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Early Gesture and Vocabulary Development in Infant Siblings of Children with Autism Spectrum Disorder

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Abstract

This study examined longitudinal growth in gestures and words in infants at heightened (HR) vs. low risk (LR) for ASD. The MacArthur-Bates Communicative Development Inventory was administered monthly from 8 to 14 months and at 18 and 24 months to caregivers of 14 HR infants diagnosed with ASD (HR-ASD), 27 HR infants with language delay (HR-LD), 51 HR infants with no diagnosis (HR-ND), and 28 LR infants. Few differences were obtained between LR and HR-ND infants, but HR-LD and HR-ASD groups differed in initial skill levels and growth patterns. While HR-LD infants grew at rates comparable to LR and HR-ND infants, growth was attenuated in the HR-ASD group, with trajectories progressively diverging from all other groups.

Keywords

infant siblings; autism spectrum disorder; gesture; vocabulary development

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The search for early markers of developmental disorders has enjoyed a long history, both because of its importance for efforts to identify at-risk children at very young ages and

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Compliance with Ethical Standards
Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.
Informed consent: Informed consent was obtained for all individual participants in the study.

facilitate access to intervention services, and for its contributions to theories seeking to explain the origins of atypical development. Researchers who study autism spectrum disorder (ASD) have utilized a number of strategies in their quest to identify early indicators of the disorder, the most recent of which has involved the prospective, longitudinal study of infants who have an older sibling with an ASD diagnosis. The rationale for this approach is grounded in the finding of an 18.7% recurrence rate for ASD among later-born siblings (Ozonoff et al., 2011). Studying infant siblings who are at heightened risk (HR) for ASD therefore presents a unique opportunity to observe when and how ASD symptoms emerge, and to do so from early in development (e.g., see Jones et al., 2014, for a review).

While our understanding of early indicators of ASD risk is still incomplete, a consistent and robust finding across studies of HR infants is that of substantial individual variability in early development (e.g., see Rogers, 2009, for a review), regardless of later developmental outcome (e.g., Bryson et al., 2007; Estes et al., 2015; Landa, Holman, & Garrett-Meyer, 2007; Messinger et al., 2013). Particularly little attention has been focused on examining variability among HR infants who do not receive an ASD diagnosis. This is somewhat surprising given that estimates suggest that up to 30% of HR infants without an ASD diagnosis have significantly delayed language skills (e.g., Yirmiya et al., 2006). Studying this subgroup of unaffected but language delayed HR infants (HR-LD) is of considerable importance for our understanding of the specificity of early ASD symptoms and our ability to distinguish clinically between early communication and language delay vs. emerging ASD.

Attempts to distinguish clinically between HR-LD and HR-ASD infants at early ages have proven very difficult (see Camarata, 2014, for an excellent discussion of this issue). Yet the ability to make the distinction between LD and ASD, which carries with it implications for the direction of early intervention, is of paramount importance. Thus, for example, while speech services alone may be appropriate for toddlers with LD, toddlers with ASD may receive greater benefits from more comprehensive early intensive behavioral intervention (e.g., Peters-Scheffer, Didden, Korzilius, & Sturmey, 2011). Given limited resources, enhancing our ability to predict with some precision whether early communication delays reflect underlying LD or ASD is an important goal.

To date only two studies have explicitly compared the development of communication and language in HR-LD and HR-ASD children. Although relatively narrow in scope, these studies nonetheless suggest that these two groups may differ in aspects of both gesture and language development from as early as the second year.

With regard to gesture, Parladé and Iverson (2015) examined longitudinal trajectories of production of gesture-vocalization coordinations (i.e., instances in which the two behaviors were produced with temporal overlap between them) sampled during naturalistic play sessions at home at 8, 10, 12, 14, and 18 months. They reported that while gesture-vocalization coordinations were initially delayed in both HR-LD and HR-ASD infants, by 12 months of age these coordinations had begun to emerge in HR-LD infants and grew at a rate comparable to those of HR infants with neither an ASD nor an LD diagnosis (HR-No Diagnosis; HR-ND) and of a group of infants with a typically-developing older sibling and no family history of ASD (Low Risk infants; LR). By contrast, the trajectory for HR-ASD infants remained relatively flat and unchanged across the observation period.

With regard to language development, Landa and Garrett-Meyer (2006) analyzed scores on the Mullen Scales of Early Learning (MSEL), a standardized developmental assessment, administered at 6, 14, and 24 months to HR-LD and HR-ASD groups. Findings indicated that although scores on the Expressive Language subscale did not differ statistically between groups across the three time points, Receptive Language scores were significantly lower for HR-ASD compared to HR-LD groups by 14 months and remained so at 24 months. While these findings are important because they address the issue of whether receptive language delays may be specific to ASD, they are limited by wide spacing among observations (6, 14, 24 months) that does not allow us to identify when the difference emerges.

In an effort to increase our understanding of the development of gesture and language in HR infants with a variety of outcomes (as assessed at 36 months), we sought to characterize trajectories of gesture and language development in three subgroups of HR infants (HR-ASD, HR-LD, HR-ND) and compare them to those of a group of LR infants. The rationale for this approach is twofold. First, in addition to allowing us to parse some of the widely reported variability in early communication and language among HR infants, the HR-ASD to HR-LD comparison allows us to examine the extent to which language issues observed in the HR-ASD group are specific to ASD or more generally characteristic of HR children with early language delays. Second, most existing studies of communication and language in HR infants have retained HR-LD infants in a broader HR-ND outcome group, and this has led to conflicting data regarding the presence of communication and language delays among unaffected HR infants. Some investigators have reported delays relative to LR comparison infants (e.g., Mitchell et al., 2006), while others have not (Estes et al., 2015; Zwaigenbaum et al., 2005). Distinguishing HR-LD children from those with age-appropriate language may clarify these discrepancies and provide a more accurate picture of variability in language abilities among HR siblings.

To determine whether the shape of developmental change in gesture and vocabulary across the first two years differed across subgroups of HR and LR infants, this study utilized data from the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 1993, 1994), a widely used parent-report measure of communicative and language development. Whereas most studies of HR infants have sampled behavior at timepoints that are relatively widely spaced (e.g., 6, 12, 18, 24, 36 months), we administered the CDI to caregivers at regular, frequent intervals across the first two years. Dense sampling schedules are critical for the precise characterization of developmental trajectories; and trajectories of early vocabulary development in particular are likely to be nonlinear (e.g., van Geert & van Dijk, 2002; van Dijk & van Geert, 2007). Indeed, as demonstrated in a simulation study, when behavior is sampled with insufficient frequency, the inferred trajectories may not accurately depict the true nature of behavioral change over time (Adolph, Robinson, Young, & Gill-Alvarez, 2008). Thus, we sampled infant gesture, word comprehension, and word production monthly from ages 8 to 14 months and twice thereafter (at 18 and 24 months) to provide data on patterns of growth in these skills in HR and LR infants. The study had two primary aims: a) to evaluate differences in modelled developmental trajectories in gesture and vocabulary between LR, HR-ND, HR-LD, and HR-ASD groups; and b) to identify points in development at which trajectories of these groups diverged.

Method

Participants

The present study included two groups of infants drawn from two separate longitudinal studies of early language and motor development. The first group consisted of 92 HR infants (48 male) from families in which an older full biological sibling had been diagnosed with Autistic Disorder (AD; DSM-IV-TR; APA, 2000) verified using DSM-IV-TR criteria and scores above the Autism threshold on the ADOS-G (Lord et al., 2000) administered prior to infant enrollment in the study. Families were recruited through a university Autism Research Program, parent support organizations, and local agencies and schools serving families of children with ASD. The second group consisted of 28 LR infants (12 male) with no family history of ASD (i.e., no first- or second degree relatives diagnosed with ASD) who participated in a separate longitudinal study (e.g., Iverson, Hall, Nickel, & Wozniak, 2007). LR infants were recruited through published birth announcements and word of mouth.

All participants in both groups were from full-term, uncomplicated pregnancies and came from English-speaking households. Parental occupations were identified for the purpose of providing a general index of socioeconomic status. Because many of the mothers were home raising their children, occupational prestige scores were calculated for fathers' occupation only. Table 1 provides demographic information for the two groups of infants. As can be seen in the table, groups were similar with regard to infant gender, ethnicity, parent age, parent education, and paternal occupational prestige (Nakao & Treas, 1994).

Procedure

As part of both larger longitudinal studies, infants and primary caregivers were visited in their homes for approximately 45 minutes each month. Visits occurred within three days of the monthly anniversary of the infant's birth. For HR infants, data collection began when the infant was 5 months old and continued at monthly intervals to the age of 14 months, with follow up visits at 18, 24, and 36 months. For the purposes of the current study, data collected from the 8- through the 24-month sessions were used.

All LR infants were observed every two weeks from 2 to 19 months. Data collected at the visits coinciding with the monthly anniversary of the child's birthday from 8 through 14 months and at 18 months were included for purposes of comparison. Nine of the LR infants were followed through 24 months as part of an extension study. For these infants, 24-month data are included. Although there was extensive overlap between the protocols for the two longitudinal studies, the focus of the research involving the LR infants was on typical development and thus observer-administered standardized assessments (e.g., Mullen Scales of Early Learning; see below) were not included Thus, the LR children who were followed as part of the extension study do not have outcome measures available. However, no developmental concerns were ever expressed by parents or research staff members, and none of thethese children received intervention services.

Measures

MacArthur-Bates Communicative Development Inventory—At each visit beginning at 8 months, a primary caregiver completed the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 1993). The CDI is a reliable and valid parent report measure of communication development in children with typical development and is a sensitive indicator of language delays in young children (Dale, Bates, Reznick, & Morisset, 1989; Fenson et al., 1993, 1994; Heilmann, Weismer, Evans, & Hollar, 2005; Miller, Sedey, & Miolo, 1995; Thal, O'Hanlon, Clemmons, & Fralin, 1999). The CDI has excellent internal consistency (*r*s = .95 to .96), test-retest reliability (*r*s = .80 to .90), and concurrent validity with tester-administered measures ($r = .72$; Bates et al., 1988; Fenson et al., 1994).

At each observation from 8 to 14 months, primary caregivers completed the Words and Gestures form of the CDI. Part I of this form consists of a 396-item vocabulary checklist organized into 19 semantic categories. Parents are asked to endorse: a) items that their child *only understands*; and b) those that s/he *both says and understands*. Part II focuses on gestures and actions and is divided into five subsections. The first two, First Communicative Gestures and Games and Routines, focus on gestures that reveal communicative intent (e.g., giving, showing, pointing) and actions that are part of everyday routines (e.g., peekaboo, pat-a-cake). The final three subsections, Actions with Objects, Pretending to Be a Parent, and Imitating Other Adult Actions, include items that ask about infants' production of actions with common objects (e.g., comb or brush his/her own hair), play actions (e.g., feeding or dressing a doll), and imitation of actions performed by adults on real or pretend objects (e.g., sweeping with a real or toy broom). Parents are requested to indicate the actions and gestures performed by their child.

The Words and Sentences form, which is normed for children from 18 to 30 months, consists of two parts: a 680-word vocabulary checklist organized into 22 semantic categories (parents endorse words that their child says) and a section on children's use of English morphology and syntax. This form was given to parents at the 18 and 24 month visits.[1]

Outcome Classification

Outcome classification occurred for HR infants at the 36-month visit and made use of scores from the CDI, the Mullen Scales of Early Learning (MSEL; Mullen, 1995) and the ADOS-G (Lord et al., 2000). The MSEL is a normed, standardized developmental assessment of language, cognitive, and motor functioning. The MSEL was administered to HR children at the 18, 24, and 36 month visits. The Receptive (RL) and Expressive (EL) Language subscales from this measure were used along with CDI scores for determining outcome group membership at 36 months.

The ADOS-G is a structured play schedule that provides systematic probes for symptoms of ASD in social interaction, communication, play, and repetitive behaviors, and has standard

[1]The Words and Gestures form was given to 11 caregivers (2 LR; 9 HR) at 18 months and 3 caregivers (all HR) at 24 months instead of the Words and Sentences form. However, as noted below, because percentile scores rather than raw scores were used in analyses of these time points, these variations will not impact results.

administration and scoring schema. It was administered by a research-reliable evaluator naïve to all previous study data. All children received either Module 1 or 2.

For purposes of the present study, HR infants were classified into one of three mutually exclusive outcome categories: a) *Autism Spectrum Disorder (HR-ASD)*, b) *Language Delay without ASD (HR-LD)*, c) *No Diagnosis (HR-ND)*.

HR-ASD—A diagnosis of ASD was given to HR infants whose scores met or exceeded algorithm cutoffs for Autism Spectrum Disorder on the ADOS-G with confirmation by clinical judgment using DSM-IV-TR criteria. Using these criteria, 14 HR infants (15%; 10 male; 2 racial or ethnic minority) were classified as HR-ASD.

HR-LD—Infants were assigned to the HR-LD subgroup if they *did not* receive a diagnosis of ASD at 36 months and had (1) Standardized scores on the CDI at or below the 10th percentile at *more than one* time point between 18 and 36 months (e.g., Ellis Weismer & Evans, 2002; Heilmann et al., 2005); and/or (2) Standardized scores on the CDI at or below the 10th percentile *and* standardized scores on the Receptive and/or Expressive subscales of the MSEL equal to or greater than 1.5 standard deviations below the mean at 36 months (e.g., Landa & Garrett-Mayer, 2006; Ozonoff et al., 2010). Twenty-seven infants (29%; 15 male; 6 racial or ethnic minority) in the HR group met criteria for HR-LD (criterion 1 n = 20; criterion 2 n = 3; both criteria n = 4).

Of the 20 infants who met criterion 1, three infants also had MSEL RL and/or EL T scores < 1.5 SDs below the mean at both 18 and 24 months; one had MSEL RL and EL scores < 1.5 SDs below the mean at both 18 and 24 months and qualified for speech services; and nine qualified for and received speech services. All of the analyses reported below were repeated with the seven infants who met criterion 1 with only low CDI scores (n = 5) or low CDI scores and low MSEL RL/EL scores at only one age (n = 2) removed, and results remained essentially unchanged.

HR-ND—The remaining 51 HR infants (55%; 23 male; 2 racial or ethnic minority) were classified as HR-ND.

Table 2 provides additional information on the HR sample by presenting MSEL Receptive and Expressive Language subscale scores and Early Learning Composite standard scores (calculated from the Visual Reception, Fine Motor, and Receptive and Expressive Language subscale scores) at 36 months of age. Relative to the HR-ND group, higher percentages of infants in the HR-ASD and HR-LD groups received early intervention services (HR-ASD = 92.85%; HR-LD = 51.85%; HR-ND = 15.68%).

Data Reduction and Analysis

The present study focused on four primary measures of communicative and language development obtained from the CDI: Early Gestures, Later Gestures, Words Understood, and Words Produced. Following manualized procedures (Fenson et al., 1993), scores for Early Gestures were obtained by totaling the numbers of gestures/actions endorsed in the First Communicative Gestures and Games and Routines subsections (maximum = 18). For

Later Gestures, scores were computed by totaling the numbers of endorsed items in the Actions with Objects, Pretending to Be a Parent, and Imitating Other Adult Actions subsections (maximum = 45). The Words Understood score was the sum total of words indicated by parents as being understood by their infant (maximum = 396). For ease of interpretation, we analyzed raw scores for these measures.

Words Produced is assessed on both versions of the CDI and thus was analyzed across the 8- to 24-month timeframe. For ages at which caregivers completed the Words and Gestures form, the Words Produced score was created by totaling the numbers of words endorsed as understood and said by the infant (maximum = 396). For visits at which the Words and Sentences form was administered, scores represent the total number of words endorsed by parents (maximum = 680; comprehension is not assessed on this version). Because the Words Produced vocabulary checklists differ across the two CDI versions, percentile rather than raw scores were used in relevant analyses. Following manualized procedures, percentile scores were obtained by using the normative table appropriate for the infant's sex (separate norms are available for boys and girls) and age at the data collection visit (Fenson et al., 1993).

Analytic Approach

To examine gesture and vocabulary growth trajectories in relation to infant risk status and 36-month outcome classification (LR; HR-ND; HR-LD; HR-ASD), we utilized Hierarchical Linear Modeling (HLM; Raudenbush, 2004; Raudenbush & Bryk, 2002). HLM permits analysis of nested, hierarchically structured data (i.e., multiple time points nested within individuals) to assess both variation *within individuals* over time (i.e. growth trajectories; Level 1) and variation *between individuals* in growth trajectories (Level 2). HLM can accommodate multiple waves of data in longitudinal designs, unequally spaced data-collection occasions, and missing data (Huttenlocher et al., 1991; Singer, 1998; Willett, Singer, & Martin, 1998). Complete CDI data were available for 92.6% of the observations for participating HR infants and 98.37% of the observations for participating LR infants from 8 to 24 months. All models were estimated using HLM for Windows, Version 7.01.

For each variable, we began the modeling process by running a fully unconditional linear model with AGE (in months) as a predictor at Level 1 and no predictors at Level 2. In order to determine the most appropriate model of individual change, we next ran a quadratic model by including AGE^2 at Level 1. Chi-square tests of deviance were calculated to determine whether the quadratic model had a significant reduction in deviance compared to the linear model (i.e., was a better fit for the data). For all 4 of our primary variables, the quadratic model was a better fit for the data.

At Level 1 of each model, HLM estimated individual quadratic growth trajectories in gesture (i.e., Early Gestures and Later Gestures from 8 to 14 months) and vocabulary (i.e., Words Understood from 8 to 14 months; Words Produced from 8 to 24 months) as a function of AGE (in months) and AGE^2. Age was centered at the initial data collection point (8 months) for all variables. The Level 1 model is shown in Equation 1:

$$Y_{it}=\pi_{0i}+\pi_{1i}(AGE_{it})+\pi_{2i}(AGE_{it}{}^{2})+e_{it} \quad (1)$$

Here, π_{0i} represents the intercept for child *i* at the centered time point (i.e. 8 months), π_{1i} represents instantaneous linear growth at the centered time point, and π_{2i} represents quadratic growth (i.e., acceleration or deceleration). The *intercept* is the anchor of the trajectory, or the initial measured level of the variable. The *instantaneous linear growth* term identifies the rate and direction of growth at the point of intercept. In a quadratic model, instantaneous linear growth changes systematically over time depending on the rate of deceleration or acceleration. Thus, while the quadratic term is independent of time, both the intercept and the instantaneous linear growth term are dependent on the point of intercept. Coefficients on the growth terms were modeled as random effects in all models.

At Level 2 (between individuals) we included time-invariant predictors (i.e., predictors that remain constant over time for a given individual), specifically gender (GEN) and outcome group (i.e., HR-ND; HR-LD; HR-ASD). Gender was included as a grand-mean centered covariate at Level 2 in light of widely reported gender differences in rate of communication and language development (e.g., Fenson et al., 1994). The LR group served as the reference group, and thus analyses at Level 2 examined differences in growth trajectories between LR infants and three outcome groups of HR infants while controlling for gender. The Level 2 models are shown in Equations 2–4:

$$\pi_{0i}=\beta_{0LR}+\beta_{01}(GEN_{i})+\beta_{0HRND}(HRND_{i})+\beta_{0HRLD}(HRLD_{i})+\beta_{0HRASD}(HRASD_{i})+r_{0i} \quad (2)$$

$$\pi_{1i}=\beta_{1LR}+\beta_{11}(GEN_{i})+\beta_{1HRND}(HRND_{i})+\beta_{1HRLD}(HRLD_{i})+\beta_{1HRASD}(HRASD_{i})+r_{1i} \quad (3)$$

$$\pi_{2i}=\beta_{2LR}+\beta_{21}(GEN_{i})+\beta_{2HRND}(HRND_{i})+\beta_{2HRLD}(HRLD_{i})+\beta_{2HRASD}(HRASD_{i})+r_{2i} \quad (4)$$

Here, variation in intercept (π_{0i}), instantaneous linear growth (π_{1i}) and quadratic growth (π_{2i}) are modeled as a function of four time-invariant child characteristics. Thus, the coefficients (β) represent deviations in initial level (i.e., intercept), rate and direction of growth at the intercept (i.e., instantaneous linear growth), and acceleration or deceleration (i.e., quadratic growth) from the average LR participant in the sample. For example, β_{1HRASD} represents the deviation of the HR-ASD group from the LR group in instantaneous linear growth at 8 months.

For each analysis, planned comparisons examined intercept and instantaneous linear growth differences over time by systematically re-centering the AGE variable so that the trajectories' intercept varied systematically with age. This allowed us to identify points at which developmental trajectories of the various outcome groups diverged and to interpret the potential effects of differing trajectories on gesture repertoire size or vocabulary size at the final time point. Additional analyses addressed specificity by examining differences between the HR-ASD group and the other HR groups (HR-ND and HR-LD). These are reported in the description of results with the appropriate p-values.

Assumptions of normality and homoscedasticity were assessed through examination of residuals. Due to modest violations of assumptions, robust standard errors (which enable computation of sensible confidence intervals and tests even when residuals are not normally distributed; Raudenbush & Bryk, 2002) are reported throughout.

Results

The overarching goal of this study was to examine differences in growth trajectories of gesture and vocabulary development between a group of LR infants and three groups of HR infants who varied in developmental outcomes at 36 months (HR-ND, HR-LD, HR-ASD). Analyses of gesture development (Early Gestures and Later Gestures) and vocabulary development (Words Understood and Words Produced) are presented in turn below. For each variable, primary analyses are supplemented by additional comparisons designed to: a) identify points at which developmental trajectories of the outcome groups diverged; and b) evaluate differences in developmental trajectories between the HR-ASD and the HR-ND and HR-LD groups respectively.

Results of the final conditional growth models for all four variables are displayed in Table 3, and point estimates and 95% confidence intervals based on these growth models are presented in Table 4. As noted above, the LR group served as the reference group in all analyses; therefore, the coefficients generated for HR-ASD, HR-LD, and HR-ND groups reflect deviations from the LR group in intercept, instantaneous linear growth, and/or quadratic growth.

Gesture Development

Early Gestures—Estimated growth trajectories for Early Gestures from 8 to 14 months are presented for each of the four participant groups in Figure 1.

As can be seen in the figure, the LR group displayed a pattern of positive growth in Early Gestures, with gradual deceleration over time. At 8 months, the HR-ND group did not differ from the LR group in total number of Early Gestures. Rate of initial growth (i.e. instantaneous linear growth) in Early Gestures, however, was significantly lower than that of their LR peers with only very slight deceleration over time, although this difference in quadratic growth just missed statistical significance ($p = .06$). The difference between the HR-ND and the LR groups in total number of Early Gestures became significant at 9 months ($p = .023$; see Figure 1).

At 8 months the total number of Early Gestures and rate of initial growth in Early Gestures for the HR-LD group were both significantly lower than those of the LR group. Over time, however, relative to that of the LR infants, the trajectory for HR-LD infants exhibited a small *acceleration* and by 14 months, Early Gestures scores for the HR-LD infants were generally comparable to those for the HR-ND group (see Table 3).

The 8-month Early Gesture scores of the HR-ASD group did not differ significantly from those of the LR group. However, HR-ASD infants, like their HR-LD peers, exhibited a significantly lower rate of initial growth in Early Gestures than LR infants. Unlike that of the HR-LD group, however, the trajectory for HR-ASD infants showed a slight deceleration over time (though significantly less than that of the LR group) so that it progressively diverged from those of the LR and HR-ND groups and crossed below that of the HR-LD group at 11 months (see Figure 1). Specifically, significant differences in Early Gestures were observed between the HR-ASD and LR groups by 9 months ($p = .006$) and between the HR-ASD and HR-ND groups by 11 months ($p = .036$). In addition, the instantaneous linear growth rate for the HR-ASD group was significantly slower than that of the HR-ND group by 10 months ($p = .032$) and that of the HR-LD group by 11 months ($p = .01$).

Later Gestures—Figure 2 displays the estimated growth trajectories for Later Gestures from 8 to 14 months for each of the outcome classification groups. As is evident in the figure, LR infants displayed positive and accelerating growth in Later Gestures scores over time. The growth trajectory for the HR-ND group was nearly identical and did not differ from that of the LR infants on any parameter.

As is also apparent, patterns of growth for the HR-LD and HR-ASD groups were attenuated compared to the LR and HR-ND groups, although in somewhat different ways. The HR-LD infants had significantly lower Later Gestures scores than their LR peers starting at 8 months, but did not differ significantly from the LR infants in rate of initial growth nor in quadratic growth, although their rate of acceleration was somewhat attenuated compared to the LR group. Thus, HR-LD infants' Later Gestures scores grew at a rate that was similar to the LR and HR-ND groups, but they remained consistently lower than those of the LR group through 14 months (14 months: $p = .002$).

In contrast, while initial Later Gestures scores and rates of initial growth (i.e., intercepts and instantaneous linear growth rates) did not differ significantly between the HR-ASD and LR groups at 8 months, the HR-ASD group's trajectory not only exhibited significantly lower acceleration over time relative to that of the LR group but also relative to those of the HR-ND ($p < .001$) and HR-LD ($p = .017$) groups. As a result, the HR-ASD group's Later Gestures trajectory showed progressively greater divergence over time from those of all three comparison groups (see Figure 2) such that Later Gestures scores for the HR-ASD group differed from those of the LR group by 10 months ($p = .02$), the HR-ND group by 11 months ($p = .006$), and the HR-LD group by 14 months ($p = .012$).

Vocabulary Development

Words Understood—Estimated growth trajectories for Words Understood from 8 to 14 months for each of the four outcome groups are presented in Figure 3. Note that intra-group variability in this measure was especially large, especially from 10 months on (see Table 4). As can be seen in the figure, the LR and HR-ND groups displayed similar, positively accelerating patterns of growth from 8 to 14 months; their trajectories did not differ on any parameter.

The HR-LD and HR-ASD groups, on the other hand, displayed different patterns of growth. Similar to the pattern observed for Later Gestures, the HR-LD group had significantly lower Words Understood scores than the LR group at 8 months, but rate of initial growth did not differ statistically between the two groups, and while the HR-LD group's rate of acceleration over time was attenuated compared to that of the LR group (see Table 2), the difference in quadratic growth did not achieve significance.

The HR-ASD group's 8-month Words Understood scores, on the other hand, did not differ significantly from those of LR infants. Although the HR-ASD group also did not differ from LR infants in rate of initial growth at 8 months, their rate of acceleration over time was significantly lower than that of the LR group and than that of the HR-ND group ($p = .002$). As a result, by 9 months, the HR-ASD group had a lower instantaneous linear growth rate compared to all three other groups (all ps $< .05$), and by 11 months significant differences between the HR-ASD group's Words Understood scores and those of the LR ($p = .005$) and HR-ND ($p = .007$) groups had become apparent. Despite the fact that the HR-ASD group had a significantly higher number of Words Understood than the HR-LD group at 8 months (see Table 2), at 11 months, the HR-ASD group's trajectory crossed below that of the HR-LD group and remained lower throughout the remainder of the observation period (although the differences between these groups from 12 to 14 months did not reach significance).

Words Produced—Words Produced data were collected monthly between 8 and 14 months, and at 18 and 24 months using either the Words and Gestures or the Words and Sentences form of the CDI (see Procedure). Because the two forms contain different numbers of words, the analyses reported below were carried out using percentile scores. Since CDI percentile scores are gender-normed, gender was not included in this model. Before presenting the percentile score analyses, for descriptive purposes, raw scores for Words Produced over the 8 to 24 month period are presented in Figure 4. Although these data should be interpreted with caution due to the inclusion of data gathered from the two CDI forms, it is apparent that word production began later and grew more slowly for both the HR-LD and HR-ASD groups relative to their LR and HR-ND peers).

Figure 5 displays the estimated growth trajectories for Words Produced percentile scores from 8 to 24 months for each of the outcome groups. Note that scores at the 50^{th} percentile fall at the mean for the normative sample; thus, we would expect the growth trajectory of a child acquiring language typically to remain relatively flat and near the 50^{th} percentile across time.

As expected, the LR group demonstrated a relatively stable trajectory across the entire 8 to 24 month period, with scores consistently near the 50^{th} percentile. Although rate of initial growth at 8 months was slightly negative, overall the LR group's trajectory showed a mild acceleration over time. The trajectory for the HR-ND group was similar to that of the LR group and did not differ from it on any parameter.

Both the HR-LD and HR-ASD groups demonstrated sharply declining trajectories of Words Produced percentile scores over time (see Figure 5). Although the HR-LD group's scores at 8 months did not differ from those of the LR group, their rate of initial growth at this age was significantly more negative. The HR-LD group trajectory did not differ from the LR trajectory in quadratic growth. Note that for percentile scores, a decreasing growth trajectory is indicative of a lack of growth in words relative to norms, not a net reduction in the number of words produced.

For HR-ASD infants, the 8-month Words Produced percentile score was significantly higher than that for the LR group. Relative to the LR group, their initial rate of growth was much lower (see Table 3) and significantly more negative. While they did not differ significantly from the LR group in quadratic growth, their trajectory displayed significantly greater deceleration than that of the HR-ND group ($p = .002$). This attenuated pattern of growth resulted in progressive divergences over time between the HR-ASD trajectory and those of the other three groups. Specifically, the HR-ASD group's instantaneous linear growth rate was significantly slower than that of the HR-ND group at 8 months ($p < .001$) and that of the HR-LD group by 11 months ($p = .044$). The HR-ASD group's Words Produced scores diverged significantly from those of the LR ($p = .033$) and HR-ND groups by 11 months ($p = .014$) and were significantly different from those of the HR-LD group by 24 months ($p = .02$).

Discussion

The present study examined longitudinal growth in early and later gestures, word comprehension, and word production in LR, HR-ND, HR-LD, and HR-ASD infants. Consistent with prior research (see Rogers, 2009), there was substantial intra-group variability on all measures. This variability was especially pronounced in word comprehension. Nevertheless, there was striking consistency in the developmental patterns revealed by our analyses. These patterns will be discussed in greater detail below, but it is worth calling attention here to the overall findings.

On all four communication variables, at 8 months HR-ASD infants' scores were similar to those of their LR peers, a result consistent with a growing number of studies that have failed to find differences between HR-ASD and unaffected HR infants in early social and communicative behavior in the first year (see Elsabbagh & Johnson, 2016, for a recent review). An examination of HR-ASD growth trajectories for all four variables, however, indicated substantial attenuation so that over time these trajectories diverged progressively from those of the other three groups. By contrast, HR-LD infants began at 8 months with the lowest early and later gesture and word comprehension scores among the four groups, but grew at rates that were generally comparable to those of LR and HR-ND infants. As a result, by late in the first year, the HR-ASD trajectories crossed below those of the HR-LD group. There were significant differences between the two groups for Later Gestures and Words Produced by 14 and 24 months respectively; for Early Gestures, a difference in instantaneous linear growth rate was apparent by 11 months. While a similar pattern was evident for Words Understood, differences between the HR-LD and HR-ASD groups did not reach statistical significance, perhaps because of the particularly large intra-group variability in this measure.

Before discussing the implications of these differing patterns of growth, a comment regarding the HR-ND group is in order. We found very few differences between the growth trajectories of the HR-ND and LR groups. The single exception was for Early Gestures. Although the two groups started out at 8 months with comparable scores, they grew at different rates. By 9 months, HR-ND infants produced significantly fewer Early Gestures than their LR peers, a difference that persisted throughout the remainder of the observation period.

Recall that the Early Gestures section of the CDI includes deictic gestures (i.e., giving, requesting, pointing, showing) and some conventional gestures (e.g., yes, no). Previous work suggests that relative to LR comparison infants, even HR infants with no subsequent ASD diagnosis produce fewer deictic gestures (Leezenbaum, Campbell, Butler, & Iverson, 2014; Winder, Wozniak, Parladé, & Iverson, 2013). But because the studies just cited employed HR samples that did not exclude infants who also meet criteria for language delay, the question of whether reduced gesture use is relatively consistent across HR infants or is the product of a subset of infants with early communication delays has remained open.

Our finding suggests that a more restricted Early Gestures repertoire prior to 14 months may on average also be characteristic of HR infants with typical outcomes at 36 months. The reason for this initial delay awaits further investigation, but at the very least it suggests that while having an older sibling with ASD may be associated with early-emerging delays in gesture, this delay – and HR group membership *per se* – is not indicative of suboptimal outcomes (see also Messinger et al., 2013).

Gesture and vocabulary development in HR-LD and HR-ASD infants are characterized by different patterns of growth over time

Gesture development—Generally speaking, the shape of the growth trajectories for the HR-LD and HR-ASD groups were consistent across both measures of gesture and distinct from one another. As previously noted, HR-LD infants started out with fewer Early and Later Gestures than HR-ASD infants. But because growth in both types of gestures for HR-LD infants was more rapid than that of the HR-ASD group, by 14 months they had surpassed the HR-ASD group and appeared to be catching up to their HR-ND and LR peers. By contrast, trajectories for the HR-ASD group were characterized by the slowest growth rates of all 4 groups, crossing below those of the HR-LD group before 12 months and remaining below them throughout the rest of the observation period.

The observation of a more restricted Early Gestures repertoire among HR-ASD infants is consistent with prior research that has identified similar differences prior to the first birthday (Mitchell et al., 2006). It also provides longitudinal evidence that reduced production of joint attention gestures (e.g., showing, pointing) by early in the second year may be specific to ASD (Watson, Crais, Baranek, Dykstra, & Wilson, 2013; see also Veness et al., 2012, for similar findings from a community sample). Moreover, there is ample evidence that older children with ASD produce symbolic play schemes and action schemes potentially learned via imitation (e.g., trying to brush teeth) less frequently or in atypical ways compared to typically-developing peers (e.g., Charman et al., 1997; Hobson et al., 2013; Rutherford et al., 2007). Many of the actions included in the Later Gestures section of the CDI are precisely these kinds of behaviors, suggesting that in infants eventually diagnosed with ASD difficulties with these abilities may already be apparent before the first birthday.

A large body of research conducted with a variety of typically- and atypically-developing populations has demonstrated that gesture is a powerful index of young children's status in the language-learning process (see LeBarton & Iverson, 2017, for a review). Indeed, for children with language difficulties, gesture can be a useful predictor of whether early communication delay will or will not persist (e.g., Thal, Tobias, & Morrison, 1990). Our data are consistent with this literature, suggesting as they do that measures of gesture development collected longitudinally distinguish HR infants who eventually receive an ASD diagnosis from those with LD. Thus, by 14 months, we observed HR-LD infants tending toward 'recovery' from initial delays in both Early and Later Gestures, while HR-ASD infants' scores continued to fall well below those of all other groups. Recent observational work by LeBarton & Iverson (2016) confirms this pattern of recovery in the HR-LD but not HR-ASD groups: at 24 months, HR-LD children produced gestures at a frequency comparable to that of HR-ND children. By contrast, HR-ASD children continued to produce significantly fewer gestures than did children in both comparison groups.

Vocabulary development—Relative to the two comparison groups, both HR-LD and HR-ASD infants exhibited significantly slower growth in word comprehension and production from 8 to 14 months. Intra-group variability for word comprehension was particularly large. This heightened variability may reflect the nature of the measure and difficulties inherent to the task of evaluating of children's understanding of words, an issue to which we will return below.

Importantly, this slowed growth took on different forms in the two groups. HR-LD infants exhibited an initial disadvantage in the word learning process, but growth over time occurred at rates comparable to non-delayed peers. HR-ASD infants, by contrast, started out looking like unaffected peers, but then grew so slowly over time that they fell progressively further behind all other groups of infants.

Although the net effect of these differences for both HR-LD and HR-ASD infants was delayed vocabulary development, their distinctive patterns of slowed growth suggest that the delays might reflect different underlying mechanisms. Given the state of the research base, any proposed explanation is necessarily speculative; and because successful word learning involves a myriad of skills (see Arunachalam & Luyster, 2016), it is unlikely that any single explanation will be sufficient to account for these differences. Nonetheless, we would like to suggest one possibility, namely that differences in rate of vocabulary growth (especially expressive vocabulary growth) between HR-LD and HR-ASD infants may relate to differences in the nature of their respective phonological representations and ways in which these become consolidated with meaning.

As a group, late talkers exhibit delays in phonological development, and these delays are apparent even before the emergence of first words (e.g., Oller, Eilers, Neal, & Schwartz, 1999). Once first words appear, late talkers produce less complex syllable structures, fewer correct consonants, and have smaller phonemic inventories (Rescorla & Ratner, 1996). In addition, like typically-developing novice word learners (Swingley, 2009; Werker, Fennell, Corcoran, & Stager, 2002), late talkers are less sensitive to the mispronunciations of words (MacRoy-Higgins, Schwartz, Schafer, & Marton, 2013), a finding that suggests that their phonological representations of word forms are less detailed and more holistic. Since learning a new word requires the creation of a detailed phonological representation of the sound sequences it contains, one which is subsequently consolidated with other information about the word (e.g., its semantic properties), late talkers are initially less successful than their typically developing peers in acquiring new words. With increasing word learning experience and continued growth in vocabulary size, however, phonological skills become more fine-tuned, and this in turn facilitates further word learning (Gershkoff-Stowe & Hahn, 2007).

For HR-LD infants, phonological representations may retain their initially holistic nature for a more extended period of time. This would interfere, at least initially, with the ability to learn new words. With sufficient word learning experience, however, phonological representations would become more detailed and word learning would accelerate. This could explain why the HR-LD group in this study exhibited initially delayed word comprehension and production but growth rates comparable to those of infants without language delays.

While research on word learning in young toddlers with or at risk for ASD is relatively sparse, studies of older children with ASD suggest that early in the word learning process, they may create even more detailed phonological representations of novel word forms than do their TD peers. Thus, for example, Norbury and colleagues (2010) found that when tested immediately following word learning trials, children with ASD not only successfully learned novel words but recalled a significantly greater percentage of correct phonemes than did a TD comparison group, a result consistent with evidence of enhanced perceptual processing of speech in ASD (Jarvinen-Pasley et al., 2008; see also Eigsti & Fein, 2013). Strikingly, however, when the researchers assessed memory for the same novel words four weeks later, the children with ASD produced significantly fewer correct phonemes and remembered significantly fewer semantic features of the words than TD comparison children. The initial highly detailed phonological representations were apparently not integrated with lexical knowledge in the same way as they are for TD children.

Although these data were collected from older, verbally proficient children with ASD, they point to a potential explanation for the substantially slowed rates of growth in word comprehension and production that we observed in HR-ASD infants. If, when initially presented with a new word, word learners with ASD prioritize its sound form at the expense of meaning, and if this detailed initial phonological representation subsequently degrades over time (see also Henderson, Powell, Gareth Gaskell, & Norbury, 2014), consolidation and integration of the new word into the semantic network may be incomplete. Qualitative differences in the time course of consolidation and integration could lead to quantitative differences in rates of word learning, with the process requiring substantially more time, and potentially more exposure in order for sound-meaning links to be sufficiently established.

Limitations of the Study

Although this study has contributed to our understanding of gesture and vocabulary development in HR infants with varying developmental outcomes, a note of caution is in order regarding the interpretation of the findings. First, the CDI is a parent report measure of early communicative development, and while its reliability with experimenter-administered and observational measures is excellent (see Fenson et al., 1994), it is possible that caregivers vary in their sensitivity to early communicative signals (especially gestures) and in the criteria they use to decide whether or not the child produces a particular gesture or comprehends or produces a given word. Words Understood may be especially difficult for parents to assess, since unlike Gestures and Words Produced, comprehension is not directly observable and can only be inferred. While the collection and coding of communication samples is time and labor-intensive and requires significant expertise, future work is needed to determine whether evidence from observational methods converges on differences of the sort described here.

Second, we did not conduct an item level analysis to examine the contents of infants' gesture and word repertoires, and thus it is unclear whether, in addition to showing different patterns of growth, HR-ASD infants also exhibit differences in the composition of their early vocabularies. There is evidence suggesting that this could be the case: in a recent paper, Lazenby et al. (2015) reported that at 12 months of age, HR-ASD infants not only had lower word comprehension and production, but also understood words that were not among those understood by non-ASD infants. This is an intriguing finding that merits replication in future longitudinal work.

Finally, as others have noted, the "baby siblings" design has its own unique limitations (Szatmari et al., 2016). Parent report measures are always subject to differences in parent perceptions and reporting, and baby siblings studies may be even more vulnerable to these differences. Thus, for example, parents of HR infants might have heightened concerns about communication and language development (e.g., Sacrey et al., 2015) and could be more attuned to their infant's communicative productions than parents of LR infants.

Conclusions and Clinical Implications

There is now considerable evidence that infants' production of vocalizations, words, and gestures affects their learning environments. Infants' communicative signals often elicit input from a responsive social partner, and this input can create timely opportunities for language learning. In addition, as infants' communication develops, adults adjust their responses, reducing those to earlier-appearing behaviors (e.g., giving and requesting gestures; vocalizations that do not contain speech sounds) and increasing the frequency and richness of those to more developmentally advanced behaviors (e.g., speech-like vocalizations; pointing and showing gestures; see Iverson & Wozniak, 2016, for a review). When infants exhibit communicative delays, caregivers have fewer opportunities to provide timely input (Leezenbaum et al., 2014; Warlaumont, Richards, Gilkerson, & Oller, 2014) or to shift response from earlier to more developmentally advanced communications. This may alter the child's communicative environment in ways that do not support learning and lead to cascading effects on communicative input and on development more broadly.

On this view, there are two general clinical implications to be drawn from our findings. First, the differences between HR-LD and HR-ASD infants not only in starting point at 8 months but in rates of growth over time suggest that frequent, repeated surveillance of HR infant communicative behavior is needed, especially for infants who appear to exhibit early delays in communicative development. On the CDI, patterns of growth in both early and later gestures and word production may be especially important to monitor in HR infants, but words comprehension should be interpreted with care, especially on an individual level, in light of the issues discussed above. Observation of slowed or absent growth over time indicates the need for more in-depth evaluation and intervention.

Second, when the existence of a communicative delay has been identified, intervention should take the form of enriching the infant's natural communicative environment. Thus, for example, caregivers could be trained to recognize and encouraged to respond to less advanced communicative behaviors (e.g., requesting gestures) with rich language that is linked to the child's current focus of attention (e.g., infant looks at the caregiver and extends a hand towards her cup to request it; caregiver responds, "Do you want some juice in your cup?", thus providing the label for the referent of the child's gesture; Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). Although a sizeable proportion of infants with early communication delays eventually 'catch up' to their peers (e.g., Thal & Katich, 1996), it is possible that a relatively naturalistic intervention of this sort might promote earlier resolution of delays and enhance infants' developmental trajectories.

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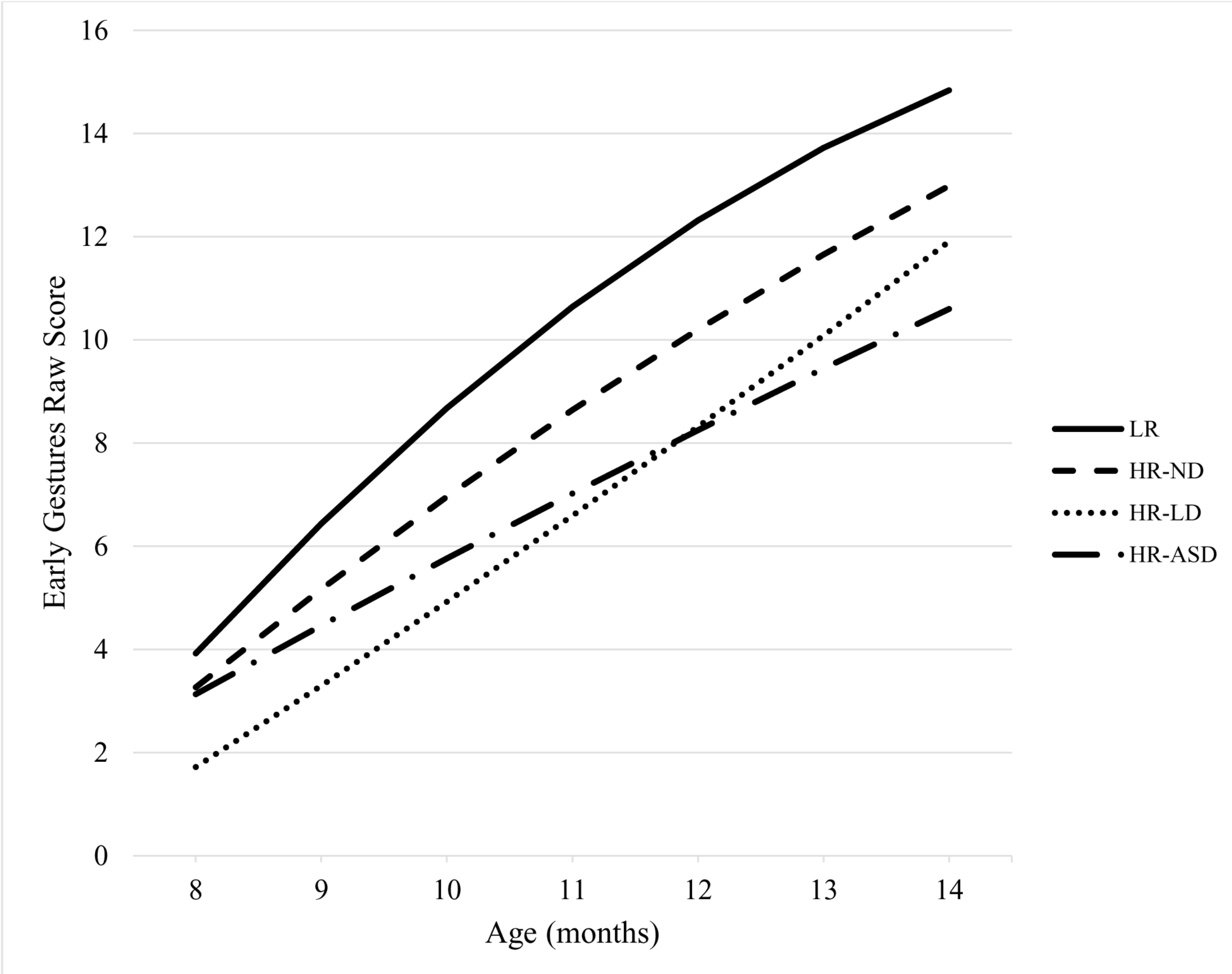

Figure 1.
Estimated growth trajectories for Early Gestures by outcome group from 8 to 14 months of age.

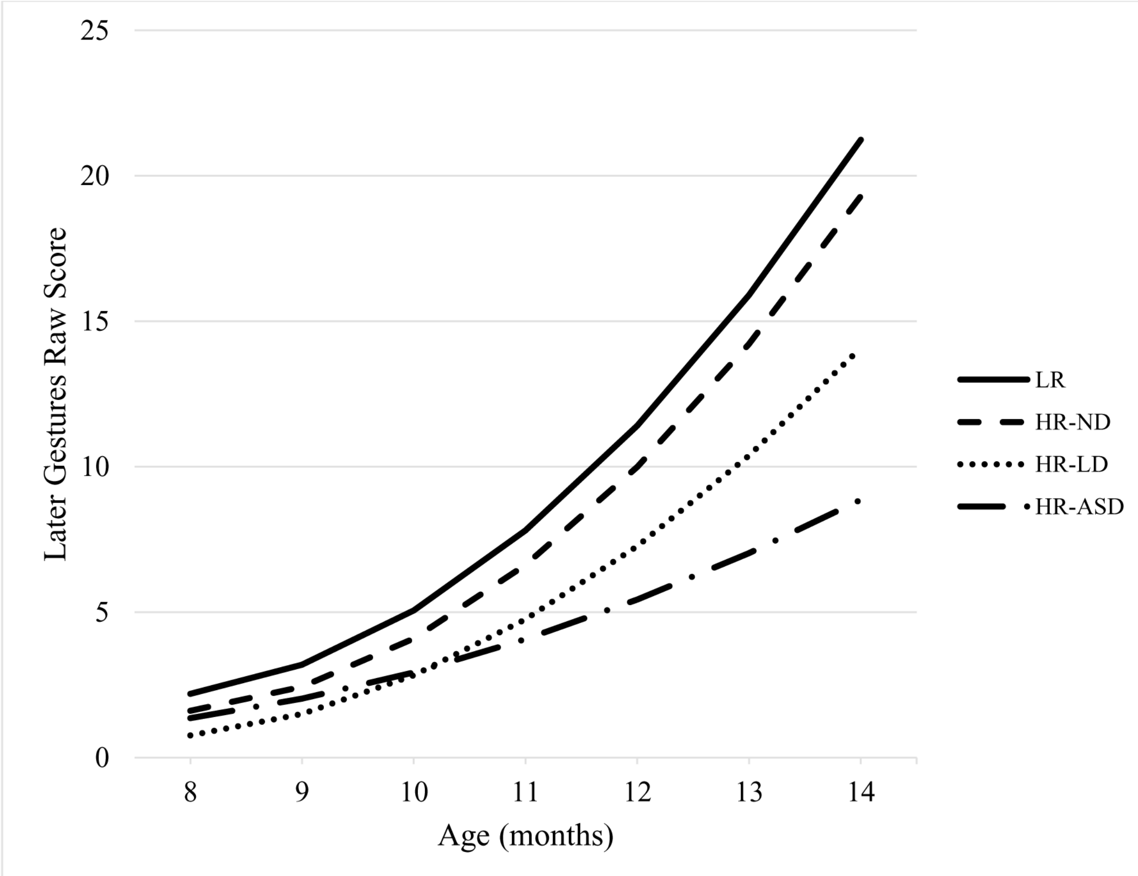

Figure 2.

Estimated growth trajectories for Later Gestures by outcome group from 8 to 14 months of age.

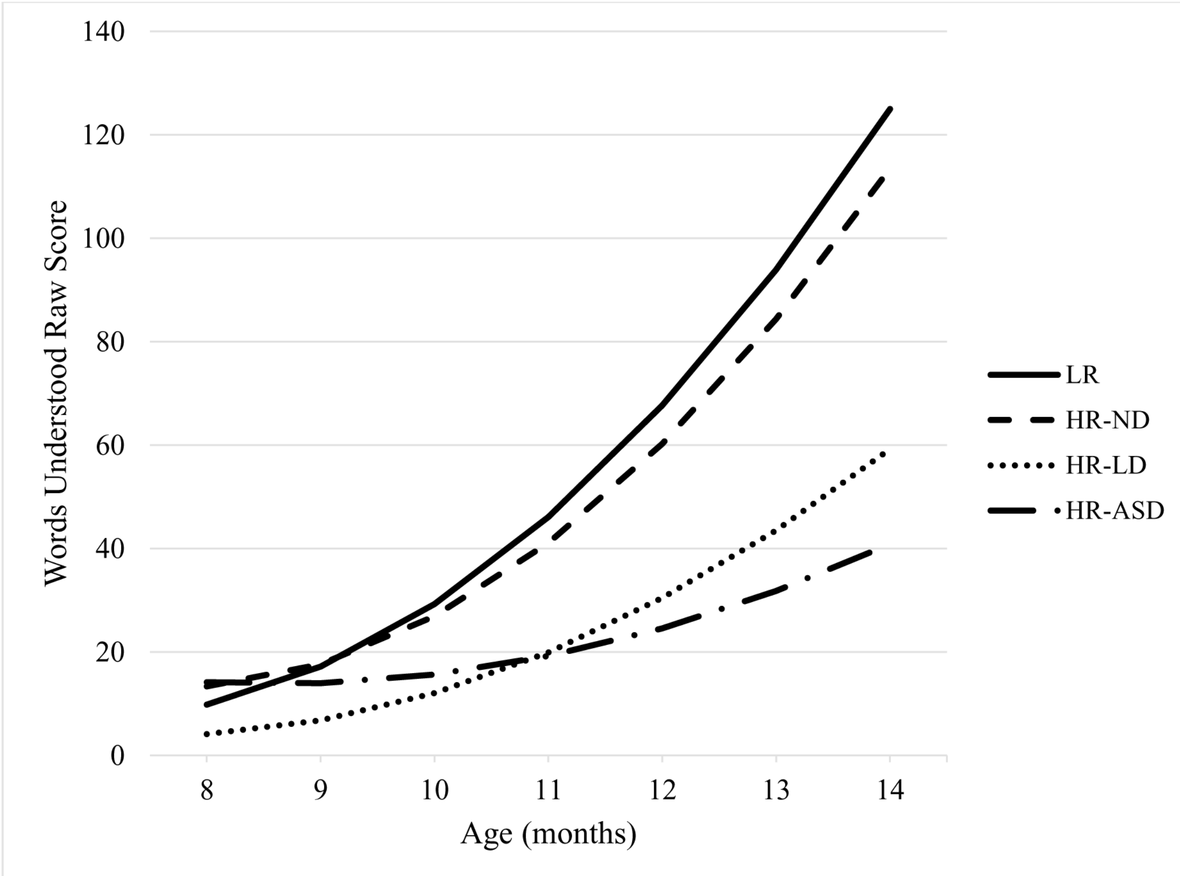

Figure 3.
Estimated growth trajectories for Words Understood by outcome group from 8 to 14 months of age.

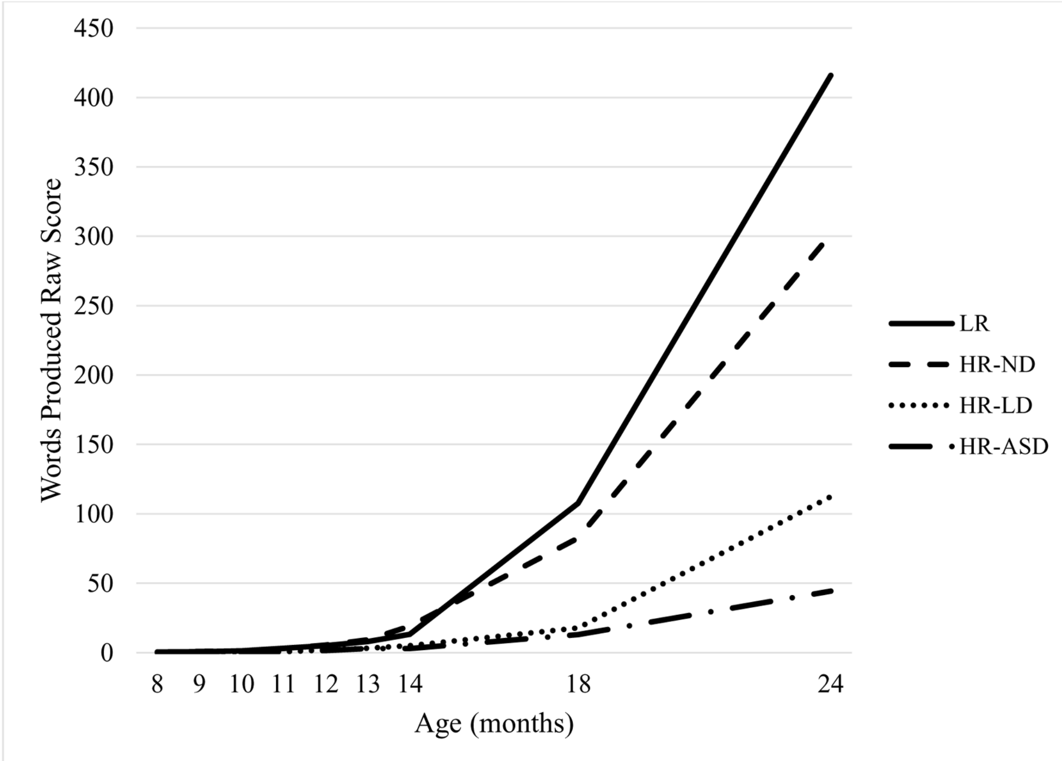

Figure 4.
Estimated growth trajectories for Words Produced (Raw Scores) by outcome group from 8 to 24 months of age.

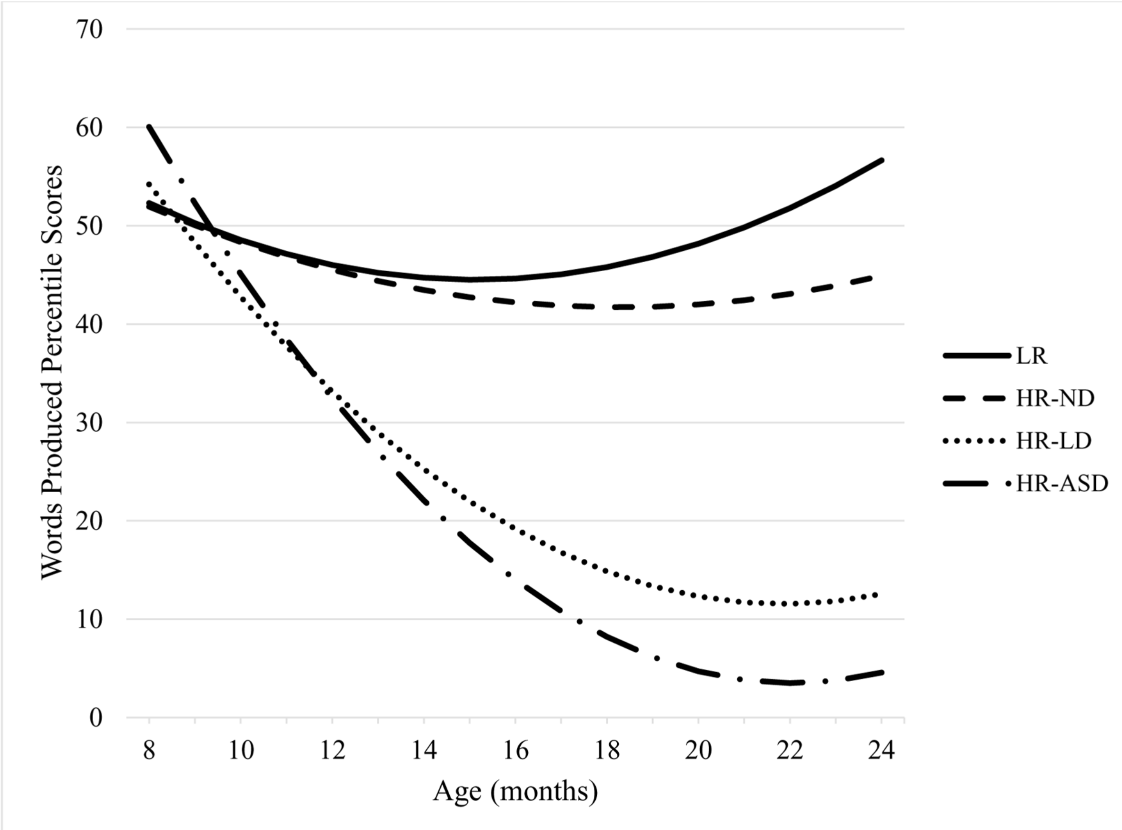

Figure 5.
Estimated growth trajectories for Words Produced (Percentile Scores) by outcome group from 8 to 24 months of age.

Table 1

Demographic Information for High Risk (HR) and Low Risk (LR) groups

	HR (n = 92)	**LR (n = 28)**
Gender		
Female (%)	44 (48%)	16 (57%)
Male (%)	48 (52%)	12 (43%)
Racial or ethnic minority (%)	10 (11%)	1 (4%)
Mean age for Mothers (SD)	34.24 (4.04)	31.92 (4.95)
Mean age for Fathers (SD)	36.72 (5.12)	33.08 (4.08)
Mean Parent Education[a] (SD)	1.24 (0.48)	1.38 (0.51)
Mean Paternal Occupational Prestige[b] (SD)	54.85 (15.49)	55.06 (15.06)

[a]Parent education based on averaging education scores for mothers and fathers.

0 = High school, 1 = Some college or college degree; 2 = Graduate or professional school.

[b]Nakao–Treas occupational prestige score. Unable to calculate for 7 LR and 6 HR fathers.

Table 2

Mean, SD, and Range for the Mullen Scales of Early Learning at 36 months for all HR outcome groups.

		HR-ND (n = 51)	HR-LD (n = 27)	HR-ASD (n = 14)
MSEL Receptive Language	M *(SD)*	33.37 *(3.65)*	29.48 *(3.02)*	21.45 *(6.27)*
Raw Scores	Range	26–43	24–37	9–29
MSEL Expressive Language	M *(SD)*	35.18 *(4.08)*	30.62 *(3.95)*	19.5 *(8.14)*
Raw Scores	Range	27–46	20–37	3–32
MSEL Early Learning Composite	M *(SD)*	109.94 *(15.86)*	94.26 (15.23)	64.4 *(13.28)*
Standard Scores	Range	78–141	61–120	49–97

Table 3

Final Models Predicting Growth Trajectories in Communication and Language with Gender and Outcome Group

	Early Gestures		Later Gestures		Words Understood		Words Produced	
	Coefficient	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**	**Coefficient**	**SE**
Intercept								
Intercept, β_{00}	3.922***	0.431	2.191***	0.355	9.848***	2.157	52.309***	2.235
Gender, β_{01}	0.297	0.456	−0.106	0.348	−3.708	2.344		
HR-ND, β_{0HRND}	−0.659	0.566	−0.581	0.455	3.526	2.883	−0.368	2.766
HR-LD, β_{0HRLD}	−2.201***	0.615	−1.437**	0.440	−5.709*	2.388	1.889	2.622
HR-ASD, β_{0HRASD}	−0.793	0.741	−0.838	0.479	4.285	4.521	7.734*	3.663
Linear Growth								
Intercept, β_{10}	2.658***	0.221	0.566	0.419	4.976	3.949	−2.189*	0.850
Gender, β_{11}	−0.082	0.244	−0.526	0.327	−0.316	2.821		
HR-ND, β_{1HRND}	−0.696*	0.301	−0.178	0.499	−3.181	4.617	0.194	1.093
HR-LD, β_{1HRLD}	−1.108**	0.350	−0.123	0.499	−3.628	4.110	−3.966***	1.117
HR-ASD, β_{1HRASD}	−1.307***	0.381	−0.010	0.526	−6.044	4.033	−5.854***	1.198
Quadratic Growth								
Intercept, β_{20}	−0.140***	0.033	0.435***	0.059	2.369***	0.492	0.154**	0.052
Gender, β_{21}	0.013	0.034	0.137*	0.056	0.178	0.445		
HR-ND, β_{2HRND}	0.083	0.044	−0.008	0.077	0.112	0.619	−0.057	0.064
HR-LD, β_{2HRLD}	0.164***	0.048	−0.138	0.077	−1.062	0.567	0.068	0.069
HR-ASD, β_{2HRASD}	0.122*	0.052	−0.319***	0.082	−1.448*	0.593	0.132	0.070

Note. SE = Standard Error; LR = Low Risk; HR-ND = High Risk No Diagnosis; HR-LD = High Risk Language Delay; HR-ASD = High Risk Autism Spectrum Disorder.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Table 4

Point Estimates and 95% Confidence Intervals for all variables at all ages.

	8 months		9 months		10 months		11 months		12 months		13 months		14 months		18 months		24 months	
	PE	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**	**PE**	**95% C.I.**
EG																		
LR	3.92	3.08–4.77	6.44	5.55–7.33	8.68	7.7–9.66	10.64	9.62–11.66	12.32	11.34–13.3	13.72	12.83–14.61	14.84	14.05–15.63	-	-	-	-
HR-ND	3.26	2.15–4.37	5.17	4.09–6.25	6.96	5.8–8.13	8.64	7.42–9.86	10.2	8.99–11.41	11.65	10.51–12.8	12.99	11.86–14.12	-	-	-	-
HR-LD	1.72	0.52–2.93	3.3	2.1–4.5	4.92	3.59–6.25	6.59	5.17–8.02	8.32	6.9–9.73	10.09	8.77–11.4	11.91	10.71–13.1	-	-	-	-
HR-ASD	3.13	1.68–4.58	4.46	3.09–5.84	5.76	4.26–7.26	7.02	5.38–8.67	8.25	6.5–10	9.44	7.61–11.28	10.6	8.62–12.58	-	-	-	-
LG															-	-	-	-
LR	2.19	1.5–2.89	3.19	2.2–4.18	5.06	3.59–6.54	7.8	5.86–9.74	11.41	9.02–13.81	15.89	13–18.79	21.24	17.73–24.75	-	-	-	-
HR-ND	1.61	0.72–2.5	2.42	1.24–3.6	4.09	2.38–5.81	6.61	4.38–8.85	9.99	7.23–12.75	14.22	10.84–17.59	19.3	15.11–23.49	-	-	-	-
HR-LD	0.75	−0.11–1.62	1.49	0.36–2.63	2.83	1.14–4.52	4.75	2.5–7.01	7.27	4.41–10.12	10.38	6.8–13.96	14.08	9.57–18.59	-	-	-	-
HR-ASD	1.35	0.41–2.29	2.02	0.82–3.22	2.93	1.15–4.7	4.06	1.72–6.41	5.43	2.49–8.36	7.03	3.39–10.66	8.86	4.32–13.4	-	-	-	-
WU															-	-	-	-
LR	9.85	5.62–14.08	17.19	10.12–24.26	29.27	16.83–41.72	46.09	28.68–63.51	67.65	45.55–89.75	93.95	67.02–120.88	124.98	92.55–157.41	-	-	-	-
HR-ND	13.37	7.72–19.02	17.65	8.11–27.19	26.89	11.31–42.46	41.09	20–62.18	60.25	33.97–86.53	84.38	52.6–116.16	113.47	75.17–151.76	-	-	-	-
HR-LD	4.14	−0.54–8.82	6.79	−0.69–14.28	12.06	−1.09–25.21	19.94	1.22–38.66	30.43	6.02–54.84	43.54	12.78–74.29	59.25	20.95–97.56	-	-	-	-
HR-ASD	14.13	5.27–22.99	13.98	4.17–23.8	15.68	1.76–29.59	19.21	0.73–37.69	24.59	1.27–47.91	31.8	2.88–60.73	40.86	4.96–76.76	-	-	-	-
WP															-	-	-	-
LR	52.31	47.93–56.69	50.27	45.9–54.65	48.54	43.74–53.35	47.12	41.68–52.57	46.01	39.87–52.15	45.21	38.4–52.01	44.71	37.31–52.11	45.79	36.67–54.91	56.65	43.75–69.54
HR-ND	51.94	46.52–57.36	50.04	44.84–55.25	48.34	42.71–53.97	46.83	40.43–53.23	45.52	38.25–52.78	44.4	36.3–52.5	43.47	34.62–52.32	41.71	30.89–52.54	44.91	30.51–59.31
HR-LD	54.2	49.06–59.34	48.27	43.22–53.31	42.78	37.18–48.37	37.73	31.29–44.17	33.13	25.8–40.46	28.97	20.83–37.12	25.26	16.41–34.1	14.85	4.45–25.24	12.55	−1.41–26.51
HR-ASD	60.04	52.86–67.22	52.29	45.38–59.2	45.1	37.88–52.32	38.49	30.63–46.34	32.45	23.84–41.06	26.98	17.63–36.33	22.08	12.07–32.09	8.21	−3.18–19.6	4.57	−8.9–18.03

Note. PE = Point Estimate; C.I. = Confidence Interval; EG = Early Gestures; LG = Later gestures; WU = Words Understood; WP = Words Produced (percentile scores); LR = Low Risk; HR-ND = High Risk No Diagnosis; HR-LD = High Risk Language Delay; HR-ASD = High Risk Autism Spectrum Disorder.