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ORIGINAL PAPER

A Longitudinal Study of Parent Gestures, Infant Responsiveness, and Vocabulary Development in Infants at Risk for Autism Spectrum Disorder

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Abstract

We investigated gestures that parents used with 12-, 18-, and 24-month-old infants at high or low risk for autism spectrum disorder (ASD; high-risk diagnosed with ASD: $n=21$; high-risk classified as no ASD: $n=34$; low-risk classified as no ASD: $n=34$). We also examined infant responses to parent gestures and assessed the extent to which parent gesture relates to vocabulary development. Parents of three groups gestured in similar frequencies and proportions. Infants, in turn, responded similarly to parent gestures regardless of the infant's ASD risk and later diagnosis. Finally, parents who gestured more at 12 months had children with better vocabulary at 36 months than parents who gestured less. These findings highlight the importance of examining parent gestures when predicting language development.

Keywords Autism spectrum disorder · High-risk infant siblings · Parent gesture · Infant responsiveness · Vocabulary development

Introduction

Autism spectrum disorder (ASD) is characterized by difficulties in social interaction and repetitive, restricted behaviors (American Psychiatric Association 2013). Communication and language deficits are also common in children with ASD (Colgan et al. 2006; Tager-Flusberg 2016). Researchers often study *gesture*, which is defined as a hand or body movement that speakers produce as a form of intentional communication (Iverson and Thal 1998), in children with ASD by turning to their infant siblings, who have an increased risk of developing ASD (hereafter, "high-risk infants"; Ozonoff et al. 2011). Previous studies suggest that in high-risk infants, gesture use is reduced compared to low-risk infants with no family history of ASD (Cassel et al. 2007; Goldberg et al. 2005; LeBarton and Iverson 2016; Leezenbaum et al. 2014; Mitchell et al. 2006; Toth et al. 2007; see Manwaring et al. 2018 for review) and that early gesture use predicts future language ability (Choi et al. 2019). Recent evidence also indicates that the developmental sequence and relations between gesture and language in young children with ASD (not limited to high-risk infants) may differ from typical development (Franchini et al. 2018; Ramos-Cabo et al. 2019; Talbott et al. 2020). Considering that *parents'* gestures are closely linked to children's gestures and language in typical development (Liszkowski et al. 2012; Liszkowski and Tomasello 2011; Rowe and Goldin-Meadow 2009), it is important to examine parental gesture use with high-risk infants, who have an elevated risk for language difficulties (Tager-Flusberg 2016).

While parent–child communication has been studied in typical development and other populations with language

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delays, such research in high-risk infants and their parents is limited. Thus, the goals of the present study were to (1) expand upon previous work examining 12-month parent gestures (Talbott et al. 2015) by longitudinally investigating parental gesture use with high- and low-risk infants at 12, 18, and 24 months, (2) complement a sister study, which examined infant gestures and parent responsiveness (Choi et al. 2019) by examining parent gestures and subsequent infant responsiveness, and (3) assess the extent to which parent gestures predict infants' later vocabulary skills. In the following sections, we outline the current literature and highlight the need for further study. The overarching aim of our work, detailing parent gesture in the present study and infant gesture in the previous study, is to provide a comprehensive picture of parent–child communication in the high-risk population for autism.

Parent Gesture Use with Children With or At-Risk for Autism

There is strong evidence that environmental factors such as parent input influence early child language development (Rowe 2012; Tamis-LeMonda et al. 2001). For example, parent verbal input has been linked to the language development of high-risk infants similar to low-risk infants (Choi et al. 2020; Swanson 2020; Swanson et al. 2019). Parents' *nonverbal* input, such as gestures, has also been shown to relate to infant gesture and language skills in typical and atypical development (Goldin-Meadow and Butcher 2003; LeBarton and Iverson 2017; Liszkowski et al. 2012; Zammit and Schafer 2011). Several studies have reported that parents of children with ASD aged between 3 and 18 years old produced similar numbers of gestures as parents of typically developing children, whereas their children with ASD showed differences in gesture production compared to typically developing peers (Baumann et al. 2019; Medeiros and Winsler 2014; Yoshida et al. 2020). Similarly, Özçalışkan et al. (2018) found that parents of younger children with ASD (M_{age} = 2;6), Down syndrome (M_{age} = 2;6), and typical development (M_{age} = 1;6), who were matched in word use, produced similar overall amounts of gestures even when their children differed in gesture use. In the high-risk infant sibling literature, Talbott et al. (2015) studied maternal gesture use with their 12-month-old high- or low-risk infants and found that mothers of high-risk infants gestured more and conveyed more meanings using gestures than mothers of low-risk infants.

In addition to the examination of the frequency of parent gesture, previous studies have investigated the *nature* of parent gesture, such as gesture categories (i.e. deictic, conventional, representational) and gesture-speech combinations (i.e. reinforcing, supplementary, disambiguate). In the typically developing population, different gesture categories used by parents have been shown to relate to increased rates of children's gestures, regulate child behavior, or facilitate child word learning (Fusaro et al. 2014; Goldin-Meadow and Butcher 2003; Goodwyn et al. 2000; Liszkowski et al. 2012; Rowe et al. 2008; Zammit and Schafer 2011). In the literature on clinical populations, there have been mixed findings on whether parents differ in the production of the gesture categories as a function of the child's diagnosis or risk. For example, Iverson et al. (2006) found that parents of children with Down syndrome produced more deictic gestures (e.g. pointing, showing) and fewer conventional gestures (e.g. head nodding or shaking) than parents of typically developing children. However, Özçalışkan et al. (2018) reported that the proportion of deictic, conventional, and representational gestures (e.g. flapping hands to indicate birds flying) did not differ among parents of children with Down syndrome, ASD, or typical development. In the high-risk infant sibling literature, Talbott et al. (2015) similarly found no group differences in the distribution of 12-month gesture categories among mothers of high- and low-risk infants, with the greatest proportion of gestures being deictic followed by conventional and representational gestures. On the infant side of communication, Choi et al. (2019) found similar distributions of gesture categories (i.e. deictic > conventional) in high- and low-risk infants at 12, 18, and 24 months, independent of their eventual ASD diagnosis.

Previous research has also studied how parents combined their gestures with speech (hereafter, "gesture-speech combinations") when interacting with their children. In general, parents often combined their gestures with speech, particularly, speech redundant with the gesture's referent (e.g. pointing at a cup + "cup") rather than producing them alone (Iverson et al. 1999; O'Neill et al. 2005). In typical development and children with language delays, gestures produced by an experimenter that were combined with novel words or sentences have been shown to aid comprehension and word learning (Capone and McGregor 2005; McNeil et al. 2000; Weismer and Hesketh 1993). Relevant to the current study, Özçalışkan et al. (2018) reported that parents of children with ASD, Down syndrome, and typical development did not differ in the proportion of different gesture-speech combination types (reinforcing, supplementary, disambiguating) even when their children showed group differences. Choi et al. (2019) also found no robust group differences in the proportional use of each gesture-speech combination type among high- and low-risk infants at 12, 18, and 24 months; however, the question of whether their *parents* differ on this variable remains unknown.

Taken together, while a few previous studies have examined parental gesture use with children with or at risk for ASD, several important gaps still remain. First, it is currently unknown whether parents of high- and low-risk infants differ in the frequency of gesture use beyond the 12-month

time point (Talbott et al. 2015). Second, it remains unclear whether parents differ in the detailed nature of gesture use (i.e. production of different types of gestures and gesture-speech combinations) with high- and low-risk infants beyond the 12-month time point. Therefore, our first goal of the present study is to provide a more comprehensive account of parents' gesture use with high- and low-risk infants at 12, 18, and 24 months of age.

Infant Responsiveness to Parent Gestures

Although parents of children with or at-risk for ASD have shown similar levels of responsiveness to infant communication as parents of typically developing children in both our previous work and other research (Choi et al. 2019; Dimitrova et al. 2016; Leezenbaum et al. 2014), research on *infants*' responsiveness to parent gestural communication is more limited. A recent study by Kuchirko et al. (2018) investigated mother–child interactions at 14–24 months and found that typically developing infants responded to maternal gestures with gestures and to maternal referential language with vocalizations and gestures. Hahn et al. (2014) found that children with Fragile X Syndrome, about 30% of whom are diagnosed with ASD (Kaufmann et al. 2004), were more likely to respond with speech to parent pointing than other gestures. Additionally, Dimitrova et al. (2017) reported that, when matched in receptive language to typically developing peers, children with ASD showed similar levels of comprehension of deictic gestures and reinforcing gesture-speech combinations produced by an examiner.

Studies with infant siblings have found that high-risk infants have lower ratings of social reciprocity and attentiveness, compared to low-risk infants (Campbell et al. 2015; Wan et al. 2013). However, these studies examined the overall reciprocity of the infants and did not look at infant responsiveness to parent gestures, specifically. Moreover, to the best of our knowledge, previous research that has examined parent gesture use with high-risk infants did not investigate how infants responded to parent gestures, which might differ depending on the infant's risk for ASD or eventual ASD diagnosis. The association between parent gesture and child language could indeed be due to the gestures eliciting some sort of response in the child. Thus, understanding child responses to parent gesture is warranted. Hence, our second research aim is to explore whether there are group differences in infant responsiveness to parent gestures.

Parent Gesture and Child Vocabulary Development

Parent gestures have been extensively studied in relation to child gestures and language in typical development. Previous findings show that parent gestures are positively correlated with child gestures such that parents who use more gestures with their children have children who gesture more (Liszkowski et al. 2012; Liszkowski and Tomasello 2011; Rowe et al. 2008). Furthermore, parent gestures during early childhood predict later child vocabulary development and mediate the relation between socioeconomic status and language skills in typically developing children (Rowe and Goldin-Meadow 2009).

Research exploring the impact of parent gestures during interactions with children with neurodevelopmental disorders is growing. Hahn et al.(2014) reported that mothers of toddlers with Fragile X Syndrome who used more gestures had children with higher receptive and expressive language scores at a later time period; however, they did not control for children's earlier language or gestural ability. In the infant sibling literature, Talbott et al. (2015) reported that 12-month parent gesture significantly, positively correlated with 18-month general language skills, measured on the Mullen Scales of Early Learning (Mullen 1995), in high-risk infants who were not diagnosed with ASD and typically developing low-risk infants; however, again, children's earlier gesture use or language was not controlled in the analyses. In the ASD literature, while children's own gesture use has been found to predict later language skills in those diagnosed with ASD (Manwaring et al. 2017) or language delays (Manwaring et al. 2019), previous studies did not examine the longitudinal associations among *parent* gestures, child gestures, and child language development. Given the limited literature on the relation between parent gesture and child language development in ASD, our third research goal is to examine whether parent gesture relates to infant gesture and *predicts* vocabulary development in high-risk infants, controlling for the various variables indicated by previous research that have been shown to relate to child language (i.e. infant gestures, infant sex, parent education, and parent word types).

The Present Study

Previous work has captured different aspects of parent–child communication and interactions in the infant sibling context (e.g. parent gesture at 12-month in Talbott et al. 2015; infant gesture at 12-, 18, and 24-month in Choi et al. 2019; parent verbal input at 12-, 18, and 24-month in Choi et al. 2020; see Wan et al. 2019 for review). Building on this line of research, the overall aim of the present study is to provide a thorough account of parent–child interactions in dyads involving high- and low-risk infants longitudinally by analyzing parent gesture use beyond the 12-month time point[1]

[1] One previous paper examined a sub-sample (37%) of the participants included in the present study to examine gesture use in maternal gesture use at a single time point (Talbott et al. 2015). By including a larger sample size ($n = 89$) and multiple time points at 12, 18, and

and examining infant responsiveness to parent gesture and later child vocabulary outcomes at 36 months. We examined parent–child interactions in three groups: high-risk infants eventually diagnosed with ASD (HRA+), high-risk infants not diagnosed with ASD (HRA-), and low-risk comparison infants (LRC) at three infant ages (i.e. 12, 18, and 24 months). Our research questions were:

1. Do parents of HRA+, HRA-, or LRC infants differ in gesture use at 12, 18, and 24 months?
2. Do HRA+, HRA-, and LRC infants differ in responsiveness to parent gestures?
3. Do parent gestures relate to infant gestures and later vocabulary development?

Methods

Participants

Participants were 89 parents and their infants who were at high or low familial risk for ASD ($n_{HRA+}=21$; $n_{HRA-}=34$; $n_{LRC}=34$) enrolled in a prospective, longitudinal study of early development of high- and low-risk infants. All infants had a minimum gestational age of 36 weeks and had no genetic or neurological disorders. For the present study, data were drawn from parent-infant dyads who participated in a 10-min free play interaction in the lab at least once at 12, 18, or 24 months and spoke English at home more than 80% of the time. Infants were recruited into one of two groups in the study. Infants who had an older sibling with an ASD diagnosis, which had been conferred by expert clinicians in the community and independently confirmed by the Social Communication Questionnaire (SCQ; Rutter et al. 2003) and/or the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000) in the lab, were defined as high risk for ASD (HRA; $n=55$). Infants who had a typically developing older sibling and no first- or second-degree relatives with ASD were categorized as low-risk comparisons (LRC; $n=34$).

At 18, 24, and 36 months, all infants were administered the ADOS to determine ASD diagnostic outcomes. If infants completed the ADOS at multiple time points (e.g. 18, 24, and 36 months), the ultimate ASD outcome classification was made at their final visit (e.g. 36 months) using previous and current assessments. While the final visit occurred at 36 months for the majority of participants (84%), it took place at 24 months for 11% of participants and at 18 months for 4% of participants. Given the research supporting high diagnostic stability of ASD diagnosis (Ozonoff et al. 2015; Zwaigenbaum et al. 2016), we decided to include those infants with a diagnosis made earlier than 36 months. The ADOS was administered by research staff with extensive experience in testing children with developmental disorders and was co-scored by an ADOS-reliable researcher via recording. If infants met criteria for ASD or received a score within three points of the cut-off score on the ADOS, a licensed clinical psychologist reviewed videos of the previous and concurrent behavioral assessments along with the ADOS scores to make a clinical judgment as ASD, no ASD, or other (e.g. ADHD, anxiety). Infants classified as 'other' were excluded from the current study. Of the high-risk infants, 21 were later diagnosed with ASD (HRA+), and 34 were not (HRA−). None of the low-risk infants included in this study were diagnosed with ASD (LRC).

Due to visits missed by families and technological problems during video recording, there were 70 parent-infant dyads at 12 and 18 months and 69 dyads at 24 months. Participant demographics, as shown in Table 1, indicated that the HRA+, HRA-, and LRC groups were comparable in infant race and family income. The majority of infants (87%) were White, and 79% of families reported having an average household income of more than $75,000. However, there were significant differences in infant sex and parent education across the three groups. Post-hoc pairwise comparisons revealed that the HRA+ group had significantly more male infants (71%) than the HRA− group (35%; $p=0.013$), which is expected since ASD is more common in males than females (Werling and Geschwind 2013). Also, parent education levels in the HRA+ group were significantly lower than those in the LRC group ($z=-3.35$, $p<0.001$). Accordingly, we included infant sex and parent education as potential demographic covariates in our regression analyses predicting child vocabulary scores. In terms of infants' language skills, there was a significant difference on the 36-month vocabulary scores measured on MacArthur-Bates Communicative Development Inventory (MB-CDI; Fenson et al. 1994); post-hoc pairwise comparisons indicated that HRA+ infants produced significantly fewer number of words than LRC infants ($z=-2.59$, $p=0.010$). A similar pattern of results was also found with 36-month receptive and expressive language scores measured on Mullen Scales of Early Learning (Mullen, 1995), indicating that HRA+ infants scored significantly lower than LRC infants on both the receptive language subscale ($t=2.81$, $p=0.020$) and the expressive language subscale ($t=3.77$, $p=0.001$).

Footnote 1 (continued)

24 months, the present study contributes to a more complete picture of parent gestural communication and its contribution to vocabulary development in the infant sibling context.

Table 1 Participant characteristics

	HRA +	HRA-	LRC	*p* (3-group)
Sample size				
12 Months	17	25	28	
18 Months	16	25	29	
24 Months	15	25	29	
Child Characteristics				
Sex (% Male)	71.4% *N* = 21	35.3% *N* = 34	50.0% *N* = 34	.038*
Race (% White)	81.0% *N* = 21	94.1% *N* = 34	88.2% *N* = 34	.269
36-Month MB-CDI Vocabulary	44.55 (28.99) *N* = 11	61.69 (18.94) *N* = 16	70.04 (20.08) *N* = 28	.013*
36-Month Mullen Receptive Language	49.00 (14.42) *N* = 14	54.32 (8.04) *N* = 22	57.64 (8.06) *N* = 33	.023*
36-Month Mullen Expressive Language	51.64 (9.16) *N* = 14	58.09 (7.00) *N* = 22	61.06 (7.78) *N* = 33	.002**
Parent Characteristics				
[a]Household Income	6.78 (2.26) *N* = 18	7.65 (1.05) *N* = 31	7.22 (1.83) *N* = 27	.306
[b]Parent Education	4.92 (1.73) *N* = 19	5.77 (1.71) *N* = 31	6.47 (1.01) *N* = 30	.008**

Data are reported as group means with standard deviations in parentheses, when applicable. The 36-month Mullen language scores are standard T scores

[a]Income was reported on an eight-point scale: (1) less than $15,000, (2) $15,000-$25,000, (3) $25,000-$35,000, (4) $35,000-$45,000, (5) $45,000-$55,000, (6) $55,000-$65,000, (7) $65,000-$75,000, (8) more than $75,000

[b]Caregiver education was reported as the highest level attained on a nine-point scale: (1) some high school, (2) high school graduate, (3) some college, (4) community college/two-year degree, (5) four-year college degree, (6) some graduate school, (7) master's degree, (8) doctoral degree, (9) professional degree. For three of our infants, either their mothers or fathers participated in caregiver-child interactions at 12, 18, and 24 months; for them, parental education levels were calculated by averaging paternal and maternal education levels. For two of our infants, only fathers participated in caregiver-child interactions, and paternal education levels were used. Maternal education levels were used for the rest of the participants

*$p < .05$, ** $p < .01$

Procedure

The present study was approved by the IRB review boards at Boston Children's Hospital and Boston University. Written, informed consent was obtained from parents prior to their participation in the study. At 12, 18, and 24 months, parent–child dyads were videotaped during a 10-min naturalistic, free-play interaction in the lab. The dyads were instructed to play as they normally would and were provided with age-appropriate toys (e.g. puzzle, book, kitchen set). For a small number of infants ($n_{12\text{-months}} = 3$; $n_{18\text{months}} = 1$; $n_{24\text{-months}} = 2$), fathers completed the interaction and were included in the analyses. For simplicity, all groups are referred to as parent–child dyads. At 36 months, children's vocabulary scores were measured using the MB-CDI (Fenson et al. 1994), which is a parent-report measure widely used in research (Frank et al. 2017).

Measures

Parent Gesture

The videotaped sessions of parent–child interactions were transcribed verbatim at the utterance level using the CHAT conventions Child Language Data Exchange System (CHILDES; MacWhinney 2000). The transcripts were then coded for gestures by two reliable, trained raters. Parent gestures were first reliably identified following previous research (Özçalışkan and Goldin-Meadow 2009), and further coded at two levels: gesture categories and gesture-speech combinations. Notably, all gestures were coded whether or not they occurred during joint attention.

Gesture categories refer to whether a gesture is deictic, conventional, or representational. Deictic gestures are those that clearly indicate an object in the environment such as pointing, showing, and reaching. Conventional gestures refer to those that have widely known or pre-established meaning

(e.g. head nodding or shaking). Finally, representational gestures are those that indicate abstract objects or actions (e.g. flapping hands to show birds flying). When examining gesture-speech combinations, we coded whether a gesture was produced alone (i.e. without speech) or in conjunction with spoken words. Words were defined as meaningful speech utterances (e.g. English words) or onomatopoeic sounds and were preceded and followed by silence or a change in topic. Words were further semantically defined as reinforcing, disambiguate, or supplementary. *Reinforcing* speech includes utterances that are redundant with the information indicated by the gesture (e.g. "dog" + pointing at dog; "yes" + nodding). *Disambiguate* speech includes utterances that clarify the referent of the gesture using a pronoun or demonstrative (e.g. "her" + pointing at sister; "there" + pointing at table). *Supplementary* speech includes utterances that add information to what the gesture indicates (e.g. "give me" or "drive" + pointing at car). Reliability was assessed by randomly selecting and double coding 20% of the transcripts, and agreement between the coders was 98.4% for coding gesture categories ($k = 0.954$, $n = 1521$) and 87.8% for coding gesture-speech combinations ($k = 0.827$; $n = 1521$).

Infant Responsiveness

Infant responsiveness to parent gestures was defined as the presence or absence of an immediate infant utterance, action, or gesture related to the parent gesture directly following the parent gesture. That is, if the infant produced a response related to the parent's gesture within the first utterance following the parent's gesture (e.g. mom showing a cup and child immediately pointing to the cup), we coded this infant response as present. Of note, we did not measure any time lapse for the infant response to the parent gesture. Responsiveness was coded by two independent raters, and reliability was assessed by randomly selecting and double coding 20% of the transcripts. High interrater agreement was achieved (95.2%, $k = 0.917$; $n = 1275$).

MacArthur-Bates Communicative Development Inventory (MB-CDI; Fenson et al. 1994)

Parents completed the MB-CDI when their children were 36-months-olds. Using a 100-item vocabulary checklist in the MB-CDI, we assessed the number of words produced by the child at 36 months and used it as the child's vocabulary size. The scale of possible scores range from 0 to 100 (words). Children's vocabulary skill, as opposed to general language ability, was chosen as our language outcome measure as a robust relation between gesture and vocabulary has been reported in previous research (e.g. Rowe et al. 2008).

Mullen Scales of Early Learning (Mullen; Mullen, 1985)

The Mullen is a standardized, normed assessment for children aged birth through 68 months. The Mullen contains five subscales: Gross Motor, Visual Reception, Fine Motor, Expressive Language, and Receptive Language. We used the 36-month standard T scores from the Receptive and Expressive Language subscales as indicators of children's general language ability.

Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000)

The ADOS is a semi-structured observational assessment designed to assess characteristics of ASD, including social and communicative abilities and repetitive, restricted behaviors. It is presented as a play-based interaction between the child and an examiner built to elicit certain behaviors and responses from the child.

Statistical Analyses

Distributions of parent gesture variables and infant responses were non-normal based on their respective histograms or Shapiro–Wilk tests. Therefore, we performed nonparametric tests such as Kruskal–Wallis H tests to compare parent gesture use and infant responsiveness across HRA + , HRA-, and LRC groups at 12, 18, and 24 months, with follow-up pairwise comparisons using Mann–Whitney U tests. Following the same reasoning, we used nonparametric Spearman's rho correlations to examine relations between parent gesture at each point in time (i.e. 12, 18, and 24 months) and child vocabulary skill at 36 months and used an adjusted p-value for multiple comparisons. Finally, we conducted multiple linear regression analyses to determine whether parent gesture use predicted later vocabulary skill above and beyond other potential controls. As previous studies documented that child sex (Huttenlocher et al. 1991), child gesture (Rowe et al. 2008), parent education (Rowe 2012), and parent speech (Hoff 2003) are associated with child vocabulary development, we controlled for these specific variables in our regression analyses.

Table 2 Descriptive statistics on total number of parent gestures, gestures produced alone, and gestures produced with speech per minute, by group and age

	HRA +	HRA-	LRC	*p* (3-group)
Total Gestures (a + b)				
12 Months	3.10 (1.58) 0.63–5.67 *N* = 17	3.90 (1.46) 1.54–7.11 *N* = 25	3.16 (1.22) 0.58–5.35 *N* = 28	.187
18 Months	3.33 (1.69) 0.68–6.75 *N* = 16	3.57 (1.47) 1.18–7.13 *N* = 25	3.27 (1.34) 1.28–6.73 *N* = 29	.774
24 Months	3.86 (2.13) 1.51–9.78 *N* = 15	3.72 (1.53) 1.40–7.87 *N* = 25	3.44 (1.45) 0.71–6.39 *N* = 29	.977
Gestures Produced Alone (a)				
12 Months	0.54 (0.42) 0–1.25 *N* = 17	0.74 (0.49) 0–2.20 *N* = 25	0.46 (0.41) 0–1.78 *N* = 28	.053 ~
18 Months	0.15 (0.13) 0–0.38 *N* = 16	0.12 (0.16) 0–0.75 *N* = 25	0.11 (0.11) 0–0.34 *N* = 29	.601
24 Months	0.18 (0.22) 0–0.66 *N* = 15	0.21 (0.17) 0–0.65 *N* = 25	0.16 (0.14) 0–0.48 *N* = 29	.408
Gestures produced with speech (b)				
12 Months	2.55 (1.40) 0.31–4.72 *N* = 17	3.17 (1.31) 1.23–6.45 *N* = 25	2.70 (1.15) 0.19–5.10 *N* = 28	.371
18 Months	3.18 (1.67) 0.56–6.38 *N* = 16	3.45 (1.48) 1.07–6.92 *N* = 25	3.16 (1.32) 1.09–6.54 *N* = 29	.838
24 Months	3.68 (2.06) 1.51–9.48 *N* = 15	3.50 (1.50) 1.30–7.63 *N* = 25	3.28 (1.40) 0.61–6.12 *N* = 29	.984

Results

Parent Gesture

Descriptive statistics on parent gesture use at 12, 18, and 24 months are provided in Table 2. Overall, parents of HRA + , HRA-, and LRC infants produced a comparable total number of gestures between 12 and 24 months.[2] When the total parent gestures were broken down into gestures produced alone and gestures produced with words, a similar pattern was found, indicating no significant group differences across the three ages and groups.

[2] Given that previous research suggests a significant relation between parent education and gesture use (e.g., Rowe and Goldin-Meadow 2009) and that we found the significant differences in parent education across groups in our sample, we tested whether the finding held with the education controlled. Our finding held, demonstrating that parent gesture did not differ by group, over and above the control for parent education.

Table 3 Descriptive statistics on infant responses (frequencies and proportions) to parent gestures per minute, by group and age

	HRA +	HRA-	LRC	*p* (3-group)
Frequencies				
12 Months	1.07 (0.63) 0.21–2.51 N = 17	1.56 (0.77) 0.47–3.10 N = 25	1.17 (0.76) 0.18–3.56 N = 28	.053 ~
18 Months	1.39 (1.08) 0.09–4.41 N = 16	1.31 (0.64) 0.50–3.30 N = 25	1.43 (0.72) 0.41–3.37 N = 29	.720
24 Months	1.94 (1.14) 0.30–4.54 N = 15	1.87 (1.07) 0.55–5.32 N = 25	1.90 (1.04) 0.41–4.86 N = 29	.955
Proportions				
12 Months	0.37 (0.16) 0.22–0.75 N = 17	0.40 (0.14) 0.18–0.67 N = 25	0.38 (0.19) 0.07–0.79 N = 28	.713
18 Months	0.42 (0.21) 0.03–0.91 N = 16	0.38 (0.12) 0.17–0.70 N = 25	0.46 (0.18) 0.16–0.77 N = 29	.217
24 Months	0.50 (0.17) 0.19–0.72 N = 15	0.50 (0.15) 0.14–0.75 N = 25	0.55 (0.15) 0.21–0.77 N = 29	.483

After investigating the number of parent gestures, we examined whether there were differences in the distribution of gesture categories (i.e. deictic, conventional, and representational) and found no significant group differences (Supplementary Figure S1). The majority of gestures produced were deictic gestures, with averages of 77% in HRA + parents, 79% in HRA- parents, and 76% in LRC parents, respectively. These deictic gestures were followed by conventional gestures and then representational gestures. Similarly, we examined the distribution of types of gesture-speech combinations (i.e., reinforcing, disambiguate, supplementary) and found no significant group differences (Supplementary Figure S2). Approximately half (48%) the gesture-speech combinations were reinforcing types across the three ages and groups, followed by supplementary and then disambiguating types. To summarize, we found that parents of HRA + , HRA−, and LRC infants exhibited similar frequency and nature of gestures when their infants were at 12, 18, and 24 months.

Infant Responsiveness

Descriptive statistics on infant responses to parent gestures are presented in Table 3. At 12, 18, and 24 months, there were no significant group differences in the number of infant responses. When comparing the proportions of infant responses that control for the differences in parent gestures, again, there were no group differences, demonstrating that HRA + , HRA−, and LRC infants were similarly responsive to their parents' gestures at 12, 18, and 24 months.

Table 4 A series of regression models predicting child 36-month MB-CDI vocabulary scores using 12-month parent gesture

	Model 1	Model 2	Model 3
Intercept	42.64***	30.99	26.09
	(8.28)	(19.62)	(19.62)
Parent gesture (12 months)	6.99*	6.08*	7.01*
	(2.34)	(2.67)	(2.72)
Infant gesture (12 months)		0.17	0.19
		(0.42)	(0.41)
Parent word types (12 months)		−0.08	−0.08
		(0.08)	(0.08)
Parent education		3.71	2.88
		(2.90)	(2.91)
Infant sex		7.96	6.54
		(7.45)	(7.40)
Group			6.12
			(4.38)
R^2 (%)	18.3	23.7	28.7

***$p < .001$

*$p < 0.05$

Parent gesture at 18- or 24-months was not correlated with 36-month MB-CDI vocabulary scores. Additionally, parent gesture use at 12-, 18-, or 24-months was not correlated with infants' receptive and expressive language scores measured on the Mullen at 36 months.

Follow-up multiple regression analyses were conducted to examine whether the effect of parents' gesture use at 12 months on infants' 36-month MB-CDI vocabulary scores remained significant, controlling for other predictors of child vocabulary such as infant sex, parent education, infant gesture, and parent speech as identified in the literature (Hoff 2003; Huttenlocher et al. 1991; Rowe 2012; Rowe et al. 2008).

Model 1 in Table 4 shows the relation between parent gesture at 12 months and MB-CDI scores at 36 months. In Model 1, the parameter estimate associated with parent gestures ($\beta = 6.99$) indicates that every additional gesture parents produced per minute at 12 months is positively associated with an approximately 7-point difference on the MB-CDI at 36 months. Model 1 also indicates that parent gestures alone explain approximately 18% of the variance in MB-CDI scores.

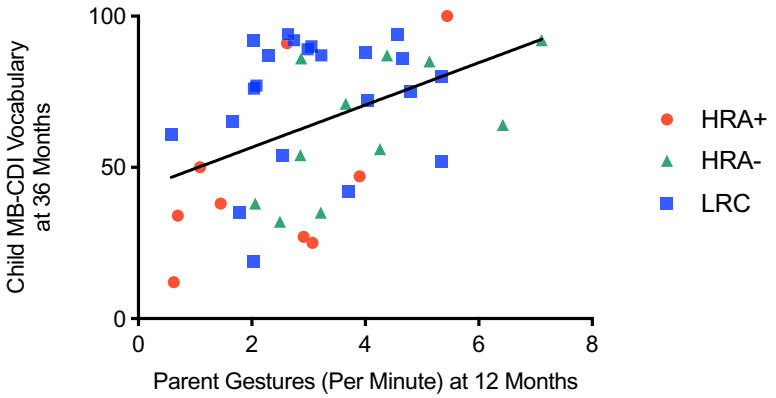

Fig. 1 Scatterplot with a best-fit line depicting the relation between parent gestures at 12 months and child MB-CDI vocabulary scores at 36 months

Note. Red dots represent data for the HRA+ group, green triangles represent data for the HRA- group, and blue rectangles show data for the LRC group.

Associations Between Parent Gesture, Infant Gesture, and Later Vocabulary Skill

The total number of parent gestures was significantly moderately correlated with the total number of infant gestures at each age ($r_s = 0.25$-0.41). Spearman's rho correlations were conducted to first examine bivariate relations between parent gesture at each time point (i.e., 12, 18, and 24 months) and infants' MB-CDI vocabulary scores at 36 months. There was a significant positive correlation between 12-month parent gesture and 36-month MB-CDI vocabulary scores ($r_s = 0.38$, $p = 0.013$), even when corrected for multiple comparisons.

Model 2 builds on the regression analyses by including infant gesture, parent word types (i.e. different number of words), parent education, and infant sex. Parent gesture at 12 months remained a significant predictor, even when controlling for these variables. None of the added variables was a significant predictor of later vocabulary. As a whole, Model 2 shows that these variables combine to explain approximately 24% of the variance in MB-CDI scores, with the majority of the variance explained by parent gesture use at 12 months.

The final step explores whether the relation between parent gesture use and infant vocabulary skill holds even when

controlling for group. Model 3 indicates that the effect of parent gesture remained significant and that the group was not a significant predictor. The interaction term between parent gesture and group was also tested to determine whether the relation differed across the HRA + , HRA-, and LRC groups. There was no interaction effect, suggesting that the relation between 12-month parent gesture and 36-month infant vocabulary skill was similar in the three groups (Fig. 1).

Discussion

In the present study, we examined whether there were differences in gestures that parents of HRA + , HRA-, and LRC infants produced at 12, 18, and 24 months, infant responses to parent gestures, and the relations between parent gestures and child vocabulary scores. We found that parents in all three groups produced comparable amounts of total gestures at 12, 18, and 24 months. Similarly, infants had comparable responsiveness to the parent gestures, regardless of their risk and diagnostic outcome. Parent gestures were positively related to infant gestures at all three ages, and parent gestures at 12 months predicted infant vocabulary scores at 36 months.

Parent Gesture

Our first research goal was to examine whether there were differences in the frequency and nature of parent gestures among HRA + , HRA−, and LRC groups at each of three time points, expanding on previous research by longitudinally studying parent gesture use at critical times of language development in children. We found that there were no significant group differences in total gestures, indicating that parents in all groups gestured at similar frequencies. Such results are consistent with previous research that reported no differences in total gestures by parents of children with ASD, parents of typically developing children, and parents of other developmental disorders (Baumann et al. 2019; Medeiros and Winsler 2014; Özçalışkan et al. 2018; Yoshida et al. 2020). Of note, Talbott et al. (2015) examined parent gesture use in a subset of the participants included in the present study and found that parents of high-risk infants produced more gestures than parents of low-risk infants at 12 months. However, once expanding on the number of participants, although the trends remained similar, this finding lost significance. Related to the null finding in parents' total gesture use, previous studies reported that parent *responses* to infant gestures were also similar across autism risk and diagnostic groups (Choi et al. 2019; Leezenbaum et al. 2014). Taken together, these results suggest that parents of high-risk infants provide similar nonverbal input, as well as the comparable rates of responses to infant communication, even when their infants have differences in early gesture production (Choi et al. 2019).

In addition to no group differences in total parent gestures, we found that parents of HRA + , HRA−, and LRC infants showed similar distributions of their gesture use between 12 and 24 months. The majority of gesture categories produced by all parents were deictic gestures, followed by conventional, and then representational. Also, the majority of gestures were combined with reinforcing speech, followed by either disambiguate or supplementary speech. These results are consistent with previous research that found similar patterns of distribution of gesture categories and gesture-speech combinations (i.e. the majority of deictic gestures and reinforcing gesture-speech combinations) in parents of typically developing infants at 16 and 20 months (Iverson et al. 1999), and in parents of children with Down syndrome, ASD, or typical development (Özçalışkan et al. 2018). In addition, Talbott et al. (2015), using an overlapping sample as the current study, similarly found a majority of deictic gestures, followed by conventional and representational when infants were 12 months old, thereby suggesting that this previous finding was replicated with a larger number of participants and held beyond the 12 month infant age point. It is hypothesized that deictic gestures and reinforcing gesture-speech combinations, which made up most of the gestures produced in the present study, may represent simpler forms of communication that can scaffold children's language development (Iverson et al. 1999) and may thus be used in similar ways by parents of HRA + , HRA-, and LRC infants.

Infant Responsiveness to Parental Gestures

Our second research goal aimed to examine infant responsiveness to parental gestures. Controlling for the differences in parental gestures, we found that infants responded comparably to parents' gestures regardless of their ASD risk and eventual diagnosis at 12, 18, and 24 months. This robust comparable responsiveness to parent gestures at all three ages was somewhat unexpected due to previous studies that found decreased reciprocity in children with ASD (Campbell et al. 2015; Wan et al. 2013) and decreased joint attention (Rozga et al. 2011). The finding may in part be attributed to how we coded the infant responsiveness. As described in the Methods, we only examined whether infants did or did not produce a response (verbal or physical) to parental gestures; we did not code detailed aspects of infant responsiveness, on which the groups might have differed. Therefore, future research should consider exploring the latency, duration, and/or specific types of infant responses to parents' gestures. Another avenue for future research is examining infants' comprehension of parental gestures and whether the

gesture comprehension is related to infants' responsiveness to parental gestures. Dimitrova et al. (2017) reported that children with ASD (aged 1–12 years old) showed similar levels of comprehension of deictic gestures and reinforcing gesture-speech combinations produced by an examiner, as typically developing children (aged 1–5 years old) who were matched in receptive language scores. As most of the gestures produced by parents in the present study were deictic and reinforcing types, we speculate that perhaps infants' comprehension of those gestures was comparable even at a younger age regardless of the infant's ASD risk or later diagnosis. Therefore, an in-depth analysis of infant responsiveness is warranted to see if the no-group differences are indeed due to comprehension of parental gestures.

Parent Gesture, Infant Gesture, and Vocabulary Development

Our third research goal aimed to explore the relation between parent gestures, child gestures, and child vocabulary. Due to comparable levels of parent gestures across groups, we did not differentiate parents by group for this research question. Consistent with previous literature in typical development (Liszkowski et al. 2012; Liszkowski and Tomasello, 2011; Rowe et al. 2008), we found that parents' gestures were significantly correlated with infants' gestures at each age (12, 18, and 24 months). Our previous paper on infant gesture found that infant gesture use at 12 months predicted later language scores at 24 months in both high- and low-risk infant groups (Choi et al. 2019). Taken together, these findings suggest that infants whose parents used more gestures also produced more gestures, potentially facilitating their own language development.

Next, our regression analyses indicated that parent gesture at 12 months was associated with child vocabulary at 36 months, even when controlling for the covariates (i.e., infant gesture, parent education, infant sex, and parent speech), suggesting that parent gesture at 12 months predicted later child vocabulary above and beyond the other predictors previously identified in the literature. Moreover, there was no interaction effect between parent gesture and group, indicating that parent gesture predicted later child vocabulary similarly in HRA+, HRA−, and LRC groups. These findings on parental nonverbal input add to a body of literature suggesting that parent input plays the same important role in vocabulary development in children with ASD and typically developing children (Bang and Nadig 2015). Of note, Talbott et al. (2015) reported that 12-month parent gesture and 18-month child language, measured using the Mullen, were significantly correlated in LRC and HRA-, but not HRA+dyads. The difference across the findings may be due to the fact that child language was assessed at different ages using a vocabulary measure (MB-CDI) in the current study (and much of the typical development literature) and that the Mullen, which assesses more general language abilities in children, was used in Talbott et al. (2015). Our sister paper, using the same parent–child data as the current study, found a predictive relationship between *infant* gestures at 12 months and Mullen receptive language scores at 24 months (Choi et al. 2019). Thus, it is possible that different language measures may capture different language ability with regards to parent and child gestures.

Taken together, our results suggest that parent gestures play an important role in child vocabulary development regardless of the infant's ASD risk and eventual diagnosis. By implication, it will be important for parents to understand the value of gestures and use gestures frequently with their infants to promote optimal language development in all children (Goodwyn and Acredolo 1998). Recently, Rowe and Leech (2019) implemented a parent gesture intervention to test whether a brief training can improve parent and child use of pointing gestures and child vocabulary. They found that a 5-min video training increased pointing gestures from 10 to 12 months in both parents and their typically developing children but had no direct effect on child vocabulary at 18 months. However, parents' *declarative* pointing gestures, which were produced to share attention or interest with their infants, increased as a result of the intervention at 12 months and predicted child vocabulary at 18 months (Choi and Rowe, under review). Considering that many existing autism interventions have a high cost and require intensive time commitment from families, this type of brief, targeted parent gesture training may be used as a supplement to ASD interventions to reach more families with infants at risk for ASD, who have a greater chance of language delays and deficits (Cassel et al. 2007; Mitchell et al. 2006; Tager-Flusberg 2016). Furthermore, investigating the communicative intentions conveyed through parent gestures in relation to child language development will be an important avenue for future research in ASD high-risk infant sibling literature.

In sum, the present study contributes to the literature by longitudinally studying parents' gesture use with high- and low-risk infants between 12 and 24 months of age and examining infant responsiveness to parent gestures, as well as the relations between parent gesture use and later infant vocabulary development. However, several limitations should be considered. First, high-risk infants (including those later diagnosed with ASD) in our sample had language scores within the range of typical development (see the Mullen language scores in Table 1) and thus may not be representative of the larger population of high-risk infants. Therefore, future research should be conducted with infants with a greater variety of language abilities to further examine the role of parents' gesture on language development. Additionally, our parent sample across the groups reported relatively

high levels of household income and education (Table 1); therefore, future research should investigate whether these findings generalize to a more representative sample of families.

Conclusion

Overall, we found that parents with and without infants at high risk for autism produced comparable levels of gestures and distribution of gesture categories and gesture-speech combinations during interactions with their infants at 12, 18, and 24 months. Despite differences in infant gesture production at 12 and 18 months (Choi et al. 2019), their parents do not appear to provide altered gesture input to their infants. Our previous studies reported that parents provided comparable levels of responsiveness and verbal input to their infants (Choi et al. 2019, 2020), and here we find that infants also had similar levels of responsiveness to parent gestures. In addition, parent and infant gestures were highly correlated across all ages, suggesting that children whose parents used more gestures also had more gestures facilitating their own language development. And finally, while child gestures at 12 months predicted receptive language at 24 months (Choi et al. 2019), parent gestures at 12 months predicted child vocabulary at 36 months, suggesting that parent gestures may be especially helpful for children during early stages of vocabulary acquisition. Knowing the current state of parent communication with their children (and vice versa) is important when developing early interventions and support services. Further studies should continue to explore the synchrony and interaction between parent and child partners in communication, as such information could prove useful for developing more targeted and effective interventions for infants at risk for ASD.

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Author Contributions BC and PS performed data coding and analyses and drafted the manuscript. MLR, HTF, and CAN critically revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interests.

Ethical Approval All procedures performed in the current study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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