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Preschool Predictors of School-Age Academic Achievement in Autism Spectrum Disorder

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Preschool Predictors of School-Age Academic Achievement in Autism Spectrum Disorder

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Abstract

Objective: Characterization of academic functioning in children with autism spectrum disorder (ASD), particularly predictors of achievement, may have important implications for intervention. The current study aimed to characterize achievement profiles, confirm associations between academic ability and concurrent intellectual and social skills, and explore preschool predictors of school-age academic achievement in a sample of children with ASD.

Methods: Children with ASD ($N = 26$) were evaluated at the approximate ages of two, four, and ten years. Multiple regression was used to predict school-age academic achievement in reading and mathematics from both concurrent (i.e., school-age) and preschool variables.

Results: Children with ASD demonstrated a weakness in reading comprehension relative to word reading. There was a smaller difference between mathematics skills; math reasoning was lower than numerical operations, but this did not quite reach trend level significance. Concurrent IQ and social skills were associated with school-age academic achievement across domains. Preschool verbal abilities significantly predicted school-age reading comprehension, above and beyond concurrent IQ, and early motor functioning predicted later math skills.

Conclusions: Specific developmental features of early ASD predict specific aspects of school-age achievement. Early intervention targeting language and motor skills may improve later achievement in this population.

Preschool Predictors of School-Age Academic Achievement in Autism Spectrum Disorder

Autism spectrum disorder (ASD) describes a group of neurodevelopmental disorders characterized by symptoms across three domains: social interaction, communication, and restricted interests or repetitive behaviors (RRBs). Individuals with ASD demonstrate impaired social reciprocity and verbal and nonverbal communication, in the presence of atypical RRBs (American Psychiatric Association (APA), 2000). ASD is an umbrella term that includes DSM-IV-TR diagnoses of Autistic Disorder (AD), Asperger's Syndrome (AS), and Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS), with specific diagnosis being determined based on the presentation and severity of symptoms in the domains listed above (APA, 2000). These three diagnostic classifications roughly correspond to ICD-10 diagnoses of Childhood Autism, Asperger Syndrome, and Atypical Autism (World Health Organization, 2016), and they are collapsed into one diagnosis, ASD, in the recently updated DSM-5 (APA, 2013). ASD is highly prevalent in the United States, with current population-based estimates from the Centers for Disease Control and Prevention (CDC) suggesting that one in every 68 children meets diagnostic criteria for the disorder (CDC, 2014).

A reciprocal relationship between social and academic competence, such that they affect each other over time, has been observed in typically developing (TD) children, with potential implications for individuals with ASD (Welsh, Parke, Widaman, & O'Neil, 2001). This bidirectional theory suggests that children with social deficits often demonstrate inattention and distractibility in the school setting, contributing to academic difficulties and poor relationships with teachers and peers. Conversely, children with academic weaknesses may become frustrated in the classroom and engage in socially disruptive behaviors, causing peer rejection or stigma (Welsh et al., 2001). For children with ASD who by definition display social deficits, these social symptoms could contribute to academic challenges, which may then exacerbate further social difficulties with peers. Indeed, individuals with ASD commonly experience social and academic challenges within the school setting, often alongside cognitive, language, and motor impairments (May, Rinehart, Wilding, & Cornish, 2013). Despite difficulty engaging with the classroom environment, a large number of students with ASD are being mainstreamed as part of the inclusion model of special education, and teachers may be ill-equipped to meet their specific needs (Brown, Oram-Cardy, & Johnson, 2013; Jones et al., 2009).

Achievement Profiles in ASD

Relatively few studies have looked at academic attainment in individuals with ASD, and findings are variable (Estes, Rivera, Bryan, Cali, & Dawson, 2011; Griswold, Barnhill, Myles, Hagiwara, & Simpson, 2002; Jones et al., 2009; Mayes & Calhoun, 2003a; Mayes & Calhoun, 2003b; Nation, Clarke, Wright, & Williams, 2006; Ricketts, Jones, Happe, & Charman, 2013; Towgood, Meuwese, Gilbert, Turner, & Burgess, 2009). Thus, specific patterns of academic strengths and weaknesses are not completely understood in children with ASD, nor are early predictors of academic performance. Even within more homogenous subgroups (e.g., high-functioning autism (HFA), AS), achievement profiles are quite variable, with individuals' scores ranging from impaired to above average across subtests (Griswold et al., 2002; Mayes & Calhoun, 2003b). Additionally, even when they display average overall achievement scores, groups of children with AS tend to have large standard deviations in specific areas, suggesting large group level variability within specific academic domains (Griswold et al., 2002).

Although the body of literature on academic functioning in ASD is relatively small, some work has been done on reading and mathematics abilities and their relationship to ASD symptoms and deficits (Jones et al., 2009; Nation et al., 2006).

Reading. Reading comprehension appears to be most consistently impaired among academic skills in ASD (Minshew, Goldstein, Taylor, & Siegel, 1994; Nation et al., 2006; Ricketts et al., 2013; Troyb et al., 2014). Studies of decoding skills show mixed findings, with some reporting impairment in word recognition (Ricketts et al., 2013) and others demonstrating average to above average word reading ability (Brown et al., 2013; Minshew et al., 1994; Nation et al., 2006). Similar variability also applies to oral vocabulary, as some studies demonstrate unimpaired single word comprehension (Minshew et al., 1994) whereas other research reports relative weaknesses in basic semantic knowledge (Brown et al., 2013). For example, one study of reading skills in children with ASD showed that these individuals display word reading, nonsense word reading, and reading fluency scores within the average range, but show impaired comprehension (Nation et al., 2006). Specifically, 65 percent of the sample performed one standard deviation or more below average on a test of reading comprehension (i.e., Neale Analysis of Reading Ability – II, NARA-II), and one third of the sample showed very severe reading comprehension deficits. Additionally, in a study comparing older children and adolescents with HFA to TD peers and individuals with optimal outcome (OO) (i.e., individuals with a history of ASD who no longer meet diagnostic criteria, see Fein et al., 2013), individuals with HFA generally performed in the average range on tests of academic achievement, with a strength in reading accuracy, but with a significant relative weakness in reading comprehension (Troyb et al., 2014). Taken together, findings suggest that children and adolescents with ASD may be less impaired, or even within the average range, in rote or simple reading skills (e.g., word reading, nonsense word reading, single word comprehension), but they appear to perform poorly compared to TD peers on tests of comprehending stories or other complex text (Brown et al., 2013; Minshew et al., 1994). This pattern of performance indicates a deficit in more complex reading skills, particularly tasks requiring social knowledge, abstraction, inference making, integration of information, and working memory.

Mathematics. Individuals with ASD also demonstrate variable mathematics skills, with greater impairment in tasks requiring mathematical reasoning or inferential processing, rather than simple calculations (Minshew et al., 1994; Troyb et al., 2014). For example, Minshew et al. (1994) showed that adolescents with HFA display intact performance of numerical computations, providing evidence for an adequate ability to apply mechanical mathematical skills and utilize simple associative processes to master rote academic tasks (e.g., basic math facts). However, individuals with ASD may have difficulty with tasks requiring problem solving abilities (Bae, Chiang, & Hickson, 2015; Troyb et al., 2014). Bae et al. (2015), in a study comparing school-age children with ASD to their TD peers, showed that individuals with ASD demonstrate impairment in mathematical word problem solving and application of mathematics to everyday situations. Although some individuals with AS or HFA demonstrate high average or superior mathematical abilities, a high proportion of children with HFA meet criteria for a learning disability in mathematics (Chiang & Lin, 2007).

Discrepancy from IQ. Academic performance in ASD may be discrepant from that predicted by a child’s overall cognitive ability. Within an HFA sample, Estes et al. (2011) showed that a majority of individuals demonstrated a discrepancy from IQ in academic achievement, defined as the ‘absolute difference between observed academic achievement and predicted academic achievement [from IQ]’ (p. 1047). Notably, 60 percent of children had low achievement in at least one academic domain, compared to IQ-based expectancy, yet 60 percent also had high achievement in at least one domain, suggesting that the typically strong association between achievement and IQ may be more complex in children with ASD. Additionally, the relationship between IQ and academic achievement in ASD may vary as a function of cognitive level (Mayes & Calhoun, 2003a; Mayes & Calhoun, 2003b). Specifically, high functioning children with ASD (i.e., average to superior IQ) tend to display average achievement, indicating that they perform at or below their intellectual level on tests of academic skills, with a particular weakness in writing. Low functioning children with ASD (i.e., IQ < 80), though, appear to demonstrate math and spelling scores commensurate with IQ, and significantly higher than predicted reading decoding performance, consistent with a relative strength in rote learning even in low functioning children. Although there is evidence of academic performance discrepant from IQ in individuals with ASD, there is no single pattern of discrepancy, with some children outperforming their expected achievement level based on IQ, whereas others underperform on multiple achievement domains.

Predictors of Achievement in ASD

Very few studies have looked at early predictors of later achievement. Estes et al. (2011) explored specific factors associated with achievement outcomes in middle childhood; in their sample, social functioning at age six years was predictive of word reading ability at age nine years, after adjusting for age six nonverbal IQ. However, no published research has examined preschool predictors of academic functioning. Developmental impairments associated with ASD typically present in early childhood, with the average age of first diagnosis in the United States between two and four years (CDC, 2014). Research suggests that many children with ASD may make considerable gains in intellectual and social-behavioral functioning with early intervention services (Estes et al., 2011). By identifying preschool predictors of school-age achievement, it may be possible to further tailor early intervention and educational strategies to maximize later academic attainment in this population.

Overall, several themes have emerged from *cross-sectional* regression-based prediction models of reading and mathematics abilities in high functioning subgroups, with findings suggesting a role for IQ, basic cognitive processes (e.g., processing speed and working memory), executive functions (e.g., attentional switching), and motor skills in explaining the variance in academic achievement in individuals with ASD (Assouline, Nicpon, & Dockery, 2012; May et al., 2013; Mayes & Calhoun, 2008).

Cognitive ability. Despite evidence of a discrepancy between IQ and academic achievement in some individuals with ASD, and in some academic areas specifically (e.g., poor writing, good word reading), global cognitive abilities are significantly related to level of achievement in this population. In children with HFA, concurrent full scale IQ (FSIQ) was the single best predictor of reading, math, and writing achievement (Mayes & Calhoun, 2008). Furthermore, using a cross-sectional predictor model in a sample of cognitively gifted children with ASD (i.e., IQ > 120), Assouline et al. (2012) found that working memory and processing speed accounted for significant variance (i.e., 61 percent) in reading achievement, working memory predicted written language achievement, and perceptual reasoning ability predicted oral language achievement. These findings suggest that basic domain general thinking skills (e.g., working memory and processing speed) also contribute to academic success in HFA.

Motor skills. An association between motor functioning and mathematical achievement has also been documented in TD children. A large-scale naturalistic observation study of TD toddlers aged 30 to 33 months revealed that, depending on level of motor skills (i.e., gross motor, fine motor, adaptive functioning, classroom skills), toddlers significantly differed in their mathematical performance (i.e., early math skills – counting, numerical series, shape and space, pattern and order, mathematical language, logical reasoning) (Reikeras, Moser, & Tonnessen, 2015). Many researchers have noted impairments in graphomotor (i.e., writing) skills and motor coordination in children with HFA and AS (Fuentes, Mostofsky, & Bastian, 2009; Ghaziuddin & Butler, 1998), and these deficits appear to specifically affect mathematical abilities (Mayes & Calhoun, 2003b). Scores on the Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery VMI) and the Wechsler Block Design subtest predicted math achievement in gifted children with ASD (Assouline et al., 2012). Impaired performance on the skills needed for these measures, including fine motor skills, visual spatial ability, working memory, and speed of processing, may also affect performance on academic testing of math skills.

Social functioning. The unique impairments in social functioning associated with ASD also seem to contribute to specific difficulties in academic attainment, particularly within the domain of reading comprehension. For example, several studies have shown that the social impairments of ASD, as measured by tests of both social cognition and general social and communication functioning (i.e., Autism Diagnostic Observation Schedule, or ADOS), contribute unique variance to reading comprehension, even after accounting for vocabulary, decoding, oral language, and nonverbal IQ levels (Asberg, Kopp, Berg-Kelly, & Gillberg, 2010; Ricketts et al., 2013). Furthermore, reading comprehension appears to fall increasingly below IQ with increasing social and communication impairments (Jones et al., 2009).

Although most previous research has focused on concurrent predictors of achievement in ASD, Estes et al. (2011) examined the association between early social skills at age six years and later reading abilities. After controlling for nonverbal IQ, better social functioning at age six years was significantly associated with greater academic achievement, particularly in the subdomain of word reading, at age nine years.

Taken together, these findings suggest that the generally poor reading comprehension abilities shown by individuals with ASD are not simply a product of weaknesses in core language skills (e.g., phonetic decoding, oral vocabulary). Thus, educational interventions aimed at improving these core language skills may not be sufficient to overcome reading comprehension deficits in the ASD population, and remediation of children's social cognition and social behavior may be crucial in improving reading comprehension.

Specific Aims

Although examination of academic achievement in children with ASD is somewhat limited and has focused almost entirely on concurrent relationships, specific impairments in reading comprehension and mathematical reasoning have emerged. Results of concurrent regression-based prediction models suggest that these deficits generally appear to be linked to level of social impairment as well as performance in the domains of intellectual ability, working memory, processing speed, and motor skills. Furthermore, specific associations between social skills and reading comprehension and motor skills and mathematics have been found.

The main goals of the current study are to (1) characterize achievement profiles in a heterogeneous sample of school-age children with ASD, (2) replicate associations between academic achievement and concurrent intellectual functioning, communication and social skills, and ASD symptoms, and (3) explore potential preschool predictors of school-age achievement.

With respect to the first aim, we hypothesize that individuals with ASD will show greater impairment in academic domains requiring reasoning and inferential processing (i.e., reading comprehension, math reasoning) as compared to more rote academic skills (i.e., word reading, numerical operations). With respect to the second aim, because concurrent regression models suggest that intellectual functioning and level of social skills account for significant and independent variance in academic abilities, we expect to confirm these associations in our sample using measures of IQ (i.e., Differential Ability Scales, Second Edition, DAS-II), adaptive social functioning (i.e., Vineland Adaptive Behavior Scales, Second Edition, VABS-II), and ASD symptoms (i.e., ADOS; Childhood Autism Rating Scale, CARS) in middle childhood.

Finally, with respect to the third aim, which has not been investigated to date, we explore early predictors of academic achievement using developmental data (i.e., Mullen Scales of Early Learning, MSEL; VABS; ADOS; CARS) collected from participants at the approximate ages of two and four years to predict school-age achievement. Based on cross-sectional regression models implicating IQ, social functioning, and motor skills in the prediction of academic performance, as well as Estes et al.'s (2011) finding that social functioning at age six years is predictive of word reading ability at age nine years, we hypothesize that early cognitive and social functioning will predict later reading ability, whereas preschool motor skills will predict school-age mathematical ability.

Methods

Participants

Participants were a subset of a sample from a larger federally funded project at the University of Connecticut. The aims of the original study focused on developing and validating the Modified Checklist for Autism in Toddlers (M-CHAT), a population-based screening measure used to detect ASD in young children (Robins, Fein, Barton, & Green, 2001). Participants screened positive on the M-CHAT between the ages of 16 and 30 months and received a developmental and diagnostic evaluation at the approximate ages of two (i.e., Time 1, T1) and four (i.e., Time 2, T2) years. To have a well-characterized sample of children with ASD, participants were deemed eligible for the current study if they received a diagnosis on the autism spectrum (i.e., either AD, PDD-NOS, or AS) at both evaluations. They were then invited back for a follow-up evaluation in middle childhood. In the current study, only children who were between the ages of eight years and 10 years, 11 months were included. Exclusion criteria included sensory impairments (e.g., blindness) or severe deficits in motor functioning (e.g., severe cerebral palsy) that would negatively impact the participant's ability to complete testing. Participants and their families were recruited either by telephone or letter.

One hundred two participants from the original M-CHAT study were deemed eligible for participation in the current study. Of those participants, 48 were contacted and given the opportunity to participate in the current study (47.1%); the remaining participants were unable to be contacted by either phone or mail. Of the 48 families, one moved (1%), seven declined participation (6.8%), and 40 were evaluated (39.2%).

During the Time 3 (T3) evaluation, a measure of academic achievement was given to a subset of children for whom time and cognitive level allowed such testing. Of the 40 children evaluated at T3, 27 completed at least some academic achievement testing. One participant was deemed an outlier for age at T2 (i.e., 8.1 years) and was excluded from the current study. The final sample contained 26 children with ASD, 22 males and four females. Caregivers self-identified their child's race as White (n = 22), Black (n = 1), or Asian/Pacific Islander (n = 2); data were missing for one participant. At T1, 13 participants were diagnosed with AD, eight participants were diagnosed with PDD-NOS, and five participants were diagnosed with ASD and low mental age (ASD-LMA), a research diagnosis given to children exhibiting diagnostic features of PDD-NOS with severe cognitive impairment (i.e., nonverbal reasoning, receptive language, and expressive language scores at a 12-month level or lower). Mean age at initial evaluation was 27.3 months (SD = 3.4). Diagnosis was confirmed on follow-up at T2, when 22 participants were diagnosed with AD and four participants were diagnosed with PDD-NOS. Mean age at the time of re-evaluation was 52.9 months (*SD* = 5.7). At T3, diagnostic classification was based on the ADOS, with 23 participants continuing to meet criteria for AD and three participants falling within the non-spectrum score range. Mean age at T3 re-evaluation was 119.5 months (*SD* = 9.9), or nine years, 11 months. Participant characteristics are summarized in Table 1.

Procedures

All preschool evaluations were completed at the University of Connecticut Psychological Services Clinic. Participants who did not have transportation were provided with a free taxi service. Initial evaluations (T1) occurred when participants were between the ages of 20 and 33 months, and all children were invited back for a second evaluation (T2) when they were between the ages of 43 and 71 months. A team of clinicians, consisting of one licensed clinical psychologist or developmental-behavioral pediatrician and one clinical psychology doctoral student, completed each evaluation. All evaluations lasted approximately three hours, including a feedback session in which diagnosis and recommendations were reviewed with the child's caregiver. Given the years in which T1 and T2 evaluations were conducted (i.e., between 2001 and 2008), all study diagnoses were assigned based on DSM-IV-TR criteria (APA, 2000).

Children diagnosed with ASD at both preschool evaluations (T1 and T2), who were between the ages of eight years and 10 years, 11 months (T3), were recruited for the current study by letter or telephone contact. Participants were offered a free developmental evaluation that was completed, either at the University of Connecticut Psychological Services Clinic or in participants' homes, by two clinical psychology doctoral students under the supervision of a licensed clinical psychologist. Evaluations were video-recorded and lasted up to four hours depending on the child's abilities and tolerance.

Measures

Times 1 and 2.

Cognitive ability. The *Mullen Scales of Early Learning* (MSEL; Mullen, 1995) is a developmental assessment of cognitive, motor, and language abilities in children aged one month to five years, eight months. It was used to assess cognitive ability at both preschool evaluations. The current study used the visual reception, fine motor, and receptive and expressive language scales. Raw scores in each domain are converted into T scores or developmental age-equivalent (AE) scores. Average estimates of internal consistency are satisfactory, ranging from .75 to .83 across all scales, and inter-rater reliability is considered strong, ranging from .91 to .99 (Mullen, 1995). MSEL AE scores demonstrate good convergent validity with other measures of cognitive functioning in children with ASD, such as the Differential Ability Scales (DAS; Elliott, 1990), with a reliability of .83 for verbal IQ (i.e., based on receptive and expressive language AE scores) and .74 for nonverbal IQ (i.e., based on visual reception and fine motor AE scores) (Bishop, Guthrie, Coffing, & Lord, 2011). Histograms revealed that MSEL T scores in each domain were not normally distributed because a large number of children received the lowest possible standard score. In order to use parametric statistical tests without violating their assumptions, AE scores were used to estimate participants' cognitive levels using a developmental quotient (DQ) according to the formula mental age (i.e., AE scores) divided by chronological age, multiplied by 100 (Reitzel et al., 2013).

Adaptive functioning. The *Vineland Adaptive Behavior Scales: Interview Edition, Survey Form* (VABS; Sparrow, Balla, & Cicchetti, 1984) is a semi-structured caregiver interview that assesses adaptive behaviors (i.e., how a child functions in his or her daily life) in the domains of socialization, communication, daily living, and motor skills. The VABS was used to quantify adaptive skills at both T1 and T2. Scores in the four domains contribute to a standardized composite measure of adaptive functioning, the Adaptive Behavior Composite (ABC). Inter-rater (i.e., inter-interviewer) reliability ranges from .62 to .78 across the four domains (Sparrow et al., 1984). Standard scores in the domains of communication and socialization were used in the current study.

ASD symptoms. The *Autism Diagnostic Observation Schedule – Generic* (ADOS; Lord et al., 2000) is a semi-structured observational assessment designed to measure symptoms of ASD in toddlerhood through adulthood. The ADOS includes four separate modules based on a participant's expressive language level and chronological age. The current study used Modules 1 or 2 during preschool evaluations. On this measure, abnormal behaviors are classified on several scales, including social, communication, combined social communication, and RRBs. Scores are used to classify each participant as having AD, an ASD, or no ASD (i.e., non-spectrum). Inter-rater reliability is considered good across all domains: social (.93), communication (.84), social communication (.92), and RRBs (.82) (Lord et al., 2000). To allow for comparison of ASD symptom severity across different ADOS modules and evaluation time points, raw scores were converted into calibrated severity scores (CSS) based on a published algorithm (Gotham, Pickles, & Lord, 2009).

The *Childhood Autism Rating Scale* (CARS; Schopler, Reichler, & Renner, 1988) is a 15-item clinician rating scale measuring autism symptom severity based on observation and caregiver report, used to quantify ASD severity at both T1 and T2. A total score is calculated by summing scores from all individual items and classifies a child into one of three groups: nonautistic (total score = 15 – 30), mildly-moderately autistic (total score = 30 – 37), and severely autistic (total score = 37 – 60). Although a cut-off of 30 is typically used for AD, a cut-off of 25.5 has been proposed for ASD more broadly (Chlebowski, Green, Barton, & Fein, 2010). Internal consistency of CARS items is high (α = .94), and inter-rater reliability is considered good at .71 (Schopler, Reichler, & Renner, 1995). CARS total scores are correlated with scores from other ASD diagnostic measures (r = .84), as well as with clinical judgment of ASD diagnosis (r = .80) (Schopler et al., 1995).

Time 3.

Cognitive ability. The *Differential Ability Scales, Second Edition* (DAS-II; Elliott, 2007) is a measure of cognitive ability in children between the ages of two years, six months and 17 years, 11 months. The DAS-II School-Age Cognitive Battery was used for the majority of participants in the current study based on their chronological age. However, nine participants were administered the DAS-II Early Years Cognitive Battery based on their cognitive level. The DAS-II provides extended General Conceptual Ability (GCA) standard scores, which were used in the current study. Average internal reliability coefficients for Early Years and School-Age cluster and composite (i.e., GCA) scores range from .85 to .97 and from .86 to .97, respectively (Elliott, 2007).

Adaptive functioning. The *Vineland Adaptive Behavior Scales, Second Edition: Survey Interview Form* (VABS-II; Sparrow, Cicchetti, & Balla, 2005) was used to assess adaptive functioning during the school-age evaluation. Internal consistency of domain and composite (i.e., ABC) scores is considered good, with reliability ranging from .88 to .97 for children aged eight to 11 years. Inter-interviewer reliability averages .74 for the ABC and .72 for domain scores in children aged seven to 18 years (Sparrow et al., 2005). The current study used standard scores in the domains of communication and socialization.

ASD symptoms. The *Autism Diagnostic Observation Schedule – Generic* (ADOS; Lord et al., 2000) and the *Childhood Autism Rating Scale* (CARS; Schopler, Reichler, & Renner, 1988) were used to measure autism-specific symptomatology at T3 in an effort to maintain diagnostic measure consistency across all three evaluation time points. Children were administered either ADOS Modules 2 or 3 based on level of expressive language; raw scores were converted into CSS to allow for comparison across modules and time. CARS total scores were also used to quantify ASD severity at ages eight to 10 years.

Academic achievement. The *Wechsler Individual Achievement Test, Second Edition* (WIAT-II; Wechsler, 2001) is a structured measure of academic achievement in children and adults between the ages of four and 85 years. The test assesses individual achievement in the domains of reading, mathematics, written language, and oral language based on performance across nine subtests. Internal consistency of subtests is generally high (i.e., above .85), with reliability of composite scores being very high (i.e., above .90) in the school-age population (Wechsler, 2001). Standard scores for the specific subtests of word reading, reading comprehension, numerical operations, and math reasoning were used in the current study.

See Table 2 for a summary of study measures by evaluation time point and construct.

Data Analytic Plan

Achievement profile analyses. To determine whether school-age individuals with ASD demonstrated greater impairment in academic skills requiring abstraction and inferential processing, a series of paired-samples *t*-tests were used to compare performance on specific subtests in the domains of reading (i.e., word reading versus reading comprehension) and mathematics (i.e., numerical operations versus math reasoning).

Predictor analyses. Consistent with the aims of the study, multiple regression analyses were conducted to determine whether cognitive abilities, adaptive skills, and ASD symptoms seen during both preschool and school-age years accounted for a significant amount of variance in school-age academic achievement.

***Data preparation*.** All data were analyzed to determine if assumptions of linear regression were violated. Histograms revealed that WIAT-II standard scores on the subtests of word reading, reading comprehension, and math reasoning were not normally distributed. Scores were adjusted using square (for word reading) and natural log (for reading comprehension) transformations. Tests of normality suggested that the distributions of these transformed outcome variables were approximately normal, thus meeting the assumptions underlying linear regression. However, because no transformation of math reasoning scores approximated normality, a bootstrapping method with 500 replications was employed. Although bootstrapping does not 'cure' non-normal data, it is less subject to problems of non-normality and is considered a better estimate of the true relationship between predictor and outcome variables. All analyses were run using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corporation, 2013) with the exception of bootstrapped regression analyses for the outcome of math reasoning, which were conducted using Stata 14 (StataCorp, 2015).

***Variable selection process*.** Multiple regression analysis was used to examine the possible variables that contribute to variation in academic achievement. For each regression, assumptions of collinearity were assessed through the evaluation of VIF and tolerance statistics. Conservative cut-offs of VIF > 4 and tolerance < .20 were used, as described in Menard (1995).

Due to concerning levels of collinearity, MSEL expressive language and receptive language developmental quotients were averaged into a single construct (i.e., MSEL verbal ability), which was tested in subsequent T1 and T2 regression analyses.

Because of the large number of constructs collected at T1 and T2, separate sub-regression models were carried out with each of the four WIAT-II subdomains as dependent variables for each set of predictor variables, including cognitive constructs (i.e., MSEL verbal ability, visual reception, and fine motor DQ scores), adaptive constructs (i.e., VABS communication and socialization standard scores), and ASD symptom constructs (i.e., ADOS CSS, CARS total scores), for both preschool time points. A similar process was used to select predictor variables for concurrent regression models. Separate sub-regression models were carried out with each of the four WIAT-II subdomains as dependent variables for each set of predictor variables, including adaptive constructs (i.e., VABS-II communication and socialization standard scores) and ASD symptom constructs (i.e., ADOS CSS, CARS total scores) collected at T3. Those variables identified within the initial sub-regression models as the strongest, or as theoretically significant, were retained and tested together as part of final models, as reported in Results. Any significant analyses were then run in an additional regression model adding T3 IQ (i.e., DAS-II GCA) in order to determine the amount of variance in academic achievement accounted for by early and concurrent predictors above and beyond a child’s level of intellectual functioning in middle childhood.

In initial sub-regression analyses, an alpha level of .1 was adopted to identify variables to be retained for subsequent analyses. An alpha level of .05 was adopted for statistical tests of final models.

Results

Differential Attrition

Analyses of variance revealed no significant differences on gender, race, cognitive ability, adaptive functioning, or ASD symptom severity at T1 and T2 evaluations between children who participated in T3 testing and those who did not (Knoch, 2014; Troyb et al., 2016).

Aim One: Achievement Profiles

A paired-samples *t*-test was conducted to compare performance on WIAT-II subtests of word reading and reading comprehension. There was a significant difference in scores on word reading ($M = 87.6$, $SD = 25.3$) and reading comprehension ($M = 74.3$, $SD = 26.7$), $t(20) = 2.829$, $p = .010$. A second paired-samples *t*-test was run to compare achievement on WIAT-II subtests of numerical operations and math reasoning. No significant difference was found between numerical operations ($M = 83.7$, $SD = 30.3$) and math reasoning ($M = 78.6$, $SD = 34.0$) scores, $t(19) = 1.666$, $p = .112$, although the difference was in the predicted direction and close to trend level significance.

Aim Two: Concurrent Predictors of Achievement

Reading. Table 3 summarizes concurrent regression analyses predicting word reading ability. A multiple regression model (Model 1a) with both T3 VABS-II communication scores and T3 CARS total scores entered as predictors accounted for 49.8% of the variance in word reading ($F(2, 19) = 9.425$, $p = .001$). As can be seen in Table 2, VABS-II communication had a significant positive regression weight, indicating that participants with higher scores were expected to have higher WIAT-II word reading scores, after controlling for ASD severity. CARS total did not contribute to the multiple regression model. A second multiple regression model (Model 1b) added T3 DAS-II GCA as a predictor; together, all three variables accounted for 59.9% of the variance in word reading ($F(3, 16) = 7.956$, $p = .002$). However, only DAS-II GCA contributed to Model 1b with a significant positive regression weight, suggesting that functional communication abilities at T3 may be subsumed by concurrent IQ.

Concurrent regression analyses predicting reading comprehension ability are summarized in Table 4. Together, both T3 VABS-II communication scores and T3 CARS total scores (Model 2a) explained 66.4% of the variance in reading comprehension ($F(2, 15) = 14.801$, $p < .001$). VABS-II communication had a significant positive regression weight, suggesting that children with higher scores on this variable have higher WIAT-II reading comprehension scores, after controlling for ASD severity. However, CARS total had a significant negative weight, indicating that, after accounting for VABS-II communication scores, those individuals with higher CARS total scores (i.e., greater ASD severity) were expected to have lower WIAT-II reading comprehension scores. A second regression model (Model 2b) added T3 DAS-II GCA as a predictor; together, all three variables accounted for 71.2% of the variance in reading comprehension ability ($F(3, 13) = 10.705$, $p = .001$). However, no individual predictor variable significantly contributed to the multiple regression model.

Mathematics. Table 5 summarizes concurrent regression analyses predicting numerical operations ability. In a linear regression model (Model 3a), T3 CARS total scores accounted for 31.2% of the variance in numerical operations ($F(1, 18) = 8.180$, $p = .010$). As shown in Table 5, CARS total had a significant negative regression weight, indicating that individuals with greater ASD severity were expected to have lower WIAT-II numerical operations scores. A multiple regression model (Model 3b) added T3 DAS-II GCA as a predictor. Together, both variables explained 72.0% of the variance in numerical operations ability ($F(2, 16) = 20.619$, $p < .001$). However, only DAS-II GCA contributed to Model 3b with a significant positive regression weight, suggesting that, after controlling for ASD severity, children with higher T3 IQ were predicted to have higher WIAT-II numerical operations scores. This result also indicates that some of the variance in numerical operations ability initially explained by ASD severity (i.e., T3 CARS total) was likely accounted for by variability in concurrent IQ.

Concurrent regression analyses predicting math reasoning ability are summarized in Table 6. A multiple regression model (Model 4a) with T3 VABS-II communication scores and T3 CARS total scores entered as predictors accounted for 45.4% of the variance in math reasoning (Wald X^2 (2, N = 17) = 13.43, p = .001). CARS total had a significant negative regression weight, suggesting that, after controlling for T3 functional communication skills, individuals with more severe ASD symptomatology were predicted to have lower WIAT-II math reasoning scores. VABS-II communication did not significantly contribute to the multiple regression model. A second regression model (Model 4b) added T3 DAS-II GCA as a predictor; together, all three variables explained 80.7% of the variance in math reasoning ability (Wald X^2 (3, N = 16) = 36.66, p < .001). As seen in Table 6, only DAS-II GCA significantly contributed to Model 4b with a positive regression weight, suggesting that, after accounting for concurrent communication abilities and ASD symptom severity, individuals with higher T3 IQ were expected to have higher WIAT-II math reasoning scores.

Aim Three: Preschool Predictors of Achievement

Reading. Table 7 summarizes regression analyses predicting word reading ability from preschool variables. Results of initial sub-regression models predicting word reading from T1 cognitive, adaptive, and ASD symptom constructs did not reveal any significant predictors; thus, a final regression model was not tested. As shown in Table 7, a multiple regression model (Model 5a) with both T2 VABS communication scores and T2 CARS total scores entered as predictors accounted for 33.2% of the variance in word reading (F(2, 22) = 5.475, p = .012).

However, neither individual predictor significantly contributed to the model. A second multiple regression model (Model 5b) added T3 DAS-II GCA as a predictor; together, all three variables explained 49.8% of the variance in word reading ability ($F(3, 19) = 6.292$, $p = .004$). DAS-II GCA contributed to the multiple regression model with a significant positive regression weight, indicating that, after controlling for T2 communication skills and ASD severity, individuals with higher T3 IQ were expected to have higher WIAT-II word reading scores. T2 VABS communication and CARS total did not significantly contribute to the regression model.

Regression analyses predicting reading comprehension ability from preschool variables are summarized in Table 8. In a linear regression model (Model 6a), T1 MSEL verbal ability explained 36.6% of the variance in reading comprehension ($F(1, 17) = 9.822$, $p = .006$) and contributed to the model with a significant positive regression weight, suggesting that children with greater verbal ability at T1 were predicted to have higher WIAT-II reading comprehension scores at T3. A multiple regression model (Model 6b) added T3 DAS-II GCA as a predictor; together, both variables accounted for 65.7% of the variance in reading comprehension ability ($F(2, 15) = 14.385$, $p < .001$). However, only DAS-II GCA contributed to Model 6b with a significant positive regression weight, suggesting that verbal ability at age two years may be subsumed by T3 IQ in the prediction of concurrent reading comprehension scores.

A multiple regression model predicting reading comprehension from T2 variables resulted in concerning levels of multicollinearity (i.e., VIF > 16) between MSEL verbal ability and VABS communication; as such, these predictors were separately analyzed as part of final regression models, along with other variables deemed significant in initial sub-regression analyses. A multiple regression model (Model 7a) with T2 MSEL verbal ability and T2 CARS total scores entered as predictors accounted for 71.4% of the variance in reading comprehension

($F(2, 14) = 17.474$, $p < .001$). MSEL verbal ability contributed a significant positive regression weight, indicating that, after controlling for CARS total, individuals with greater verbal ability in preschool were predicted to have higher WIAT-II reading comprehension scores at school age. CARS total did not significantly contribute to Model 7a. A second multiple regression model (Model 7b) adding T3 DAS-II GCA as an additional predictor explained 74.1% of the variance in reading comprehension ability ($F(3, 12) = 11.442$, $p = .001$). However, no individual predictor variable significantly contributed to the multiple regression model. A multiple regression model (Model 7c) with both T2 VABS communication scores and T2 CARS total scores entered as predictors accounted for 73.1% of the variance in reading comprehension ability ($F(2, 17) = 23.142$, $p < .001$). As can be seen in Table 8, VABS communication had a significant positive regression weight, indicating that, after controlling for ASD severity, children with higher communication abilities at age four years were expected to have higher WIAT-II reading comprehension scores in middle childhood. CARS total did not significantly contribute to the overall model. A subsequent multiple regression model (Model 7d) added T3 DAS-II GCA as a predictor. Together, all three variables explained 76.1% of the variance in reading comprehension ($F(3, 15) = 15.890$, $p < .001$). Notably, only VABS communication contributed a significant positive regression weight to Model 7d, suggesting that preschool functional communication predicts school-age reading comprehension ability above and beyond T3 IQ.

Mathematics. Table 9 summarizes regression analyses predicting numerical operations ability from preschool variables. Although they did not reach significance in initial sub-regression analyses, T1 and T2 MSEL fine motor scores were entered into final regression models based on existing literature suggesting a theoretical link between motor functioning and mathematical skills. A multiple regression model (Model 8) with both T1 MSEL fine motor scores and T1 CARS total scores entered as predictors did not account for significant variance in numerical operations (R^2 = .234, $F(2, 16) = 2.450$, $p = .118$).

Together, both T2 MSEL fine motor scores and T2 CARS total scores (Model 9a) explained 46.9% of the variance in numerical operations ability ($F(2, 16) = 7.057$, $p = .006$). As shown in Table 9, MSEL fine motor had a significant positive regression weight, indicating that, after accounting for ASD severity, children with higher fine motor abilities at age four years were expected to have higher WIAT-II numerical operations scores between the ages of eight and 10 years. CARS total did not significantly contribute to the regression model. A second multiple regression model (Model 9b) added T3 DAS-II GCA as a predictor; together, all three variables accounted for 70.9% of the variance in numerical operations ($F(3, 14) = 11.372$, $p < .001$). However, only DAS-II GCA contributed a positive regression weight to the model, suggesting that the variance in numerical operations ability initially explained by preschool fine motor skills may be subsumed by T3 IQ.

Regression analyses predicting math reasoning ability from preschool variables are summarized in Table 10. A multiple regression model (Model 10a) with both T1 MSEL fine motor scores and T1 CARS total scores entered as predictors explained 33.6% of the variance in math reasoning (Wald X^2 (2, N = 17) = 8.25, $p = .016$). As shown in Table 10, MSEL fine motor had a significant positive regression weight, indicating that individuals with stronger fine motor skills at two years were predicted to have higher WIAT-II math reasoning scores at school age, after accounting for T1 ASD symptom severity. CARS total did not contribute significantly to the regression model. Model 10b added T3 DAS-II GCA as a predictor; together, all three variables accounted for 77.2% of the variance in math reasoning ability (Wald X^2 (3, N = 16) = 41.09, $p < .001$). However, only DAS-II GCA contributed to the multiple regression model with a significant positive regression weight, suggesting that variance in math reasoning initially explained by T1 fine motor skills may be better accounted for by T3 IQ.

Despite not reaching significance in initial sub-regression analyses, T2 MSEL fine motor scores were entered into final multiple regression models based on theoretical associations between math abilities and motor functioning shown in the previous literature. Together, T2 MSEL fine motor scores, T2 VABS communication scores, and T2 CARS total scores (Model 11a) accounted for 51.2% of the variance in math reasoning (Wald X^2 (3, N = 17) = 22.33, $p <$ .001). However, no individual predictor significantly contributed to the regression model. A second multiple regression model (Model 11b) added T3 DAS-II GCA as a predictor; all four variables explained 78.5% of the variance in math reasoning ability (Wald X^2 (4, N = 16) = 18.10, p = .001). Only DAS-II GCA had a significant positive regression weight, suggesting that, after controlling for T2 fine motor skills, functional communication, and ASD severity, children with higher T3 IQ were expected to have higher WIAT-II math reasoning scores. That is, the variance in school-age math reasoning ability explained by cognitive, adaptive, and social functioning at age four years may be subsumed by concurrent IQ.

Discussion

The purpose of the current study was threefold: first, to characterize achievement profiles in the domains of reading and mathematics; second, to replicate associations between cognitive, adaptive, and social functioning and concurrent academic abilities seen in the existing literature; and third, to examine potential preschool predictors of school-age academic achievement. Prior research has implicated intellectual capacity, social skills, and motor functioning in the prediction of academic ability, largely in homogenous subgroups of children with ASD, including those with AS and HFA. Furthermore, the unique constellation of symptoms associated with ASD appears to put children at greater risk for academic weaknesses, particularly in achievement domains requiring inferential processing and abstraction (e.g., reading comprehension, math problem solving). ASD symptoms in the areas of cognition, communication, and socialization generally present in the preschool period and negatively impact the child's ability to engage in learning opportunities, thus exacerbating achievement deficits. Knowing that early functioning predicts subsequent academic attainment would allow professionals who work with young children with ASD to both help families form appropriate expectations for their child's educational future and, perhaps more significantly, target early intervention strategies to potentially maximize later academic success in this population.

As expected, the results of the current study showed that individuals with ASD, even within a heterogeneous sample (i.e., including both low- and high-functioning children), demonstrate greater impairment in reading comprehension compared to word reading ability. This is consistent with the existing body of literature, which suggests that deficits in reading comprehension shown in many individuals with ASD are not simply reflective of deficits in word decoding, as this domain appears largely intact (i.e., within the broadly average range). Instead, impaired reading comprehension is likely a product of more general impairments in linguistic processing and social understanding (Jones et al., 2009; Nation et al., 2006). Skilled reading and reading comprehension requires skills in word recognition, phonetic decoding, receptive language (i.e., the ability to understand verbal material), and processing of more abstract and inferential material. Individuals with ASD often demonstrate an impaired ability to integrate meaningful information, focusing on details instead (Fitch, Fein, & Eigsti, 2015; Happe & Frith, 2006; Kanner, 1943). This may underlie deficits in the ability to make inferences, as well as poor social cognition (Ricketts et al., 2013). Together, these deficits likely contribute to impaired skills necessary for skilled reading comprehension (Ricketts et al., 2013). These reading findings are consistent with the general language profile of ASD, in which individuals show difficulty with comprehension of complex verbal material, pragmatic language, verbal reasoning and abstraction, and non-literal language (Tager-Flusberg, 1996). They may thus have difficulty inferring intentions of characters and causal connections between story events, contributing to impaired reading comprehension (Troyb et al., 2014).

However, a similar pattern was not found with respect to mathematical abilities; that is, performance on numerical operations, which assesses rote arithmetic ability, and math reasoning, which tests broader mathematical understanding, did not significantly differ, although the observed difference was in the expected direction and approached trend level significance. Although there are fewer studies on math skills than on reading ability in individuals with ASD, research suggests that academic domains requiring problem solving, such as math reasoning, are generally more impaired than rote numerical skills. Despite failing to replicate this finding in the current study, overall, children's WIAT-II scores did trend in the direction of weaker performance on subtests requiring reasoning and abstraction. As seen in Table 1, WIAT-II word reading and numerical operations scores fell within the low average range, whereas reading comprehension and math reasoning scores fell within the borderline classification, indicating greater impairment. Math reasoning may be more impaired than numerical computation ability in individuals with ASD because of the greater need to use a 'linguistic, varied, and conceptually demanding' approach to problem solving (Jones et al., 2009, p. 726). As such, it is likely that math deficits in ASD reflect an underlying difficulty with comprehension of linguistic information and inferential processing as well as impaired working memory.

With respect to the second aim of the current study, which sought to confirm associations between cognitive and social functioning and concurrent academic attainment, results were largely consistent with hypothesized findings, in that level of intellectual functioning and, to an extent, adaptive social skills, at ages eight to 10 years significantly predicted concurrent academic achievement. Specifically, the results of concurrent regression analyses indicated that children with higher school-age functional communication abilities were expected to have higher reading skills in the domains of both basic word reading and reading comprehension. Additionally, individuals with greater ASD severity tended to have lower academic abilities, particularly within the skills of reading comprehension, numerical operations, and math reasoning. However, overall, concurrent IQ accounted for significant variance in academic achievement (i.e., in word reading, numerical operations, and math reasoning abilities) above and beyond that explained by adaptive and ASD symptom constructs. This finding is largely consistent with previous literature suggesting that FSIQ is the best predictor of concurrent academic ability.

Overall, the results of preschool regression analyses suggested that early cognitive, adaptive, and social functioning accounts for a significant proportion of variance (i.e., 33 to 73 percent) in school-age academic ability. Despite this, exploration of regression weights indicated that it may be difficult to specifically predict school-age achievement, particularly within the domains of word reading, numerical operations, and reading comprehension, from functioning at the approximate ages of two and four years. Moreover, it appears that the variance in school-age academic ability explained by preschool cognitive, adaptive, and ASD symptom constructs may be largely subsumed by school-age IQ. However, several interesting variables emerged as significant in preschool prediction analyses, with potentially important implications for early intervention in ASD. The fact that these variables were largely subsumed under school-age IQ is in line with Dennis et al.'s (2009) argument that FSIQ combines 'genetic, biological, neural, cognitive, educational, and experiential' constructs, thereby necessarily subsuming heterogeneous and often relevant variance (p. 341). To use IQ as a covariate, or to adjust for IQ in a regression model, then, may lead to an underestimation of the contributions of specific cognitive variables that go into both IQ and the outcome of interest (Dennis et al., 2009); as such, we believe it is valuable to interpret notable preschool variables, regardless of the impact of school-age IQ on the statistical significance of findings.

Several important themes, particularly relating to early language and motor functioning, emerged from preschool prediction analyses. Preschool verbal abilities significantly predicted reading comprehension ability at T3. Of particular note, functional communication skills at age four years accounted for significant variance in school-age reading comprehension, even after controlling for T3 cognitive level. Contrary to our hypotheses, though, social skills and level of ASD symptomatology seen at ages two and four years did not significantly predict later academic achievement. Although the observed associations diminished once T3 IQ was added to regression models, results also supported the reported link between motor functioning and academic achievement. Specifically, consistent with hypothesized findings, fine motor skills at two years significantly predicted math reasoning ability between the ages of eight and 10 years, and four-year-old fine motor abilities predicted school-age numerical operations scores. From a simplistic standpoint, the association between motor and academic functioning might be explained by the fact that most academic tasks involve the use of fine motor skills. That is, performance of basic written computations (i.e., WIAT-II numerical operations) requires graphomotor skills as well as hand-eye coordination to grasp a writing utensil and form letters and numbers correctly and in sequence. Mathematical problem solving tasks (i.e., WIAT-II math reasoning), too, generally involve tracking of visual information, which requires fine motor control of eye movements. However, the motor-achievement linkage appears to be much more complex, with both skills potentially relying on a shared manipulation of internal neural representations (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010; Ito, 2005). Ito (2005) suggests that individuals use a model of the body in the external environment to predict and execute desired motor actions; similarly, for certain academic skills, particularly those relating to mathematical ability, the internal representation may be abstract symbols which are then manipulated toward a solution. As infants and toddlers motorically explore their environment and develop early motor skills, it is likely that they build a neural infrastructure that later allows them to execute simple and complex cognitive and academic tasks (Grissmer et al., 2010). Thus, foundational motor skills acquired early in development appear to be necessary for successful attainment of mathematical abilities by middle childhood.

Taken together, the results of the current study have implications for early intervention and educational strategies in children with ASD. Although achievement profiles in ASD are highly variable, it is necessary for teachers and intervention providers to recognize well-established deficits in skills requiring inference and reasoning, including reading comprehension and math problem solving. Increasing awareness of the academic profile in ASD would allow education professionals working with this population to teach to students' strengths and either bypass or bolster weaknesses. That is, individuals with ASD may benefit from rote learning, repetition, visual representations, and hands-on instruction to build basic academic skills (i.e., decoding, vocabulary, arithmetic), whereas more specialized instruction in inferential and pragmatic language use might encourage development of weaker areas (i.e., reading comprehension). Furthermore, results of preschool predictor analyses suggest that it may be possible to meaningfully impact later academic functioning by intervening on language and motor skills in the preschool period, thereby establishing foundational skills that may then translate into improved school-age academic performance.

Limitations and Future Directions

Due to several limitations, the results of the current study should be interpreted and generalized with some caution. Most significantly, the sample on which these findings were based was small, and a power analysis revealed that only large effects would likely be detected; as such, these results may have failed to identify true associations of smaller effect size. Although it would be difficult to collect a large sample of children who were diagnosed with ASD early in development and subsequently followed and re-evaluated throughout preschool and middle childhood, doing so would allow for more definitive and specific conclusions about the ability to predict school-age academic functioning from cognitive, adaptive, and social constructs seen in the preschool period. Furthermore, it is possible that a larger sample would allow the math reasoning-numerical operations difference to reach statistical significance.

Additionally, based on the recruitment area of the current study, this sample was predominately White (85 percent). Therefore, the results of the present study may not generalize well to a broader ASD population, both in regards to geographical location and racial identity. Future studies should attempt to replicate these findings in a more racially and geographically diverse sample. Furthermore, although the current study contributes to the literature on academic achievement in ASD by including a functionally diverse sample of children with ASD, this heterogeneity, particularly within a small sample size, prevented exploration of potential patterns of impairment and prediction unique to specific subgroups. As such, future research should focus on examining academic attainment and early predictors of later academic functioning in well-defined subgroups of various functional levels, particularly lower-functioning individuals with ASD.

Finally, because of the original goal of the larger study (i.e., to validate an ASD-specific screening tool) of which the current study was one component, there was no readily available comparison group of TD individuals. Thus, the results of the present study may not be unique to individuals with ASD. Future studies should also investigate the development of academic abilities in other groups, including TD children and children with other neurodevelopmental disorders, to determine the extent to which specific patterns of early prediction observed in the present study are unique to ASD.

To our knowledge, this is the first study to examine preschool predictors of academic achievement in a well-characterized sample of children with a history of ASD. Future research should build on current study findings by assessing the impact of early intervention, particularly services targeting language and motor skills, on later academic ability in the domains of reading and mathematics. Targeted intervention during the preschool period may also influence later need for educational intervention, specifically type and extent of specialized instruction. As the educational climate for children with ASD continues to shift, with more individuals being placed in mainstream, or general education, classrooms with their TD peers, it is increasingly necessary to improve our understanding of achievement in individuals with ASD and, more importantly, to develop and refine strategies to encourage academic success in this population.

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Table 1

Participant Characteristics

Variable	*n*	*M*	*SD*	Range
Cognitive constructs				
T1 MSEL receptive language	24	37.7	17.2	12.0 – 84.9
T1 MSEL expressive language	24	40.6	16.8	10.5 – 77.8
T1 MSEL visual reception	23	61.8	18.3	19.2 – 92.0
T1 MSEL fine motor	24	68.5	13.2	44.2 – 95.2
T2 MSEL receptive language	22	53.8	27.1	19.5 – 118.4
T2 MSEL expressive language	23	51.9	26.7	15.7 – 89.5
T2 MSEL visual reception	23	64.8	31.0	24.8 – 131.0
T2 MSEL fine motor	23	61.1	22.5	17.3 – 93.3
T3 DAS-II GCA	24	80.0	28.7	25 – 130
Adaptive constructs				
T1 VABS communication	26	63.9	5.5	55 – 78
T1 VABS socialization	26	66.4	6.3	56 – 77
T2 VABS communication	26	63.6	15.1	47 – 93
T2 VABS socialization	26	61.6	10.3	51 – 90
T3 VABS-II communication	25	75.2	15.6	53 – 108
T3 VABS-II socialization	25	70.1	17.6	45 – 129
ASD symptom constructs				
T1 ADOS CSS	25	7.0	1.9	4 – 10
T1 CARS total	25	33.3	3.8	27 – 40
T2 ADOS CSS	26	6.7	1.6	3 – 10
T2 CARS total	25	32.7	4.9	24.5 – 44.5
T3 ADOS CSS	26	6.9	2.1	1 – 10
T3 CARS total	23	30.3	6.0	19 – 41
Academic achievement constructs				
T3 WIAT-II word reading	26	87.7	25.7	40 – 121
T3 WIAT-II reading comprehension	21	74.3	26.7	40 – 120
T3 WIAT-II numerical operations	22	85.1	30.3	40 – 147
T3 WIAT-II math reasoning	20	78.6	34.0	40 – 140

Note: Total $N = 26$. Means and standard deviations presented are based on MSEL developmental quotient (DQ) scores ($M = 100$, $SD = 15$); DAS-II, VABS, VABS-II, and WIAT-II standard scores ($M = 100$, $SD = 15$); ADOS calibrated severity scores (CSS) (non-spectrum = 1 – 3, ASD = 4 – 5, AD = 6 – 10); and CARS total scores (ASD cut-off = 25.5).

Table 2

Measures by Evaluation Time Point and Construct

	Evaluation Time Point	
Construct	Times 1 and 2	Time 3
Cognitive ability	MSEL	DAS-II
Adaptive functioning	VABS	VABS-II
ASD symptoms	ADOS	ADOS
	CARS	CARS
Academic achievement	-	WIAT-II

Note: MSEL = Mullen Scales of Early Learning; DAS-II = Differential Ability Scales, Second Edition; VABS = Vineland Adaptive Behavior Scales; VABS-II = VABS, Second Edition; ADOS = Autism Diagnostic Observation Schedule – Generic; CARS = Childhood Autism Rating Scale; WIAT-II = Wechsler Individual Achievement Test, Second Edition

Table 3

Summary of Concurrent Multiple Regression Analyses Predicting Word Reading

	Model 1a			Model 1b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T3 VABS-II communication	173.9	51.9	.729**	94.3	55.3	.404
T3 CARS total	22.8	141.4	.035	96.2	138.3	.159
T3 DAS-II GCA				84.1	32.9	.561**
R^2		.498			.599	
F		9.425**			7.956**	

Note: **p* < .05; ***p* < .01; *B* = unstandardized coefficient, *β* = standardized coefficient

Table 4

Summary of Concurrent Multiple Regression Analyses Predicting Reading Comprehension

	Model 2a			Model 2b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T3 VABS-II communication	.010	.004	.443*	.008	.005	.341
T3 CARS total	-.025	.011	-.451*	-.019	.012	-.337
T3 DAS-II GCA				.004	.003	.302
R^2		.664			.712	
F		14.801**			10.705**	

Note: *$p < .05$; **$p < .01$; *B* = unstandardized coefficient, *β* = standardized coefficient

Table 5

Summary of Concurrent Multiple Regression Analyses Predicting Numerical Operations

	Model 3a			Model 3b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T3 CARS total	-2.640	.923	-.559*	-.379	.793	-.079
T3 DAS-II GCA				.969	.200	.799**
R^2		.312			.720	
F		8.180*			20.619**	

Note: **p* < .05; ***p* < .01; *B* = unstandardized coefficient, *β* = standardized coefficient

Table 6

Summary of Concurrent Multiple Regression Analyses Predicting Math Reasoning

	Model 4a		Model 4b	
Variable	*B*	SE_B	*B*	SE_B
T3 VABS-II communication	.595	.695	-.126	.532
T3 CARS total	-2.804*	1.230	-1.220	1.114
T3 DAS-II GCA			1.049**	.331
R^2	.454		.807	
Wald X^2	13.43**		36.66**	

Note: *$p < .05$; **$p < .01$; *B* = unstandardized coefficient

Table 7

Summary of Preschool Multiple Regression Analyses Predicting Word Reading

	Model 5a			Model 5b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T2 VABS communication	92.2	64.8	.360	14.4	65.2	.060
T2 CARS total	-207.9	203.0	-.259	-82.7	181.1	-.112
T3 DAS-II GCA				78.6	32.2	.583*
R^2		.332			.498	
F		5.475*			6.292**	

Note: *$p < .05$; **$p < .01$; *B* = unstandardized coefficient, *β* = standardized coefficient

Table 8

Summary of Preschool Multiple Regression Analyses Predicting Reading Comprehension

	Model 6a			Model 6b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T1 MSEL verbal ability	.014	.004	.605**	.005	.004	.230
T3 DAS-II GCA				.009	.002	.660**
R^2		.366			.657	
F		9.822**			14.385**	
	Model 7a			Model 7b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T2 MSEL verbal ability	.008	.003	.551*	.005	.004	.339
T2 CARS total	-.032	.021	-.340	-.031	.023	-.339
T3 DAS-II GCA				.004	.003	.279
R^2		.714			.741	
F		17.474**			11.442**	
	Model 7c			Model 7d		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T2 VABS communication	.017	.004	.757**	.013	.005	.575*
T2 CARS total	-.009	.013	-.132	-.007	.013	-.102
T3 DAS-II GCA				.004	.002	.274
R^2		.731			.761	
F		23.142**			15.890**	

Note: *$p < .05$; **$p < .01$; *B* = unstandardized coefficient, *β* = standardized coefficient

Table 9

Summary of Preschool Multiple Regression Analyses Predicting Numerical Operations

	Model 8					
Variable	*B*	SE_B	*β*			
T1 MSEL fine motor	.942	.541	.391			
T1 CARS total	-1.9	2.0	-.213			
R^2		.234				
F		2.450				
	Model 9a			Model 9b		
Variable	*B*	SE_B	*β*	*B*	SE_B	*β*
T2 MSEL fine motor	.829	.312	.636*	-.069	.371	-.052
T2 CARS total	-.533	1.8	-.071	.135	1.4	.018
T3 DAS-II GCA				.981	.288	.895**
R^2		.469			.709	
F		7.057**			11.372**	

Note: *$p < .05$; **$p < .01$; *B* = unstandardized coefficient, *β* = standardized coefficient

Table 10

Summary of Preschool Multiple Regression Analyses Predicting Math Reasoning

	Model 10a		Model 10b	
Variable	*B*	SE_B	*B*	SE_B
T1 MSEL fine motor	1.431*	.625	.100	.494
T1 CARS total	-1.425	2.389	.524	1.787
T3 DAS-II GCA			1.040**	.247
R^2	.336		.772	
Wald X^2	8.25*		41.09**	
	Model 11a		Model 11b	
Variable	*B*	SE_B	*B*	SE_B
T2 MSEL fine motor	.933	.556	-.173	.405
T2 VABS communication	-.028	1.227	-.867	1.159
T2 CARS total	-1.393	2.759	-2.263	2.665
T3 DAS-II GCA			1.261**	.509
R^2	.512		.785	
Wald X^2	22.33**		18.10**	

Note: *p < .05; **p < .01; *B* = unstandardized coefficient