also correlated strongly with general ability ($r =.44$, p < .01). Research has reported weaker correlations between shifting and general ability (FSIQ) in normal adults ($r = .23$: Friedman et al, 2006) and in average and intellectually gifted children ($r = .3$: Arffa 2007). The stronger correlations found in the current study align with results of other studies of children with ASD that ranged from .45 to .50 (Liss et al., 2001; Pellicano, 2010b). These combined results indicate that WCST performance relates more strongly to general ability in children with ASD than in typically developing children and adults. Since WCST performance for the group as a whole was significantly below average, this could mean that children with ASD must rely more upon overall ability to overcome deficits in flexibility. The current study included an additional performance-based measure of cognitive flexibility; the Concept Formation test from the Woodcock-Johnson Tests of Cognitive Ability. Although this test is primarily a measure of fluid reasoning, it also taps cognitive flexibility (Mather & Woodcock, 2001), and in this study it correlated strongly with the WCST measures, especially Total Errors ($r = .53$, p < .01). Concept Formation had slightly stronger relationships with the reading variables than did the other cognitive flexibility measures, ranging from .25 to .28 (p < .05), yet these were smaller than the correlations from the WJ-III normative sample, suggesting a weaker relationship between word reading and flexibility for early elementary children with ASD.

The results of a series of regression analyses that utilized cognitive flexibility measures to predict basic reading indicated that only Concept Formation could predict a significant, though modest (adjusted $r^2 = .06$; p < .03) amount of the variance when entered alone. However, none of the cognitive flexibility measures was able to add to the predictive power of the previously constructed model that included five cognitive, language, and phonemic factors. Since the performance measures correlated strongly with General Intellectual Ability it is possible that cognitive flexibility was mediated though nonverbal and language abilities; in other words, that differences in flexibility affected development and had therefore already been captured in the other measures.

Other researchers who have reported significant relationships between cognitive flexibility and basic reading skills either did not control for cognitive ability (Altemeier et al.,

2008) or limited their consideration to verbal ability alone (Cartwright et al., 2010). In contrast, in a recent study of 214 typically developing elementary-aged children, researchers found WCST measures did not contribute significantly to a model predicting word reading after IQ and other factors had been entered (Mayes et al.,2009). A recent meta-analysis found a significant effect size for shifting (cognitive flexibility) ability on reading achievement above the effect of intelligence alone, but reading measures in some studies included fluency or comprehension (Yeniad et al., 2013).

It is difficult to disentangle cognitive flexibility, language, and cognition in a correlational study because cognitive and language development is theoretically affected by cognitive flexibility. Cognitive flexibility is believed to impact referential learning and lexical development (Adamson et al., 2001; Ben-Itzchak & Zachor, 2007), so few tests of cognition and language are free of its influence. It is likely that cognitive flexibility impacts basic reading skills primarily through the development of cognitive, language, and phonological abilities. As seen in Appendix C, the WCST measures correlated significantly with IQ (r = .44, .42, p < .01) and Oral Language (r = .38, .40, p < .01). An ad-hoc series of regressions using individual cognitive flexibility measures to predict Phonemic Awareness found significant power for Concept Formation (r = .56, r^2= .30, t=5.24, p < .00), WCST Total Errors (r = .25, r^2= .05, t=2.00, p < .05), and WCST Perseverative Responses (r = .29, r^2= .07, t=2.31, p < .03). If the relationship between cognitive flexibility and word reading is primarily through the development of phonological skills, its effect on reading would have been absorbed by the inclusion of Sound Blending and Sound Awareness in the final regression model.

Although performance-based cognitive flexibility measures correlated modestly with basic reading skills, in these analyses they offered no unique contribution to the prediction of basic reading once nonverbal and language attributes were considered. Despite the fact that results summarized herein did not support a predictive role of cognitive flexibility for basic reading, the null hypothesis (that cognitive flexibility has no predictive power for Basic Reading Skills) cannot be confirmed. Besides problems with interrelationships among cognitive skills and measurement construct fuzziness, a power analysis indicated that a sample size nearly twice as large (121) would be necessary to confirm that cognitive flexibility has no significant relationship with word reading. Thus, a definitive analysis awaits future research.

Parent Ratings. Although the performance-based cognitive flexibility measures correlated with reading and cognitive ability, parent ratings did not. The parent rating score for cognitive flexibility was taken from the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). Most parents in the study reported levels of executive function problems in their children well above average for typically developing children the same age, consistent with other research involving children with ASD (Boyd et al., 2009; Gilotty et al., 2002; Kenworthy et al., 2009; Zandt et al.,2009). The referenced studies found significant relationships between BRIEF ratings and autistic behaviors, and the current study found a similar correlation between the Shift measure and the SCQ parent checklist of autistic behaviors ($r = .37$, $p < .01$); however, there were no significant relationships with any reading, language, or cognitive measures.

The Shift measure also did not correlate with the performance-based cognitive flexibility measures. This surprising lack of association has been found in other studies of children with ASD (Teunisse et al., 2013; Zandt et al., 2009), and children with AD/HD (Mahone, Cirino, et al, 2002). A recent review of the literature found extremely weak correlations between BRIEF ratings and performance-based tests such as the WCST (Toplak, West, and Stanovich, 2013). The research team theorized that the assessments were measuring different constructs or aspects of executive function. They argued that while performance-based measures assess processing efficiency in structured situations, parent and teacher ratings address goal-oriented behaviors in the real world. For the purpose of this study, the acquisition of basic reading skills might therefore be expected to relate more strongly to cognition-based performance measures than to parent ratings of goal-oriented behaviors in widely diverse environments.

Other researchers have expressed deeper concerns about the validity of the BRIEF in measuring executive function constructs (McAuley, Chen, Goos, Schachar & Crosbie, 2010). McAuley et al. found no significant correlations between performance measures of inhibition, working memory, and monitoring, and the BRIEF scales for these abilities. Zandt et al. (2009) questioned whether the BRIEF actually assesses overall impairment, adaptive behaviors, or levels of parent concerns. Teunisse et al., (2013), questioned whether a halo effect might be impacting BRIEF results, with parent expectations influencing both their ratings and their child's behaviors. They also suggested that high intercorrelations among construct ratings on the BRIEF

evidenced contamination of the parent Shift rating with other constructs such as overall functioning and emotional adjustment.

Some of the problems with the validity of the BRIEF relate to concerns about parent ratings in general. Only modest inter-rater reliability on rating scales has been found between parents (Mascendaro, Herman & Webster-Stratton, 2012) and between parents and teachers (Achenbach, McConaughy & Howell, 1987; McCandless & O'Laughlin, 2007). Reed and Osborne (2013) have suggested that differences between parent and teacher ratings do not relate to child behavior differences in the two environments but to each rater's frame of reference; while teachers have a broader reference for typical child behavior, parents may refer to smaller, more specific groups of children. For example, parents of children in a special treatment program may compare their child to the others in that program rather than using a more global reference.

To summarize, it appears that the BRIEF, which has merit for the planning of clinical and educational interventions, may have more limited utility in research as a valid measure of specific executive function constructs. A better assessment of problems with cognitive flexibility in the natural environment would be useful for future research.

Conclusions

There is a rich history of research into the reading skills of people with ASD, but most studies either utilized extremely small samples or included participants with a wide range of age and ability. The design of the current study was carefully crafted to diminish bias, control for possible mediating factors, and provide a rich variety of cognitive, language, achievement, and cognitive flexibility measures for study.

Some comparisons can be made between the current study sample and participants in research studies cited throughout this paper. The literature review focused on 12 recent studies investigating reading skills and ASD. Sample sizes for these studies ranged from 3 to 384, but only two were larger than the 63 children in the current study. Even the Mayes & Calhoun research (2003a, 2003b, 2008) that is frequently cited in the ASD literature drew from a sample of only 63 children ranging from 6 to 15 years old. Participant ages in the twelve reviewed studies ranged from 3 to 20 years, but only two studies were restricted to children between five and ten years, when word reading abilities are typically developing. Most studies reviewed in

this paper included children with cognitive impairments, although half used cutoff criteria to bring group means within average. Only the current study utilized a sample size greater than 14 while focusing on children without significant cognitive impairment enrolled in elementary grades. Although a random sampling strategy could not be used for participant selection, children were recruited through a variety of schools, clinics, public media, and parent groups across the state. The resulting sample was diverse, including girls (13%), non-white children (13%), rural, suburban and urban communities, and parent educational attainment that ranged from eighth grade through professional and doctoral degrees. This community sample centered on high functioning children with ASD served in general education and/or resource programs, but the full continuum of special education services was represented. In short, the greatest contribution of this study may have been to use a broad selection of quality standardized assessments to measure cognitive, language, literacy, and executive function abilities in a diverse sample of high-functioning, early elementary children with ASD.

The results of this study extended previous findings that high-functioning children with ASD are both similar to, and different from, typically developing age-mates. General Intellectual Ability was average, and verbal and nonverbal abilities were slightly above average, but processing speed, working memory and retrieval fluency were below. Weaknesses in processing speed, memory and recall have been reported in other studies of children with ASD (Kenworthy et al., 2009; Mayes & Calhoun, 2007, 2008; Russo et al., 2006; Southwick et al., 2011). Language abilities were surprisingly strong for this sample, but the group did exhibit a clear weakness in the comprehension of complex directions. Phonemic Awareness was also surprisingly strong, but tasks requiring word retrieval (generating words that rhymed) were more difficult.

The young children with ASD in this study have generally been advantaged by early diagnoses and early intervention, yet they still exhibited significant deficits in cognitive flexibility, working memory, processing speed, fluency, and complex language comprehension. Regular and special educators can easily miss such weaknesses and the educational implications because the children present with average verbal and nonverbal abilities and only minor language impediments. This study confirms earlier research concerning cognitive and executive function weaknesses in high-functioning children with ASD and the message that

accommodations and individualized instruction are necessary for academic success and good outcomes in adulthood.

Although cognitive flexibility, working memory, processing speed, fluency, and language comprehension are areas of weakness for children with ASD, only working memory (Numbers Reversed) had a moderate relationship with basic reading. Working memory (Digit Span) has also been found to be important for the development of word reading skills in typically developing children (Mayes et al., 2008), and may be related to cognitive flexibility (Hale et al., 2002) . It is not clear whether the other abilities are unimportant for the development of word reading skills or whether some children with ASD are able to compensate with other strengths.

The correlates of word reading for high functioning children with ASD appear to be comparable to those for typically developing children. Phonemic Awareness, Nonverbal Ability, and General Intellectual Ability were all strongly correlated with Basic Reading Skills. A regression model using five cognitive, language, and phonemic awareness tests from the WJ-III was able to predict 55 percent of the variance in Basic Reading. This supports other research suggesting that there is little that is unique in the development of word reading skills for high-functioning children with ASD, but that those who can problem-solve, memorize, understand language, and mentally manipulate speech sounds will usually be able to learn to read words. Four of these tasks (Visual-Auditory Learning, Sound Blending, Sound Awareness, and Picture Vocabulary) would be useful in the diagnosis of high-functioning children having trouble with beginning reading skills, as they could reveal skill weaknesses (symbol memorization, phonemic awareness, phonological knowledge, vocabulary) contributing to the difficulty.

Results from the Cognitive Flexibility measures were unsupportive of expectations based on theory and past research. Although there is considerable evidence that people with ASD have difficulty shifting sets and thinking flexibly, the measures used in this study related negligibly or weakly with Basic Reading Skills. It is possible that the relationship between cognitive flexibility and basic reading skill is more complex than theorized, especially for children with ASD, and cannot be fully investigated with a correlational study. The negative effects of cognitive rigidity on learning and functioning are clear, yet a more positive strong interest in reading has been hypothesized to contribute to hyperlexia. There is also a question of timing in any impact of cognitive flexibility on word reading; once the ability to perceive words on

multiple levels (phonological, orthographic, semantic) has been attained, difficulty shifting contexts may not have a clear effect.

In summary, there is a wide range of word reading ability in children with ASD, but the skills of most children are commensurate with phonemic awareness and nonverbal ability. Certainly some children perform below average, and a small percentage (6 to 16 percent) have significant difficulty with Basic Reading Skills, but this is not unlike the percentage of children with reading problems in the general population. Future research should focus on these children to see if their profiles are similar to children with dyslexia.

Limitations and Suggestions for Further Research. Although care was taken to ground the study in past research, including the measurement of constructs, limitations of the cognitive flexibility measures discovered during data collection may have influenced the findings. Specifically, there were possible limitations in the validity of parent ratings and the reliability of the WCST.

Parent ratings appeared to be influenced to some degree by perceived context and attitudes. It became apparent while scoring parent questionnaires after each child's assessment that the ratings of about 15 percent of the parents were inconsistent with clinical impressions and assessment results. Some parents of very high-functioning children listed numerous areas of weakness for their child, perhaps because they were closely comparing their child to typically developing age peers or referencing an ideal of a bright child with no impairment. In contrast, some parents of children with more severe disabilities appeared to respond using a different frame of reference; for a child with moderate or severe autism, they found few additional weaknesses worth noting. It is possible that parents used other children in their child's educational program as a reference for such questions, as suggested by Reed & Osborne (2013).

Relatedly, none of the non-white parents listed enough classic indicators of autism for their child to meet the recommended cutoff for ASD on the Social Communication Questionnaire, despite the facts that they had volunteered for a study of children with autism and their children met eligibility criteria comparable to those of all other children in the sample. This may reflect a protective reluctance to view their child harshly or to reveal all suspected deficits to a stranger. Diagnostic prevalence rates for ASD are lower for non-white than for white children (CDCP, 2012), which may reflect a cultural reluctance to identify autistic behaviors in children.

However, a considerable percentage of false negatives on the SCQ have been found in other studies of children with ASD (Brooks & Benson, 2013; Chandler et al., 2007; Corsello et al., 2007; Ghazuiddin et al., 2010) and recommendations have been made for lower cutoff scores.

These issues with parent responses may help explain the lack of significant relationships with other measures; however, other researchers have also found weak relationships between parent ratings and other measures, including performance measures of executive function (Anderson, Anderson, Northam, Jacobs, & Mikiewicz, 2002; Toplak et al, 2013; Teunisse et al., 2012; Vriezen & Pigott, 2002; Zandt et al., 2009). There is clearly a need for further development and research relating to parent ratings of functioning for children with disabilities, and other instruments should be considered for further research.

Isolated concerns with the computerized WCST also became evident as the study progressed. A few children made comments to the examiner during the instructions or the execution of the task claiming to have had prior experience with similar tasks or games ("This is just like a game my teacher has at school" or "I have a game at home like this"). Children were not asked during administration about their experience with similar tasks, so it is not known if other participants had also practiced a similar activity and therefore may have performed better than expected. Another concern was that a few of the youngest children struggled with the basic task; they could match two identical items, but had difficulty categorizing non-identical cards by one criterion (color, number, or shape). The test was normed for children as young as six, but it may have been too challenging for some six and seven year olds with ASD, who were still struggling to discern the multiple attributes of a card (decentration); concerns about the appropriateness of the WCST for younger children with ASD have been expressed by other researchers (Russo et al., 2007). The WCST scores for one child were removed from analyses due to validity concerns of this nature, but the impact of task difficulty or experience was less clear for other children. Although the WCST is a classic estimate of cognitive flexibility, other measures better suited for children in this age range should be considered for future investigations.

To summarize, research about executive functions has often been challenged by instrument limitations; although there is considerable support for the existence of constructs such as cognitive flexibility, the development of accurate measures unconfounded with overall ability or other factors has been difficult. The instruments used to measure cognitive flexibility may

have limited the results, and future researchers should continue to review and select the best instruments available.

Future research should also look more closely at high-functioning children in the ASD population who have reading problems to investigate whether there are any differences in relationships with predictor factors. While it was heartening to find such strong word reading skills in the current sample, the number of children with reading disability (four below the 15th percentile, ten below the 25th) was too small to provide the statistical strength needed for useful conclusions regarding this subset of the sample. Additional children may be recruited in the future to expand the size of this subgroup.

A larger sample size overall would also have increased statistical power and accuracy. Although a sample of 63 high-functioning children in a small age range was a strength of this study, a power analysis suggested that 121 participants would be necessary to confirm the null hypothesis that cognitive flexibility does not add to the prediction of basic reading after controlling for the other factors.

In summary, this study indicated that word identification and decoding skills are intact for most children with ASD with average or above-average ability, and predictors of basic reading skills are similar to those for typically developing children. However, a small minority of high functioning children with ASD do have difficulty with basic reading skills. Future research should focus on these children, perhaps through group comparisons, to learn more about their patterns of strength and weakness.

APPENDIX A

List of Abbreviations

AD/HD	Attention Deficit/Hyperactivity Disorder
ASD	Autism Spectrum Disorder
BRIEF	Behavioral Rating Inventory of Executive Function
FSIQ/IQ	Full Scale Intelligence Quotient (General Intellectual Ability)
NVIQ	Nonverbal Intelligence
PDD-NOS	Pervasive Developmental Disorder, Not Otherwise Specified
SCQ	Social Communication Questionnaire
SD	Standard Deviation
VIQ	Verbal Intelligence
WCST	Wisconsin Card Sorting Test
WJ-III	Woodcock Johnson III NU

Parent Questionnaire Items

A: Child's name _____ Birthdate _____ Sex: M   F
Address_____
City_____ State _____ Zip _____
Languages Spoken at Home _____

B: Parent/Guardian Information
Your name _____Relationship to child_____
Phone number: Home_____ Work or Cell_____
Father_____Email_____
Education Level_____ Profession _____
Mother _____ Email _____
Education Level _____ Profession _____
With whom does the child live? (e.g., both parents, step-parent, grandparent, etc.)
_____

C: Diagnosis (Autism, Asperger's, PDD-NOS, ASD) or Special Education Eligibility
Child's current diagnosis_____ Date _____
Made by _____Professional Title_____
Address _____ City _____ State _____
Previous diagnosis if any_____
When?_____ Made by_____

D: Other Diagnoses
Has your child been diagnosed with Attention Deficit/Hyperactivity Disorder (AD/HD)?
_____By whom, when, etc._____
Does your child have a vision, hearing or physical disability?_____
Has your child been diagnosed with any other medical or psychological condition? _____
Please describe_____

E: Child's Current Language Ability (check one): ____Nonverbal ____Some words
_____Sentences ____A little delayed ____Typical for age _____Above average

F: Current Education Program
School _____ District_____Grade _____
Attends (check all that apply): ____Regular Class ____Resource Room
____Special Education Class
Additional information:_____
Current related services (Speech/Occupational Therapy/Other):_____

G: Past Education Programs (check all that apply)
2012-2013 attended: __Regular Class   ___Resource Room __Special Education Class
Grade ____   Services_____
2011-2012 attended: __Regular Class   ___Resource Room __Special Education Class
Grade ____   Services_____
2010-2011 attended: __Regular Class   ___Resource Room __Special Education Class
Grade ____   Services_____
2009-2010 attended: __Regular Class   ___Resource Room __Special Education Class
Grade ____   Services_____
2008-2009 attended: __Regular Class   ___Resource Room __Special Education Class
Grade ____   Services_____
Has your child ever repeated a grade? _____ Which one?_____

H: Reading Interventions
Has your child had special classes or tutoring that focused on reading or pre-reading skills?
_____   What, when, how long and how often?
_____

I: Reading: Does your child recognize at least 50 words?   Yes   No
Can your child consistently identify at least 10 letters?   Yes   No
Approximate age child could: Read name _____ Recite alphabet _____
Read a few words _____ Read a beginning book _____
Your child's interest in books: ___High ____ Very little ____ Dislikes
Interest in written letters and words: ____High ____Some ___Very little ____ Dislikes
Please comment on your child's attitude and interest in reading _____
_____

J: Current and Past Interventions
Please check any treatments your child has received and describe in detail below.

___Applied Behavior Analysis (ABA)   ___Floortime   ___The Son-Rise Program
___Social Comm/ Emotional Regulation/ Transactional Support (SCERTS)
___Training and Education of Autistic & Related Communication Handicapped Children
  (TEACCH) ___Relationship Development Intervention (RDI)

Therapies: ___Speech and Language   ___ Occupational ___Physical
___Sensory Integration ___Auditory Integration ___Pivotal Response (PVT)
___Verbal ___Cognitive Behavior ___Other

Communication: __ Picture Exchange Communication System   ___ Sign Language
Health: ___ Special Diet ___ Vitamins/Herbal Products ____ Other

Intervention_____
Year/Frequency/Duration_____

Other information_____

Intervention _____
Year/Frequency/Duration_____
Other information_____

Intervention _____
Year/Frequency/Duration_____
Other information_____

K: Development
At approximately what age (in months) could your child do the following without assistance?
Sit up by self_____ Crawl _____ Walk _____
Language: Respond to name_____ Say first word _____
Put two words together_____ Speak in sentences_____
Did your child ever lose skills? If so, please describe
_____

L: Medical
Timing of Birth: _____ full term   _____ weeks *early* or   _____ weeks *late*
Problems at birth_____
Medical issues 1st year_____
Medical issues age 1-2 _____
Medical issues ages 3-present _____
Current medications_____
Past medications_____

M: Behavioral Problems
First year (eating, sleeping, excessive crying)_____
Preschool years_____
Current (emotions, eating, sleeping, self-care, following directions)
_____

N: Reading: How often do you:
Read with your child at home?	Daily Every other day	Weekly	Rarely
Write with your child at home?	Daily Every other day	Weekly	Rarely
Take your child to the library?	Daily Every other day	Weekly	Rarely
Play learning or alphabet games?	Daily Every other day	Weekly	Rarely

O: Additional information _____

APPENDIX C

Correlation Matrix

	Basic Reading	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2. Word Identification	.97**														
3. Nonword Decoding	.96**	.86**													
4. Gen Intellectual Ability	.54**	.51**	.52**												
5. Verbal Ability	.43**	.44**	.35**	.78**											
6. Verbal Comprehension	.38**	.39**	.31*	.75**	.93**										
7. General Information	.40**	.43**	.34**	.71**	.95**	.77**									
8. Nonverbal Ability	.61**	.59**	.57**	.91**	.69**	.65**	.64**								
9. Visual-Auditory Learning	.56**	.56**	.51**	.60**	.40**	.36**	.38**	.71**							
10. Spatial Relations	.34**	.30*	.35**	.59**	.36**	.33**	.34**	.60**	.33**						
11. Sound Blending	.52**	.53**	.47**	.44**	.37**	.32**	.35**	.61**	.33**	.13					
12. Concept Formation	.28*	.27*	.25*	.79**	.66**	.65**	.58**	.76**	.31*	.38**	.19				
13. Cognitive Efficiency	.36**	.29*	.40**	.80**	.42**	.34**	.43**	.58**	.33**	.55**	.22	.51**			
14. Visual Matching	.18	.11	.23	.52**	.31*	.28*	.29*	.41**	.21	.45**	.01	.46**	.62**		
15. Numbers Reversed	.36**	.32*	.38**	.69**	.34**	.26*	.36**	.48**	.29*	.42**	.27*	.37**	.88**	.17	
16. Retrieval Fluency	.06	-.02	.12	.54**	.35**	.31*	.33**	.37**	.23	.25*	.08	.37**	.63**	.62**	.40**
17. Rapid Naming	.09	.00	.18	.43**	.28*	.27*	.26*	.30*	.16	.32**	.11	.21	.55**	.601	.32*
18. Phonemic Awareness	.64**	.61**	.62**	.73**	.68**	.65**	.63**	.76**	.46**	.31*	.63**	.56**	.42**	.22	.40**
19. Incomplete Words	.28*	.25*	.28*	.50**	.46**	.41**	.46**	.38**	.21	.34**	.00	.44**	.43**	.27*	.38**
20. Sound Awareness	.59**	.56**	.56**	.69**	.66**	.66**	.59**	.70**	.48**	.26*	.46**	.57**	.37**	.20	.35**
21. Oral Language	.39**	.40**	.32**	.79**	.91**	.86**	.85**	.71**	.49**	.34**	.34**	.65**	.46**	.32*	.38**
22. Story Recall	.13	.15	.08	.62**	.69**	.67**	.63**	.55**	.40**	.24	.22	.51**	.36**	.27*	.28*
23. Understand Directions	.27*	.27*	.27*	.81**	.80**	.75**	.75**	.72**	.39**	.48**	.34**	.68**	.58**	.45**	.45**
24. Picture Vocabulary	.45**	.49**	.36**	.56**	.78**	.74**	.73**	.54**	.45**	.26*	.32*	.38**	.16	.01	.20
25. Oral Comprehension	.30*	.31*	.25*	.67**	.77**	.72**	.73**	.54**	.36**	.17	.17	.62**	.43**	.38**	.31*
26. Shift Scale BRIEF	-.04	-.04	-.05	.09	.09	.08	.09	.06	.10	-.01	-.04	.10	.03	.07	.00
27. WCST Total	.22	.20	.23	.44**	.37**	.26*	.43**	.44**	.27*	.29*	.01	.53**	.30*	.27*	.20
28. WCST Perseverative R	.22	.22	.20	.42**	.42**	.36**	.41**	.41**	.23	.18	.15	.43**	.25	.23	.16
29. SCQ	.00	-.03	.02	.08	.04	-.05	.10	.08	.17	.10	.05	-.05	.14	.09	.12

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

	16	17	18	19	20	21	22	23	24	25	26	27	28
16. Retrieval Fluency													
17. Rapid Naming	.60**												
18. Phonemic Awareness	.17	.22											
19. Incomplete Words	.23	.20	.58**										
20. Sound Awareness	.15	.20	.93**	.40**									
21. Oral Language	.42**	.39**	.65**	.43**	.65**								
22. Story Recall	.38**	.39**	.45**	.35**	.46**	.83**							
23. Understand Directions	.51**	.42**	.60**	.39**	.58**	.85**	.65**						
24. Picture Vocabulary	.13	.20	.54**	.36**	.51**	.81**	.58**	.54**					
25. Oral Comprehension	.41**	.36**	.54**	.356	.58**	.88**	.73**	.71**	.53**				
26. Shift Scale BRIEF	.05	.03	.04	-.02	.09	.06	.03	.03	-.02	.18			
27. WCST Total	.22	.11	.25*	.23	.31*	.38**	.31*	.32*	.27*	.34**	-.11		
28. WCST Perseverative R	.33**	.10	.29*	.12	.37**	.40**	.29*	.41**	.27*	.31*	-.03	.69**	
29. SCQ	.09	.11	.01	-.02	.01	.00	-.03	.01	-.01	.00	.37**	-.13	.01

** Correlation is significant at the .01 level (2-tailed).

* Correlation is significant at the .05 level (2-tailed).

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