Patterns of Growth in Verbal Abilities Among Children With Autism Spectrum Disorder

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Verbal skills were assessed at approximately ages 2, 3, 5, and 9 years for 206 children with a clinical diagnosis of autism \((n = 98)\), pervasive developmental disorders-not otherwise specified \((PDD-NOS; n = 58)\), or nonspectrum developmental disabilities \((n = 50)\). Growth curve analyses were used to analyze verbal skills trajectories over time. Nonverbal IQ and joint attention emerged as strong positive predictors of verbal outcome. The gap between the autism and other 2 groups widened with time as the latter improved at a higher rate. However, there was considerable variability within diagnostic groups.

Children with autism most at risk for more serious language impairments later in life can be identified with considerable accuracy at a very young age, while improvement can range from minimal to dramatic.

**Keywords:** autism, PDD, growth trajectories, verbal age equivalent, verbal skills

Communication impairment is a core feature of autism \((American Psychiatric Association, 1994)\) and one of the most frequent reasons for referral among children who are later diagnosed with autism spectrum disorder \((ASD); Tager-Flusberg, Paul, & Lord, 2005)\). Moreover, the accumulated evidence from longitudinal studies of young children with and without an ASD indicates that those with impairments in verbal skills are at increased risk for less favorable outcomes later in life. Early language abilities predict social functioning, academic achievement, and psychiatric outcome in late childhood and adulthood \((e.g., Beitchman et al., 2001; Gillberg & Steffenburg, 1987; Kobayashi, Murata, & Yoshinaga, 1992; Venter, Lord, & Schopler, 1992)\). Long-term outcome is more limited for language-impaired children with ASD compared with language-impaired children with nonspectrum disorders \((Howlin, Mawhood, & Rutter, 2000)\). These findings have direct implications for quality of life and the financial costs of services for such individuals. Hence, a growing body of research and theory seeks to better understand the ways in which the verbal skills of children with ASD might be improved or maximized through the identification of key factors affecting verbal outcome.

A handful of prospective studies have examined potential factors believed to facilitate or hamper the development of verbal skills in ASD. Joint attention, probably the most widely studied predictor of outcome, refers to “behaviors used to follow or direct the attention of another person to an event or object to share an interest in that event or object” \((Siller & Sigman, 2002, p. 77)\). Theory suggests that a child’s ability to initiate and respond to bids for joint attention is essential to the development of social-cognitive and verbal abilities \((Mundy & Neal, 2001)\). Empirical findings lend support to this claim. In one study, joint attention had the strongest relation to concurrent language ability relative to other social skills such as social orienting and attention to distress \((Dawson et al., 2004)\). Of seven longitudinal studies, all found a positive association between one or more aspects of joint attention (alternating gaze, pointing, showing) and subsequent verbal skills regardless of the measures used \((e.g., Charman et al., 2003; Mundy, Sigman, & Kasari, 1990; Sigman & McGovern, 2005)\). The time between initial and follow-up assessments varied from 1 to 15 years, and from preschool to adulthood. The relationship held...
regardless of initial language level (e.g., Sigman & McGovern, 2005).

Controlling for initial language or verbal level makes it possible to assess both the unique contributions of other key factors that may be related to early verbal skills as well as the stability of verbal scores over time. When initial verbal IQ scores are not available, many studies have used nonverbal IQ as a control because it is usually highly correlated with concurrent verbal skills (e.g., Bono, Daley, & Sigman, 2004). Prospective studies have been fairly consistent, despite the use of different measures and outcomes, in documenting a strong positive correlation between initial nonverbal or verbal competence and subsequent verbal skills 2–8 years later (e.g., Charman et al., 2005; Stevens et al., 2000; Stone & Yoder, 2001; Turner, Stone, Pozdol, & Conneor, 2006) to more than 15 years later (Mawhood, Howlin, & Rutter, 2000; Sigman & McGovern, 2005), though there are a few counter examples (e.g., Charman et al., 2003; Mundy et al., 1990). The lack of association in some studies may have been due to small sample size, measurement error, or real changes in verbal skills among very young children, thus making initial measurements less reliable predictors of various long-term outcomes (Lord & Schopler, 1989).

Some research has tested the effect of symptom severity at early ages on subsequent verbal skills. For children with autism, greater impairment at age 3 in the areas of restricted and repetitive behaviors and socialization have been associated with poorer language outcomes at age 7 (Charman et al., 2005). Moreover, a diagnosis of autism, compared with the broader diagnosis of pervasive developmental disorders-not otherwise specified (PDD-NOS) for preschool-age children, predicted poorer language outcome 2–3 years later (Charman et al., 2003), even after accounting for initial nonverbal and language scores (Thurm, Lord, Lee, & Newshaffer, in press). In yet another study (Mawhood et al., 2000), a high-functioning autism group was more impaired on language and verbal IQ measures at age 7.5 years than children with receptive language disorder only. Although the autism group enjoyed gains in their verbal skills by 24 years of age, they had significantly more problems in the use and understanding of language than the non-ASD group with a language disorder. Studies with nonspectrum comparison groups most always report less optimal outcomes for children with ASD than those with nonspectrum disabilities, such as language and other developmental delays (e.g., Mawhood et al., 2000; Sigman & Ruskin, 1999).

Other studies have tested the effects of various types of interventions on verbal skills in ASD. Although it is not always clear whether improvement is due to the treatment, maturation, or other factors, research has reported positive effects for interventions that vary in type and scope, such as those specifically targeting joint attention, communication skills, as well as more general education programs (e.g., Howlin & Rutter, 1989; McGee, Krantz, & McClanahan, 1985; Rogers, 2005; Smith, Groen, & Wynn, 2000; Turner et al., 2006). However, there is a need for better information on the characteristics of different subgroups and trajectories of development so that early intervention efforts can be optimally formulated and targeted. The emphasis placed on various skills may need to vary considerably for different 2- and 3-year-olds with ASD.

Regardless of the predictors considered, prospective studies generally report overall gains in abilities for ASD children (e.g., Mawhood et al., 2000; Sigman & Ruskin, 1999), with considerable variability in outcomes, from large gains to decreases in verbal skills over time relative to age norms (e.g., Mawhood et al., 2000; Stevens et al., 2000; Turner et al., 2006). Although these studies provide a foundation for studying the development of verbal abilities in ASD populations, some methodological challenges are evident, most notably, sample size restrictions. Much of the research to date involves sample sizes well under 50, making it difficult to identify subgroups within ASD and to assess the relative importance of multiple predictor variables.

In addition, few studies of verbal skill development in autism populations involve samples of children less than age 3 at the initial assessment. Theories concerned with the neuroplasticity of a child’s brain from birth to preschool contend that this is a dynamic and critical period of development (e.g., Mundy & Neal, 2001). From this perspective, typically developing children are born with relatively unorganized synaptic connections and a predisposition toward orienting to social stimuli. In the first few years of life, these connections are pruned and shaped by input from the outside environment. At the same time, the child’s preferences influence the kind of response he or she receives from the social environment. For a child with ASD, an initial deficit in joint attention may set in motion a cumulative, negative feedback cycle in which an “impoverishment” of social information prevents healthy neurological development that would ordinarily provide the foundation for subsequent social cognition, behavior, and verbal skills. However, the high degree of give-and-take between biological and environmental factors most typical of early childhood may allow greater responsiveness to the influence of the environment (i.e., greater development and growth). Hence, the ability to detect and prevent potential long-term impairments in early childhood may have important implications for intervention.

The unique characteristics of the data for the present study allowed for the simultaneous consideration of multiple factors affecting long-term verbal skills among various diagnostic groups, beginning when the children were still in the early stages of acquiring language. Specifically, we prospectively examined the rate and pattern of growth in verbal abilities between the ages of 2 and 9 years for children who differed with respect to early diagnosis of autism, PDD-NOS, or nonspectrum disabilities. This study had two main objectives. The first was to contrast the differences between diagnostic groups in the development of verbal skills. We were interested in the degree to which age 2 predictors were related to outcome through age 9. Children diagnosed with autism at age 2 were expected to have fewer verbal skills than PDD-NOS and nonspectrum children at intake, with group inequalities increasing over time. Nonetheless, all groups were expected to show gains with respect to verbal age equivalence scores even though relative improvement for the children with fewer verbal abilities would not likely keep pace with age norms for typically developing children. Age 2 nonverbal age equivalent (NVAE) and joint attention were expected to contribute positively to the level and rate of improvement in subsequent verbal skills.

The second, more exploratory objective was to longitudinally examine differences within diagnostic groups in verbal abilities. We hypothesized considerable variability in outcomes within the autism and PDD-NOS groups, including a narrowing of the gap from typical development for a substantial proportion of ASD children from ages 2 to 9. In other words, we expected diagnosis
or symptom severity and other characteristics to be predictive but not definitive of later outcome. We expected the least variability in the autism group on the basis of previous analyses of this sample up to age 5 (Taylor, Pickering, Lord, & Pickles, 1998). In light of theory and research suggesting substantial change in early childhood verbal abilities, we used change itself as a predictor of age 9 outcome for children with ASD. More specifically, we hypothesized that changes in key predictors (i.e., verbal and nonverbal skills, symptom severity) between the ages of 2 and 3 would contribute to the age 9 verbal age equivalent over and above cross-sectional data obtained at age 3.

Method

Participants

Eligible participants were consecutive referrals younger than 37 months of age from agencies across North Carolina and metropolitan Chicago serving very young children with developmental delays. All 221 families agreed to participate in the study initially. One later withdrew and six other families became ineligible for inclusion when the children reached the age of 36 months before the first assessment could be scheduled. With the exception of the children’s age, these seven families did not differ demographically from the other 97% of families who participated in the study. Participants consisted of 192 children (162 males, 30 females), referred for evaluation for possible autism, and 22 nonautistic developmentally delayed (DD) children (10 males, 12 females) recruited in North Carolina. The autism referral group comprised children under age 3 from four North Carolina state-funded autism centers (n = 111) or a Chicago autism clinic within a private university hospital (n = 81). Exclusion criteria included moderate to severe sensory impairments or cerebral palsy, known genetic abnormalities, or poorly controlled seizures. Nearly one half the 214 participants (47%) received a diagnosis of autism at age 2, whereas the other half was divided between children with PDD-NOS (28%) and those without ASD (25%). The nonautism group consisted of children with some degree of mental retardation or a language delay (91%), whereas the remainder had other disabilities such as attention-deficit/hyperactivity disorder (ADHD) or a medical condition. There was a mix of children from rural and urban locations. Ethnic minorities, the vast majority of whom were African American, accounted for a sizable proportion of the sample (33%). A third of the children had mothers with a high school education or less, whereas parent education for the remainder of the sample ranged from some college (29%) to completion of a college degree (38%).

All children were first seen at approximately age 2, with a mean age of 29 months (SD = 5.17). The number of subsequent assessments varied by site and referral status. The North Carolina autism referral group was assessed at approximately ages 2, 3, 5, and 9, whereas the other two groups were seen at three of the four time points (i.e., the DD group was not seen at age 3, and Chicago referrals were not seen at age 5). Of the original 214 participants, 5 were lost to follow-up after the initial assessment; another 37 were lost by age 9 because of geographical location, unreachable status, or refusal to participate. Although African American families with less education were lost to the study at a significantly higher rate than Caucasians and families with more education, attrition was not related to original diagnosis, gender, or verbal or nonverbal IQ. The present study includes the 206 children who were seen multiple times (at least twice) and were administered diagnostic and psychometric instruments from the list described below.

Measures

Diagnostic instruments. The Autism Diagnostic Instrument-Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994) is a comprehensive, standardized parent interview designed to distinguish children with ASD from non-ASD and DD populations. Algorithm scores are totaled for each of three domains, consistent with those outlined in the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (American Psychiatric Association, 1994): social behaviors, communication, and repetitive interests. Parents were administered the ADI-R in the final two assessments when the children were ages 5 and 9. The ADI-R distinguishes between participants who have acquired sufficient verbal skills to be scored on language usage questions (daily, functional use of three-word phrases that sometimes include a verb for a code of “0”) and those who have not (mostly single words for a code of “1”; fewer than five words used on a daily basis for a code of “2”). A toddler version of the ADI-R, which includes a number of additional items specific to the first 2 years of life, was given when the children were 2- and 3-years-old (see Lord, Shulman, & DiLavore, 2004).

The Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) and one of its predecessors, the Pre-Linguistic Autism Diagnostic Observation Schedule (PL-ADOS; DiLavore, Lord, & Rutter, 1995), acquire diagnostic information through direct observation of the child by a trained clinician. An administration consists of a series of socially constructed play tasks administered in a semistructured manner. An algorithm calculates summary scores for the social and communication domains. Children in the present study were given the PL-ADOS at ages 2 and 3, which was scored using the algorithm for the Module 1 ADOS (for children without phrase speech). The ADOS was administered in subsequent assessments. Children were observed with one of three modules, depending on whether they used single or no words (M1), phrase speech (M2), or fluent speech (M3).

Each member of the research clinical team established interrater reliability exceeding 90% exact agreement (κ > 0.70) for all items on the ADI-R and 80% exact agreement (κ > 0.60) on codes for the PL-ADOS and ADOS for three consecutive administrations before the study began. Reliability was maintained through consensus coding approximately every sixth administration with a second rater who was blind to referral status.

Psychometric instruments. The Vineland Adaptive Behavior Scales (VABS; Sparrow, Balla, & Cicchetti, 1984) is a standardized parent interview of the child’s everyday adaptive functioning, which yields domain scores in the areas of communication, daily living skills, social skills, and motor development, as well as an adaptive behavior composite score. Adequate validity and reliability have been established for both the adaptive behavior composite and the individual subscales of the VABS (Sparrow et al., 1984).

The Infant Mullen Scales of Early Learning (Mullen, 1985) is a normed measure of verbal and nonverbal cognitive abilities for children below the 36-month level in the Gross Motor, Fine Motor, Nonverbal Cognition (i.e., “Visual Reception”), Receptive Lan-
guage, and Expressive Language domains. The standard version of the Mullen (Mullen, 1989) for children below the 60-month level was administered to older children who were unlikely to achieve a basal score on cognitive tests of a higher skill level such as those described below. (For specific procedures used to determine the appropriate test for a child, please see the Verbal and nonverbal test selection section.)

The Differential Ability Scales (DAS; Elliott, 1990), another measure of verbal and nonverbal cognitive abilities, was normed on a national sample of children between the ages of 2 years, 6 months and 17 years, 11 months. If children in the present study met age requirements and seemed able to achieve a basal score, then they were administered the school-age version. This version includes the Conceptual Similarities and Word Definition subtests of verbal ability along with four nonverbal reasoning and spatial abilities subscales. If the school-age version (DAS-S) was not appropriate, then children were given the preschool version (DAS-P). Its verbal cluster includes Verbal Comprehension and Naming Vocabulary subtests along with three additional subtests for measuring nonverbal ability.

The Wechsler Intelligence Scale for Children-III (WISC-III; Wechsler, 1991) was only administered to the highest functioning children at age 9. The WISC-III measures cognitive abilities for children who score developmentally between the ages of 6 years and 16 years, 11 months. Five subtests are mandatory for computation of summary verbal scores, including information about common events, places, and people; similarities in word pairs; comprehension; vocabulary; and arithmetic problems answered orally. Like the other psychometric instruments previously described, the WISC-III measures “language” skills with respect to syntax and semantics as well as other verbal skills not typically included in linguistic studies (e.g., tests of memory, general knowledge, and conceptual and quantitative abilities expressed orally). Five additional subtests measure different facets of nonverbal cognitive skills.

Joint attention measure. This measure was based on factor analyses of the ADOS and consisted of summed scores from several items depending on developmental level (see Gotham, Risi, Pickles, & Lord, 2007). For children with some speech, the composite variable includes the gestures, pointing, showing, and spontaneous imitation of joint attention items. For nonverbal children, the measure comprises the gestures, use of other’s body to communicate, response to name, and response to joint attention items. Item scores ranged from 0 to 2 or 3. The composite variable was reverse coded so that higher scores indicate greater skill.

Procedure

The full battery of diagnostic and psychometric instruments was administered at each assessment free of charge. Verbal feedback and a written report were provided to families. Written informed consent was obtained from parents prior to each assessment, as indicated by the University’s Institutional Review Board.

Diagnostic classification. The ADI-R parent interview was typically administered in the home, whereas direct observation of the child took place at a nearby clinic or, in later assessments, at school with the parent observing. Following the two-part evaluation, an overall best estimate diagnosis of autism, PDD-NOS, or other nonspectrum disability was jointly determined by two trained staff members, including doctoral-level research associates, child psychiatrists, or clinical psychologists. The decision for the best estimate diagnosis was based on the clinicians’ summary reports, psychometric and diagnostic algorithm scores, as well as videotapes of the direct observation of the child. (For a more detailed description of the procedures, see Lord et al., 2006.) Diagnosis in the present study refers to the age 2 best estimate classification.

Verbal and nonverbal test selection. The “preferred” verbal age equivalent at each measurement varied according to the child’s developmental level and was selected from the list of psychometric instruments described above. In order to determine the most appropriate cognitive ability test, children’s level of functioning was initially estimated from verbal and adaptive skill scores on the VABS parent interview, administered prior to the direct testing of the child. Test selection followed a hierarchy from the most to least difficult to complete: WISC-III, DAS-S, DAS-P, and the Mullen. Children were administered the test with the greatest degree of difficulty appropriate to their estimated abilities. If either basal or ceiling scores could not be obtained, then participants were given the next test up or down in the hierarchy. Verbal ability was then constructed by averaging the age equivalence scores from the various verbal skill subtests of the chosen cognitive test in the hierarchy. Age 2 verbal abilities were scored exclusively from the Mullen (n = 206). The remaining age cohorts were split between various tests in the hierarchy: 179 Mullens and 1 DAS-P for age 3; 82 Mullens, 41 DAS-Ps, and 3 DAS-Ss for age 5; 55 Mullens, 41 DAS-Ps, 29 DAS-Ss, and 39 WISC-IIIIs for age 9. We used verbal age equivalents because a majority of the children were language delayed and many could not be assigned a standard score. Moreover, age equivalents are more appropriate indices of change compared with standard scores, which are intended to show stability (Charman & Howlin, 2003). Because we elected to use verbal scores from developmental and intelligence tests, and collinearity within domains was very high (Elliott, 1990; Taylor et al., 1998), we did not attempt to separate receptive and expressive language abilities. NVAEs were scored from the Mullen for all 206 participants at age 2.

Analyses. Growth curve analysis with SAS Proc Mixed (SAS for Windows release 9.1.3) was used to examine longitudinal growth in verbal age equivalents from approximately age 2 to age 9. In the present study, a random (separate) intercept and slope were calculated for each child as a control for the high correlations among repeated measures on the same individuals over time. We used the growth models to compare the three diagnostic groups with respect to (a) the relative starting points at 24 months of age (i.e., the intercept); (b) the rate of change from age 2 to age 9 (i.e., the slope); and (c) the pattern of change from age 2 to age 9 (i.e., linear vs. quadratic). Because data for more than three time points were available, higher order polynomials were also considered in order to determine the shape of the curve. Covariates were added as fixed effects to examine how much they accounted for variation in the intercept and slope: age at testing, gender, ethnicity, mother’s education, site, and age 2 nonverbal and joint attention skills. We tested the effects of these variables in three steps. Controlling only for basic demographic variables, we first wanted to examine group differences in early verbal skills and rate of change over time by diagnostic category before adding the other covariates of interest. In the second step, we added joint attention and NVAE to the model to see whether they accounted for group differences in
verbal abilities at the first assessment. Age was centered at 24 months so the intercept could be interpreted as the mean verbal age equivalent at 2 years old. Finally, we added the time interactions with these two covariates to see how the slope or rate of change in verbal skills over time was affected.

The estimates for both the covariance and beta parameters were obtained by restricted maximum likelihood methods (REML) so that the results would be less biased (Verbeke & Molenberghs, 2000). To test for group differences in slopes and intercepts, we used t statistics reported for each parameter, calculated as the ratio of the parameter estimate divided by the standard error. To examine whether rate of change in the verbal age equivalents over time differed significantly from zero, we used t tests for linear combinations of variables representing the slopes.

A power analysis was carried out for a comparison of the growth curve slopes for the diagnostic groups from age 2 to age 9 (Diggle, Heagerty, Liang, & Zeger, 2002). For an effect size of .15 with 80% power, and sample sizes of 50 children in each of the PDD and nonspectrum groups and 100 participants with autism, we estimate that we can detect a difference in slopes of .33 units per month between groups (i.e., the difference in slopes between the autism and PDD groups in our data), assuming a residual variance of 25, a correlation among observations on the same participant of .68 (again generated from our data), and an alpha of .05.

A mixture modeling procedure called TRAJ (Jones, Nagin, & Roeder, 2001) was used to focus more specifically on the variability in outcomes within the ASD subsample. Intended to complement growth curve analysis, PROC TRAJ is an exploratory procedure written for use in SAS that identifies linear and nonlinear patterns in longitudinal data and classifies the sample into groups. We ran the procedure using an uncensored, normal distribution for the age equivalent scores to see whether distinct sub-groupings would emerge within ASD. We compared the absolute value of the Bayesian information criterion (BIC) between respective models (smaller indicates a better fit) to determine the optimal number of groups. (See Jones et al., 2001, for use of the BIC for nonnested model selection.) The contribution of factors related to assignment to groups with varying growth trajectories was also assessed. Because group membership changed slightly, depending on which covariates or “risk factors” were included, we could not compare nested models. For covariates, we therefore used t tests for the individual parameter estimates and change in the absolute value of the overall BIC as criteria for improvement of model fit. Odds ratios (ORs) were calculated for the parameter estimates so that the relative contributions of risk factors could be assessed.

Finally, least square regressions were conducted in order to examine whether changes in key predictor variables (i.e., verbal and nonverbal age equivalents, restricted and repetitive behaviors, ADOS social-communication total algorithm score, and joint attention) between the ages of 2 and 3 contributed significantly to the age 9 verbal age equivalent over and above cross-sectional data obtained at age 3. The change variables were added into the second block.

### Results

Table 1 is a general approximation of expressive language level by diagnosis for children who were seen at age 9, where language level was measured by which ADOS module a child was able to take and whether the child had sufficient language to be administered questions about language deviance in the ADI-R. Almost one quarter of the autism group and more than half the PDD-NOS and nonspectrum children were using complex sentences to talk about topics outside of the immediate physical context by age 9 (the ADOS definition of fluent). Another 24%–31% of the children in each group were using sentences but were not fluent speakers. Finally, 29% of the autism group and fewer than 10% of the PDD-NOS and nonspectrum children were still nonverbal (i.e., using fewer than five words daily according to the ADI-R). The analyses that follow examined how children within each diagnostic group arrived at their age 9 or most recent level of verbal ability as measured at the time of their last assessment.

#### Between-Group Differences

**Reduced model.** Table 2 includes the growth curve models that tested for changes in verbal abilities from 2 to 9 years of age. Coefficients of special interest for each model are in bold. First, note in Model 1 that the intercept of 9.4 months is the average verbal age equivalent score for the sample at age 2. Also, the positive and significant effect of age indicates gains in verbal age equivalents over time for the sample as a whole. Significant unexplained variance in the random slopes and intercepts remains after accounting for age. This reduced model serves as a basis for comparison with subsequent models as we consider the contributions of other factors.

**Differences by diagnosis.** Model 2 of Table 2, depicted graphically in Figure 1A, tested for differences in verbal abilities over the 7-year period according to age 2 diagnosis. As expected, the PDD-NOS and nonspectrum groups differed from children with

<table>
<thead>
<tr>
<th>Language level</th>
<th>Autistic (n = 84)</th>
<th>PDD-NOS (n = 46)</th>
<th>Nonspectrum (n = 42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex sentences (ADOS Module 3)</td>
<td>23.8</td>
<td>58.7</td>
<td>54.8</td>
</tr>
<tr>
<td>Sentences but not fluent (ADOS Module 2)</td>
<td>23.8</td>
<td>26.1</td>
<td>31.0</td>
</tr>
<tr>
<td>Words but not sentences (ADOS Module 1; ADI-R = 1)</td>
<td>23.8</td>
<td>10.9</td>
<td>7.1</td>
</tr>
<tr>
<td>No or few consistent words (ADI-R = 2)</td>
<td>28.6</td>
<td>4.3</td>
<td>7.1</td>
</tr>
</tbody>
</table>

*Note.* Four children were not administered ADOSs; level of language was inferred from ADI, Vineland, and best verbal IQ scores. PDD-NOS = pervasive development disorders—not otherwise specified; ADOS = Autism Diagnostic Observation Schedule; ADI-R = Autism Diagnostic Instrument-Revised
autism in a number of respects. First, the main effect coefficients for diagnosis show that differences in verbal abilities were already significant by age 2, with the nonspectrum and autism groups scoring the highest and lowest, respectively. Second, the Group × Time interactions were also significantly different, with the PDD-NOS and nonspectrum children improving at a faster rate over time compared with the children with autism. In other words, it was expected that group differences would remain after controlling for other factors such as ethnicity, mother’s education, and site. Results supported this prediction. Gender was always nonsignificant when included. Not predicted, but interesting, was the finding that improvements in verbal abilities began to level off for the nonspectrum group before age 9, whereas both ASD groups continued to improve without slowing through age 9. This decelerating pattern for the nonspectrum group was both significantly different from zero (not shown in Table 2), t(254) = −3.40, p < .001, and from the other two groups.

Covariates affecting the starting point. Model 3 adds several covariates in order to account for the observed variability in the intercepts, or diagnostic group differences in verbal age equivalents at 24 months. NVAE and joint attention at the first assessment were both significant (p < .001) and associated with superior verbal abilities at 24 months. When the effects of these two covariates were accounted for, the diagnostic group differences in verbal age equivalents at 24 months became nonsignificant. Closer inspection revealed that group differences became nonsignificant with the addition of joint attention alone. This was not the case for NVAE, though its effects remained positive and significant with or without the inclusion of joint attention in the model. Moreover, when either joint attention or NVAE were excluded from Model 3, the model with joint attention but not NVAE had a better fit than the model with NVAE but not joint attention. (BICs were 4853.2 and 4886.0, respectively.) Hence, consistent with our expectations, NVAE, and joint attention in particular, reduced group inequalities at 24 months. NVAE and joint attention at the first assessment were both significant (p < .001) and associated with superior verbal abilities at 24 months. When the effects of these two covariates were accounted for, the diagnostic group differences in verbal age equivalents at 24 months became nonsignificant. Closer inspection revealed that group differences became nonsignificant with the addition of joint attention alone. This was not the case for NVAE, though its effects remained positive and significant with or without the inclusion of joint attention in the model. Moreover, when either joint attention or NVAE were excluded from Model 3, the model with joint attention but not NVAE had a better fit than the model with NVAE but not joint attention. (BICs were 4853.2 and 4886.0, respectively.) Hence, consistent with our expectations, NVAE, and joint attention in particular, reduced group inequalities in age 2 verbal age equivalents.

Covariates affecting the rate of change. Model 4 tested the hypothesis that the same covariates accounting for intercept differences would also account for variation in the slopes or rate of growth in verbal abilities over time by diagnosis. Although the
interaction between joint attention and time was nonsignificant (not shown in Table 2), the interpretation of this finding was not entirely clear, given the moderate correlation between joint attention and diagnostic category (r = .59; p < .001). However, when diagnostic category was excluded from the model, the Joint Attention × Time interaction still did not reach significance, although there was a nonsignificant trend (p > .10) for those with better joint attention skills at age 2 to progress more rapidly over time. However, NVAE had a clear positive and significant effect on the slope so that children with higher IQs made greater gains in verbal ability than their peers. Cognitive abilities accounted for considerable variability in the growth rate over time, as can be seen graphically in the contrast between Figures 1A (Model 2) and 1B (Model 4). Whereas inequalities between diagnostic groups assume a fanlike spread over time in Figure 1A, this pattern is somewhat minimized in Figure 1B after controlling for the time interactions with NVAE.

Although the residual variance in Model 4 was relatively normally distributed, there were a few outliers for whom the model fit poorly. Seven children (10 observations) had particularly large residuals (with a chance occurrence of p < .01). These were children who made unusually good progress, as reflected by a change diagnosis over time, either from autism to PDD-NOS or from PDD-NOS to nonspectrum, and general improvements across multiple domains, including verbal, nonverbal, and general adaptive skills. When these cases were removed from the analysis, the main findings remained unchanged, although the decelerating pattern of growth in verbal skills that was observed in the nonspectrum sample also became significant for the PDD-NOS group. There was still a trend (p < .10) for the nonspectrum group’s growth rate to slow down over time relative to that of the autism group.

In summary, symptom severity related to diagnostic grouping and lack of joint attention skills, along with age 2 NVAE, account for a substantial amount of cross-sectional and longitudinal variation in verbal age equivalents from age 2 to 9. Overall, the random effects at the bottom of Table 2 show a reduction in the unexplained variance in the intercepts (by 66%) and slopes (by 35%) between growth curve Model 1 and Model 4. However, these results reveal little about the variability within the respective diagnostic groups, particularly for the children with ASD.

Within-Group Differences

Variability in outcomes. We predicted considerable variability in outcomes, with marked improvements in verbal abilities between the ages of 2 and 9 years for a substantial proportion of ASD children, particularly for the PDD-NOS group, though we were uncertain what proportion would show substantial improvement and the extent of the improvement. Figures 2A–C display the trajectories for individuals within each diagnostic group, where the dotted line represents typical development (i.e., age equivalent matches chronological age). Consistent with expectations, a noticeably larger proportion of children with autism clustered at or near the bottom, showing little improvement with time compared with children in the other groups. However, contrary to expectations, the range of outcomes, including variability in the slopes and intercepts, was as great or greater for the autism sample despite the much lower mean verbal ability score at age 9 (48 months) than the PDD-NOS (82 months) or nonspectrum (67 months) groups. The distributional pattern for the autism group was somewhat bimodal, with more individuals clustered at the high and low ends. At the high end, a larger number of children with autism than with nonspectrum disabilities, for example, were
near or above age norms by age 9. There was a great deal of variation within the PDD-NOS group as well, though outcomes were more evenly distributed.

Within-group variability for the children with ASD was further examined with growth mixture modeling in PROC TRAJ. The results produced four distinct subgroups on the basis of the level of improvement in verbal abilities over time. The four-group model fit the data best, with the smallest BIC (2175) as compared with those for the two-, three-, and five-group solutions (2316, 2236, and 2340, respectively). With little ambiguity, the mean probability of an individual’s assignment to one group over the other three ranged from .91 to .97, depending on the group. Further evidence of good fit is shown visually in Figure 3, in which the discrepancies between the observed (solid lines) and expected values (elongated, dashed lines) are minimal. Again, growth trajectories, were mostly linear and fan shaped with a slight, positive quadratic effect for the most improved group ($p < .001$).

Notably, when the data were divided into four ASD groups, the higher and lower extremes became more visible. As expected, a substantial minority of the ASD children—about one third ($n = 53$)—showed dramatic improvement and were doing quite well at the time of the last measurement. By age 9, the average score for the two most improved groups was close to age norms or above, despite having scored below age level at the first assessment. However, the two least improved groups showed more modest average gains of about 12 and 37 months (Groups 1 and 2, respectively) over the 7-year period. Group 1 consisted mainly of nonverbal children with few or no words in the last assessment; 82% of this group were administered a Module 1 ADOS at age 9. Most of the children in Group 2 were speaking in phrases and some sentences but were not yet fluent speakers when last seen; 70% of these children were given a Module 2 ADOS at age 9. Nevertheless, 54% of the children initially diagnosed with PDD-NOS were in one of the two most improved groups. And, notably, just under 20% of the children initially diagnosed with autism were in one of the two most improved groups.

We also considered a number of potential “risk” factors that could make assignment to higher or lower functioning groups more likely. Covariates were added to the model one at a time to see whether the resulting model was a better fit, as indicated by the significance of the parameter estimates and a corresponding decrease in the BIC. When NVAE was added to the no-risk model,

![Figure 2](image2.png)

**Figure 2.** Growth in verbal age equivalents (AEs; solid lines) from age 2 to age 9 for individual children grouped by age 2 diagnosis. A–C: display of the trajectories for individuals within each diagnostic group. The dotted line represents typical development (i.e., AE score = chronological age). Descriptive statistics for each diagnostic group are as follows: Autism, $n = 98$, mean verbal AE at 9 years old = 48 months, intercept SD = 3.40, slope SD = .43; pervasive developmental disorders-not otherwise specified (PDD-NOS), $n = 58$, mean verbal AE at 9 years old = 82 months, intercept SD = 3.87, slope SD = .42; nonspectrum autism spectrum disorder (NON-ASD), $n = 50$, mean verbal AE at 9 years old = 67 months, intercept SD = 3.15, slope SD = .27.

![Figure 3](image3.png)

**Figure 3.** Predicted growth trajectories in verbal age equivalents (AEs; solid lines) from age 2 to age 9 for all children ever diagnosed with autism or pervasive developmental disorders-not otherwise specified ($n = 166$) by level of improvement. PROC. TRAJ procedure generated 4 subgroupings: Group 1 (Gr. 1), $n = 70$ (56 with autism at age 2); Group 2 (Gr. 2), $n = 43$ (23 with autism at age 2); Group 3 (Gr. 3), $n = 30$ (11 with autism at age 2); Group 4 (Gr. 4), $n = 23$ (7 with autism at age 2). The dotted line represents typical development (i.e., AE score = chronological age).
the absolute value of the BIC decreased from 2169 to 2134. Next, we added caregiver’s education as a covariate. It did not add to the overall model fit (BIC = 2138). Most group differences were nonsignificant, although children with the most highly educated parents were more likely to fall into the most rapidly developing trajectory group (Group 4) over the other three groups (OR = 2.69; p < .01). We kept this variable in the model due to possible implications for intervention and future research. Site, gender, and race were dropped because these variables were not significant risk factors for group assignment either alone or in combination with the other covariates. To the model with NVAE and caregiver’s education, we added symptom severity measures separately from each other due to moderate correlations among them. The restricted and repetitive behavior ADOS algorithm total at age 2 was not a significant risk factor for group assignment and resulted in a poorer model fit. Age 2 joint attention made a significant contribution (BIC = 2135; OR = 1.51; p < .05) so that fewer skills significantly increased the likelihood of assignment to the lowest functioning group compared with the other three groups but did not distinguish among the top three groups.

Finally, our “best” model (BIC = 2069), shown in Table 3, included a NVAE, caregiver education, and age 2 ADOS social-communication total. In general, fewer social-communication symptoms and higher NVAE resulted in assignment to a higher, more progressive trajectory group. For example, for every one unit increase in NVAE and social-communication symptoms, the odds of assignment to Group 4, the fastest growing group, were 1.25 times greater than assignment to Group 1, the least improved group, whereas a child with a one-unit increase in social-communication symptoms had only .41 times the odds of being placed in Group 4 over Group 1. Caregiver education had the largest effect size in terms of increasing the odds of assignment into Group 4 rather than into Group 1 (OR = 2.98; p < .05).

In addition, not shown in Table 3, children in Group 4 tended to have a higher NVAE (OR = 1.09; p < .01) and parents with more years of education (OR = 2.32; p < .05) than children in Group 3, the second fastest growing group. Social-communication symptoms did not affect the likelihood of assignment into Group 4 versus Group 3.

**Growth in early childhood and subsequent verbal abilities.** We also examined within-group variation using change itself as a predictor of later outcome for children with ASD. Changes in NVAE, joint attention, restricted and repetitive behaviors, social-communication total, and verbal age equivalents from ages 2 to 3 were all significantly correlated with verbal skills at age 9, indicating that children who had more positive change scores (i.e., higher verbal and nonverbal skills, fewer symptoms) during the 12-month interval had subsequently stronger verbal skills. To see whether change variables added additional explanatory power to age 3 cross-sectional data, we conducted multiple regression analysis. In the first block, we included age at first assessment, NVAE at age 3, and social-communication ADOS algorithm total at age 3. Parameter estimates for change in NVAE and social-communication difficulties were significant predictors of verbal skills at age 9 (p < .01 and p < .001, respectively). None of the change variables for joint attention, NVAE, or verbal mental age, however, provided additional explanatory power to age 3 cross-sectional data when they were added in the second block (adjusted R² = .00). The variance explained by the age 2 and 3 cross-sectional data was already very high (39% and 57%, respectively). Results were nearly identical when we substituted age 3 verbal age equivalents for NVAE as well as other symptom change variables (e.g., joint attention, restricted and repetitive behaviors) for social-communication scores. We also examined the same models separately for the PDD-NOS and autism groups with similar results.

**Discussion**

The ability to track developmental trajectories over 7 years in a relatively large sample of children referred for possible autism at age 2 offers messages of both hope and realism for the verbal outcome of children receiving early diagnoses within the autism spectrum. The findings indicate progress in the development of verbal skills for almost all children with initial diagnoses of ASD at age 2, with a strikingly broad range of outcomes. Yet, in contrast

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**Table 3: Parameter Estimates and Odds Ratios for Risk Factors Predicting Verbal Age Equivalents From Age 2 to Age 9 (n = 166)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Risk factor</th>
<th>β</th>
<th>SE</th>
<th>OR</th>
<th>95% CI</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Least improved</strong></td>
<td>1 Nonverbal age equivalent</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Social-communication symptoms total</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Caregiver education</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>2 Nonverbal age equivalent</td>
<td>.07</td>
<td>.02</td>
<td>1.07</td>
<td>1.04, 1.12</td>
<td>3.80***</td>
<td>2.47*</td>
</tr>
<tr>
<td></td>
<td>Social-communication symptoms total</td>
<td>−.20</td>
<td>.08</td>
<td>0.82</td>
<td>0.69, 0.96</td>
<td>−2.47</td>
</tr>
<tr>
<td></td>
<td>Caregiver education</td>
<td>.20</td>
<td>.25</td>
<td>1.22</td>
<td>0.75, 1.97</td>
<td>0.81</td>
</tr>
<tr>
<td>3 Nonverbal age equivalent</td>
<td>.13</td>
<td>.03</td>
<td>1.14</td>
<td>1.07, 1.22</td>
<td>3.94***</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Social-communication symptoms total</td>
<td>−.74</td>
<td>.15</td>
<td>0.48</td>
<td>0.36, 0.64</td>
<td>−5.00***</td>
</tr>
<tr>
<td></td>
<td>Caregiver education</td>
<td>.25</td>
<td>.39</td>
<td>1.29</td>
<td>0.60, 2.74</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>Most improved</strong></td>
<td>4 Nonverbal age equivalent</td>
<td>.22</td>
<td>.04</td>
<td>1.25</td>
<td>1.14, 1.36</td>
<td>4.96***</td>
</tr>
<tr>
<td></td>
<td>Social-communication symptoms total</td>
<td>−.89</td>
<td>.17</td>
<td>0.41</td>
<td>0.29, 0.57</td>
<td>−5.29***</td>
</tr>
<tr>
<td></td>
<td>Caregiver education</td>
<td>1.09</td>
<td>.51</td>
<td>2.98</td>
<td>1.08, 8.21</td>
<td>2.11†</td>
</tr>
</tbody>
</table>

*Note.* Dashes indicate reference group.

*p < .05. **p < .01. ***p < .001.
to some previous reports (Charman et al., 2005), the growth patterns of these children predicted on the basis of a comprehensive assessment at age 2 were not chaotic but followed predictable patterns of change from 2 to 9 years. This change was systematically related to the early best estimate diagnosis, NVAE estimated from a standard developmental scale (Mullen, 1989), and joint attention as measured by a standardized observation scale (DiLavore et al., 1995; Gotham et al., 2007). The combination of these factors meant there were children with early diagnoses of autism who made more progress than some children with PDD-NOS. Contrary to our expectations, the amount of change from age 2 to 3 did not account significantly for additional variance.

Compared with children with other developmental disorders, the children with ASD showed greater heterogeneity and range of trajectories, which speaks to the necessity for intervention approaches that can address the diverse needs of this population. The four subgroups generated from the data on the basis of age 2 characteristics (in Figure 3) make sense from both empirical and theoretical standpoints, with needs beginning to diverge widely as children approached middle childhood. The slowest developing group with fewer nonverbal skills and the greatest symptom severity was composed of children who were still nonverbal or possessed very limited verbal skills 7 years after the initial assessment. Lack of joint attention skills was a risk factor for assignment to this group only, suggesting that mastery of preverbal social skills could be a high treatment priority for these children. The two middle groups were distinguished more by social-communication symptom severity than by nonverbal mental age. Moreover, closer inspection revealed that many of the children in the lower middle group, though verbal, were not yet speaking in fluent sentences. As other researchers have suggested (e.g., Aldred, Green, & Adams, 2004; Kasari, Freeman, & Paparella, 2001), children with this profile might benefit most from interventions that actively target speech therapy as well as general cognitive skills.

Finally, the two most rapidly progressing groups had near normal to above-average verbal skills by age 9, with higher NVAEs and caregiver education as the only factors predicting placement into the top versus the upper middle trajectory group. This is in keeping with findings from another study by Schmidt, Risi, and Lord (2007) that reveal that children with the most success in social situations are not necessarily those with the highest IQ. Treatment for children in these two groups might focus less on mastery of speech and general cognitive skills as they mature and more on fine-tuning strengths and targeting specific problems in the area of social communication. In addition, the finding that more caregiver education increases the likelihood of placement into the highest trajectory group suggests a need to ensure greater access to and awareness of available treatment interventions for families with fewer socioeconomic resources.

The degree to which treatment may have influenced later outcome was not addressed. There are a number of other limitations and caveats to this study. Although we were able to retain 80% of the original sample over the 7-year period, attrition was greater in more socially disadvantaged families. The mostly nonsignificant effects of demographic variables may therefore have been related in part to our inability to follow some of the families in the most difficult circumstances. Additionally, children identified as young as age 2 and families that sought help for them at this early age may not be representative of children who are first referred at older ages. One might expect the children to have more severe problems than children referred at later ages and the families to be more proactive or to have stronger support than later referrals. A further limitation is that our estimates of verbal skills were not comprehensive measures of spontaneous expressive and functional receptive language but are based on verbal scores from standardized developmental and cognitive tests that emphasize receptive and expressive vocabulary. We hope to carry out more detailed analyses of language measures in the future. Future research will need to examine longitudinal trends for other outcomes such as adaptive skills and the relationships between the various outcome trajectories. With increasing attempts to deal with the possible neurobiological substrates to ASD and the recognition that there may be multiple “autisms” (DeLong, 1999; Pelphrey, Adolphs, & Morris, 2004), including trajectories as an aspect of the phenotype, may help us understand these complex disorders.

References


Mullen Scales of Early Learning


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