Published in final edited form as:
J Autism Dev Disord. 2014 April ; 44(4): 828–845. doi:10.1007/s10803-013-1936-2.

Characterization and Prediction of Early Reading Abilities in Children on the Autism Spectrum

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Abstract

Many children with autism spectrum disorder (ASD) have reading profiles characterized by higher decoding skills and lower reading comprehension. This study assessed whether this profile was apparent in young children with ASD and examined concurrent and longitudinal predictors of early reading. A discrepant profile of reading (higher alphabet and lower meaning) was found in 62% of this sample. Concurrent analyses revealed that reading proficiency was associated with higher nonverbal cognition and expressive language, and that social ability was negatively related to alphabet knowledge. Nonverbal cognition and expressive language at mean age 2½ years predicted later reading performance at mean age 5½ years. These results support the importance of early language skills as a foundation for reading in children with ASD.

Keywords

emergent literacy; reading; language; comprehension; autism spectrum disorder

Children with autism spectrum disorder (ASD) present with a broad range of cognitive and language skills (Ellis Weismer et al. 2010; Joseph et al. 2002; Rapin et al. 2009; Tager-Flusberg and Joseph 2003; Wilkinson 1998). It might be expected that these children also would show wide variability in reading skills from an early age. Nation and colleagues (2006) found that school-age children with ASD generally performed within the typical range for word reading accuracy. However, the participants varied in their performance, ranging from floor to ceiling effects on comprehension measures. Despite accurate decoding skills, many school-age children with ASD exhibit difficulties with reading comprehension (Huemer and Mann 2010; Jones et al. 2009; Nation et al. 2006). It is unclear, however, when comprehension difficulties may begin and what early factors predict reading ability in this heterogeneous population. This study examines early reading abilities at mean age 5½ in a large sample of young children with ASD.

One theory of reading development and disorders is the simple view of reading (Gough and Tunmer 1986; Hoover and Gough 1990). The simple view of reading specifies that the ultimate goal of reading is reading comprehension, and the two primary components that lead to good reading comprehension are decoding and listening comprehension. Decoding is

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considered to encompass skills such as phonological awareness, orthographic coding, and rapid serial naming that lead to fluent printed word recognition skills (Pennington and Bishop 2009). Listening comprehension, on the other hand, is the understanding of linguistic information and relies upon knowledge in many domains of language including vocabulary and morphosyntax (Catts and Hogan 2003) as well as pragmatics (Pennington and Bishop 2009; Ricketts et al. 2013). Reading is generally accepted to be a highly linguistic task (Catts et al. 1999, 2003, 2006; McArthur et al. 2000). Thus, an individual’s oral language abilities largely predict their reading abilities.

Types of Reading Disorders

Disruptions may occur in the reading process, and reading disabilities can be classified based on problems that arise in decoding or comprehension abilities (Catts et al. 2003). One reading profile involves deficits in both decoding and comprehension. These readers are referred to as having a mixed reading disability (RD; Catts and Kamhi 2005), garden-variety poor readers (Gough and Tunmer 1986) or having a language-learning disability (Catts and Kamhi 2005; Catts et al. 2003). Decoding processes may either break down in the visual interpretation of the letters, or more commonly, phonological processing (Cain et al. 2000; Catts et al. 2005, 2006), and these poor readers are referred to as poor decoders or individuals with dyslexia (Catts and Kamhi 2005; Catts et al. 2003, 2006). This is known as the poor decoder reading profile.

Where the breakdown occurs in reading comprehension is less certain, but weak oral language abilities have been sufficiently documented in poor comprehenders, such as those with specific language impairment (SLI; Bishop et al. 2009; Catts and Hogan 2003; Catts et al. 1999, 2003, 2005, 2006; Nation et al. 2004). Individuals who are purely poor comprehenders do not have phonological processing issues like those observed in dyslexia (Bishop et al. 2009; Cain et al. 2000; Catts et al. 2005, 2006; Nation et al. 2004). Other non-linguistic factors that may affect reading comprehension include aspects of cognition such as working memory (see Carretti et al. 2009 for a review) as well as background knowledge and motivation (Taboada et al. 2008). This profile, when decoding is adequate but comprehension is poor, describes readers referred to as poor comprehenders or those with a specific comprehension deficit (Catts and Kamhi 2005). It is this poor comprehender profile that largely characterizes many individuals with ASD.

Reading Abilities in Children with ASD

The history of reading instruction for children with exceptional educational needs is important to consider before examining what is known about reading abilities in individuals with ASD. Following the standard approach of the time, “the readiness model,” children with ASD were previously not provided reading instruction on the basis that prerequisite skills (e.g., knowing all sound-letter correspondences) were not demonstrated (Erickson 2000; Mirenda 2003). Only recently has the perspective under the emergent literacy view supported the notion that individuals with developmental disabilities should be taught to read (Kluth and Darmody-Latham 2003; Koppenhaver and Erickson 2003; Koppenhaver et al. 1991). Given this fairly recent shift, relatively little is known about how individuals with developmental disabilities, including ASD, learn to read. Understanding reading development in individuals with ASD seems like a promising area because many of these individuals can acquire decoding skills and reading comprehension treatment approaches are effective for some children (Kamps et al. 1994; O’Connor and Klein 2004; Whalon and Hanline 2008; Whalon et al. 2009).

Nation and colleagues (2006) evaluated decoding, reading comprehension, and language abilities in a small sample of children with ASD (*N* = 41) with a mean age of 10 years. In this sample, nine children (primarily the younger children in the sample) were unable to read, resulting in a sample of 32 children. Of the remaining children, 65% had poor reading comprehension on the *Neale Analysis of Reading Comprehension, Second Edition* (NARA-II). When the less skilled and skilled comprehenders were compared, the less skilled comprehenders had impairments in vocabulary and oral language comprehension. Thus, in this study examining the nature of reading profiles in ASD, a large number of children were especially poor at reading comprehension relative to decoding abilities (poor comprehenders), and reading comprehension performance was related to oral language abilities.

An extremely discrepant decoding-comprehension profile, with decoding significantly outpacing comprehension, has commonly been referred to as hyperlexia. There is some debate as to whether this group exists or not (Grigorenko et al. 2003; Groen et al. 2008; Minshew et al. 1994; Nation 1999) as well as debate about how hyperlexia should be defined (see Grigorenko et al. 2003; Nation 1999 for a discussion of these definitional issues). This is noteworthy because many of the individuals classified as having hyperlexia are individuals with an ASD diagnosis (Grigorenko et al. 2003). While some individuals with ASD may meet qualifications for this classification, others do not. As noted by Nation and colleagues (2006), individuals with ASD can have average to good, but not excellent, decoding skills and still have poor comprehension.

Beyond profiling reading abilities of individuals on the autism spectrum, few studies have examined the individual skills or processes needed for reading in this population (Brown et al. 2013; Ricketts 2011). If a child with ASD is a reader, he/she typically performs within the normal range on measures of reading rimes and nonwords (Calhoon 2001; Nation et al. 2006) as well as word recognition (Gabig 2010). In one study that specifically examined phonological skills in children with ASD, performance on phonological awareness tasks was variable and there was no relationship between measures of phonological awareness and reading accuracy or non-verbal IQ for the ASD group (Gabig 2010). However, the ASD group showed a strong positive relationship between receptive vocabulary and elision performance, but this relationship was not found in the typically developing comparison group. Gabig suggested that the reduced vocabulary performance in the ASD group may have hampered more advanced phonological processing. Some skills related to decoding ability seem to be relatively intact, while other skills have much more variable performance. Current evidence suggests that these skills, such as phonological awareness, are not necessarily related to decoding abilities but could be related to language performance in children with ASD.

There is scant information about the underlying mechanisms leading to the breakdown in reading comprehension for individuals with ASD. Early research proposed that the breakdown in reading processes was related to semantic and possibly syntactic processing (Frith and Snowling 1983). More recently, studies support the notion that both decoding ability and oral language skills factor into reading comprehension difficulties in ASD (Norbury and Nation 2011; Ricketts et al. 2013). In a meta-analysis of 36 small-scale studies (Brown et al. 2013), decoding skill and semantic knowledge were found to be the two strongest predictors of reading comprehension. It is important to note that these studies focused on older children and adolescents, and often only included participants who were high functioning. While these limitations should be considered for future research, current results suggest that decoding and oral language play some role in reading comprehension abilities of individuals with ASD, as the simple view of reading would predict.

In a strict interpretation of the simple view of reading (Gough and Tunmer 1986; Hoover and Gough 1990), receptive language abilities are hypothesized to be a predictor of reading abilities. The role of expressive language ability versus receptive language ability has not been well examined with respect to reading because of the predictions of the simple view of reading. Most studies have examined receptive language ability in relation to reading ability (Catts et al. 2003, 2006; Huemer and Mann 2010; Kendeou et al. 2009; Nation et al. 2006), or if both were measured, expressive and receptive language abilities were combined for analysis (Lanter et al. 2012; Nation and Snowling 1998; Nation et al. 2004, 2010). In one study with typically developing children, receptive and expressive language skills were measured and analyzed separately, and while closely related, oral expression and listening comprehension did differentially relate to reading comprehension and written expression (Berninger and Abbott 2010). Additional evidence that supports the role of expressive language ability in reading is research on narrative ability and reading (Adlof et al. 2010; Bishop et al. 2009). Thus, both receptive and expressive language have been shown to play at least some role in reading ability, but the contribution of each language domain is not well known.

Expressive language development is extremely delayed in many young children with ASD but those individuals who develop verbal abilities earlier have better outcomes (Whitehouse et al. 2009; Wodka et al. 2013). Additionally, an atypical language profile (i.e., in which expressive language performance is relatively higher than receptive) is common in the majority of children with ASD at an early age (Charman et al. 2003; Ellis Weismer et al. 2010; Hudry et al. 2010; Luyster et al. 2007; Volden et al. 2011). Given that expressive and receptive abilities disassociate to some degree in children with ASD, it is critical to adequately capture the relation of these different language abilities to reading skills.

Findings suggest that characteristics of autism in SLI (SLI + ASD) lead to a distinctly different reading profile in this group relative to an SLI group without any autism symptomology (SLI-only; St. Clair et al. 2010). Specifically, the SLI + ASD subgroup had significantly higher decoding scores than the SLI-only subgroup, but the groups did not differ for reading comprehension. In other words, the SLI + ASD subgroup had a larger discrepancy between decoding and reading comprehension, despite the fact that the two groups did not differ on any language measures. Interestingly, expressive language was the strongest predictor of reading comprehension for the ASD + SLI subgroup. Expressive language was also the strongest predictor of reading comprehension for the SLI-only subgroup, but receptive language also remained significant.

Social impairments are thought to impair reading comprehension abilities in children with ASD (Bishop and Norbury 2002; Ricketts et al. 2013). In a model that examined decoding, language, and pragmatic abilities as predictors of reading comprehension, all three were significant predictors for a large sample of school-age ASD children (Ricketts et al. 2013). Thus, reading comprehension appears to not only be affected by decoding and oral language abilities, as suggested by the simple view of reading, but also other factors such as social impairment and potentially, other ASD-specific characteristics.

Emergent Literacy

Over the years it has become increasingly clear that reading impairments do not only surface when conventional reading begins during the school-age years, but that strengths and weaknesses are apparent beginning in the emergent literacy period. Emergent literacy refers to a period before actual reading begins in which pre-readers start to explore literate activities (e.g., pretending to read a book, scribbles that the child dictates as words) and when skills that support reading begin developing (van Kleeck and Schuele 2010;

Whitehurst and Lonigan 1998). Similar to the simple view, emergent literacy skills are broken into code-related and oral language skills. Code-related skills include print conventions (e.g., knowing the orientation of books), emergent writing (e.g., scribbling), knowledge of graphemes (e.g., naming letters), grapheme-phoneme correspondence (e.g., mapping sounds to letters), and phonological awareness (e.g., rhyming words; Storch and Whitehurst 2002). Phonological sensitivity and letter knowledge are the two most stable and robust predictors of later reading abilities (Gallagher et al. 2000; Lonigan et al. 2000). These skills have been well-studied, and their implications for reading ability have been well-established as documented in the report by the National Early Literacy Panel (NELP; Shanahan et al. 2008).

Language skills include oral language skills such as phonological awareness, receptive and expressive vocabulary, narrative ability, and conceptual knowledge. The role of language has been less clearly established compared to code-related skills in early literacy despite its strong relation in later literacy development (Dickinson et al. 2010; Lonigan and Shanahan 2010). Oral vocabulary (Roth et al. 2002; Walley et al. 2003) and narrative comprehension (Lynch et al. 2008) seem especially important for later development of reading comprehension. Further support for the role of language in reading ability comes from the fact that many children with poor language abilities later have poor reading outcomes, and it appears that deficits begin early during the emergent literacy period (Boudreau and Hedberg 1999; Boudreau 2005; Cabell et al. 2010; Puranik and Lonigan 2012). Language abilities are important for developing reading skills, and this appears to be the case from an early stage in development.

When code-related skills were directly compared to oral language skills in a large-scale, longitudinal study by Storch and Whitehurst (2002), skills related to decoding and emergent writing predicted code-related skills in pre-kindergarten and kindergarten. These code-related skills then continued to predict both decoding and reading comprehension through the fourth grade. On the other hand, receptive and expressive vocabulary, narrative recall, conceptual knowledge, and word structure knowledge all significantly contributed to oral language abilities in pre-kindergarten and kindergarten. Altogether, these oral language skills also predicted code-related skills in these grades. Oral language did not predict first or second grade reading, a time when the focus of learning to read is primarily on decoding ability. However, oral vocabulary skills were strongly related to third and fourth grade oral language skills (when comprehension becomes the focus), which was moderately related to reading comprehension. Similarly, Kendeou and colleagues (2009) found that oral language and decoding skills were closely related before kindergarten, but began to disassociate thereafter. Together, these studies provide evidence that early skills for decoding and oral language are important for later reading success.

Socioeconomic status (SES) has also been documented to differentiate reading outcomes (Fitzgerald et al. 1991; Sénéchal et al. 1998), but more recent findings suggest that this effect is mediated by maternal beliefs about reading (Cottone 2012; Curenton and Justice 2008; Roberts et al. 2005; Sénéchal and LeFevre 2002). In an investigation by Skibbe and colleagues (2008), mothers of preschool children with SLI had less positive beliefs regarding their children's reading achievement than mothers of typically developing children; while SES was the only predictor of print-related knowledge for the combined groups, there were no significant predictors for the SLI group alone. Schooling clearly affects literacy skills (Cunningham and Carroll 2011), and both teacher direct instruction (Piasta et al. 2012) and teacher language (Dickinson and Porche 2011) are possible sources of support for the development of these early reading skills. It seems that home and preschool environments could play some role in developing emergent literacy, especially when focused on age-appropriate skills that promote code and language skills, but the effect is often indirect, mediated by other early literacy skills.

In summary, the emergent literacy period is a time when children start exploring literate activities and begin developing initial skills that support decoding such as phonological awareness, print principles, and early writing. During this time, development in language skills such as vocabulary and narrative ability are also important for later reading, especially reading comprehension. Therefore, understanding emergent literacy skills is an important consideration for understanding reading development.

Little is known about early reading development in ASD during the emergent literacy period. In the only published study to date, Lanter and colleagues (2012) examined 41 children with ASD from age 4; 0 to 7; 11. Participants were divided into three groups based on language performance: typical language, mild-moderate language impairment, and severe language impairment (LI). Emergent literacy performance was compared among these three groups using the Emergent Literacy Profile (ELP; Dickinson and Chaney 1997). The ELP is not a norm-referenced test, but as the authors argued, there are currently no well-validated emergent literacy tests for children with disabilities (Baker et al. 2010; Lanter et al. 2012). As expected, performance for total emergent literacy and emergent writing was highest for the typical language group who outperformed the mild-moderate LI group who in turn performed better than the severe LI group. The authors also conducted a parent interview to assess home literacy beliefs and practices. The interview confirmed that parents supported literacy development, reported their children to be motivated by print, and viewed literacy as a strength. The findings of Lanter and colleagues (2012) document that many young children on the autism spectrum acquire some degree of reading ability and that their families are aware and supportive of the development of these skills. While the sample sizes were small in this study, the role of language ability in reading is also supported for this population.

Purpose of the Current Study

Reading ability is a strong predictor of academic and social outcomes (Catts et al. 2006; Catts et al. 2005; Schoon et al. 2010; Schuele 2004; Whitehouse et al. 2009) and it is becoming increasingly important to investigate literacy development in ASD because of educational policy implications (Lanter and Watson 2008). An increased understanding of reading development in children on the autism spectrum could help to improve academic and social outcomes for these individuals. More specifically, examining early reading ability in young children who are beginning readers could provide insight into when the poor comprehender profile emerges. Furthermore, examining early reading abilities in addition to early cognitive, linguistic, and ASD-specific predictors could elucidate who is and is not likely to develop early reading skills, and in turn, inform early interventions.

The purpose of the current study was to 1) identify whether the poor comprehender profile appears during the emergent literacy period in children with ASD; 2) assess concurrent predictors of emergent reading abilities at a mean age of 5½; 3) determine the factors at a mean age of 2½ that predict reading skills at a mean age of 5½ years in children with ASD; and 4) compare early reading performance on a clinician-administered standardized test to a parent report measure of reading abilities in children with ASD.

Method

Participants

Participants were recruited as part of a larger longitudinal study from the state of [omitted for blind review] through local early intervention programs, medical clinics, and from the general community using posted fliers and magazine and newspaper advertisements. All participants lived in the state of [omitted for blind review] at the time of their initial visit. A total of 219 families contacted the project. Exclusionary criteria included known chromosomal abnormalities, cerebral palsy, frank neurological insult, uncorrected vision or hearing impairments, prematurity, multiple birth, bilingualism, or seizure disorder. Participants with cleft palate (1), hearing impairment (1), prematurity (9), multiple birth (5), bilingualism (10), and seizure disorder (1) were excluded (n = 27). Participants later diagnosed with seizures (5) were not excluded from the present sample. Fifteen participants did not meet inclusionary criteria for the targeted age range. An additional 25 participants did not complete their first visit, and therefore, were not included in the study. Thus, a total of 67 children were not included from the original pool of families who contacted the project.

A total of 152 participants enrolled in the longitudinal project for a total of four assessment visits separated by approximately one year (i.e., Visit 1, Visit 2, Visit 3, and Visit 4, respectively for each year). Twenty-three participants did not meet criteria for ASD at Visit 1 (n = 21) or Visit 2 (n = 2); therefore, these participants were excluded from the current sample. Two participants entered the project at Visit 2, and were also excluded in this sample. After these exclusions were applied, 127 participants qualified for ASD and took part in the initial visit.

Overall, the retention rate of 88% across the four years of the longitudinal study was high. Of the 127 participants seen at Visit 1, 26 participants discontinued. Twelve participants did not return after Visit 1for reasons including: families did not wish to return, could not be contacted, were scheduled but did not come for their visit, or had a death in the family. Six participants discontinued after Visit 2 and 8 more participants discontinued after Visit 3 for the same reasons as described for Visit 1. Participants who dropped out (n = 26) were compared at Visit 1 to participants who continued (n = 101) in a one-way analysis of variance (ANOVA); they did not differ in terms of gender, age, socioeconomic status, calibrated ADOS severity (see Gotham, Pickles, & Lord, 2009), cognition, receptive language, or expressive language, *ps* = .10 to .95.

Of the remaining 101 participants from the original longitudinal dataset, participants were included in this sample if they completed all three subtests on the *Test of Early Reading Ability, Third Edition* (TERA-3; Reid et al. 2001) at the fourth visit. Ninety-four (82 males, 12 females) of the 101 participants completed the TERA-3 at Visit 4. For all seven participants who did not receive the TERA-3, behavior issues were indicated as the reason for discontinuing testing. Participants who did not receive the TERA-3 were compared to participants who received the TERA-3. At Visit 1, these two groups did not differ in a one-way ANOVA on gender, ethnicity, age, SES, or expressive language, *ps* = .37 to .98, only marginally did not differ on ADOS severity (*p* = .08) and receptive language (*p* = .06), but did differ on cognition (*p* = .02). At Visit 4, the two groups did not differ on gender, ethnicity, SES, age, or receptive language, *ps* = .14 to .98; they marginally did not differ on ADOS severity (*p* = .08), but did differ on cognition (*p* = .02) and expressive language (*p* = .02). The children who did not receive the TERA-3 appear to be a group that primarily differs from those who completed this test on cognition and language ability. As noted, the primary reason these children did not receive the TERA-3 was due to behavior issues;

therefore, a child's reading ability, or inability, cannot be directly inferred from the lack of TERA-3 scores in this sample because the test was not attempted with these children.

During the first visit, children received an initial ASD diagnosis from an experienced examiner using the toddler research version of the *Autism Diagnostic Interview, Revised* (ADI-R; Rutter et al. 2003), the *Autism Diagnostic Observation Schedule* (ADOS; Lord et al. 2002) or the *Autism Diagnostic Observation Schedule-Toddler Module* (ADOS-T; Luyster et al. 2009), and expert clinical judgment. The majority of children received a best estimate diagnosis of autism (n = 87), with only a small subset receiving a PDD-NOS diagnosis (n = 7). Children were diagnosed again at Visit 4 following the same criteria as Visit 1. All children continued to meet criteria for an ASD diagnosis. However, two children shifted from a PDD-NOS diagnosis at Visit 1 to an autism diagnosis at Visit 4 and one participant shifted from an autism diagnosis at Visit 1 to a PDD-NOS diagnosis at Visit 4. This resulted in 89 children with an autism diagnosis and five children with a PDD-NOS diagnosis at Visit 4.

The mean age of participants at Visit 1 was 30.77 months (SD = 4.16 months; range = 23–39 months). The mean age of participants at Visit 4 was 66.44 months (SD = 4.96 months; range = 57–79 months). For clarity and ease of interpretation, the age at Visit 1 is referred to as mean age 2½, and similarly, age at Visit 4 is referred to as mean age 5½. Twenty-four participants were in kindergarten for 1–10 months at Visit 4. Socioeconomic status, as measured by maternal education level, ranged from 11 to 20 years (M = 14.5, SD = 2.2). Children were primarily white (n = 83), but the sample also included children who were African American (n = 2), Hispanic (n = 1), Native American (n = 1), and other (n = 7). This longitudinal project was approved by the [omitted for blind review] Social and Behavioral Sciences Institutional Review Board and all families provided written consent for their child to participate in the project. Previous studies ([omitted for blind review]) using the larger longitudinal sample or a subset of the larger longitudinal sample have focused on spoken language acquisition. This study is unique in assessing children's reading abilities.

Procedure and Materials

The battery of assessment measures reported in the current article was administered during the initial visit at mean age 2½ and the final visit at mean age 5½. At each visit, participants were seen for two sessions, each lasting three to four hours. One session assessed language and communication as well as reading at Visit 4. All assessments in this session were conducted by a certified speech-language pathologist. The other session assessed cognition and autism symptoms, and assessments were administered by experienced and trained clinicians with a psychology or child development background.

Autism diagnostic measures—The ADI-R (Rutter et al. 2003) is a semi-structured parent interview during which parents answer questions regarding qualities of reciprocal social interaction, communication and language, and restricted and repetitive, stereotyped interests and behaviors. The ADOS (Lord et al. 2002) or ADOS-T (Luyster et al. 2009) is a semi-structured assessment which consists of activities that enable the examiner to observe behaviors related to communication and social skills in individuals with ASD. The ADI-R and ADOS or ADOS-T along with clinical judgment were used to assess autism diagnosis and severity. Calibrated autism severity scores were calculated from raw scores on the ADOS or ADOS-T to limit the effects of age and verbal IQ (Gotham et al. 2009).

Cognitive ability—The *Mullen Early Scales of Learning* (Mullen; Mullen 1995) was used as an indicator of nonverbal cognition at mean age 2½ and 5½. A Nonverbal Ratio IQ score was calculated by taking the average of the Visual Reception and Fine Motor age equivalent scores (i.e., the "Mullen Nonverbal Mental Age"), dividing it by the child's chronological age in months, and multiplying the resulting value by 100. This score has been used in previous research (Rogers et al. 2003), and was recently validated relative to the *Differential Abilities Scale* in children with ASD (Bishop et al. 2011). The Visual Reception scale assesses performance in visual discrimination and visual memory and is normed from birth to 5; 8. This scale has acceptable internal consistency (r = .79), test-retest reliability (r = .85), and concurrent and construct validity. The Fine Motor scale measures fine motor coordination, planning, and control. This scale also has acceptable internal consistency (r = .75), test-retest reliability (r = .83), and concurrent and construct validity.

Language ability—Receptive and expressive language skills were evaluated using the *Preschool Language Scale, Fourth Edition* (PLS-4; Zimmerman et al. 2002). The PLS- 4 provides an Auditory Comprehension (AC) standard score (M = 100, SD = 15) and an Expressive Communication (EC) standard score (M = 100, SD = 15). However, because standard scores on the PLS-4 were significantly skewed toward the lower end of the distribution, raw scores were converted to standardized residuals where age was regressed on the raw scores to normalize the distribution of scores. These standardized residuals were used to calculate all correlations and regressions. The PLS-4 is age-normed for children from birth to 6; 11. The manual reports the following values for test internal consistency (AC, $r > .66$; EC, $r > .73$), test-retest reliability (AC, $r > .83$, EC, $r > .82$), sensitivity (AC > 78%; EC > 74%) and specificity (AC > 89%; EC > 75%). This test also has been validated for testing language in children with ASD (Volden et al. 2011).

Early reading ability—The *TERA-3* (Reid et al. 2001) assessed reading skills at mean age 5½. The TERA-3 consists of three subtests. The Alphabet subtest measures knowledge of sound-letter correspondence, letter names, number of sounds and syllables, and initial and final sounds. The Conventions subtest evaluates understanding of book handling, print conventions, punctuation, capitalization, and spelling. The Meaning subtest assesses comprehension of printed words, sentences, and paragraphs. The test is intended for use with children 3; 0 – 7; 11. The TERA-3 provides normative scaled scores for each of the three subtests (M = 10, SD = 3). The test also provides an overall Reading Quotient standard score (M = 100, SD = 15). The test was normed on typically developing children, and has good internal consistency ($\alpha > .83$), test-retest reliability ($r > .87$), and moderate concurrent validity.

Parent report of socialization and early reading ability—The *Vineland Adaptive Behavior Scales, Second Edition* (Vineland-II; Sparrow et al. 2005) is a parent report measure that entails a semi-structured interview and is comprised of several subdomains that make up four general domains: Communication, Daily Living Skills, Socialization, and Motor Skills. The Vineland-II is appropriate for use from birth to age 90, and was normed on a large sample including children with ASD. The Socialization domain standard score was used as a measure of social ability. The Socialization domain standard score includes the Interpersonal Relationships, Play and Leisure Time, and Coping Skills subdomains. The standard score (M = 100, SD = 15) is computed as the sum of each subtest's *v*-scale scores. The Socialization domain has good internal consistency (r = .93), test-retest reliability (r = .88), and content and construct validity. Additionally, for our purposes, the Written Communication subdomain, part of the Communication domain, was used as a measure of parent report of literacy-related abilities. On this subdomain, examples of items include "Identifies at least 10 printed letters of the alphabet" or "Copies own first name." Parents respond 'usually', 'sometimes or partially,' 'never,' or 'don't know' to each item. Parents were asked to report on their child's literacy abilities at the time of the interview, mean age

5½. The Written Communication subdomain has good internal consistency (r = .82), test-retest reliability (r = .89), and content and construct validity.

Analysis approach—To address the first research question regarding reading profiles, paired samples t-tests were initially used to compare mean performance on each of the TERA-3 subtests for the entire group. Effect sizes were calculated using Cohen's d with the subtest means and standard deviations (Dunlap et al. 1996). As a follow-up, to explore the heterogeneity across the ASD reading profile, a series of latent profile analyses (LPA) were fitted using the Alphabet, Conventions, and Meaning subtest scores as variables. Using Mplus (Muthén and Muthén 2012), solutions were requested ranging from 1 to 6 classes in which the mean level on each variable varied across classes, but within-class variance was constant. To verify the interpretation of each profile, paired sample t-tests were conducted within each class to examine differences between the Alphabet, Conventions, and Meaning subtests. Each child was classified into the class with the highest posterior probability based on the LPA.

To examine concurrent and longitudinal predictors for the second and third research questions, bivariate correlations among the areas of interest were examined at mean age 2½ and mean age 5½. To determine significant concurrent (at mean age 5½) and longitudinal (from mean age 2½ to mean age 5½) predictors of overall reading ability, a series of multiple regression analyses were conducted in which different variables were entered in three blocks to determine the best four-predictor model that accounted for the most variance in each outcome variable (TERA-3 RQ and Alphabet, Conventions, and Meaning subtest performance). Block 1 always contained nonverbal cognition as both a control variable and a variable of interest. SES, autism severity, and socialization comprised the second block where two of these three variables were entered in a given model. In the third block, receptive language (AC) and expressive language (EC) were entered alternately. Evaluated models included: 1) nonverbal cognition, SES, autism severity, and AC; 2) nonverbal cognition, SES autism severity, and EC; 3) nonverbal cognition, SES, socialization, and AC; 4) nonverbal cognition, SES, socialization, and EC; 5) nonverbal cognition, autism severity, socialization, and AC; and 6) cognition, autism severity, socialization, and EC.

For the final research question, performance on the TERA-3, a standardized clinician-administered measure, was compared to parent report of reading ability on the Vineland-II Written Communication subdomain. Raw scores on the Vineland-II were converted to standardized residuals in which age was regressed on the raw scores to account for age variance. These scores were then correlated, using a Pearson bivariate two-tailed correlation, with each component of the TERA-3.

Results

Emergent Literacy Profiles

The performance of this sample of young children with ASD (Table 1) was compared to the TERA-3 normative sample. At mean age 5½, the children earned a mean Reading Quotient score of 88.64 (SD = 22.81), indicating that the group mean fell within the normal range. The mean score on the Alphabet subtest (M = 11.00, SD = 4.66) was within normal range and even slightly above the mean for the normative sample. However, the mean scores on the Conventions (M = 6.80, SD = 3.37) and Meaning (M = 6.91, SD = 3.94) subtests fell below normal range. In the overall sample, no statistically significant difference was found between the Conventions and Meaning subtest scores (t = −0.42, p = .676, d = −0.03). Scores on both the Conventions (t = 11.03, p < .001, d = 1.03) and the Meaning (t = 11.81, p < .001, d = 0.95) subtests were significantly different from the Alphabet subtest (Figure 1). The alphabet-conventions and alphabet-meaning effect sizes were both large effects.

Latent profile analysis (LPA) was used to explore the heterogeneity in this sample and to determine whether there were different profiles of performance. Upon completing 1- to 6-class LPA solutions, we found that the Bayesian Information Criterion (BIC) was minimized for the 4-class solution. Figure 2 shows the profile for each class for the 4-class solution; the within-class variances were 3.28, 2.67, and 4.85 for the Alphabet, Conventions, and Meaning variables, respectively. The estimated proportions in each class were .07, .40, .21, and .31 for classes 1, 2, 3 and 4, respectively. Apparent from the profile plots is the relative elevation of the Alphabet performance compared to both the Conventions and Meaning performance within both Profiles 2 and 3. Mean performance for these profiles (Table 2) on each subtest was compared. Only in Profiles 2 and 3 did we observe statistically significant differences both between Alphabet and Conventions (t = 14.35, p < .001, d = 3.41 for Profile 2; t = 15.94, p < .001, d = 4.70 for Profile 3) and between Alphabet and Meaning (t = 10.05, p < .001, d = 2.30 for Profile 2; t = 13.93, p < .001, d = 3.94 for Profile 3).

Concurrent Predictors of Early Reading Ability

Correlation findings indicated that the TERA-3 Reading Quotient was significantly positively correlated with nonverbal cognition, SES, social ability, and receptive and expressive language at mean age 5½ (Table 3), and negatively correlated with autism severity. Similarly, there was a significant, positive correlation between Alphabet, Conventions, and Meaning performance and nonverbal cognition, SES, social ability, and receptive and expressive language. Autism severity was negatively correlated with performance on the Alphabet, Conventions, and Meaning subtests.

The best concurrent regression model (Table 4) for the TERA-3 RQ accounted for 64% of the variance, and included nonverbal cognition, SES, social ability, and expressive language. Nonverbal cognition (β = .47, t = 3.74, p < .001), social ability (β = −.28, t = −2.35, p = .021), and expressive language (EC; β = .54, t = 4.43, p < .001) emerged as significant individual predictors, and SES (β = .13, t = 1.90, p = .061) approached significance. For the Alphabet subtest, the best concurrent regression model accounted for 57% of the variance, and variables in this model included nonverbal cognition, SES, social ability, and receptive language (AC), and all variables in this model were significant individual predictors: nonverbal cognition (β = .52, t = 3.43, p = .001), SES (β = .16, t = 2.08, p = .041), social ability (β = −.46, t = −3.57, p = .001), and receptive language (AC; β = .55, t = 3.63, p < .001). The best concurrent regression model accounted for 46% of the variance in the Conventions subtest scores, and included cognition, SES, social ability, and expressive language, but only expressive language was a significant predictor (β = .68, t = 4.59, p < .001). Lastly, the best concurrent regression model accounted for 53% of the variance in the Meaning subtest performance at mean age 5½. Nonverbal cognition, autism severity, social ability, and expressive language were included in the model. Nonverbal cognition (β = .41, t = 2.95, p = .004) and expressive language (EC; β = .38, t = 2.72, p = .008) emerged as the two significant individual predictors of performance on the Meaning subtest.

Longitudinal Predictors of Early Reading Ability

Results indicated that the TERA-3 Reading Quotient at mean age 5½ (Visit 4) was significantly correlated with nonverbal cognition, SES, autism severity (negatively), social ability, and oral language abilities at mean age 2½ (Visit 1) (see Table 3). The Alphabet subtest was significantly correlated with nonverbal cognition, SES, autism severity (negatively), and language abilities. The association between the Alphabet subtest and social ability approached significance (p = .06). Cognition, SES, social ability, and oral language abilities were significantly correlated with Conventions subtest performance. Lastly, all variables were significantly correlated with performance on the Meaning subtest.

The best longitudinal regression model included Visit 1 cognition, autism severity, SES, and expressive language entered as predictors, and accounted for 46% of the variance in overall reading abilities on the TERA-3 Reading Quotient at Visit 4. The two significant longitudinal predictors of the TERA-3 Reading Quotient were nonverbal cognition ($\beta = .48$, $t = 4.62$, $p < .001$) and expressive language (EC; $\beta = .21$, $t = 2.17$, $p = .033$). After examining overall reading ability, predictors of performance for each of the subtests were also determined. The best longitudinal regression model for the Alphabet subtest accounted for 37% of the variance. Longitudinal predictors in this model included nonverbal cognition, autism severity, SES, and receptive language (AC), but nonverbal cognition was the only significant individual predictor ($\beta = .55$, $t = 4.55$, $p < .001$). For the Conventions subtest, the best longitudinal model accounted for 29% of the variance with nonverbal cognition, autism severity, SES, and expressive language (EC) entered as predictors. Nonverbal cognition was a significant predictor of conventions performance ($\beta = .33$, $t = 2.73$, $p = .008$), and expressive communication approached significance ($\beta = .22$, $t = 1.96$, $p = .053$). The best longitudinal model for the Meaning subtest included nonverbal cognition, autism severity, social ability, and expressive language (EC), and accounted for 46% of the variance. Nonverbal cognition ($\beta = .47$, $t = 4.73$, $p < .001$) and PLS-4 expressive communication ($\beta = .30$, $t = 2.76$, $p = .007$) were the two significant individual predictors of performance on the Meaning subtest.

TERA-3 Concurrent Validity

The parent report measure, the Vineland-II Written Communication subdomain, was significantly and strongly correlated with overall early reading ability as indexed by the TERA-3 Reading Quotient ($r = .78$, $p < .001$). Similarly, parent report of early reading was significantly and strongly correlated with the Alphabet subtest ($r = .76$, $p < .001$) and the Meaning subtest ($r = .71$, $p < .001$). Performance was also significantly correlated with the Conventions subtest ($r = .59$, $p < .001$), but the association was not quite as strong.

Discussion

Early Reading Profile

Previous work in school-age, higher functioning children with ASD has demonstrated that the poor comprehender profile with lower reading comprehension relative to decoding is common (Huemer and Mann 2010; Jones et al. 2009; Nation et al. 2006; Ricketts et al. 2013). However, it was previously unknown when this profile emerges in development. The first research question examined whether the poor comprehender reading profile that has been observed later in development for children with ASD was apparent during the emergent literacy period. At mean age 5½, findings indicated that this sample of children with ASD achieved overall scores in the normal range on a standardized test of early reading ability; however, they displayed an uneven profile when separate components of the reading process were considered. That is, they demonstrated a relative strength in alphabet knowledge and a relative weakness in explaining and understanding the meaning of words and symbols. This profile with higher alphabet knowledge (a precursor for decoding) than understanding meaning is indicative that the poor comprehender profile in ASD is apparent very early in learning to read.

When the heterogeneity in this sample was more closely examined, four early reading profiles emerged. Two of the four profiles exhibited higher alphabet performance relative to conventions and meaning performance. The two profiles differed in relative severity in that performance was higher, especially for conventions and meaning, in Profile 2 than in Profile 3. Together, these two profiles accounted for 62% of the children in this sample. This percentage is very similar to the 65% of poor comprehenders reported by Nation and colleagues (2006) in their school-age sample. Two additional profiles emerged with 31% of the sample performing at low levels on all three subtests in Profile 4, and 7% of the current sample performing at high levels across all subtests in Profile 1.

These results extend prior findings regarding reading ability in individuals with ASD (e.g., Huemer and Mann 2010; Jones et al. 2009; Nation et al. 2006) to a younger sample, and further contribute to the understanding of the heterogeneity in early reading in ASD by identifying distinct profiles. Together, this evidence suggests that some children with ASD have advanced early literacy skills while other children have very delayed early literacy skills. However, the majority of children on the autism spectrum appear to demonstrate a discrepant profile indicative of the poor comprehender profile seen later in development. Therefore, the discrepant profile seems to emerge in children with ASD during their early exposure to literacy activities. This is not surprising, as it has been observed that many children with ASD are interested in the alphabet from a very early age (Mirenda 2003). Additional work is needed, however, to confirm that phonological awareness as well as other emergent literacy skills are being developed in these individuals. Further, in consideration of how the discrepant profile develops, it is important to establish how to help these children connect meaning to print from an early stage in reading development.

Concurrent Predictors of Emergent Literacy Ability

The simple view of reading and research with children without ASD suggests that oral language abilities and socioeconomic status are particularly important indicators of early reading performance (Catts et al. 1999; Curenton and Justice 2008; Fitzgerald et al. 1991). In addition to accounting for language abilities and SES, variables such as cognition, social abilities, and autism severity are important in predicting various outcomes in ASD (Henninger and Lounds Taylor 2013; Howlin et al. 2004; Whitehouse et al. 2009), and therefore, were included in the models of early reading abilities in this study. Although cognition is no longer considered in diagnosing reading disorders (Nation et al. 2002; Stanovich 1991), nonverbal cognitive ability is a strong indicator of performance in other areas of development for the ASD population, such as language and social communication (Joseph et al. 2002; Whitehouse et al. 2009) as well as adaptive behavior (Ray-Subramanian et al. 2011). As expected, concurrent nonverbal cognition was a strong predictor of overall reading ability as well as in predicting alphabet knowledge and understanding meaning from text. Interestingly, concurrent nonverbal cognitive abilities were not predictive of knowledge of literacy conventions.

In addition to nonverbal cognition, language was a strong concurrent predictor of reading abilities in young children with ASD. Importantly, expressive and receptive language were evaluated separately in our models given that receptive and expressive language abilities do not appear to develop congruously (i.e., expressive language abilities are relatively higher than receptive language abilities) in young children with ASD (Charman et al. 2003; Ellis Weismer et al. 2010; Hudry et al. 2010; Luyster et al. 2007; Volden et al. 2011). In typical reading development and based on the simple view of reading, receptive language is expected to more strongly relate to reading abilities than expressive language (Catts and Hogan 2003; Catts et al. 1999, 2006; Gough and Tunmer 1986; Hoover and Gough 1990; Storch and Whitehurst 2002). In this sample of young children with ASD, expressive and receptive language differentially predicted reading abilities, with expressive language serving as the better predictor of reading performance. Receptive language only predicted alphabet knowledge whereas expressive language predicted overall reading ability, knowledge of literacy conventions, and understanding of meaning from text.

This robust role of language abilities in literacy parallels findings in typically developing children that support the role of language in reading (Catts et al. 2003, 2006; Lonigan et al.

2000; McArthur et al. 2000) and lends some additional support for the role of oral language in reading as specified in the simple view of reading in children with ASD (Ricketts et al. 2013). These findings differ from previous work in typical development and in children with language impairment in that expressive language ability appears to be a better predictor of reading ability than receptive language in these young children with ASD. The results of this study, however, support the notion put forth by St. Clair and colleagues (2010) that ASD-specific characteristics may result in a specific reading profile, and that expressive language is a stronger predictor in individuals with SLI and autism symptomology. The role of expressive versus receptive language abilities in early reading in ASD will be further discussed below.

Socioeconomic status was also a significant predictor of alphabet performance for children with ASD. Additionally, socioeconomic status, although not significant, was included in the models that best predicted overall reading and literacy conventions. This is consistent with research which has documented the role of socioeconomic status in learning to read in terms of parent literacy levels, parent beliefs, and home literacy experiences for typically developing children (Curenton and Justice 2008; Fitzgerald et al. 1991; Roberts et al. 2005; Sénéchal and LeFevre 2002) as well as for children with specific language impairment (McGinty and Justice 2009; Skibbe et al. 2008).

Interestingly, lower social abilities predicted better alphabet knowledge in this sample of children with ASD. On the surface this finding might seem counterintuitive; however, enhanced alphabet knowledge, or interest in individual letters that comprise words rather than an appreciation of how letters combine to form meaningful words, is consistent with weak central coherence accounts of cognitive processing in autism (Happé and Frith 2006). It is conceivable that increased social impairment is related to more restricted interests in ASD such that repeated focus on letters leads to high levels of mastery of this component of early literacy. The specific role of social abilities in relation to alphabet knowledge should be explored in future studies.

Longitudinal Predictors of Emergent Literacy Ability

Child and demographic variables obtained at the time of diagnosis (mean age 2½), including nonverbal cognition, autism severity, socioeconomic status, social abilities, and oral language, were used to predict later emergent literacy performance at mean age 5½. As expected, early nonverbal cognition was a strong predictor of later reading performance, and this was consistent for overall performance as well as for alphabet performance, knowledge of literacy conventions, and understanding meaning. In addition to nonverbal cognition, expressive language was an important predictor of early reading ability, particularly for understanding meaning. Autism severity, SES, and social abilities at 2½ were not significant individual predictors of emergent literacy performance at 5½ in the current sample, though these variables did contribute to the overall model. Again, the role of cognition and oral language as the best predictors of later reading performance is consistent with previous work examining outcomes in children with ASD (Henninger and Lounds Taylor 2013; Howlin et al. 2004; Whitehouse et al. 2009).

Expressive versus Receptive Language in Early Reading

The finding that early expressive language was a significant longitudinal and concurrent predictor of reading in this study, but receptive language played a much more limited role, should be viewed cautiously and must be interpreted within the context of the reasons for including expressive language in the first place. First, the role of oral language (both receptive and expressive) is supported in previous research in reading abilities in ASD for both early literacy (Lanter et al. 2012) and conventional literacy (St. Clair et al. 2010; Frith and Snowling 1983; Nation et al. 2006; Norbury and Nation 2011; Ricketts et al. 2013). Secondly, expressive language ability is a strong predictor of overall outcomes for individuals with ASD (Henninger and Lounds Taylor 2013; Howlin et al. 2004).

There are several possible explanations for why expressive language is a more robust predictor of early reading ability in ASD. One possibility is that there is something unique about ASD characteristics, as suggested by St. Clair et al. (2010), that leads to this intriguing relationship of expressive language and reading abilities in children with ASD or children with ASD characteristics. More specifically, expressive language ability may be a stronger predictor in this population because of the atypical receptive-expressive profile that is often observed in young children with ASD. It is not known why the profile occurs—it may reflect an actual disproportionate deficit in receptive language ability, an over-estimation of expressive language, or inadequate assessment measures for evaluating comprehension skills in toddlers with ASD. Alternatively, it could be the case that at this young age, those children who have better productive language abilities have had greater opportunities or more enriched experiences to engage in literacy-related activities. To explore this, future studies should account for home or educational-setting literacy experience in relation to language and reading outcomes in children with ASD.

One other potential explanation for the relation of expressive language and reading ability is that the test was biased toward verbal (spoken) responses. The TERA-3 requires some verbal responses, and so to explore this, the proportion of verbal answers for each subtest was calculated as part of a post-hoc analysis. That is, the proportion of responses was calculated in which a verbal response is prompted using standard administration. Key words in the examiner's instructions for prompted *nonverbal* responses included words like "show" or "point" whereas key words for *verbal* responses included "tell" or "explain." Of the 29 items in the Alphabet subtest, 14 (48%) were verbal. The Conventions subtest had a much lower proportion of verbal items with 8 of the 21 (38%) prompting a verbal response. Lastly, of the 30 items on the Meaning subtest, 19 (63%) prompted a verbal response. Expressive language ability was a significant individual predictor of performance on the Meaning and Conventions subtests, but not the Alphabet subtest. It is possible that the larger percentage of prompted verbal responses was related to poor performance and expressive ability on these subtests. However, performance was low on the Conventions subtest, and this subtest had the smallest proportion of verbal items. Thus, it does not seem that the relation of expressive language to early reading ability is purely an artifact of the test measure.

Given that oral language was such a robust predictor of reading abilities, it is essential to understand how language develops in children with ASD. Supporting adequate language development is clearly important for developing emergent literacy skills (Dickinson et al. 2003, 2010; Storch and Whitehurst 2002; Whitehurst and Lonigan 1998). Emergent literacy skills are also important predictors of later conventional reading (Cabell et al. 2010, 2011; Storch and Whitehurst 2002); therefore, better oral language, especially expressive skills, at the time of beginning reading are likely to be a good indicator of better conventional reading success in children with ASD.

Tentative Model of Early Reading Abilities in ASD

Based on the findings from this study, we propose an initial model of early reading abilities in ASD. Following the simple view of reading, alphabet is indicative of decoding abilities and meaning is indicative of reading comprehension abilities in this model as two primary skills of early reading. Knowledge of literacy conventions is not included as a specific component because it does not directly map onto a component of the simple view of reading. As shown in Figure 3, this model posits that expressive language skills strongly predict meaning performance, and to some extent receptive language contributes to successful alphabet knowledge in ASD. Additionally, nonverbal cognition is accounted for in both alphabet knowledge and meaning comprehension in this model given the wide range of cognitive abilities in children with ASD, including some with co-morbid intellectual disability. Socioeconomic status is posited to influence early reading abilities, specifically with respect to alphabet knowledge. Further, this model includes autism severity and social abilities as two autism-specific characteristics that contribute to early reading abilities in ASD, with autism severity predicting overall early reading abilities and social abilities predicting alphabet knowledge. These components account for both overall early reading ability as indicated by the large rectangle as well as a specific component of early reading as indicated by the arrows. The larger ovals reflect the most robust predictors, namely oral language (particularly expressive language) and nonverbal cognition, with the smaller ovals representing variables that appear to play a more delimited role. Given the early stage of empirical investigation on this topic, we have not attempted to detail the complex relationships among the various variables hypothesized to influence early reading abilities in ASD; however, we might speculate that social impairment and autism severity are somewhat overlapping variables that moderate the level of early reading skills and that SES serves as an index of the home literacy environment/exposure. This model is proposed as a tentative framework for continuing to explore how early reading develops in ASD.

Use of the TERA-3 for Children with ASD

Some investigators have suggested that there currently is no way to assess emergent literacy skills in children with severe developmental disabilities because of the verbal nature of the tests (Baker et al. 2010). This is a reasonable consideration. The final objective of this study was to examine the concurrent validity of the TERA-3 with children with ASD. Parent report of written communication skills assessed by the Vineland-II was strongly correlated with scores on the TERA-3. This finding suggests that the TERA-3 provides comparable information to an existing standardized parent report measure of written communication and replicates the results of Lanter and colleagues (2012) in the sense that parents appear to be well attuned to their children's literacy abilities. As described above, children with differing verbal abilities could complete at least some items on the TERA-3. Thus, it appears that expressive language ability does not unduly limit performance on this measure and that the TERA-3 is a viable standardized measure for assessing emergent literacy abilities in 5½-year-old children with ASD.

Conclusions and Future Directions

In summary, findings indicated that this sample of children with ASD displayed overall reading levels that fell in the normal range on a standardized test of early reading ability (TERA-3), although their performance was quite variable. Four early reading profiles emerged in this sample. Two profiles were at the extreme ends of the spectrum with high performance across all subtests or low performance across all subtests. Two other profiles characterized participants who had extremely discrepant (higher) scores in alphabet knowledge relative to understanding of literacy conventions and meaning. These two profiles differed in terms of relative severity, but together included 62% of the participants. Results of concurrent regression analyses indicated that reading proficiency at mean age 5½ was associated with higher nonverbal cognition and better expressive language, and that social ability was inversely related to alphabet knowledge (i.e., poorer social skills were associated with more advanced alphabet knowledge). Nonverbal cognition and expressive language abilities at mean age 2½ predicted early reading performance at mean age 5½. Finally, performance on the TERA-3 was highly associated with parent report of early literacy skills for this sample of children with ASD.

This study contributes to the scant empirical literature regarding early reading abilities in young children with ASD. A limitation of the current study is that it did not directly account for literacy exposure, which could have been a significant contributing factor for knowledge of literacy conventions. Similar to literacy exposure, it is possible that treatment effects and skills learned in various in-home and early childhood educational approaches could have impacted early reading ability. These factors should be incorporated as possible predictors in future studies of emergent literacy for young children on the autism spectrum. Future investigations are needed to better understand the mechanisms underlying reading facility in children with ASD, including the effects of treatment, literacy exposure, and specific language skills on emergent reading abilities as well as to refine the model of factors that influence early reading for children with ASD.

Acknowledgments

This research was supported by the National Institutes of Health grants T32 DC005359 (Ellis Weismer, PI), R01 DC007223 (Ellis Weismer, PI), and P30 HD03352 (Mailick, PI). The authors would like to thank Professor Daniel Bolt for his assistance with statistical analysis and Courtney E. Venker for her thoughtful feedback on this manuscript. Special thanks to all of the children and families who participated in this research.

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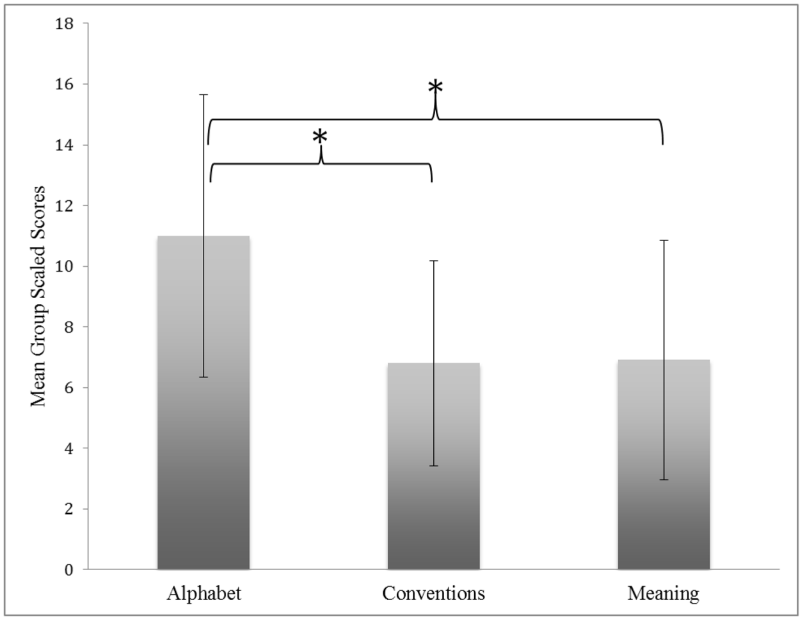

Figure 1.
Comparisons of performance across the *Test of Early Reading Ability, Third Edition* (TERA-3) subtests: Alphabet, Conventions, and Meaning.
Note. Error bars indicate one standard deviation. Significant comparisons are bracketed and starred.

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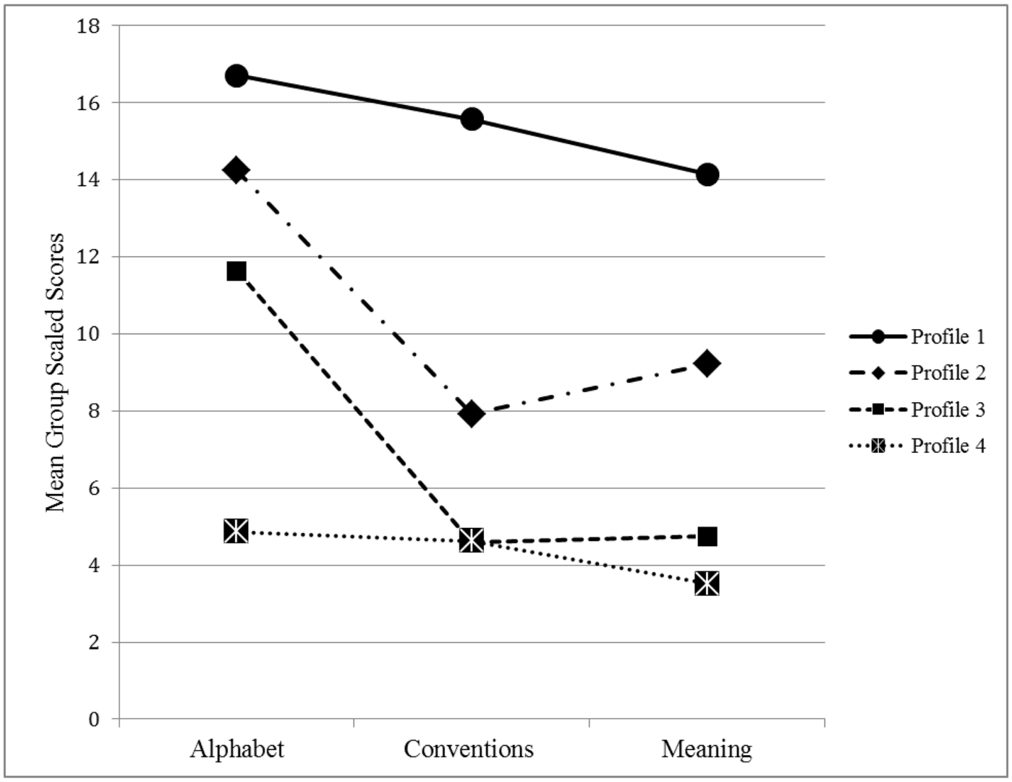

Figure 2.
Early reading profiles of children with ASD based on a Latent Profile Analysis (LPA).
Note. Four-class model Bayesian Information Criterion (BIC) = 1438.5; Profile 1: n = 7; Profile 2: n = 39; Profile 3: n = 19; Profile 4: n =29.

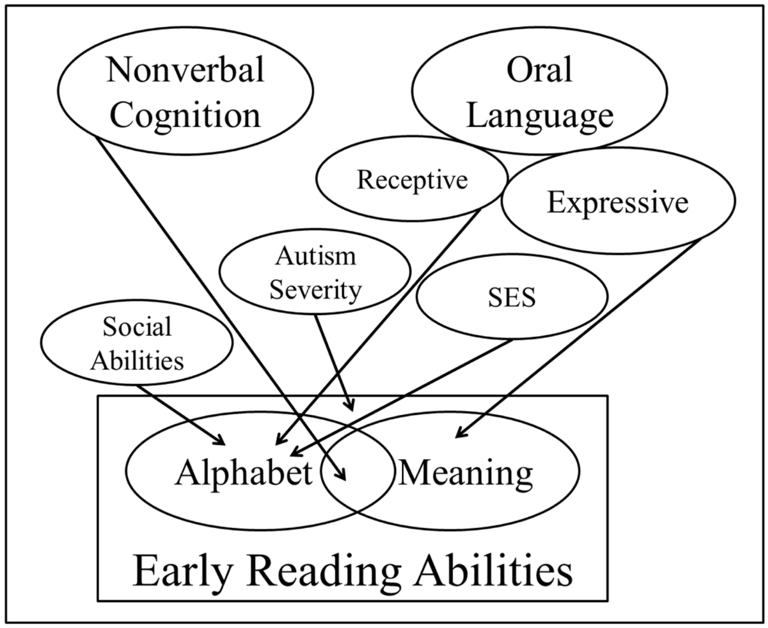

Figure 3.

Tentative model of early reading abilities in ASD.

Note. Represented is visual schema of the proposed model underlying early reading abilities in children with ASD. Following the simple view of reading (Gough and Tunmer 1986; Hoover and Gough 1990), early reading abilities are captured by alphabet knowledge (decoding) and understanding of meaning (reading comprehension). Arrows indicate specific predictive components for representative areas. Size of the ovals represents relative strength of the components in predicting early reading abilities.

Table 1

Descriptive information for autism diagnostic, cognitive, language, and early reading measures.

	Time 1			Time 2		
Measure	***M***	***SD***	**Range**	***M***	***SD***	**Range**
Age[a]	30. 84	4. 16	23–39	66. 44	4. 96	57–79
SES[b]	14. 45	2. 16	11–20	14. 45	2. 16	11–20
ADOS Severity[c]	7. 34	1. 79	4–10	7. 09	1. 80	3–10
Cognition[d]	76. 98	14. 88	38–115	78. 04	17. 90	35–108
PLS-4 AC SS[e]	60. 83	13. 09	50–117	82. 69	26. 35	50–129
PLS-4 AC SR[f]	. 10	1. 01	−1.64–4.28	. 05	. 97	−2.26–1.26
PLS-4 EC SS[g]	72. 73	10. 97	50–103	80. 10	25. 83	50–133
PLS-4 EC SR[h]	. 02	. 97	−2.11–2.43	. 07	. 97	−2.10–1.44
Vineland-II Socialization[i]	77. 91	6. 69	61–98	76. 81	10. 21	55–92
Vineland-II WC AE[j]				64. 02	12. 49	22–90
Vineland-II WC SR[k]				. 04	. 99	−2.37–2.31
TERA-3[l]						
RQ[m]				88. 64	22. 81	51–149
Alphabet[n]				11. 00	4. 66	3–19
Conventions[n]				6. 80	3. 37	2–18
Meaning[n]				6. 91	3. 94	1–19

Note.

[a] In months;

[b] Socioeconomic status as measured per mother's years of education completed;

[c] *Autism Diagnostic Observation Schedule* Severity score as calculated per Gotham et al. (2009);

[d] *Mullen Early Scales of Learning* Nonverbal Ratio IQ scores;

[e] *Preschool Language Scale, Fourth Edition* Auditory Comprehension standard score (M = 100, SD = 15) for descriptive purposes only;

[f] *Preschool Language Scale, Fourth Edition* Auditory Comprehension standardized residual (age regressed on raw scores);

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[g] *Preschool Language Scale, Fourth Edition* Expressive Communication standard score (*M* = 100, *SD* = 15) for descriptive purposes only;

[h] *Preschool Language Scale, Fourth Edition* Expressive Communication standardized residual (age regressed on raw scores);

[i] *Vineland Adaptive Behavior Scales, Second Edition* Socialization domain standard score (*M* = 100, *SD* = 15);

[j] *Vineland Adaptive Behavior Scales, Second Edition* Written Communication subdomain age equivalent scores for descriptive purposes only;

[k] *Vineland Adaptive Behavior Scales, Second Edition* Written Communication subdomain standardized residuals (age regressed on raw scores);

[l] *Test of Early Reading Ability, Third Edition*;

[m] Reading Quotient (composite score; *M* = 100, *SD* = 15);

[n] TERA-3 subtests scaled scores (*M* = 10, *SD* = 3).

Table 2

Mean performance for the early reading profiles on the *Test of Early Reading Ability*, *Third Edition* (TERA-3) subtests and reading quotient.

Measure	*M*	*SD*	Range
Profile 1 (*n* = 7)			
Alphabet[a]	16. 71	1. 25	15–19
Conventions[a]	15. 57	1. 90	13–18
Meaning[a]	14. 14	3. 29	10–19
Reading Quotient[b]	135. 00	10. 49	121–149
Profile 2 (*n* = 39)			
Alphabet[a]	14. 23	1. 95	9–17
Conventions[a]	7. 92	1. 74	5–11
Meaning[a]	9. 21	2. 40	4–14
Reading Quotient[b]	102. 95	7. 58	91–119
Profile 3 (*n* = 19)			
Alphabet[a]	11. 63	1. 67	9–14
Conventions[a]	4. 58	1. 31	3–8
Meaning[a]	4. 74	1. 82	2–8
Reading Quotient[b]	80. 58	6. 74	66–91
Profile 4 (*n* = 29)			
Alphabet[a]	4. 86	1. 66	3–8
Conventions[a]	4. 62	1. 55	2–9
Meaning[a]	3. 52	1. 94	1–10
Reading Quotient[b]	63. 48	8. 63	51–87

Note.

[a]TERA-3 normative sample performance is $M = 10$, $SD = 3$;

[b]TERA-3 normative sample performance is $M = 100$; $SD = 15$.

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Table 3

Intercorrelations of predictors at mean age 5½ with early reading scores at mean age 5½ (below the diagonal) and intercorrelations of predictors at mean age 2½ with early reading scores at mean age 5½ (above the diagonal).

Measure	1	2	3	4	5	6	7	8	9	10
1. TERA-3[a] RQ[b]	—	.90**	.86**	.91**	.65**	.38**	−.22*	.23*	.44**	.48**
2. Alphabet[c]	.90**	—	.62**	.71**	.60**	.37**	−.24*	.19◆	.34**	.39**
3. Conventions[c]	.86**	.62**	—	.74**	.48**	.31**	−.13	.21*	.34**	.40**
4. Meaning[c]	.91**	.71**	.74**	—	.63**	.32**	−.21*	.21*	.49**	.50**
5. Cognition[d]	.74**	.69**	.57**	.70**	—	.41**	−.28**	.26*	.63**	.49**
6. SES[e]	.38**	.37**	.31**	.32**	.38**	—	−.10	.19	.30**	.39**
7. Severity[f]	−.29**	−.22*	−.30**	−.27**	−.38**	−.21*	—	−.12	−.29**	.02
8. Social ability[g]	.57**	.46**	.47**	.60**	.80**	.39**	−.53**	—	.27**	.49**
9. AC[h]	.72**	.69**	.57**	.65**	.87**	.35**	−.43**	.81**	—	.51**
10. EC[i]	.74**	.64**	.66**	.69**	.82**	.32**	−.47**	.79**	.91**	—

Note:

[a] *Test of Early Reading Ability, Third Edition*;

[b] Reading Quotient;

[c] TERA-3 subtests;

[d] *Mullen Early Scales of Learning* Nonverbal Ratio IQ scores;

[e] Socioeconomic status as measured per mother's years of education completed;

[f] *Autism Diagnostic Observation Schedule* Severity score as calculated per Gotham et al. (2009);

[g] *Vineland Adaptive Behavior Scales, Second Edition* Socialization domain standard scores;

[h] *Preschool Language Scale, Fourth Edition* Auditory Comprehension standardized residual scores (age regressed on raw scores);

[i] *Preschool Language Scale, Fourth Edition* Expressive Communication standardized residual scores (age regressed on raw scores);

* $p < .05$;

** $p < .01$;

♦ $p = .06$.

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Table 4

Multiple regressions of concurrent predictors at mean age 5½ of the *Test of Early Reading Ability*, *Third Edition* (TERA-3) overall and subtest performance.

	TERA-3											
	RQ[a, b]			Alphabet[c]			Conventions[d]			Meaning[e]		
	β	***t***	***p***	β	***t***	***p***	β	***t***	***p***	β	***t***	***p***
Block 1												
Cognition[f]	.47	3.74	< .001	.52	3.43	.001	.16	1.03	.307	.41	2. 95	.004
Block 2												
Severity[g]										.06	. 71	.481
SES[h]	.13	1.90	.061	.16	2.08	.041	.13	1.50	.138			
Social ability[i]	−.28	−2.35	.021	−.46	−3.57	.001	−.24	−1.64	.104	.00	. 03	.978
Block 3												
EC[j]	.54	4.43	< .001				.68	4 .59	< .001	.38	2.72	.008
AC				.55	3.63	< .001						

Note: A four-predictor model was determined by entering block 1, then two of three variables from block 2, and then either variable from block 3; All predictors were entered to the model in the order shown; The best model (accounted for the greatest amount of variance) for each outcome variable is displayed;

[a]Reading Quotient;

[b]R^2 = .64, adjusted R^2 = .62, $F(4, 88) = 38.24$, $p < .001$;

[c]R^2 = .57, adjusted R^2 = .55, $F(4, 88) = 29.28$, $p < .001$;

[d]R^2 = .46, adjusted R^2 = .44, $F(4, 88) = 18.87$, $p < .001$;

[e]R^2 = .53, adjusted R^2 = .51, $F(4, 89) = 25.53$, $p < .001$;

[f]*Mullen Early Scales of Learning* Nonverbal Ratio IQ score;

[g]*Autism Diagnostic Observation Schedule* Severity score as calculated per Gotham et al. (2009);

[h]Socioeconomic status as measured per mother's years of education completed;

[i]*Vineland Adaptive Behavior Scales, Second Edition* Socialization domain standard score;

[j] *Preschool Language Scale, Fourth Edition* Expressive Communication standardized residuals (age regressed on raw scores);

[k] *Preschool Language Scale, Fourth Edition* Auditory Comprehension standardized residuals (age regressed on raw scores).

Table 5

Multiple regressions of longitudinal predictors from mean age 2½ to mean age 5½ of the *Test of Early Reading Ability*, *Third Edition* (TERA-3) overall and subtest performance.

	TERA-3											
	RQ[a,b]			Alphabet[c]			Conventions[d]			Meaning[e]		
	β	*t*	*p*	β	*t*	*p*	β	*t*	*p*	β	*t*	*p*
Block 1												
Cognition[f]	.48	4.62	< .001	.55	4.55	< .001	.33	2.73	.008	.47	4. 73	< .001
Block 2												
Severity[g]	−.11	−1.20	.236	−.09	−.95	.346	−.08	−.77	.442	−.11	−1. 28	.204
SES[h]	.08	.83	.412	.13	1.31	.194	.09	.81	.418			
Social ability[i]										−.06	−. 61	.545
Block 3												
EC[j]	.21	2.17	.033				.22	1.96	.053	.30	2. 76	.007
AC[k]				−.06	−.54	.592						

Note: A four-predictor model was determined by entering block 1, then two of three variables from block 2, and then either variable from block 3; All predictors were entered to the model in the order shown; The best model (accounted for the greatest amount of variance) for each outcome variable is displayed;

[a]Reading Quotient;

[b]$R^2 = .46$, adjusted $R^2 = .43$, $F(4, 77) = 16.24$, $p < .001$;

[c]$R^2 = .37$, adjusted $R^2 = .34$, $F(4, 78) = 11.53$, $p < .001$;

[d]$R^2 = .29$, adjusted $R^2 = .25$, $F(4, 77) = 7.71$, $p < .001$;

[e]$R^2 = .46$, adjusted $R^2 = .43$, $F(4, 78) = 16.37$, $p < .001$;

[f]*Mullen Early Scales of Learning* Nonverbal Ratio IQ score;

[g]*Autism Diagnostic Observation Schedule* Severity score as calculated per Gotham et al. (2009);

[h]Socioeconomic status as measured per mother’s years of education completed;

[i]*Vineland Adaptive Behavior Scales*, *Second Edition* Socialization domain standard score;

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[j] *Preschool Language Scale, Fourth Edition* Expressive Communication standardized residuals (age regressed on raw scores);

[k] *Preschool Language Scale, Fourth Edition* Auditory Comprehension standardized residuals (age regressed on raw scores).