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Preschool language variation, growth, and predictors in children on the autism spectrum

Susan E. Weismer¹ and Sara Kover^{1,2}

¹Department of Communication Sciences & Disorders and Waisman Center, University of Wisconsin-Madison, WI, United States

²Department of Speech and Hearing Sciences, University of Washington, Seattle, WA, United States

Abstract

Background—There is wide variation in language abilities among young children with autism spectrum disorder (ASD), with some toddlers developing age-appropriate language while others remain minimally verbal after age 5. Conflicting findings exist regarding predictors of language outcomes in ASD and various methodological issues limit the conclusions that can be drawn about factors associated with positive language growth that could provide insights into more effective intervention approaches for increasing communication skills.

Methods—Language development was investigated in 129 children with ASD participating in four assessments from mean age 2½ years (Visit 1) through 5½ years (Visit 4). Language ability was measured by a clinician-administered test of comprehension and production. Hierarchical linear modeling was used to identify predictors of language ability. Stability of language status was examined in subgroups of Preverbal versus Verbal children identified at Visit 1. Discriminant function analysis was used to classify another subset of cases according to Low Language (minimally verbal) versus High Language outcome at Visit 4.

Results—ASD severity was a significant predictor of growth in both language comprehension and production during the preschool period, while cognition predicted growth in production. For the highest and lowest language performers at Visit 4, cognition, maternal education, and response to joint attention correctly classified over 80% of total cases. The vast majority of children who were preverbal at 2½ years attained some level of verbal skills by 5½ years.

Conclusions—Findings indicate that it is possible, by 2½ years, to predict language growth for children with ASD across the preschool years and identify factors that discriminate between children who remain minimally verbal at 5½ years from those with high language proficiency. Results suggest that early intervention focused on reducing core ASD symptoms may also be important for facilitating language development in young children with ASD.

Correspondence: Susan E. Weismer, Department of Communication Science & Disorders and the Waisman Center, University of Wisconsin-Madison, 1500 Highland Avenue, Madison, WI 53705; ellisweismer@wisc.edu.

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Keywords

Language growth; autism spectrum disorders; preverbal; minimally verbal; language predictors

Introduction

Developing spoken language by 5 years of age is considered an important milestone for children with autism spectrum disorders (ASD) since acquiring this benchmark is associated with improved long-term outcomes (Tager-Flusberg & Kasari, 2013). While most children with ASD have difficulties with pragmatic aspects of language related to core deficits in social communication, structural language (i.e., semantics, syntax, morphology, phonology) varies widely (Pickles, Anderson, & Lord, 2014). It has been proposed that there are subgroups of children on the autism spectrum with and without language impairment (Boucher, 2012), ranging from children who remain minimally verbal at school onset to those with high language proficiency. Identifying the factors that lead to this dramatic variation in language development is critical for understanding ASD phenotypes and planning targeted interventions.

Various child characteristics and environmental variables have been examined as possible predictors of language outcomes in ASD. Prior research has demonstrated that nonverbal cognition is a positive predictor of language abilities in children with ASD (Anderson et al., 2007; Thurm, Lord, Lee, & Newschaffer, 2007; Thurm, Manwaring, Swineford, & Farmer, 2014). Anderson and colleagues (2007) reported that nonverbal IQ was a strong positive predictor of language growth from age 2 through 9 years in a large sample of children with ASD who had varying levels of language proficiency. Nonverbal cognition was a robust predictor of language level in a longitudinal study focused on minimally verbal children with ASD (Thurm et al., 2014). Similarly, a retrospective study by Wodka, Mathy, and Kalb (2013) employed data from a large sample (N=535) of minimally verbal children (Simons Simplex Collection) who were at least 8 years old and who had not acquired phrase/fluent speech until 4 years of age or later. Determination of language level was primarily made based on which ADOS module was administered at the initial assessment. Higher nonverbal IQ (along with better social skills, and younger age of acquisition) was significantly associated with acquisition of phrase/fluent speech. While there are relatively few negative findings, a small-sample study found that low versus high nonverbal IQ at 20 months was not significantly associated with language outcomes at 42 months for children with autism or pervasive developmental disorder (PDD) (Charman et al., 2003).

Severity of ASD symptoms has been investigated as a possible predictor of language development. For instance, Charman et al. (2003) found that preschool children with a diagnosis of autism had relatively poorer language outcomes at a subsequent assessment (2–3 years later) than children with PDD-Not Otherwise Specified (PDD-NOS). Charman et al. (2005) reported that greater autism symptom severity in restricted and repetitive behaviors (RRB) and socialization at 3 years was associated with lower language abilities at 7 years. Thurm et al. (2014) used calibrated ADOS domain scores (Hus, Gotham, & Lord, 2012) to examine the role of ASD symptom severity in young children who had not yet developed

spoken language. They found that change in calibrated social affect (SA) domain of the ADOS, but not RRB, predicted language outcomes one year later in minimally verbal children with ASD; however, when nonverbal cognition was added to the model SA severity no longer predicted expressive language.

Joint attention has been found to be a predictor of language outcome in ASD (Anderson et al., 2007; Charman et al., 2003; Sigman & McGovern, 2005). For example, Charman et al. (2003) reported that an experimental measure of joint attention (gaze switching) was predictive of receptive language outcomes such that high joint attention at 20 months was associated with higher language comprehension skills at 42 months. In the study by Anderson and colleagues (2007) joint attention was a significant predictor of language change; however, it was not found to be a predictor of rate of communication development in a study by Toth, Munson, Meltzoff, and Dawson (2006). Distinct forms of joint attention involving initiation of joint attention (IJA) versus response to joint attention (RJA) appear to be associated with different developmental abilities and there are conflicting findings about which component of joint attention is most closely associated with language skills in ASD (Pickard & Ingersoll, 2014).

Environmental variables, including family socio-economic status (SES) and the impact of intervention, have also been shown to play a role in language development in children with ASD. Although it is typical to distinguish between variables within the child versus those outside the child for the sake of discussion, in reality child characteristics and environmental factors are often intertwined. Research on variation in typical language development has clearly established the importance of SES with respect to the linguistic input that children receive and the impact of that input on children's language development (Hart & Risley, 2003). Similarly, Warlaumont, Richards, Gilkerson, and Oller (2014) recently reported that maternal education was related to overall levels and specific patterns of parent-child interactions in typically developing and ASD groups. These investigators provided evidence for a weakened 'social feedback loop' in which young children with ASD produced a relatively lower proportion of speech-like vocalizations than typically developing children and maternal responses were less contingent on whether or not the vocalizations were speech related. Anderson et al. (2007) found that caregiver education was a key factor in increasing the odds that a child with ASD was assigned to the most improved versus least improved language group. On the other hand, SES was not found to be a significant predictor of language outcome in preschoolers with ASD in a study by Stone and Yoder (2001).

Most young children on the autism spectrum receive various types of interventions which are intended to promote development. Stone and Yoder (2001) found that amount of speech/language treatment predicted language outcomes in young children with ASD. In a large-scale study, Mazurek, Kanne, and Miles (2012) examined retrospective treatment data from the Simons Simplex Collection as a predictor of change in social communication. Results indicated that increased ASD treatment intensity predicted improvement, with response to treatment being best among individuals with relatively higher nonverbal IQ. Various treatment studies have demonstrated the interplay between ASD severity and/or cognitive level with intervention outcomes, including development in language and communication

skills (Ben-Itzhak, Watson, & Zachor, 2014; Zachor & Ben-Itzhak, 2010). For non-treatment studies that attempt to identify predictors of language outcomes it can be extremely challenging to disentangle child characteristics such as ASD severity and cognitive level from the influence of intervention since children with more severe symptoms and/or cognitive impairment are much more likely to have received the most intervention.

Most research on language outcomes in ASD is restricted to examinations of levels of functioning at one or more follow-up assessments. However, other studies have provided insight into predictors of language growth trajectories and varying language profiles through the use of growth curve modeling techniques (Anderson et al., 2007; Bopp, Mirenda, & Zumbo, 2009; Pickles et al., 2014; Tek, Mesite, Fein, & Naigles, 2014; Toth et al., 2006). Toth et al. (2006) found that rate of communication development across the preschool and early school-age period in children with ASD was predicted by a combination of deferred imitation and toy play skills, but not joint attention. On the other hand, results by Anderson and colleagues (2007) indicated that nonverbal IQ and joint attention were significant predictors of language growth in children with ASD from age 2 to 9 years. A recent investigation by Pickles et al. (2014) extended the examination of language growth reported by Anderson et al. (2007) to 19 years. Using multivariate latent growth curve modeling, this study identified seven classes of language development based on parent report of language comprehension and production abilities from a measure of adaptive behavior. Results from Pickles et al. highlight the relative stability of language development in ASD beyond six years of age and point to the preschool years as a period of considerable variation in language change. Findings by Tek and colleagues (2014) reinforce the extreme variability in structural language abilities in preschool children with ASD. These investigators used individual growth curve analyses across a 1½ year period to examine various grammatical measures based on spontaneous language samples from typically developing (TD) toddlers ($n=18$) and two subgroups of young children with ASD, high-verbal ($n=8$) and low-verbal ($n=9$). The ASD-high verbal subgroup displayed increases on most language measures across time with growth trajectories that were quite similar to the TD group, whereas the ASD low-verbal subgroup performed poorly on most of the language measures and demonstrated few significant grammatical gains.

In summary, prior research has established that there is wide individual variability in structural language abilities in children with ASD during the preschool period (Pickles et al., 2014). Most studies of language development have understandably focused on verbal children, though there are a few recent studies of language development that have focused exclusively on minimally verbal children (Paul, Campbell, Gilbert, & Tsiouri, 2013; Thurm et al., 2014). Some investigations of predictors of language outcomes have only examined expressive language skills (Smith, Mirenda, Zaidman-Zait, 2007; Tek et al., 2014) or combined comprehension and production into a global language measure (Anderson et al., 2007; Toth et al., 2006). In light of research indicating atypical comprehension-production profiles in young children with ASD (Ellis Weismer, Lord, & Esler, 2010; Hudry et al., 2010), it is critical to examine these processes separately. Many studies of predictors of language outcomes involve a single follow-up assessment (Charman et al., 2003; Paul, Chawarska, Cicchetti, & Volkmar, 2008; Thurm et al., 2014) or only provide information

about language outcome *levels* at multiple follow-up assessments (Charman et al., 2005; Sigman & McGovern, 2005), rather than factors related to positive *growth* trajectories over development. With two exceptions (Bopp et al., 2009; Tek et al., 2014), studies that have employed growth curve modeling techniques to examine language development in ASD have relied on parent report of language skills gleaned from general developmental measures (Pickles et al., 2014; Toth et al., 2006) or used a composite of different measures across development (Anderson et al., 2007) rather than using a measure designed specifically to assess the primary construct of interest, namely, language abilities. In a study by Ellis Weismer et al. (2010) the specific measure of language abilities used by Pickles et al. (2014) and Toth et al. (2006) for their growth curve analyses was found to reveal a different pattern of relationship between language comprehension and production in young children with ASD than two other measures of language development and was less highly correlated with the alternate measures than the other assessment instruments. The small-sample study by Tek et al. (2014) used specific grammatical measures derived from language samples but focused exclusively on expressive language growth. Although the study by Bopp et al. (2009) used a clinician-administered language measure, all predictor variables were based on parent report and the data were drawn from intervention studies that were not designed with the intent of exploring predictors of language growth.

The present study addresses each of the shortcomings of prior studies focused on predicting language growth through the use of a prospective, longitudinal design in which a well-defined research sample of children with ASD was evaluated at four points throughout the preschool period. *Both language comprehension and production were assessed using the same clinician-administered test of language development across time in a sample with wide variation in language functioning*, ranging from those who remained minimally verbal after 5 years of age to those who had high normal structural language. This is the first study to use ADOS calibrated severity scores to examine the role of ASD symptom severity relative to cognition and other potential predictors of growth in both language comprehension and production. These scores have been designed to provide a metric of severity that mitigates the secondary influences of cognitive and language abilities in the estimation of ASD symptoms. Another unique contribution of the current study is that it examines the extreme upper range of language abilities in young children with ASD and seeks to identify variables that distinguish between those children with very positive language outcomes (who retain their ASD diagnosis) from children who remain minimally verbal.

The purposes of the present study were to: (1) examine predictors of early language comprehension and production levels in toddlers with ASD and predictors of their language growth trajectories across the preschool period; (2) identify factors that discriminate between subgroups of children with low language (minimally verbal) outcomes versus high language outcomes at school entry; and (3) assess individual variation with respect to the stability of preverbal language status at 2½ years across the preschool period.

Methods

Participants

Participants in this study consisted of 129 children (112 males, 17 females) with ASD who were enrolled in a longitudinal investigation of language development. The sample was recruited from the community through various means and was assessed by an experienced team of psychologists and speech-language pathologists, as described in more detail elsewhere (e.g., Venker, Ray-Subramanian, Bolt, & Ellis Weismer, 2014). Written informed consent was obtained from parents prior to their child's enrollment in this study, which was approved by the Institutional Review Board at the University of Wisconsin-Madison. Exclusionary criteria included chromosomal abnormalities, cerebral palsy, prematurity, multiple birth, bilingualism, and seizure disorder. Inclusionary criteria consisted of ASD diagnoses based on DSM IV-TR diagnostic criteria (APA, 2000) at each of multiple assessments conducted at a mean age (months) of 30.8 ± 4.1 (Visit 1), 44.2 ± 4.1 (Visit 2), 56.9 ± 4.7 (Visit 3), and 66.6 ± 4.9 (Visit 4). This ASD sample was recruited in two cohorts and only one of the cohorts was randomly selected to be assessed at Visit 3 whereas all children were assessed at the other three visits. Therefore, the sample sizes across visits were as follows: Visit 1=127; Visit 2=117; Visit 3=64, Visit 4=103 (2 children of the 129 total only participated in Visits 2, 3, and 4). Data from the entire sample was used to address research question 1.

In order to address question 2, data from 31 children were included in the analysis of Low Language ($n=16$) versus High Language ($n=15$) subgroups at Visit 4. We targeted roughly 15% at each end of the distribution (High Language $15/103=14.5\%$; Low Language $16/103=15.5\%$). The High Language subgroup at 5½ years was determined by selecting 15 children with the highest PLS total standard scores (114–131). High language status was confirmed by the fact that these children had normal range PPVT-4 scores, and at least phrase speech based on administration of ADOS Module 2, 5+ years (4/15 children) or fluent speech based on administration of ADOS Module 3 (11/15 children). There were 26 children who obtained the lowest possible standard score of 50 on the PLS at 5½ years so the Low Language subgroup was identified through a combination of language level from the ADOS and PLS scores. Only 11 children from the sample had received ADOS Module 1, No Words at the final visit (5½ years). All of those children were included in the Low Language subgroup even though one child had obtained a standard score of 54 on the PLS. Of the remaining 16 children who had scores of 50 on the PLS, we selected 5 additional children who had received ADOS Module 1, Words who had the lowest reported number of words on the ADOS (5–10 words).

For question 3, two subgroups of children were identified based on the version of the ADOS/ADOS-T module that they were administered at Visit 1. The Verbal subgroup ($n=61$) received: Toddler, words; Module 1, words; or Module 2, under 5 years. The Preverbal subgroup ($n=66$) received: Toddler, no words or Module 1, no words.

Measures

The Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 2002) and ADOS-Toddler module (ADOS-T; Luyster et al., 2009) are semi-structured observational tools designed to be used in evaluation of ASD. The Autism Diagnostic Interview, Revised (ADI-R, Rutter, DiLavore, & Risi, 2003) is a parent interview instrument that provides information regarding reciprocal social interaction, communication, and restricted repetitive interests and behaviors. These two measures along with expert clinical judgment were used to determine ASD diagnosis. Scores from the ADOS were used to compute autism calibrated severity scores (CSS; Gotham, Pickles, & Lord, 2009), with Module 1 algorithms used for the corresponding items on the Toddler Module.

The Preschool Language Scale-4 (PLS-4; Zimmerman, Steiner, & Pond, 2002) is comprised of two core subscales: Auditory Comprehension (AC) and Expressive Communication (EC), which assess vocabulary and grammatical abilities. Receptive vocabulary was also assessed at Visit 4 using the Peabody Picture Vocabulary Test-4 (PPVT-4; Dunn & Dunn, 2007); PPVT-4 standard scores were used along with PLS-4 scores to establish the Low versus High Language outcome subgroups.

The Cognitive scale of the Bayley Scales of Infant and Toddler Development-III (Bayley-III; Bayley, 2006) was used to evaluate children's cognitive skills. Socialization domain standard scores from the Survey Interview Form of the Vineland Adaptive Behavior Scales-II (Vineland-II; Sparrow et al., 2005) were used to measure participants' social skills. Joint attention was measured using the Early Social Communication Scales (ESCS; Mundy et al., 2003) to evaluate number of initiations of joint attention (IJA) and proportion of responses to joint attention (RJA). Socioeconomic status (SES) was indexed by number of years of maternal education via self-report on a background form. Parent questionnaires were used to obtain measures of children's treatment history, including average hours per month and cumulative number of months of Birth-to-3 speech/language therapy and average hours per month and cumulative number of months of ASD intervention. At Visit 4, the majority of children were reported to be receiving individual ASD intervention that primarily involved ABA (applied behavior analysis) treatment, with a substantial number of children also using PECS (Picture Exchange Communication System) and Social Stories.

Statistical analysis

The analysis for question 1 consisted of hierarchical linear modeling (HLM) using HLM 7 Hierarchical Linear and Nonlinear Modeling software (Raudenbush, Bryk, & Congdon, 2010). A random slope and intercept model was fit to language production (PLS-EC = Preschool Language Scale-4, Expressive Communication) and comprehension (PLS-AC = Preschool Language Scale-4, Auditory Comprehension) standard scores across four time points (Visit 1–4). Predictors were all comprised of Visit 1 (V1) data with the exception of the treatment variable which was derived from Visit 4 data. SES was indexed by number of years of maternal education, COG (cognition) was measured via the cognitive composite score from the Bayley-III, SOCIAL skills were indexed by the socialization domain standard score from the Vineland, CSS refers to calibrated (ASD) severity scores derived from the ADOS/ADOS-T, and RJA (response to joint attention) was measured by the ESCS. The

following *final* models incorporating significant individual predictors were used to separately analyze growth in comprehension and production. These formulas only include the predictors that were significant when tested individually; therefore, neither IJA nor treatment was included in the final models because they were not significant individual predictors for the entire sample.

Level-1 Model

$$PLS_EC_{ij} \text{ or } PLS_AC_{ij} = \beta_{0j} + \beta_{1j} * (TIME_{ij}) + r_{ij}$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * (SES_j) + \gamma_{02} * (V1COG_j) + \gamma_{03} * (V1SOCIAL_j) + \gamma_{04} * (V1CSS_j) + \gamma_{05} * (V1RJA_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} * (SES_j) + \gamma_{12} * (V1COG_j) + \gamma_{13} * (V1SOCIAL_j) + \gamma_{14} * (V1CSS_j) + \gamma_{15} * (V1RJA_j) + u_{1j}$$

For question 2, a discriminant function analysis was employed with a subset of the data using SPSS Version 21.0 (IBM Corp., 2012). A limit of 3 discriminating predictors was used within a given model based on a combination of considerations regarding inter-correlations among potential predictor variables and the small sample sizes of the subgroups. To address question 3, descriptive analyses were computed to assess the proportion of children in the Verbal and Preverbal subgroups at Visit 1 who were minimally verbal at Visit 4 (i.e., fell into the Low Language subgroup).

Results

Descriptive statistics for the entire sample and the Preverbal versus Verbal subgroups at Visit 1 and subgroups with Low Language versus High Language outcomes at Visit 4 are presented in Table 1. Children within the full sample exhibited considerable variability in ASD severity, cognition, joint attention, social skills, maternal education, amount of intervention, and language abilities and the subgroups differed significantly on a number of these domains.

When entered individually into the HLM model, cognition, socialization, RJA, maternal education, and ASD severity were each identified as significant predictors of the slope and/or intercept of comprehension and/or production. Treatment was not a significant predictor of either intercept or slope for language comprehension or production, nor was IJA. Tables 2 and 3 provide a summary of the statistical results of the HLM analysis for language comprehension (PLS-AC) and production (PLS-EC), respectively, when all five significant predictors were entered into the model simultaneously. There was a significant positive correlation between the residual random intercept and slope for comprehension ($r = .58$) and production ($r = .73$), meaning that children with better language at age 2½ showed increased rate of language growth controlling for the effects of the five predictors. Language

comprehension level at Visit 1 (intercept) was significantly predicted by cognition ($p<.001$). Language production level at Visit 1 (intercept) was predicted by cognition ($p<.001$), social skills ($p=.002$), autism severity ($p=.009$), maternal education ($p=.022$), and RJA ($p=.032$). ASD severity at Visit 1 was a significant predictor of change across time (slope) for language comprehension ($p=.027$) and production ($p<.001$). Additionally, cognition at Visit 1 was a significant predictor of productive language growth (slope; $p<.001$).

Discriminant function analyses were used to classify a subset of cases according to Low versus High Language ability at Visit 4. The intent behind this analysis was to identify early variables that could discriminate children with language outcomes at the upper and lower ends of the distribution. The same predictors considered in the HLM analyses of the full sample were examined in these analyses with the exception of treatment. Treatment was omitted as a classification variable because there was a significant, negative correlation between treatment and language abilities for the Low/High Language outcome subgroups which was assumed to be due to the way ASD services were accessed in Wisconsin (those with most severe impairments received more services). As summarized in Table 1, the Low Language subgroup had significantly more hours per month of ASD treatment ($p=.012$) and more total months of ASD treatment ($p=.017$) than the High Language subgroup. The best 3-predictor model included nonverbal cognition, SES, and RJA and correctly classified 92.3% of valid cases: 85.7% of high language cases and 100% of low language cases. Cognition alone correctly classified 85.7% of cases: 92.3% for low language and 80.0% for high language.

As described in the Participant section, the High and Low Language outcome subgroups were not just a random sample of a larger sample of children with equivalently high or low language abilities. That is, these subgroups comprised the top/bottom 15% of the sample. Given this fact and the relatively small size of the groups, we elected to employ a 'leave-one-out' cross-validation approach for the discriminant function analysis. Cross validation using SPSS was completed in which each case was classified by the functions derived from all cases other than that case. Eighty-one percent of cross-validated grouped cases were correctly classified (79% High Language, 83% Low Language). This validation indicates that these three variables (cognition, maternal education, and RJA) do a reasonable job of classifying language outcomes at the upper and lower end of the distribution.

Histograms of the data from the discriminant function analyses are presented in Figure 1 for cognition, maternal education, and RJA, respectively. As illustrated in Figure 1A, there was relatively limited overlap in the Low versus High Language subgroups with respect to early cognition, such that none of the High Language children had cognitive composite scores on the Bayley-III that fell outside of the typical range (80–120) whereas roughly half of the Low Language children attained cognitive scores that fell in the intellectual disabilities range (<70). There was more overlap in maternal education across the two language outcome subgroups as seen in Figure 1B; however, more than half of the mothers of the High Language children had at least an undergraduate college degree (16–18 years) whereas half of the mothers of the Low Language children had at most a high school education (11–12 years). Figure 1C depicts that there was a good deal of overlap in RJA abilities at Visit 1 for the two language outcome subgroups, with the primary discriminator being the absence

of any early RJA in more children in the Low Language (relative to High Language) subgroup.

Descriptive data were examined to assess the degree of stability in language categorizations across the preschool period. At Visit 1 (2½ years) approximately half of the sample was designated as Preverbal ($n=66$) and the remainder were Verbal ($n=61$), as operationally defined in the Participant section. All of the children in the Low Verbal subgroup (16/16) at Visit 4 (5½ years) had been in the Preverbal subgroup at Visit 1. The majority of children (12/15) in the Visit 4 High Language subgroup had been in the Verbal subgroup at Visit 1; however, a subset of children (3/15) with High Language at Visit 4 was Preverbal at Visit 1. Viewed from another perspective, only 16 of 66 (24%) children who were preverbal at Visit 1 were identified as minimally verbal at Visit 4, while 50 of 66 (76%) had developed some verbal skills by Visit 4.

Discussion

The findings from the current study indicate that it is possible to predict language growth trajectories for children with ASD during the preschool years and to identify factors that discriminate between children who remain minimally verbal at 5½ years from those with high language proficiency. Results from the HLM analyses suggest that children who have better comprehension or production abilities at 2½ years will likely demonstrate more language growth throughout the preschool period than those whose early language skills are more limited. These findings are consistent with prior research that has shown that early language performance is predictive of later language outcomes (e.g., Charman et al., 2005; Luyster, Qiu, Lopez, & Lord, 2007). While relatively higher language facility is associated with greater language gains over development, it appears that young children whose productive language abilities are toward the lowest end of the ASD range of performance may actually lose ground in terms of decreasing standard scores (not actual language skills) relative to normative sample expectations (also see discussion of this point in a report of the trajectory of ASD severity classes for this same sample of children by Venker et al., 2014). This result is in line with the findings of Anderson et al. (2007), who similarly observed a widening gap in language abilities of children with ASD relative to comparison groups across development. On the other hand, results of the current study indicate that there is a considerable amount of shifting in language abilities across development, at the individual-child level, such that some children who were preverbal at 2½ years exhibited high levels of language proficiency by 5½ years and the vast majority of preverbal toddlers achieved some degree of spoken language.

The two child characteristic variables that played the largest role in language development during the preschool period were cognition and ASD severity. Cognitive abilities at 2½ years predicted initial language comprehension and production levels in toddlers with ASD and were a positive predictor of growth in productive language through age 5½ years. Additionally, early cognition was a robust classifier of children who remained minimally verbal versus those with high language proficiency after age 5. These results support prior evidence that early cognition is an important predictor of language development in ASD for a wide range of ability levels (Anderson et al., 2007; Thurm et al., 2007) as well as for

children who are minimally verbal (Thurm et al., 2014; Wodka et al., 2013). ASD severity predicted initial level of language production in the current study and was negatively associated with growth trajectories during the preschool period for language comprehension and production. These results are consistent with research that has found an association between severity of ASD diagnosis/symptoms and subsequent language development (e.g., Charman et al., 2005) but contrast with those of Thurm et al. (2014) who reported that overall ASD severity did not predict later language in minimally verbal children with ASD once cognition was also taken into account. The discrepancy between the current findings and the Thurm et al. (2014) results may relate to the fact that their study focused solely on children who were preverbal at the initial assessment. Findings from a related study of the trajectory of autism severity based on the same sample of children as the present study provide insights into the relation between cognition and autism severity (Venker et al., 2014). Toddlers with the lowest cognitive abilities were significantly more likely to exhibit persistent, severe autism symptoms across development than to fall into one of the other trajectory classes of autism severity; however, similar growth rates of nonverbal cognition were observed across the four autism severity classes that were identified. In the current study bivariate correlations between cognitive standard scores and calibrated severity scores for the entire sample were modest at Visit 1 ($r = -.261$, $p = .003$) and nonsignificant at Visit 4 ($r = -.159$, $p = .193$), with this same pattern observed when considering only the Preverbal subgroup at Visit 1 ($r = -.328$, $p = .009$) and Visit 4 ($r = -.280$, $p = .186$). Furthermore, some children who had low cognitive abilities nevertheless developed verbal skills. Therefore, it appears that cognition and ASD symptom severity are, at least to some extent, distinct factors influencing language development and that limited language abilities in children with ASD are not just a reflection of global developmental delay.

Joint attention did not predict rate of language change in the present study, which was similar to the findings of Toth et al. (2006). These results contrast with other research that has highlighted the importance of joint attention in language development for children with ASD (Anderson et al., 2007; Sigman & McGovern, 2005). In the present study, early RJA did, however, contribute to the classification of minimally verbal children from those who were highly language proficient by the end of the preschool period. Specifically, a disproportionate number of children who showed no evidence of RJA at 2½ years were minimally verbal at 5½ years (Low Language subgroup).

Findings revealed that variables indexing child characteristics had a stronger impact than environmental variables on language development in this sample of preschool children with ASD. Maternal education was not a significant predictor of language growth but this factor did help discriminate between Low and High Language outcome subgroups. There are several ways in which mother's level of education might impact child language development either indirectly or more directly. With respect to direct influences, research has shown that higher SES mothers (compared to lower SES) provide more language input to their children, which is associated with expanded child vocabularies (Hart & Risely, 2003). Differences in maternal education have also been demonstrated to have effects on parental linguistic input to young children with ASD (Warlaumont et al., 2014). Other influences of SES on language development may be more indirect. For the current project, a post hoc analysis indicated that there was a positive, modest correlation between the number of years of

mother's education and child nonverbal cognition ($r=.271$, $p=.002$), as well as between maternal education and amount of intervention ($r=.206$, $p=.038$). Maternal education could be an index of both genetic and environmental influences that bear on child cognitive abilities, which in turn affect language development. Alternately, mothers with higher levels of education may have more resources at their disposal to facilitate access to early intervention for their child (see Anderson et al., 2007). Various studies have shown that amount of intervention predicts language outcomes in children with ASD (Mazurek et al., 2012; Stone & Yoder, 2001), although treatment was not a significant predictor of language growth in this study. It is important to point out that the impact of treatment was examined in only one analysis in the current study; we suspect a confound between amount of treatment and initial level of functioning given the criteria required to access intensive ASD intervention in Wisconsin.

In summary, the primary contributions of this study are the following new findings: a) Cognition predicts growth in expressive language abilities across the preschool period, whereas ASD severity predicts growth in both comprehension and production; b) Cognition and ASD symptom severity are, at least to some extent, distinct factors influencing language development and limited language abilities in young children with ASD are not just a reflection of global developmental delay; c) There is a subgroup of children (distinguished mainly by their strong cognitive skills) who have high levels of structural language proficiency, even though they retain their ASD diagnosis; and d) Although verbal language status at 2½ years is a positive prognostic sign, preverbal status at 2½ years is not necessarily a negative indicator of language outcome at 5½ years at the individual-child level.

Limitations and clinical implications

It is important to note that in this type of observational study interpretations are limited to identifying associations and that no causal relationships can be inferred. Also, even though we carefully selected participants to meet enrollment criteria and made every attempt to recruit broadly from the community, it may be the case that children whose families participate in this type of longitudinal project are not representative of the broader population of ASD. In addition, treatment was not a focus of the broader longitudinal study from which these data were drawn and was not controlled. Although a few children in the current study also participated in a small pilot intervention study that involved parent training (Venker, McDuffie, Ellis Weismer, & Abbeduto, 2012), all participants were encouraged to enroll in available treatments within their local communities. Finally, although we carefully considered potential predictors of language development based on prior literature and our own preliminary findings, there are always other variables that might have been examined.

Clinical implications of these findings suggest that early intervention focused on addressing core ASD symptoms may be important for facilitating language development as well as decreasing autistic features since higher levels of ASD severity predicted slower growth in language trajectories. Improving social interaction is usually considered to be the primary link to increasing communication; however, the association between restricted, repetitive

behavior (RRB) and language development should not be overlooked (Paul et al., 2008; Ray-Subramanian & Ellis Weismer, 2012). Toddlers with lower cognitive abilities (especially those from environments with lower SES) will likely have more challenges with language acquisition than more cognitively able toddlers with ASD and are likely to need intensive early intervention focused directly on building communication skills. Intervention programs that train parents to be highly responsive to their child's communicative attempts and facilitate specific linguistic structures can be a useful approach for promoting language development in children with ASD (Naigles, 2013; Venker et al., 2012). This type of intervention may also help strengthen the social feedback loop that has been proposed to be important for early speech development (Warlaumont et al., 2014). While targeted early intervention focused on joint attention has been reported to facilitate spoken language outcomes in children with ASD, the evidence is mixed with respect to the role of joint attention in rate of language growth. Based on results from the present study and recent findings by Paul et al. (2013) showing that joint attention served to moderate the effects of different interventions for minimally verbal children with ASD, we might suggest that the importance of joint attention in language development is at the preverbal stage or for children who remain minimally verbal after age 5 years.

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Key points

- This prospective study examines predictors of preschool language growth trajectories in children with ASD using a clinician-administered measure of language development (instead of general cognitive or developmental measures) to assess language comprehension and production.
- Using calibrated severity scores for core symptoms of ASD, we showed that initial ASD severity was a significant predictor of change in both language comprehension and production from 2½ to 5½ years.
- Cognition at 2½ years was a significant predictor of growth in language production and was a robust discriminator (in combination with maternal education and RJA) between children with ASD who remained minimally verbal versus those with high language proficiency at 5½ years.
- While verbal language status at 2½ years was a positive prognostic sign, preverbal status at 2½ years was not necessarily a negative indicator of language outcome at 5½ years at the individual-child level.
- The findings suggest that early intervention that effectively addresses core ASD symptoms may also have a positive impact on language development in preschoolers with ASD.

Figure 1.

Number of children in the Low Language (white bars) and High Language (hatched bars) outcome (Visit 4) subgroups with respect to: A) cognitive composite score on the Bayley-III at Visit 1; B) maternal years of education; C) response to joint attention on the Early Social Communication Scales at Visit 1.

Table 1

Descriptive data means, standard deviations (SD) and partial eta squared effect sizes (ES) for participants from the entire sample and the Preverbal/Verbal subgroups and Low/High Language outcome subgroups

Variable (Visit 1)	Entire Sample (N=129)	Preverbal/Verbal at Visit 1 (n=66 / n=61)	Effect Size	Low/High at Visit 4 (n=16 / n=15)	Effect Size
Age (mo)	30.8 (4.1)	29.3 / 32.5** (3.9 / 3.6)	.15	30.1 / 30.0 (4.9 / 4.4)	NS
Maternal education (yr)	14.3 (2.2)	14.1 / 14.5 (2.2 / 2.2)	NS	13.6 / 15.9** (2.3 / 1.8)	.23
ASD severity ^a	7.6 (1.9)	7.9 / 7.3 (2.1 / 1.7)	NS	8.7 / 6.8** (1.8 / 1.7)	.23
Cognition ^b	84.8 (12.1)	80.3 / 89.5** (11.0 / 11.5)	.15	72.7 / 98.7*** (9.0 / 11.3)	.63
Social skills ^c	77.6 (6.8)	75.3 / 80.0** (6.1 / 6.8)	.12	73.9 / 81.3** (6.2 / 4.6)	.33
IIA ^d	5.3 (7.6)	3.2 / 7.4** (4.0 / 9.6)	.08	2.2 / 5.6 (3.0 / 6.1)	NS
RIA ^e	.46 (.33)	.31 / .62** (.28 / .30)	.22	.23 / .56* (.33 / .37)	.18
<u>Treatment</u>					
Birth-to-3 S/L Tx hr/mo ^f	3.4 (1.6)	3.6 / 3.0 (1.4 / 1.9)	NS	3.3 / 2.8 (1.1 / 0.9)	NS
Total mo S/L Tx ^g	11.2 (6.2)	11.2 / 11.3 (5.9 / 6.6)	NS	9.6 / 10.6 (7.6 / 8.6)	NS
ASD Tx hr/mo ^h	51.8 (46.6)	60.3 / 43.2 (45.4 / 46.4)	NS	70.1 / 25.3* (39.8 / 52.6)	.20
Total mo ASD Tx ⁱ	13.7 (12.4)	15.3 / 11.9 (11.3 / 13.0)	NS	18.4 / 6.7* (12.7 / 12.1)	.19
<u>Language (Visit 4)</u>					
PLS-4 Total ^j	79.1 (27.0)	66.9 / 92.5*** (22.9 / 24.8)	.23	50.3 / 120.9*** (1.0 / 5.5)	.99
PLS-AC ^k	81.7 (26.5)	70.3 / 94.5*** (23.5 / 23.8)	.21	52.2 / 120.5*** (5.0 / 4.6)	.98
PLS-EC ^l	78.8 (25.9)	67.4 / 91.2*** (22.5 / 23.7)	.21	50.1 / 116.9*** (0.3 / 7.8)	.98
PPVT-4 ^m	88.1 (22.1)	78.8 / 98.0*** (22.1 / 16.5)	.20	52.7 / 113.5*** (20.4 / 10.2)	.81

* p<.05

** p<.01

*** p<.001

^a Calibrated severity score calculated from ADOS/ADOS-T

^b Cognitive composite score on the Bayley-III

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- ^c Socialization Domain standardized score on the Vineland Adaptive Behavior Scale-II
- ^d Number of initiations of joint attention on the Early Social Communication Scales (ESCS)
- ^e Proportion of responses to joint attention from the ESCS
- ^f Average hours per month of Birth-to-3 speech-language therapy
- ^g Total months of Birth-to-3 speech-language therapy
- ^h Average hours per month of ASD treatment Visit 4
- ⁱ Total months of ASD treatment Visit 4
- ^j Total standard score on the Preschool Language Scale-4 (PLS-4)
- ^k Standard score on the Auditory Comprehension scale of the PLS-4
- ^l Standard score on the Expressive Communication scale of the PLS-4
- ^m Standard score on the Peabody Picture Vocabulary Test-4

Table 2
Final estimation of fixed effects (with robust standard errors) for hierarchical linear model of language comprehension

Fixed Effect	Coefficient	Standard error	t-ratio	d.f.	p-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	-13.032718	14.832206	-0.879	105	0.382
Maternal education, γ_{01}	0.767795	0.439621	1.746	105	0.084
Cognition ^a , γ_{02}	0.682557	0.121958	5.597	105	<0.001
Social skills ^b , γ_{03}	-0.007593	0.153104	-0.050	105	0.961
ASD severity ^c , γ_{04}	0.123413	0.681213	0.181	105	0.857
RJA ^d , γ_{05}	8.182705	4.278416	1.913	105	0.059
For TIME slope, β_1					
INTRCPT2, γ_{10}	-17.643907	9.153551	-1.928	105	0.057
Maternal education, γ_{11}	0.657734	0.339973	1.935	105	0.056
Cognition, γ_{12}	0.077242	0.063196	1.222	105	0.224
Social skills, γ_{13}	0.198198	0.106108	1.868	105	0.065
ASD severity, γ_{14}	-0.896485	0.400650	-2.238	105	0.027
RJA, γ_{15}	0.256918	2.359206	0.109	105	0.913

^a Cognitive composite score on the Bayley-III at Visit 1

^b Socialization Domain standardized score on the Vineland Adaptive Behavior Scale-II at Visit 1

^c Calibrated ASD severity score calculated from Visit 1 ADOS

^d Proportion of responses to joint attention from the Early Social Communication Scales (ESCS) at Visit 1

Table 3
Final estimation of fixed effects (with robust standard errors) for hierarchical linear model of language production

Fixed Effect	Coefficient	Standard error	t-ratio	d.f.	p-value
For INTRCPT1, β_0					
INTRCPT2, γ_{00}	-27.713219	11.016976	-2.516	105	0.013
Maternal education, γ_{01}	1.094593	0.470731	2.325	105	0.022
Cognition, γ_{02}	0.405397	0.108551	3.735	105	<0.001
Social skills, γ_{03}	0.452753	0.141568	3.198	105	0.002
ASD severity, γ_{04}	1.495372	0.559107	2.675	105	0.009
RIA, γ_{05}	7.702200	3.551832	2.169	105	0.032
For TIME slope, β_1					
INTRCPT2, γ_{10}	-4.475764	9.002099	-0.497	105	0.620
Maternal education, γ_{11}	0.306424	0.310416	0.987	105	0.326
Cognition, γ_{12}	0.190011	0.055376	3.431	105	<0.001
Social skills, γ_{13}	-0.031608	0.102845	-0.307	105	0.759
ASD severity, γ_{14}	-1.559833	0.418648	-3.726	105	<0.001
RIA, γ_{15}	0.154823	2.647293	0.058	105	0.953

^a Cognitive composite score on the Bayley-III at Visit 1

^b Socialization Domain standardized score on the Vineland Adaptive Behavior Scale-II at Visit 1

^c Calibrated severity score (CSS) calculated from Visit 1 ADOS/ADOS-T

^d Proportion of responses to joint attention from the Early Social Communication Scales (ESCS) at Visit 1