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Modeling Longitudinal Change in the Language Abilities of Children with Autism: Parent Behaviors and Child Characteristics as Predictors of Change

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Abstract

The objective of the current study was to evaluate the patterns of longitudinal change in the language abilities of 28 children with autism during early and middle childhood. Results from fitting a series of multilevel models showed that children's rate of language growth was independently predicted by (a) children's responsiveness to others' bids for joint attention, and (b) parents' responsiveness to their children's attention and activity during play. Both predictive relations could not be explained by initial variation in global developmental characteristics such as IQ, mental age, or language abilities. These findings support a social-pragmatic view on language acquisition which emphasizes the collaborative process through which children and their parents negotiate shared meaning.

Keywords: Autism; language development; parent-child interaction; longitudinal study; joint attention

Modeling Longitudinal Change in the Language Abilities of Children with Autism: Parent Behaviors and Child Characteristics as Predictors of Change

An important milestone in children's early social development is the ability to coordinate their interest in external objects or events with other people. In typical development, this ability gradually emerges between 9 and 15 months and is frequently referred to as the origin of joint attention. During this time period, a range of new communicative behaviors are consolidated in children's behavioral repertoire: infants start to follow their mothers' gaze direction and pointing gesture to determine the focus of her attention, infants alternate their gaze between an interesting object or event and their mothers' face, and they start to point to and show objects to capture their mothers' interest (e.g., Carpenter, Nagell, & Tomasello, 1998). Importantly, the emergence of these behaviors changes the way in which parents and children coordinate their attention and activity during toy play. Initially, it is the parents who carry a large share of the responsibility to ensure that a shared interest in an object or event is established. Only gradually, as infants acquire the ability to play a more active role in coordinating their interest with other people (i.e., as children acquire joint attention behaviors), do parents relinquish responsibility to their children (Bakeman & Adamson, 1984; Kaye, 1982).

Responsive parental behaviors and the origin of language. During early stages of development, parents use at least two interactive strategies to establish and maintain episodes of coordinated attention and activity. (1) Parents frequently engage their young children in familiar interactive routines such as hiding and finding objects or shared book reading. Bruner (1981) argued that such interactive routines, which he referred to as language learning formats, are ideally suited to focus children's attention on a specific aspect of their environment and provide maximum opportunity for parents to highlight interesting moments of the shared experience. (2)

Parental communication tends to be contingent upon children's focus of attention, ongoing activity, and communicative signals (Collis, 1977). Particularly during the early period from 9 to 15 months, several longitudinal studies have found that responsive parental behaviors reliably predict children's subsequent rate of language acquisition. That is, parents who are more likely to provide language input that is contingent upon children's attention and activity have children who subsequently develop language at a faster rate than children of parents who are less likely to provide contingent language initially (e.g., Akhtar, Dunham, & Dunham, 1991; Carpenter et al., 1998; Smith, Adamson, & Bakeman, 1988; Tamis-LeMonda, Bornstein, & Baumwell, 2001).

Children's use of social-pragmatic cues to inform language learning. The findings reviewed above suggest that early word learning often involves the parent labeling the object or action to which the child is currently attending. However, as they develop, children also acquire the ability to interpret various social-pragmatic cues reflecting the communicative intentions of other people. For example, Baldwin found that infants as young as 16 months of age are able to check the speaker's gaze direction to determine which object the speaker is referring to (Baldwin, 1991). Similarly, Tomasello and colleagues showed that between 18 and 27 months, children monitor an increasing variety of contextual cues, and use this information to inform language learning. These cues include (a) the speakers' facial affect, (b) the novelty of an object from the speakers' point of view, (c) the intentional or accidental nature of the speaker's actions, and (d) expectations about the focal moments of interactive routines (Akhtar, Carpenter, & Tomasello, 1996; Akhtar & Tomasello, 1996; Tomasello & Akhtar, 1995; Tomasello & Barton, 1994). Further, as children's language increases, the linguistic context of novel words or expressions becomes important for interpreting the speaker's communicative intent (Floor & Akhtar, 2006).

The acquisition of spoken language in children with autism. Despite meaningful differences in their interactive experiences (Hart & Risley, 1995), most children do master all the important milestones of early language development. One possible mechanism that protects children against variation in language input involves children's emerging ability to interpret others' social-pragmatic cues. For example, children who learn to interpret others' attentional cues are able to understand the meaning of parental utterances across a greater variety of situations. At the same time, children who lack joint attention may be (a) at increased risk for language delay, and (b) particularly dependent on language input that is contingent upon the child's ongoing experiences. Children with autism show a characteristic deficit in joint attention. Previous research has demonstrated that children with autism *respond to joint attention* (that is, follow an adult's gaze or pointing gesture to an object) less than either typically developing or developmentally delayed children. Similarly, they *initiate joint attention* less than children in these other groups in that they make fewer attempts to direct the attention of another person to an object or event by either pointing, showing, or alternating their gaze between an object and another person's eyes (Loveland & Landry, 1986; Mundy, Sigman, Ungerer, & Sherman, 1986; Sigman & Ruskin, 1999). In addition, when compared to typically developing children, most children with autism develop language late and at significantly slower rates (Lord & Paul, 1997).

Longitudinal studies are important tools to identify early abilities and interactive experiences that predict children's developmental trajectories. During the last decade, a growing number of longitudinal samples have been collected to investigate the development of spoken language in children with autism (Anderson et al., 2007; Charman, 2003; Charman et al., 2005; Drew, Baird, Taylor, Milne, & Charman, 2007; Sigman & Ruskin, 1999; Stone & Yoder, 2001; Toth, Munson, Meltzoff, & Dawson, 2006). Important support for the social-pragmatic view on language development comes from a longitudinal sample collected by Sigman and colleagues. The authors recruited a group of preschoolers with autism (CA = 47 months) who were followed over a period of nine years (N = 51) and 15 years (N = 48). Longitudinal change in children's language abilities was evaluated using standardized tests of children's expressive and receptive language skills, including the Reynell Developmental Language Scales (Reynell, 1977) and the Childhood Evaluation of Language Fundamentals-Revised (CELF-R, Semel, Wiig, & Secord, 1987). Results show that young children with autism who responded more frequently to others' bids for joint attention (RJA) showed better language skills after nine (Sigman & Ruskin, 1999) and 15 years (Sigman & McGovern, 2005) than children who initially responded less to others' bids for joint attention. This predictive relation could not be explained by initial variation in children's language abilities. In addition, a sub-sample of 25 preschoolers with autism was used to investigate the role of parents in fostering the development of spoken communication in children with autism (Siller & Sigman, 2002). Findings show that parents of young children with autism who were more responsive to their children's focus of attention and ongoing activity during early play interactions (maternal synchronization) had children who developed superior language over a period of 10 and 16 years than did children of parents who were less responsive initially. Again, the longitudinal link between parental behaviors and children's language outcome could not be attributed to initial child characteristics such as joint attention, language, or IQ.

To date, the study reported by Siller and Sigman (2002) is the first and only published longitudinal study to investigate the predictive relation between responsive parental behaviors and the language development of children with autism. In contrast, the predictive link between RJA and children's subsequent language gain has also been investigated in a longitudinal sample of 166 toddlers who met diagnostic criteria for Autism Spectrum Disorder (ASD) during the second year of life (Anderson et al., 2007). The authors reported that 96 children in this sample were speaking in phrases and sentences by age 9, while 70 children remained largely nonverbal (i.e., few or no words at outcome). Using a composite score that included response to joint attention and response to name, the authors reported that individual differences in early joint attention behaviors significantly differentiated between these two groups of children. That is, the presence of early joint attention behaviors significantly increased the likelihood of children developing phrase speech over time. Interestingly, among the 96 children who did develop phrase speech, the authors found no significant relation between individual differences in early joint attention behaviors and children's subsequent gains in spoken language. It has been argued that joint attention behaviors are best understood as "starter set" skills that "set the stage for social and communicative exchanges in which language can develop" (p. 1001, Toth et al., 2006). Once this stage is set, representational skills including functional/symbolic toy play (Sigman & Ruskin, 1999; Toth et al., 2006) and imitation (Charman, 2003; Stone & Yoder, 2001) may become important for children's continued language development.

Finally, longitudinal studies evaluating the predictive link between early initiations of joint attention (IJA) and children's subsequent language trajectories reveal a rather complex picture. On the one hand, most studies that investigate this prediction report a correlation between IJA and children's subsequent language gains. On the other hand, only two studies found this prediction to remain significant once initial variation in global developmental characteristics was statistically controlled (Charman, 2003; Sigman & Ruskin, 1999). Other studies suggested that the longitudinal prediction between IJA and language gain is not specific and can be attributed to initial variation in other child characteristics such as language age, nonverbal IQ, play skills, or imitation (Drew et al., 2007; Sigman & Ruskin, 1999; Stone & Yoder, 2001; Toth et al., 2006). Again, it has been suggested that differences in sample characteristics may account for these seemingly inconsistent findings (Toth et al., 2006). The specific link between IJA and language gain may be particularly important when studying children who are during early stages of language development.

The current study. Autism is a neurodevelopmental disorder with strong genetic influences. Moreover, the nature of these abnormalities is likely to constrain a child's potential for language learning. At the same time, it has been suggested that interactive experiences may be particularly powerful in promoting the language development of children whose biological constitution puts them at risk for language delay (Tannock & Girolametto, 1992). For example, Landry, Smith, Swank et al. (2001) reported that maternal responsiveness had a bigger impact on the cognitive and social development of preterm children than it had on children born full-term. Siller and Sigman (2002) reported the first study to show that responsive parental behaviors reliably predict the long-term language outcomes of children with autism. For the current study, we recruited an independent sample of young children with autism, aiming to replicate and extend these findings.

Recent years have witnessed major advances with regards to statistical methods for analyzing longitudinal data (e.g., mixed models, Singer & Willett, 2002; Weiss, 2005). The objective of the current study was to take advantage of these modern statistical methods (i.e., mixed models for longitudinal data) and evaluate the patterns of longitudinal change in the language abilities of 28 children with autism during early and middle childhood. Specifically, we aimed to test three hypotheses and explore one research question. We predicted that the rate of language growth in children with autism is predicted by (a) children's responsiveness to others' bids for joint attention, and (b) parents' responsiveness to their children's attention and activity. In addition, we hypothesized that both predictive relations are independent from each other and cannot be explained by initial differences in language abilities, mental age, or IQ. Finally, we aimed to investigate the longitudinal link between children's early initiations of joint attention and their subsequent gains in language.

Methods

Participants

The families participating in this research were recruited from the UCLA Autism Evaluation Clinic between 1997 and 2000. Subjects who participated in this research were different individuals than those included in the samples presented by Siller and Sigman (2002) or Sigman and Ruskin (1999); however, the current research sample does overlap with one other published report (Bono, Daley & Sigman, 2004). Parents of young children with a clinical diagnosis of ASD were contacted by the clinic staff and invited to participate. Forty families entered the study and were administered two standardized diagnostic procedures: the Autism Diagnostic Interview-Revised (ADI-R, Lord, Rutter, & Le Couteur, 1994) and the Autism Diagnostic Observation Schedule-Generic (ADOS-G, Lord et al., 2000). Although all 40 families participated in our research project, this analysis included a sub-sample of children who (a) entered our study with a language age of 36 months or less (not met by 6 subjects); (b) were seen for a home visit at study entry (not met by 1 subject); (c) participated in two or more waves of data collection (not met by 2 subjects); and (d) met diagnostic criteria for Autistic Disorder (not the broader category of ASD) on either the ADI-R <u>or</u> the ADOS-G (not met by 3 subjects). Out of the remaining 28 children, 27 met diagnostic criteria for Autistic Disorder on the ADOS-G (the only child who met criteria for the broader classification of ASD at baseline met diagnostic criteria for Autistic Disorder when reevaluated one year later); 24 children also met diagnostic criteria for Autistic Disorder on the ADI-R (one subject was not administered the ADI-R); 3 children met criteria for Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS) on the ADI-R, defined as falling within 2 points of autism cutoffs for algorithm criteria (Risi et al., 2006). The sample included 22 boys/6 girls and children's chronological ages ranged between 31 and 64 months; descriptive information is presented in Table 1. Mothers ranged in age between 23 and 42 years (M = 35.7, SD = 5.5) and varied considerably with regards to their educational background: 21% had an advanced degree (e.g., master's, doctoral), 29% had completed a standard college degree (e.g., B.A.), and 46% had a high school diploma. At study entry, 50% of mothers worked at least part-time outside of the home. The sample was predominantly European American (68%) but included groups of children with Hispanic (11%), Asian (7%), or mixed (14%) ethnic origin. Finally, as indexed by a median household income between $80,000 and $100,000 per year, the participating families are best described as upper middle class.

-- *Insert Table 1 about here* --

Procedures

This study included four waves of data collection. Initial assessments (wave 1) occurred during three individual sessions. Two assessment sessions were held at the UCLA Medical Center and included an evaluation of nonverbal communication, a test of cognitive development, and a standardized language assessment. In addition, a home visit was scheduled during which an episode of mother-child interaction was videotaped. For 79% of the families, all three sessions were held within a period of 8 weeks (for 3 families, 2 families, and 1 family, sessions were scheduled within 3, 4, and 5 months, respectively). Once the initial assessments were completed, families were invited to participate in three waves of follow-up visits (waves 2 to 4). The mean time intervals in months (with standard deviations in parentheses) between waves 1 to 4 were 12.3 (1.5), 12.7 (1.2), and 20.2 (3.5), respectively. During each follow-up assessment, a standardized language measure was administered. Due to subject attrition, only 20 of our 28 subjects participated in all four waves of data collection. In addition, 3 children were missing one of four data points because we were not able to establish a basal/ceiling level on the administered language measure. In order to determine how representative the follow-up sample is of the children who were originally recruited, a series of ANOVAs was computed comparing the 11 subjects who missed at least one data point (nine children missed one data point; two children missed two data points) with the 17 subjects for which complete data were available. Dependent variables included in this analysis were intake variables such as chronological age, nonverbal mental age, nonverbal IQ, language age, and maternal education. None of the corresponding F-statistics approached significance ($p > .20$).

Assessments of developmental and language skills. To evaluate nonverbal cognitive abilities at study entry, children were administered the Visual Reception and Fine Motor subscales of the Mullen Scales of Early Learning (MSEL, Mullen, 1995). The items on these subscales do not require the ability to understand verbal instructions or produce a verbal response. Both scales provide age equivalent scores for children's abilities which were averaged to compute a single nonverbal mental age score (NVMA). Even though the MSEL provides norm-referenced T-scores, most children in this study scored outside the range of differentiated scores. For this reason, children's nonverbal IQ scores (NVIQ) were computed as NVMA divided by chronological age. For one child who passed the highest items on the MSEL, the NVMA/NVIQ scores were based on two nonverbal subscales of the Stanford-Binet Intelligence

Scales: 4th Edition (Pattern Analysis and Bead Memory Sections, Thorndike, Hagen, & Sattler, 1986).

Children's language abilities were evaluated across all four waves of data collection. As a result, children's language scores varied substantially, both between individuals and over time (the range of age equivalent scores was 0 to 7 years). Since there is not a single measure that is standardized across this broad range of abilities, children's language scores were derived from three different measures, depending on children's developmental level. All three measures provide age equivalent scores combining children's expressive and receptive language abilities: (1) Reynell Developmental Language Scales (RDLS, Reynell, 1977), (2) Mullen Scales of Early Learning (MSEL, Receptive and Expressive Language Scale, Mullen, 1995), and (3) the Childhood Evaluation of Language Fundamentals-Revised (CELF-R, Semel et al., 1987). Most language scores were based on the RDLS which differentiates children performing between 13.5 and 61 months. For children who did not attain a basal level on the RDLS, the MSEL were used to derive children's language scores; we used the CELF-R if we were able to establish a basal level on this measure. Table 2 shows descriptive information on children's language abilities and the language measures used at each wave of data collection. Finally, we used wave 1 data to evaluate the consistency between language measures. That is, at wave 1, all children except one were administered both, the MSEL and the RDLS. An intraclass correlation coefficient (ICC = .86) revealed excellent agreement between the two measures. In addition, wave 1 data revealed a strong correlation between the expressive and receptive language scales ($r = .87$, $p < .001$), providing support for our decision to use a single language age equivalent score for all subsequent analyses.

-- Insert Table 2 about here --

Early Social Communication Scale (ESCS). The ESCS (Seibert, Hogan, & Mundy, 1982) is designed to assess nonverbal communication behaviors of young children. In this procedure the child and examiner sat facing each other at a small table. A set of toys was in view but out of reach to the child. The examiner presented and/or activated the toys on the table one at a time. The child-examiner interaction was videotaped and coded for two kinds of joint attention behaviors: child initiations for joint attention (IJA) and child responses to bids for joint attention (RJA). IJA was measured as the frequency of child behaviors used to direct the attention of the examiner to an event or object as an act of sharing (alternates gaze between an active mechanical toy or a toy in his hand and the tester's face, points towards a toy within reach or a poster, or shows a toy to the tester). RJA was evaluated by the tester pointing to the left, right, and behind the child (6 trials), and is measured as the percentage of instances where the child followed the point by turning his head and eyes in the designated direction. The mean duration of the ESCS was 21 minutes (SD = 4). Exploratory analyses showed that children's joint attention scores were not associated with differences in testing time. To establish interobserver reliability, 10 examiner-child interactions were reviewed independently by two trained observers. The joint attention scores of both observers were compared using an intraclass correlation coefficient, showing excellent agreement (ICC $\geq$ .97). Finally, to explore the validity of this measure, we computed correlation coefficients between the RJA/IJA scores from the ESCS and the corresponding scores from the ADOS-G. Non-parametric Spearman correlations revealed significant associations for both variables (RJA: Rho = - .60, $p < .01$; IJA: Rho = - .47, $p < .05$). The significant level of intermethod agreement supports the validity of the two ESCS variables included in this analysis.

Mother-child interactions. The initial wave of assessments included a home visit during which an episode of mother-child interaction was videotaped. Mothers were presented with a standardized set of toys, instructed “to play as they normally would”, and videotaped with a hand held camera for approximately 14 minutes (M = 13.8, SD = 1.7). The videographer was instructed to capture an optimal view of (a) the child’s face, (b) the toy the child was playing with, and (c) the mother’s hands. Background noises (e.g., TV, open window, air conditioning) were avoided as much as possible. Videotaped interactions were coded with an observational computer system (The Observer Video-Pro, NOLDUS), using a streamlined version of the coding system introduced by Siller and Sigman (2002). This coding system focuses on three behavioral dimensions: (1) maternal indicating behaviors, (2) maternal verbal behaviors, and (3) children’s toy directed attention. Each dimension was coded in several passes through the video. Interactions were coded by a team of five undergraduate research assistants who were blind with regards to the research hypotheses and children’s assessment results.

Maternal indicating behaviors. Coders first identified the onset of distinct indicating behaviors defined as (a) mothers pointing at a specific toy or (b) mothers showing/offering toys to their children. In a second pass through the video, we evaluated for each indicating behavior as to whether it was synchronized with the child’s attention or not. To make this determination, coders reviewed the one second interval prior to the onset of each indicating behavior. If, during this interval, the child was already gazing at the same toy the mother was about to reference, the maternal indicating behavior was coded as *synchronized with the child’s attention*. If, on the other hand, the maternal behavior aimed to redirect the child’s attention to a different toy, the behavior was coded as *unsynchronized with the child’s attention*.

Maternal verbal behaviors. During a separate pass through the video, observers marked the onset of distinct verbal utterances. Once the onset of each utterance was determined, a second coder decided whether each utterance was *synchronized with the child's attention*. To make this determination, we applied the same coding rules that were previously described for maternal indicating behaviors. Finally, in a third pass through the video, we evaluated the content of each maternal utterance. That is, for each utterance, we determined whether it was *synchronized with the child's actions* or not. An utterance was determined to be *synchronized with the child's actions* if the mother commented on an action the child was already performing prior to the onset of the utterance (e.g., by describing the child's action or providing reinforcement). On the other hand, an utterance was determined to be *un-synchronized with the child's actions* if the mother verbally suggested an action that was different from the action the child was already performing. For example, if the child was engaged with racing the dump truck on the floor and the mother said, "Can you dump the truck?", the maternal utterance would be coded as *un-synchronized with the child's actions*. On the other hand, if the mother said "Oh boy, this truck is driving fast!" the utterance would be coded as *synchronized with the child's actions*.

<u>Children's toy directed attention.</u> This part of the coding system was designed to measure the proportion of observation time children were attending to the target toys. Siller and Sigman (2002) used a continuous approach to coding children's toy directed attention. In an attempt to streamline the coding process, the current study used a random sampling approach. That is, we selected a random sample of 100 still frames for each videotaped interaction (on average 7 random frames per minute). From each still frame, coders determined whether the child was looking at one of the target toys or not. Based on this random sample of 100 events, we estimated the percentage of children's toy-directed attention. Preliminary analyses showed a high level of consistency between the continuous and the random sampling approach to coding children's toy directed attention (intraclass correlation, ICC = .83).

Reliability. The coding system described above involves multiple observers making multiple passes though each video. The data derived during this coding process were merged later to count the frequency of specific combinations of codes. This coding process makes it necessary that observers do not only agree on the total frequency of behaviors, but also on the exact timing of individual events. If such second-by-second agreement is established, it can generally be assumed that merged scores derived from the raw data will also agree (Bakeman & Gottman, 1997). Interobserver reliability was established between the first author and five undergraduate research assistants using videotaped interactions from 10 mother-child dyads. To evaluate reliability for coding the onset of maternal behaviors (i.e., indicating behaviors, verbalizations), a tolerance of 2 seconds was used, and percentage agreement indices were calculated. This seemed appropriate since interobserver differences in timing were very small (96% of agreements were within 0.5 seconds). Thus, the possibility of chance agreement is negligible. Percentage agreement indices for the onset of maternal verbalizations and indicating behaviors were 84% and 75%, respectively. For the determination as to whether maternal behaviors were *synchronized with the child's attention* or not, Kappa coefficients showed a mean agreement of .82 and ranged between .80 and .83. Similarly, Kappa coefficients showed an agreement of .75 for the decision whether maternal utterances were *synchronized with the child's action* or not. Finally, intraclass correlations revealed an agreement of .96 for measuring the percentage of *children's toy directed attention*.

Three measures of maternal synchronization. Frequency counts were used to compute three composite scores, evaluating the degree to which maternal behaviors were synchronized with children's attention and actions. Specifically, the three measures were based on (a) the percentage of maternal indicating behaviors that were synchronized with children's attention

(MS1), (b) the percentage of maternal verbal utterances that were synchronized with children's attention (MS2), and (c) the percentage of maternal verbal utterances that were synchronized with both, children's attention *and* action (MS3). All three measures were designed to control for the mothers' opportunity to act in synchrony. According to our definitions, mothers only have the opportunity to act in synchrony at times during which the child is attending to one of the target toys. For this reason, our three measures of maternal synchronization were computed by dividing the percentage of synchronized behaviors by the percentage of time children were attending to toys. For example, MS1 was computed using formula 1.

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Analysis

The objective of this study was to evaluate the patterns of longitudinal change in the language abilities of 28 children with autism during early and middle childhood. Specifically, we were interested in early characteristics of the children and their interactive experiences that explain the variability among individual growth trajectories. Data analysis consisted of three parts: (1) The first set of analyses was primarily descriptive (parallel plots, sample means, standard deviations, histograms, and skewness statistics) to explore whether the predictor and outcome variables were best analyzed on the original or logged scale; (2) The second set of analyses was exploratory and involved zero-order correlations between all predictor and outcome variables as well as three measures of language gain (after minus before); (3) To examine our developmental hypotheses we fit a series of multilevel models for longitudinal data using SAS Proc Mixed. Multilevel models of longitudinal change postulate statistical models at each of two levels. The Level-1 model (within-subject model) describes each individual's change trajectory using growth curve parameters such as intercept (representing the individual's initial status) and slope (representing the individual's rate of linear growth). Simultaneously, individual differences in these growth curve parameters are modeled as part of the Level-2 model (between-subject model). Thus, the Level-2 model represents individual differences in growth curve parameters as a function of the predictors, addressing our key research questions. The final models testing our developmental hypotheses were specified as Random Intercept Models.

Results

Descriptive Analyses

A parallel plot of the original language data as a function of children's chronological age is presented in Figure 1. The corresponding sample means and standard deviations are presented in Table 2. Descriptive information indicates that, overall, children's language abilities increased over time. However, the rate of change varied considerably across children. That is, a few children showed relatively large language gains while the majority of children gained language rather slowly. Since deviations from the normal distribution of the dependent variable may bias the effect estimates of multilevel models, children's language scores were log transformed (base 2) for all subsequent analyses. Table 1 presents descriptive statistics (i.e., mean, median, standard deviation, range) for all predictor variables. Results indicate that all variables evidence sufficient variability to justify including them as predictors into our models. However, the distribution of two predictors (i.e., NVMA, MS1) evidenced a slight positive skew which was corrected by log transforming (base 2) children's original scores.

-- *Insert Figure 1 about here* --

Correlation Analyses

Table 3 presents zero-order correlations between all predictor and outcome variables, including three measures of language gain. Language gain was calculated by subtracting the log transformed language score of wave 1 from the log transformed language scores of waves 2, 3, and 4. Results show that children's initial language skills were concurrently correlated with other child characteristics including NVIQ, NVMA, RJA, and IJA. In addition, early indicators of global development (language age, NVMA, NVIQ) as well as joint attention (RJA, IJA) reliably predicted all three subsequent waves of language outcome. However, only joint attention (RJA, IJA) but not chronological age, language age, NVMA or NVIQ predicted children's subsequent language gain. Finally, children's language gain was predicted by all three measures of maternal synchronization (MS1, MS2, MS3).

-- Insert Table 3 about here --

Multilevel Modeling Analyses

This analysis aimed to evaluate the unique contributions of joint attention and maternal synchronization in predicting children's rate of language growth. To test our developmental predictions, we specified a series of multilevel models for longitudinal data: (1) we fit two unconditional models to examine the variability of language scores between and within subjects as well as the mean and variability of individual growth parameters (intercepts and slopes). (2) We fit a series of multilevel models, each including one Level-2 predictor. Predictors included three measures of global development (CA, NVMA, NVIQ), two measures of joint attention (RJA, IJA), and three measures of maternal synchronization (MS1, MS2, MS3). (3) We fit a series of single predictor models to explore the role of potentially confounding variables including socioeconomic status, subject attrition, and the base rates of maternal behaviors. (4) Relevant predictors were incorporated into a model that included multiple Level-2 predictors: measures of global developmental characteristics were entered first; measures of joint attention were entered second; and measures of maternal synchronization were entered last. (5) We explored the appropriate random effect structure of the ‘best’ multi predictor model: Random Intercept (RI) or Random Intercept and Slope (RIAS). (6) The final test of our developmental hypotheses used the most parsimonious random effect structure (Random Intercept) to specify three multi predictor models. The three models included all relevant child characteristics and one measure of maternal synchronization.

Unconditional models. The first step of model development was to fit two unconditional models. The first unconditional model (Unconditional Means Model, UMM) was specified with a random intercept assuming that even though children may vary in language abilities, each individual’s developmental trajectory is completely flat. Instead of describing change, this model describes and partitions the variation in children’s language scores. The second unconditional model (Unconditional Growth Model, UGM) was specified with both random intercept and slope assuming that individuals differ not only with regard to their initial language abilities (intercept) but also with regard to their subsequent rate of language growth (slope). The variance components of the UMM show that the variation of language scores between subjects ($\sigma_0^2 = .391$) is about 1.5 times larger than the variation of language scores within subjects ($\sigma_e^2 = .256$). Adding a linear slope to the Level-1 model (UGM) reduces the unexplained variance (σ_e^2) by about 83%, indicating that a large percentage of variation is associated with a subject-specific *linear* time trend. Finally, the fixed effects of the UGM provide estimates for the intercept ($\gamma_{00} = 3.980$) and slope ($\gamma_{10} = .272$, $p < .001$) of the population average change trajectory. Transformed back to the original scale of age equivalent scores, the estimated average participant entered our study with language abilities of 15.8 months and gained an additional 12 months while participating in our study for 3 years.

Single predictor models for substantive predictors. The second step of model development was to fit a series of single predictor models. Variables were entered simultaneously as predictors of children's initial language status and their subsequent rate of language growth. All models were specified as RIAS models. Results showed that children's initial language status was reliably predicted by RJA ($F_{(1,43)} = 50.7$, $p < .001$); IJA ($F_{(1,43)} = 6.2$, $p < .05$); NVMA ($F_{(1,43)} = 38.3$, $p < .001$); and NVIQ ($F_{(1,43)} = 18.2$, $p < .001$). Moreover, the rate of children's language growth was reliably predicted by initial variations in RJA ($F_{(1,43)} = 9.85$, $p < .01$), IJA ($F_{(1,43)} = 7.3$, $p < .01$), and all three measures of maternal synchronization (MS1: $F_{(1,43)} = 8.97$, $p < .01$; MS2: $F_{(1,43)} = 5.74$, $p < .05$; and MS3: $F_{(1,43)} = 6.89$, $p < .05$). In contrast, children's language growth was not predicted by initial variation in NVMA ($F_{(1,43)} = 0.03$, $p = .87$) or NVIQ ($F_{(1,43)} = 1.83$, $p = .18$). Finally, variation in initial CA was not related to the slope or intercept of children's language trajectories.

Single predictor models for potentially confounding variables. It is possible that the association between initial levels of maternal synchronization and children's subsequent language gain is spurious. That is, other variables that determine children's language gain could also be concurrently associated with the level of maternal synchronization. First, the families' socioeconomic status (e.g. annual family income, years of maternal education) could produce such a spurious finding. Second, a spurious association could also be the result of confounds associated with our research design (e.g. variation in the observation time of mother-child play interactions, subject attrition). Finally, the formula used to compute the measures of maternal synchronization was designed to control for differences in the base rate of maternal behaviors (i.e., the total frequency of verbal utterances or indicating behaviors) as well as the proportion of time children were attending to toys. For this reason, our findings would be difficult to interpret if these control variables were themselves related to children's language outcome. To examine the validity of these alternative explanations, we fit a series of single predictor models. The results showed that none of the variables mentioned in this paragraph was reliably linked to the intercept or slope of children's language trajectories.

Stepwise model development. To examine which variables were independent predictors of children's language outcome, relevant predictors were incorporated into a model that included multiple Level-2 variables: measures of global developmental characteristics were entered first; measures of joint attention were entered second; and measures of maternal synchronization were entered last. Within each level of this hierarchy, variables were entered stepwise. Improvements in model fit were evaluated by comparing fit statistics (-2 Log Likelihood statistic) across nested models. Results from fitting these models are reported in Table 4. At *Step 1*, NVMA was entered as a predictor of children's initial language status, $\chi^2_{(1)} = 24.7$, $p < .001$. Thereafter, none of the other measures of global development (CA, NVIQ) significantly improved model fit, neither as a predictor of children's initial language status, nor as a predictor of children's rate of language growth. At *Step 2*, adding RJA as a predictor of intercept and slope improved model fit significantly, $\chi^2_{(2)} = 22.9$, $p < .001$. Adding IJA to this two predictor model did not significantly improve the fit of the model, $\chi^2_{(2)} = 1.4$, $p = .49$. Finally, we tested whether the measures of maternal synchronization predicted children's language outcome independently of initial child characteristics (NVMA; RJA). Results from *Step 3* of model development suggest that MS1 is associated with the largest improvements in model fit, $\chi^2_{(2)} = 7.5$, $p < .05$. None of the other measures of maternal synchronization added to the fit of the model thereafter.

-- *Insert Table 4 about here* --

Exploring the random effect structure. All previous conditional models were specified as RIAS models. This random effect structure estimates three level-2 variance components: (1) the unexplained variance of the intercepts, σ_0^2, (2) the unexplained variance of the slopes, σ_1^2 and (3) the covariance between the residual intercepts and slopes, σ_{01}. Table 4 shows that as predictors are added to the model, the variability of unexplained slopes (σ_1^2) decreases in size. For example, the unexplained variability of slopes in the UGM is $\sigma_1^2 = .015$. Results from a z-test indicate that this variability is significantly different from zero ($z = 2.27$, $p < .05$), indicating significant variability of growth rates across children. In comparison, at *Step 3*, the unexplained variability is $\sigma_1^2 =.004$ and no longer significantly different from zero ($z = 1.11$, $p = .13$). This lack of residual variability raises the question whether the RIAS model provides an appropriate test for our developmental hypotheses. Specifically, our data seem to favor the more parsimonious RI model, which is the exact same model as repeated measure ANOVA. To compare the fit of the RIAS model to the more parsimonious RI model, we specified the *Step 3* fixed effects both ways. The Bayes Information Criterion (BIC) of the RIAS and RI model was 75.8 and 72.7, respectively. Thus, model comparison favored RI with a probability of 96% over RIAS.

The final models. As a final test of our developmental hypotheses, we re-specified the fixed effects of the 'best' multi predictor model (*Step 3*, NVMA, RJA, MS1) using RI as the model's random effect structure. The independent contributions of the predictor variables were evaluated using Wald tests. Results from fitting this model are reported in Table 5. In addition, we specified two models to test the predictive relations between MS2/MS3 and children's subsequent language growth. Given the evident colinearity between the three measures of maternal synchronization, models included all relevant child characteristics (NVMA, RJA) and one of the remaining measures of maternal synchronization (i.e., MS2, MS3). Results from fitting these two models are also presented in Table 5. Fixed effect estimates predicting children's initial language status show significant effects for RJA, and to some degree also for

NVMA. Thus, variations in language skills at study entry were concurrently associated with variations in joint attention and mental age. Fixed effects predicting children's rate of language growth showed significant effects for RJA and all three measures of maternal synchronization (MS1, MS2, MS3). In turn, children's initial responsiveness to others' bids for joint attention reliably predicted their subsequent rate of language acquisition. Similarly, children whose parents showed higher levels of synchronization during initial play interactions developed language more rapidly than children of parents who were less synchronized initially. Figure 2 provides a graphical representation of the relations between RJA/MS2 and language outcome. Graphical representations of the relations between MS1/MS3 and children's language were consistent with the results presented for MS2.

-- *Insert Table 5 and Figure 2 about here* --

Discussion

One of the biggest challenges that professionals face is helping parents of young children with autism understand what they can expect for their children's future. The challenge arises because very little is known about (a) the stability of global developmental delays over time, (b) early abilities that predict children's developmental trajectories and (c) interactive experiences that foster their developments. The objective of the current study was to evaluate the patterns of longitudinal change in the language abilities of 28 children with autism during early and middle childhood. The study had three major findings. First, preschoolers with autism who were more responsive to others' bids for joint attention acquired subsequent language at a faster rate than children who were less responsive initially. Second, parents whose behaviors were more responsive to their children's ongoing interest and activity during early play interactions had children who developed superior language skills than did children of parents who were less responsive during play. Finally, both predictive relations were independent from each other and could not be explained by initial variation in global developmental characteristics such as IQ, mental age, or language skills.

Compared with typical development, most children with autism acquire language late and at significantly slower rates. In the current sample, 16 children continued to understand and use very little language throughout the study (language age below 2 ½ years); 7 children acquired language skills within the 2 ½ to 4 year range; and only 5 children surpassed the level of a typically developing 5 year old. Anderson et al. (2007) reported a similar pattern of language growth in children who met diagnostic criteria for *Autistic Disorder* during the second year of life. From a statistical viewpoint, this distribution of language gain scores raises concerns because deviations from the normal distribution may lead to biased estimates, incorrect standard errors, and erroneous inferences (Singer & Willett, 2002). With the exception of Siller and Sigman (2002), who reported nonparametric tests to confirm their findings, the fact that language outcomes (and growth rates) are not distributed normally in most samples of children with autism has not been addressed in longitudinal research. In this analysis we chose a rather conservative approach to testing our developmental hypotheses. That is, we log transformed children's original language scores to yield a normal distribution.

Very few previous studies have evaluated questions about change in the language abilities of children with autism using a multilevel model analysis (Anderson et al., 2007; Toth et al., 2006). This modern method for analyzing longitudinal data has important advantages over traditional methods. One advantage over wave-to-wave regression is that hypotheses concerning multiple waves of outcomes can be tested in a single analysis. In addition, multilevel model analysis accommodates missing data points as well as individual variation in the spacing of repeated waves of data. This being said, in using these modern methods with small sample sizes it is necessary to ensure that all assumptions that enter the model are indeed met by the data. For the current study, we are convinced that small sample size is not a concern: (1) all predictor and outcome variables were distributed normally; (2) all models specified as part of this analysis fit satisfactorily using maximum likelihood methods; (3) results from specifying various intermediate models produced consistent results; (4) final models were specified with a parsimonious Random Intercept structure, which is the exact same model as repeated measure ANOVA; and (5) the results from the multilevel modeling analysis were consistent with the zero-order correlations reported in Table 3.

By employing a multilevel modeling framework, this research enables us to address two separate questions about the longitudinal relationships between language abilities, mental age, and IQ in autism. (1) The first question concerns the stability of individual differences over time. Findings show that initial measures of nonverbal mental age and IQ correlated significantly with all follow-up measures of children's language outcome. Similarly, results from fitting the Unconditional Means Model evidence substantial correlations between the four repeated language measures (average intraclass correlation coefficient; ICC = .60). Thus, individual differences in global developmental delays (i.e., level of functioning, mental retardation) explain a significant portion of observed variation in children's language scores at outcome (Howlin, Goode, Hutton, & Rutter, 2004). (2) A separate question concerns how the language abilities of children with autism change over time. Specifically, we investigated whether initial measures of language, mental age, or IQ predict differences in children's rate of change. In short, we did not find evidence that this is the case. The Unconditional Growth Model evidenced a lack of association between children's language abilities at study entry (intercept) and their subsequent rates of language growth (slope; $\sigma_{01} = .30$, $p > .10$). Similarly, results from fitting single predictor models showed that the rate of change in children's language abilities was not predicted by initial variation in nonverbal mental age or IQ. The finding that initial variation in global developmental delays failed to explain how much language children gained during subsequent years is surprising. Given the small size and heterogeneity of the current research sample (children's chronological age ranged from 2 ½ to 5 ½ years) it is possible that these non-significant findings can be attributed to a lack of statistical power. However, in a recent study of 166 children with ASD, Anderson et al. (2007) also reported a non-significant covariance between intercept and slope ($\sigma_{01} = .30$, *ns*) when fitting an Unconditional Growth Model to their longitudinal data. Similarly, several other longitudinal studies that focused their analyses or enrollment on nonverbal preschoolers with autism have also reported that early IQ scores were not related to subsequent language gains (Charman et al., 2003; Lord & Schopler, 1989; Mundy, Sigman, & Kasari, 1990; Sigman & Ruskin, 1999).

The social-pragmatic view, as outlined in the introduction to this paper, characterizes language learning as a process of matching language input with experiences. More recently, this view has been extended by emphasizing the collaborative process through which children and their parents negotiate shared goals, intentions, and actions (Tomasello, Carpenter, Call, Behne, & Moll, 2005). The current study investigated interactive behaviors of preschoolers with autism and their parents: Children's responsiveness to others' bids for joint attention (RJA) and initiations of joint attention (IJA) were evaluated during a standardized interaction with an examiner; parental responsiveness to the child's focus of attention (MS1; MS2) and activity (e.g., goals, intentions, actions; MS3) was evaluated during an episode of parent-child play.

Results show that early initiations of joint attention (IJA) reliably predicted children's subsequent 3 to 4 year gains in spoken language. Importantly, the predictive link between IJA and language gains could not be explained by initial variation in global developmental characteristics such as chronological age, nonverbal mental age or nonverbal IQ. However, the current study also found that the predictive link between IJA and children's subsequent language gains was no longer significant once RJA was added to the model. Preliminary descriptive analysis of our intake variables showed that IJA evidenced sufficient variability to justify inclusion as a predictor. However, it is important to point out that the vast majority of initiations of joint attention produced by the children in this study were quite subtle: 86% of initiations were solely based on eye contact; only 14% involved gestures such as pointing or showing.

In the current data set, RJA was the strongest child characteristic to predict subsequent linguistic development. Controlling for RJA, none of the other child characteristics reliably predicted children's rate of language gain. In contrast, all three measures of maternal synchronization contributed independent information when added individually to the model of initial child characteristics. Thus, findings from this research suggest that both children with autism (i.e., RJA) and their parents (i.e., maternal synchronization) contribute to the success of shared encounters. Moreover, both partners' contributions reliably and independently predicted children's subsequent rate of language growth. These findings replicate and extend the findings presented by Sigman and colleagues (Sigman & Ruskin, 1999; Siller & Sigman, 2002).

It is currently unknown why some parents of children with autism are more responsive to their child's focus of attention and ongoing activity than others. Research on typical development has provided some evidence showing that early child characteristics (e.g., joint attention, language skills) impact the subsequent development in the quality of caregiver-child interaction (Markus, Mundy, Morales, Delgado, & Yale, 2000). The possibility that early child characteristics elicit different levels of parental responsiveness raises questions about the causal network that underlies the predictive association between maternal synchronization and children's subsequent language growth. The challenge arises because if the level of synchronization constitutes a maternal adaptation to a specific characteristic of the child, it would be possible that it is this child characteristic that in itself determines the child's future development. Findings from this research, as well as findings presented by Siller and Sigman (2002) did not provide evidence for such a spurious correlation. None of the initial child characteristics evaluated in our research (e.g., language skills, mental age, IQ, joint attention) were able to explain the predictive relation between maternal synchronization and children's subsequent language gain. This being said, managing a collaborative activity with a young child with autism is a challenging task, even for trained professionals. The strategies that we choose to overcome these challenges will likely be affected by (a) specific child behaviors (e.g., the variability and appropriateness of the child's play, the child's ability to include others when playing with a toy) and (b) our perceptions of these behaviors (e.g., whether we perceive the child's play as constructive, whether we feel excluded or rejected). So far, the relations between child characteristics, parental cognitions and parental responsiveness have not been investigated.

The evident correlations between children's repeated language measures raise questions about the relative size of the predictive relations identified in this research. Results show that mothers with low synchrony scores (1 SD below average on MS2) had children who gained an estimated 3.1 months of language skills per year. In contrast, mothers with high synchrony scores (1 SD above average on MS2) had children who gained language at an annual rate of 6.3 months. Thus, maternal synchronization accounted for 3.2 months of children's annual language gain. Compared to typical development, this effect size seems small. Even children with highly synchronized parents will likely have difficulties narrowing the developmental gap that separates them from their typically developing peers. However, when this effect size is compared to findings from intervention studies, the relation between maternal synchronization and language gain seems clinically significant. In a randomized trial, Smith and colleagues (Smith, Groen, & Wynn, 2000) compared two groups of children with Autism Spectrum Disorders: (1) an intensive treatment group that averaged 26 weekly hours of behavioral intervention for a period of 1 to 3 years; (2) a parent training group receiving 5 weekly hours of behavioral training for a period of 3 to 9 months. Results show that the parent training group gained 4.2 months of language skills per year, while the intensive treatment group gained an average of 6.1 months.

In a recent review of the epidemiological literature, Fombonne (2006) concluded that only 36% of children with Autism Spectrum Disorder (ASD) meet the stricter diagnostic criteria for Autistic Disorder, while 64% meet criteria for Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS) or Asperger Syndrome. Several of the more recent longitudinal studies (Anderson et al., 2007; Toth et al., 2006) reflect this diagnostic distribution. The current sample included only children who met diagnostic criteria for Autistic Disorder on either the ADOS-G or the ADI-R (82% met criteria on both measures). We chose these criteria because the developmental hypotheses tested in our research seem particularly important during the early stages of children's social and communicative development. Moreover, recent clinical trials have demonstrated that interventions targeting joint attention are most effective for children who enter treatment with relatively low levels of language abilities and object exploration (Kasari, Paparella, Freeman, & Jahromi, 2008; Yoder & Stone, 2006). The question of whether similar developmental mechanisms also operate in higher functioning children with PDDNOS or Asperger Syndrome is a worth topic for future research.

Although findings from this longitudinal study are important, there are limitations to the conclusions that can be drawn. First, the current sample was rather small and variable with regards to children's chronological age at study entry. A larger and more homogeneous sample would be helpful for exploring specific interactions between measures of children's global development, joint attention, and responsive parental behaviors. Second, correlational findings do not allow us to draw firm conclusions about the underlying causal mechanisms. For this reason, we need to move towards experimental designs where subjects are randomly assigned to different treatment conditions.

Recent years have witnessed an advent of social-pragmatic interventions that aim to increase responsive parental behaviors during play (e.g., Aldred, Green, & Adams, 2004; Drew et al., 2002; Ingersoll & Gergans, 2007; Schertz & Odom, 2007; Siller, Hutman, & Sigman, 2007; Wetherby & Woods, 2006). Several of these parent-mediated intervention models are currently being evaluated using randomized controlled trials. Based on these studies, researchers will be able to test: (1) whether it is possible to modify the synchronous behaviors of parents in interacting with their children with autism; (2) whether these parent-mediated intervention models are efficacious for improving children's language development; and (3) whether changes in *maternal synchronization* mediate between intervention group assignment and children's subsequent gains in spoken communication. If all three predictions were to be supported, the causal link between synchronized parental behaviors and improvements in language development could be more fully drawn.

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Table 1

Descriptive Information About the Sample at Study Entry Including All Predictor Variables

	M (SD)	Median (Range)
Developmental measures		
Chronological age	45.2 (8.4)	47 (31 – 64)
Nonverbal mental age (NVMA)[1]	25.4 (8.4)	24.3 (12.5 – 52.5)
Nonverbal IQ (NVIQ)[1]	57.5 (19.8)	57.5 (25 – 122)
Early Social Communication Scale		
Responsiveness to bids for joint attention (RJA)	.38 (.38)	.25 (0 – 1)[3]
Initiations of joint attention (IJA)	7.5 (6.5)	6 (0 – 24)[3]
Maternal synchronization		
(a) Summary scores		
MS1	.89 (.34)	.87 (.26 – 2.20)
MS2	1.01 (.18)	1.01 (.58 – 1.59)
MS3	.70 (.18)	.71 (.38 – 1.12)
(b) Raw scores		
Maternal indicating behaviors[2]	17.0 (9.3)	15.2 (3.4 – 42.0)
Maternal verbal behaviors[2]	123.8 (33.7)	122.8 (46.7 – 196.0)
Maternal utterances: Synch. w/ attention (%)	74.1 (16.8)	78.6 (40.5 – 97.7)
Maternal utterances: Synch. w/ attention & action (%)	51.3 (15.1)	56.8 (24.8 – 71.8)
Children's toy directed attention (%)	75.1 (17.9)	81.1 (31.3 – 96.0)

Note. Chronological age and NVMA are reported in months.

[1] NVMA/NVIQ were based on the Mullen Scales of Early Learning and in one case the Stanford-Binet Intelligence Scale-Fourth Edition (SB-IV).

[2] Maternal verbal and indicating behaviors are presented as rates per 10 minutes of observation time.

[3] Nine children received a RJA score of 0; two children received an IJA score of 0.

Table 2

Descriptive Information About Children's Language Scores and Language Measures Used at Each Wave of Data Collection

	Wave 1	Wave 2	Wave 3	Wave 4
N	28	28	24	19
Chronological age				
Mean (SD)	45.2 (8.4)	57.5 (8.9)	69.5 (9.1)	89.0 (9.1)
Language age				
Mean (SD)	16.6 (7.1)	21.5 (9.2)	27.4 (14.6)	37.9 (24.2)
Language measures				
Mullen Scales of Early Learning (MSEL)	50%	21%	13%	-
Reynell Developmental Language Scales (RDLS)	50%	79%	83%	79%
Childhood Evaluation of Language Fundamentals-Revised (CELF-R)	-	-	4%	21%

Note. Chronological and developmental ages are reported in months. Eleven subjects (39%) were given the same language assessment across all waves of data collection: MSEL for 2 subjects (wave 4 missing); RDLS for 9 subjects.

Table 3

Zero-Order Correlations Between All Predictor and Outcome Variables

	1	2	3	4	5	6	7	8	9
Child predictors									
1 CA	--								
2 Language age	.03	--							
3 NVMA	.04	.75***	--						
4 NVIQ	-.45*	.62***	.83***	--					
5 RJA	-.07	.78***	.66***	.61***	--				
6 IJA	-.07	.42*	.34~	.43*	.67***	--			
Maternal synchronization									
7 MS1	-.17	.16	-.01	.10	.30	.29	--		
8 MS2	-.01	-.26	-.58**	-.41*	-.06	.23	.47*	--	
9 MS3	-.01	.11	-.21	-.12	.28	.37*	.48*	.71***	--
Language outcome									
Wave 2	-.03	.91***	.72***	.64***	.84***	.49**	.38*	-.18	.19
Wave 3	-.05	.78***	.52**	.50*	.85***	.50*	.36~	.05	.28
Wave 4	-.30	.75***	.56*	.61**	.86***	.68**	.42~	.33	.56*
Language gain									
Wave 1 and 2	-.14	-.10	.02	.10	.24	.23	.55**	.16	.22
Wave 1 and 3	-.16	-.05	-.17	-.02	.35~	.30	.44*	.36~	.36~
Wave 1 and 4	-.36	.12	.06	.28	.54*	.47*	.67**	.60**	.62**

Note. Log transformed scores were used for language age, NVMA, and MS1.

~p<.10. *p<.05. **p<.01. ***p<.001.

Table 4

Parameter Estimates (SE) of Fixed Effects and Variance Components From a Hierarchy of Random Intercept and Slope Models with Children's Language Abilities as Outcome

	UGM	**Step 1**	**Step 2**	**Step 3**
Fixed effects: Initial status				
Intercept	3.980*** (.112)	3.980*** (.072)	3.978*** (.058)	3.984*** (.057)
NVMA		.990*** (.157)	.400* (.163)	.442* (.165)
RJA			.949*** (.203)	.886*** (.216)
MS1				.059 (.110)
Fixed effects: Rate of change				
Intercept	.272*** (.030)	.273*** (.030)	.271*** (.025)	.264*** (.022)
RJA			.220** (.068)	.176** (.060)
MS1				.103* (.040)
Variance components: Level 1				
Within-person, σ_e^2	.044*** (.009)	.044*** (.009)	.044*** (.009)	.046*** (.010)
Variance components: Level 2				
In initial status, σ_0^2	.318*** (.094)	.117** (.040)	.065** (.027)	.060** (.026)
In rate of change, σ_1^2	.015* (.007)	.016** (.007)	.009* (.005)	.004 (.004)
Covariance, σ_{01}	.030 (.019)	.028* (.012)	-.001 (.009)	-.001 (.008)
Fit statistics				
-2 Log Likelihood	93.1	68.4	45.5	38.0

Note. UGM is an Unconditional Growth Model. Step 1 adds a main effect of NVMA. Step 2 adds a main effect for RJA and the RJA * Time interaction effect. Step 3 adds a main effect for maternal synchronization (MS1) and the MS1 * Time interaction effect; this model is the 'best' Random Intercept and Slope (RIAS) model fit to explain growth in children's language. Time was measured as years since study entry. Predictors were centered around the sample average. Models were fit using Full Maximum Likelihood (ML) estimation.

*p<.05. **p<.01. ***p<.001.

Table 5

Parameter Estimates (SE) of Fixed Effects and Variance Components From Three Random Intercept Models to Estimate the Independent Contributions of Joint Attention and Maternal Synchronization in Predicting Children's Language Outcome

	Model A	**Model B**	**Model C**
Fixed effects: Initial status			
Intercept	3.988*** (.060)	3.973*** (.063)	3.976*** (.063)
RJA	.935*** (.225)	.983*** (.250)	.994*** (.260)
NVMA	.393* (.168)	.375 (.243)	.378 (.202)
MS1	.043 (.116)		
MS2		-.289 (.484)	
MS3			-.006 (.423)
Fixed effects: Rate of change			
Intercept	.260*** (.019)	.280*** (.018)	.274*** (.019)
RJA	.169** (.051)	.196*** (.049)	.146* (.056)
MS1	.112** (.035)		
MS2		.407*** (.118)	
MS3			.259* (.114)[1]
Variance components: Level 1			
Within-person, σ_e^2	.056*** (.009)	.055*** (.009)	.059*** (.010)
Variance components: Level 2			
In initial status, σ_0^2	.064** (.022)	.075** (.025)	.073** (.024)

Note. Models were specified as Random Intercept (RI) models. Models included main effects for

RJA and NVMA and the RJA * Time interaction effect. Model A adds a main effect for MS1 and the MS1 * Time interaction effect. Model B adds a main effect for MS2 and the MS2 * Time interaction effect. Model C adds a main effect for MS3 and the MS3 * Time interaction effect.

[1]This fixed effect was only marginally significant if the model was specified using RIAS, $F(1, 43) = 2.96$, $p = .09$.

*$p<.05$. **$p<.01$. ***$p<.001$.

Figure Caption

Figure 1. Parallel plot of language age as a function of children's chronological age.

Figure 2. Fitting multilevel models for subjects with low and high RJA/MS2 scores. Effect estimates were derived from Model B (Table 5). Low/high scores were defined as scores of 1 SD below/above the sample average.

Figure 1

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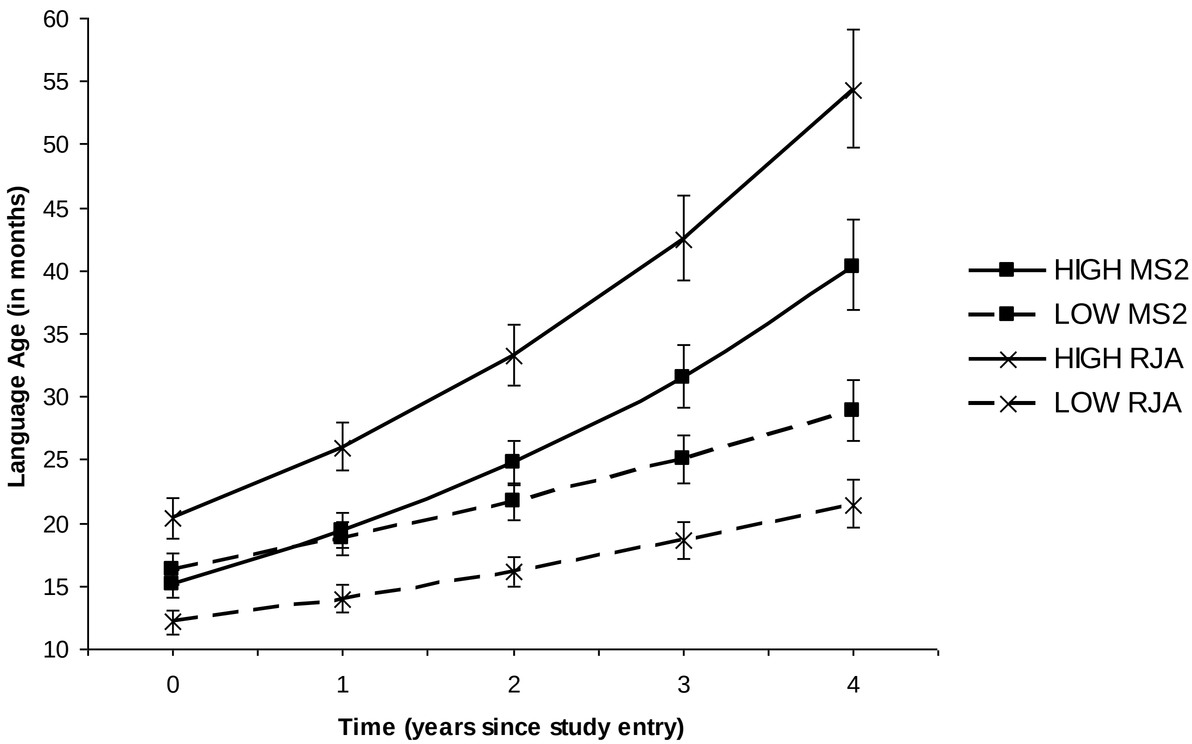
Figure 2


60
55
50
45
40
35
30
25
20
15
10
Language Age (in months)
0
1
2
3
4
Time (years since study entry)
HIGH MS2
LOW MS2
HIGH RJA
LOW RJA