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RESEARCH ARTICLE

Infants who develop autism show smaller inventories of deictic and symbolic gestures at 12 months of age

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Abstract

Gestures are an important social communication skill that infants and toddlers use to convey their thoughts, ideas, and intentions. Research suggests that early gesture use has important downstream impacts on developmental processes, such as language learning. However, autistic children are more likely to have challenges in their gestural development. The current study expands upon previous literature on the differences in gesture use between young autistic and non-autistic toddlers by collecting data using a parent-report questionnaire called the MCDI–Words and Gestures at three time points, 12, 18, and 24 months of age. Results ($N = 467$) showed that high-likelihood infants who later met diagnostic criteria for ASD ($n = 73$ HL-ASD) have attenuated gesture growth from 12 to 24 months for both deictic gestures and symbolic gestures when compared to high-likelihood infants who later did not meet criteria for ASD ($n = 249$ HL-Neg) and low-likelihood infants who did not meet criteria for ASD ($n = 145$ LL-Neg). Other social communicative skills, like play behaviors and imitation, were also found to be impacted in young autistic children when compared to their non-autistic peers. Understanding early differences in social communication growth before a formal autism diagnosis can provide important insights for early intervention.

Lay Summary

As infants learn to talk, they use gestures to communicate. In this study, we used a parent-report questionnaire to look at the group level differences of gestures in the first 2 years of life by comparing infants who later developed autism to infants who did not develop autism. We found that infants who later developed autism have fewer gestures and a slower rate of gesture growth compared to infants who

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did not develop autism. Play behaviors and imitation skills were also impacted in young autistic children when compared to their non-autistic peers.

KEYWORDS
ASD, communication, development, gesture, infants, MCDI

INTRODUCTION

Symbols are an important hallmark of communication development (Deloache, 1995; Tomasello et al., 2005). Using symbols allows for representation of meaning (DeLoache, 2004). For example, in young children, a banana can represent a telephone during pretend play, or the act of waving hands can represent saying "goodbye." Symbolic communication can take many forms: gestures, words, and even drawings. For children, immersion in the symbolic world begins early in development (Rakoczy et al., 2017). However, signs of emerging symbolic communication skills for young children are difficult to discern until they can demonstrate them through motor acts like gestures.

Development of communicative gestures and representational skills

In the first 2 years of life, gestures develop gradually. The first form of gestures that emerge are intentional communicative gestures (also called deictic gestures). Infants usually demonstrate deictic gestures at around 8 to 10 months of age (Bretherton & Bates, 1979). Deictic gestures include showing, pointing, giving, and reaching to communicate based on the environmental context (Iverson et al., 1994). These initial forms of gestures usually appear before or around the emergence of spoken language; hence, these types of gestures are often called prelinguistic gestures (Colonnesi et al., 2010; Iverson & Goldin-Meadow, 2005; Liszkowski, 2014; Spencer, 2011).

The mastery of deictic gestures sets the stage for more advanced forms of gestures, like symbolic gestures (Werner & Kaplan, 1964). Symbolic gestures require the symbolic system and representational skills. The symbolic system refers to the ability to use symbols to represent absent objects, and representational skill refers to the ability to link a symbol to a referent (Bates et al., 1979; Corrigan, 1983; Piaget, 1952). It is speculated that deictic gestures help build the foundation for the symbolic system because the development of symbolic understanding occurs when children's pointing elicits referent-labeling of objects from caregivers (Goldin-Meadow, 2007). By connecting the labels to the referent, infants learn to understand what the referent symbolizes (e.g., pointing to a ball reflects that a spherical shape represents a ball). This type of learning is a precursor to the development of object-word pairings in young children.

As infants mature past 11 months, they begin to use play schemes to learn how to use symbols to communicate meaning (Fein, 1981; McCune, 1995, 2009). Play schemes are carried out when toddlers are using the functional aspects of the object (e.g., a telephone used as a telephone) and are manipulating the referent (e.g., banana as a telephone). Examples of play schemes are functional play, pretend play, and symbolic play. While these are not necessarily considered true forms of gestures, as they do not meet the communicative and symbolic criteria described by Acredolo and Goodwyn (1988), they do help children understand the relationship between two objects (Escalona, 1973; Thiemann-Bourque et al., 2019). Ultimately, this type of learning allows toddlers to carry out symbolic representation as they learn how to decontextualize sensorimotor schemes from the referents to create abstract symbols (McCune-Nicolich, 1981; Orr, 2020; Werner & Kaplan, 1964).

As toddlers practice deictic gestures and play schemes, they begin to develop the skill of combining mental representations of relationships between objects. At this stage, children begin to understand that objects, events, and people have properties that can be independent of their own actions (Corrigan, 1983). This leads to the emergence of symbolic gestures (also called representational gestures; Acredolo & Goodwyn, 1988). Symbolic gestures convey specific intentions, and the message of these gestures can be conveyed in different social and situational contexts (Iverson et al., 1994; Stefanini et al., 2009). These gestures include actions that represent a specific semantic meaning through an identified referent, like flapping arms to represent a bird, and cultural-bound gestures like nodding to say "yes" (Manwaring et al., 2019). Demonstrations of advanced representational skills occur when toddlers can create abstract symbols to communicate with a social partner (e.g., throwing action to represent "ball").

Gestures facilitate language and cognition

Gestures are an important developmental milestone for infants and toddlers because gestures facilitate language and cognitive development. Symbols in gestures are thought to share common origins with linguistic symbols, like spoken language (Piaget, 1962, p. 19). Symbolic skills in gestures and spoken language require mental representation (Piaget, 1952), and mental representation is a cognitive skill (Corrigan, 1983). Early gesture use enables growth in language and cognition due to the early

training in linking symbols to referents, resulting in the overall growth of the symbolic system (Clough & Duff, 2020; Goldin-Meadow, 2015; Goldin-Meadow & Alibali, 2013; Tomasello, 2010). Hence, gestures are positively associated with language and cognition (Goldin-Meadow & Alibali, 2013; Golomb & Cornelius, 1977; Iverson & Goldin-Meadow, 2005; Kelly et al., 2010; Kuhn et al., 2014; McCune, 1995; McGillion et al., 2017; Orr & Geva, 2015; Özçalışkan et al., 2016; Rowe et al., 2008).

Parental inventories of gestures and symbolic abilities

The MacArthur-Bates Communicative Developmental Inventory—Words and Gestures (MCDI–Words and Gestures; Fenson et al., 2006) is a parent-report questionnaire that has been used by researchers to measure the development of communicative and symbolic gestures (Choi et al., 2020, 2021; Lucca & Wilbourn, 2018; Morin-Lessard et al., 2021; Talbott et al., 2015). Specifically, the instrument delves into the developmental milestones of symbolic gestures, from deictic gestures to early emerging symbolic gestures. As the questionnaire investigates the development of symbolic gestures, it also taps into the development of representational skills. While the MCDI–Words and Gestures is intended to capture the development of typical children between the ages of 8 and 18 months of age, researchers have used the instrument outside this age range to assess the gesture profiles of autistic children (Choi et al., 2020; Franchini et al., 2018; Iverson et al., 2018; West et al., 2020).

The MCDI–Words and Gestures is divided into two categories: Early Gestures and Later Gestures. Early Gestures consists of deictic gestures, conventional gestures (culturally bound gestures like nodding to say "yes"), and games and routines (e.g., playing patty cake). Demonstration of these social-communicative actions are examples of interacting with the social world (Vallotton & Ayoub, 2010), and these skills are necessary for the development of early symbolic abilities. On the other hand, Later Gestures represent the improvement of symbolic skills. Items in Later Gestures include imitating adult actions, knowledge of appropriate usage of items and actions (functional play), and using objects to represent other objects (symbolic play). To demonstrate Later Gestures, children need to understand the meaning and intention behind complex adult behaviors and object use (Acredolo & Goodwyn, 1988; Fenson et al., 2006). Items in Later Gestures are not considered "true" gestures; however, they are motor acts that facilitate symbolic understanding. Thus, Later Gestures is sometimes called symbolic gestures.

Challenges in gestures for ASD children

Autism spectrum disorder (ASD) is a neurodevelopmental disorder that is associated with challenges in social communication and interactions as well as the presence of restricted and repetitive patterns of behavior (American Psychiatric Association, 2013; CDC, 2020). As gestures are a social behavior, challenges and delays in deictic and symbolic gestures use for ASD individuals are documented and likely to occur (Choi et al., 2020; González-Sala et al., 2021; Iverson et al., 2018; Ramos-Cabo et al., 2019; Ramos-Cabo et al., 2021; West et al., 2020). These differences have been found using a variety of research measurements including parent-report questionnaires (Choi et al., 2020; Iverson et al., 2018), retrospective video recordings (Colgan et al., 2006; Watson et al., 2013), behavioral coding (Delehanty & Wetherby, 2021, 2022; Thiemann-Bourque et al., 2012, 2019), and behavioral assessments (Hobson et al., 2015; Lee et al., 2016; Talbott et al., 2015; Veness et al., 2012; Ye et al., 2021).

Before 2 years of age, autistic children often produce fewer gestures and have a smaller inventory of gestures when compared to non-autistic children. Group differences in gesture use have been reported for infants who are at high likelihood for ASD (HL) and later meet diagnostic criteria for ASD (HL-ASD; Choi et al., 2020; Franchini et al., 2018; Iverson et al., 2018; Manwaring et al., 2018; Mitchell et al., 2006). For example, Iverson et al. (2018) conducted a small study ($n = 14$ HL-ASD) that looked at the trajectory of gesture development from 8 to 14 months of age for infants with and without high likelihood for ASD by collecting the quantity of gestures with the MCDI–Words and Gestures. The researchers found that HL-ASD infants have attenuated gesture development from 8 to 14 months of age in both Early and Later Gestures when compared to three peer groups: infants with low likelihood for ASD who did not meet criteria for ASD (LL-Neg), infants with high likelihood for ASD who did not meet criteria for ASD (HL-Neg), and infants with high likelihood for ASD who showed signs of early language delays (HL-LD).

In another study including infants with a family history of autism, Franchini et al. (2018) collected longitudinal MCDI–Words and Gestures data on gesture use when infants were 9 to 24 months of age. Using a data-driven (i.e., agnostic to diagnostic outcome) approach, results revealed three developmental trajectories: high, intermediate, and low gesture inventories. In addition, results showed that there was a greater percentage of the HL-ASD group in the low trajectory group when compared to the percentage of HL-Neg and LL-Neg infants. However, when comparing across the HL-ASD infants, more HL-ASD infants fell into the intermediate trajectory than in the low or high trajectories.

Symbolic skills within the first 2 years were also found to be affected in autistic children

(Christensen et al., 2010; Landa et al., 2007; Wetherby et al., 2004, 2007). Specifically, Christensen et al. (2010) and Landa et al. (2007) found that HL-ASD infants (respectfully) showed less functional and symbolic play than HL-Neg and LL-Neg infants. Using a population screening approach, Wetherby et al. (2004, 2007) found similar results. Toddlers who met the criteria for autism at 30 months of age showed less functional and symbolic play compared to toddlers without autism. Overall indications in the literature suggest that autistic toddlers are more likely to be challenged in the mastery of symbolic skills.

These challenges in symbolic skills are persistent beyond the first 2 years of life for many autistic children (Hobson et al., 2013, 2015; Jarrold, 2003; Lee et al., 2016; Rutherford et al., 2007; Rutherford & Rogers, 2003; Strid et al., 2013; Thiemann-Bourque et al., 2019). Hobson et al. (2013) tested pretend play skills in autistic children aged 2–7 years and a language-matched group of non-autistic children with developmental delays. Hobson et al. found lower pretend play scores in the autistic group when compared to the developmental delay group—a pattern suggesting that challenges in the symbolic skills specific to pretend play may be uniquely impacted by autism. Lee et al. (2016) added more nuance to the symbolic difficulties in autistic children as they found that autistic children between the ages of 3 and 7 years had more difficulties generating symbolic play on their own than their non-autistic peers. Taken together, the results from previous studies suggest that challenges in symbolic skills are present early on and continue to be a challenge for some autistic children well into the school age years.

Goals of the current study

Despite a growing body of literature on the challenges many autistic children experience with communicative gestures and symbolic skills, there are limited longitudinal studies that investigate gesture use within the first 2 years of life. Of the existing literature, only two studies have looked at the development of symbolic gestures along with communicative gestures during infancy, and neither study included a time point beyond 14 months of age (Iverson et al., 2018; West et al., 2020). The goal of the current study is to use a prospective research design with a large sample of infants to assess the development of communicative and symbolic gestures in the first 2 years. To accomplish this goal, the MCDI–Words and Gestures measure (Fenson et al., 2006) was collected at 12, 18, and 24 months of age from parents of infants with an increased likelihood of autism who later meet diagnostic criteria for autism (HL-ASD, $n = 73$). Control groups included infants with a high likelihood of having autism who were not diagnosed with autism (HL-Neg, $n = 249$) and infants with a low likelihood of having autism who were not diagnosed with autism (LL-Neg, $n = 145$). We hypothesize that the HL-ASD group will have smaller Early and Later Gestures inventories at all three time points and show attenuated growth relative to the HL-Neg group and the LL-Neg group.

TABLE 1 Participant demographic.

	LL-Neg	HL-Neg	HL-ASD
n	145	249	73
Sex (%)			
Female	60 (41%)	116 (47%)	17 (23%)
Male	85 (59%)	133 (53%)	56 (77%)
Race (%)			
African American	4 (3%)	5 (2%)	2 (3%)
Asian	2 (1%)	4 (2%)	1 (1%)
More than one	11 (8%)	22 (9%)	11 (16%)
Unknown	0 (0%)	1 (0%)	1 (1%)
White	128 (88%)	217 (87%)	58 (78%)
Hispanic (%)	6 (4%)	15 (6%)	4 (5%)
Maternal Ed (%)			
Some college or less	19 (13%)	74 (30%)	33 (45%)
College degree	61 (42%)	113 (45%)	23 (32%)
Graduate degree	65 (45%)	62 (25%)	17 (23%)

METHODS

Participants

Data from this study were collected by the Infant Brain Imaging Study (IBIS) Network at four locations: the University of North Carolina at Chapel Hill, the University of Washington, The Children's Hospital of Philadelphia, and Washington University in St. Louis. Families were enrolled in the study when infants were between 3 and 12 months of age, with follow-up assessments at 12, 18, and 24 months of age. Institutional Review Boards approved the study procedures at each of the four data collection sites. Written informed consent was obtained from the parent or legal guardian of all participants prior to enrollment. The LORIS data management platform served as the behavioral and clinical hub for data collection, curation, and archiving (Das et al., 2016).

The present study includes infants who (1) completed the MCDI–Words and Gestures (Fenson et al., 2006) at 12, 18, and/or 24 months and (2) completed assessments for clinical best estimate diagnosis of ASD at 24 months ($N = 467$; 274 Male and 193 Female; see Table 1). Participants who were outliers based on chronological age older than 27 months of age on the MCDI–Words and Gestures ($N = 8$; 2 LL-Neg, 5 HL-Neg and 1 HL-ASD) were excluded from the analyses because such data have

the potential to influence longitudinal trajectories. Clinical best estimate diagnoses were made by licensed clinicians based at 24 months of age on DSM-IV TR criteria for autistic disorder or pervasive developmental disorder–not otherwise specified (hereafter ASD) using all available assessment data (Estes et al., 2015). Materials include the Autism Diagnostic Observation Schedule (Lord et al., 2000), the Autism Diagnostic Interview-Revised (Rutter et al., 2003), the Mullen Scales of Early Learning (Mullen, 1995), and the Vineland Adaptive Behavior Scales II (Sparrow et al., 2005). A priori examiner training and administration and scoring reliability procedures were implemented to ensure comparability of data across sites. Further details of the assessment and diagnostic protocol can be found in Estes et al. (2015).

Infants were separated into three groups: HL-ASD, HL-Neg, and LL-Neg. Infants were considered HL if they had an older sibling with ASD confirmed with the Autism Diagnostic Interview-Revised and medical records. HL infants were grouped as HL-ASD if the infants themselves met the clinical best estimate for ASD at 24 months. HL infants were grouped as HL-Neg if the infants did not meet the clinical best estimate for ASD at 24 months. LL-Neg infants had siblings that were typically developing, no first-degree relatives with ASD, and did not receive a diagnosis of ASD themselves at 24 months.

Procedure

The MCDI–Words and Gestures is a parent-report questionnaire designed to capture early language and communication development for typically developing children between the ages of 8 and 18 months (Fenson et al., 2006; Hutchins, 2013). However, this inventory has been used in various clinical and nonclinical populations, with the same efficacy in assessing language and communication skills, including autistic children from 8 months of age up to 36 months (Charman et al., 2003; Iverson et al., 2018; Luyster et al., 2008; Mitchell et al., 2006; Smith et al., 2007). To measure the growth of gestures in the first 2 years of development and because it is expected that some HL infants may have language delays (HL-ASD and HL-Neg), the MCDI–Words and Gestures form was collected at 12, 18, and 24 months of age (Landa & Garrett-Mayer, 2006; Swanson et al., 2017). The current work focuses on the Actions and Gestures section of the MCDI, which includes sections on Early and Later Gestures. Early Gestures consists of "First Communicative Gesture" and "Games and Routines," with a total possible raw score of 18. Later Gestures consist of "Actions with Objects," "Pretending to be a Parent," and "Imitating Other Adult Actions," with a total possible raw score of 45.

Analysis

To longitudinally characterize the development of gesture inventories for each group, general linear mixed models were used to analyze both Early and Later Gestures with the `lmerTest` package (Kuznetsova et al., 2020) in R 4.1.0 (R Core Team, 2021). General linear mixed models were used because this program can analyze repeated dependent variables and can handle missing data through maximum likelihood estimation. Dependent variables for the models were Early and Later Gestures raw scores from the MCDI–Words and Gestures. Predictor variables included the diagnostic grouping at 24 months, chronological age in months, and the interaction between diagnostic grouping and chronological age. Covariates were selected a priori and included the sex of the infants, the data collection sites, and maternal education. These covariates were included in all models. A random intercept for each participant was included in the models to account for repeated measures. To compare the differences in gesture growth in Early and Later Gestures, estimated marginal slopes were used as a pairwise comparison with a Tukey correction. Estimated marginal slopes were estimated with the R package `emmeans` (Lenth et al., 2022).

Cross-sectional analysis with generalized linear models was used to look at the effect sizes for the main effects of diagnostic grouping and age and the effect sizes of pairwise differences within the diagnostic grouping at 12, 18, and 24 months. Generalized linear models for cross-sectional analyses were performed with the `stats` package in R (R Core Team, 2021). Dependent variables were Early and Later Gestures from the MCDI–Words and Gestures. Predictor variables were diagnostic grouping and chronological age in months. Covariates include the sex of the infants, the data collection sites, and maternal education. Effect sizes (eta-squared; η^2) for the main effects of diagnostic grouping and chronological age in months were conducted with the `effectsize` R package (Ben-Shachar et al., 2020). Effect sizes, eta-squared, were estimated using the sum of squares of the main effects divided by the total sum of squares. Cohen's d was used for effect sizes of the pairwise differences for the diagnostic grouping using the `emmeans` R package (Lenth et al., 2022). Cohen's d was computed using the estimated pairwise differences divided by the standard deviation of the data.

RESULTS

We examined the differences in longitudinal gesture inventories across three different groups: LL-Neg,

TABLE 2 Age, Macarthur-Bates Communicative Development Inventory—Words and Gestures scores, and Mullen Scales of Early Learning: expressive and receptive language scores.

	LL-Neg	HL-Neg	HL-ASD
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
Age 12 months			
n	112	199	57
Age (months)	12.60 (0.65)	12.57 (0.56)	12.60 (0.63)
Mullen expressive	12.83 (2.76)	11.94 (2.94)	10.34 (2.90)
Mullen receptive	12.40 (1.93)	11.14 (2.44)	9.70 (2.52)
Early raw scores (*SD*)	10.70 (2.63)	10.09 (2.94)	8.26 (3.34)
Later raw scores (*SD*)	14.30 (7.46)	11.23 (6.67)	8.79 (6.34)
Age 18 months			
n	51	80	23
Age (months)	18.45 (0.64)	18.35 (0.92)	18.38 (1.00)
Early raw scores (*SD*)	14.88 (2.22)	14.18 (2.63)	11.74 (4.03)
Later raw scores (*SD*)	29.46 (7.24)	26.27 (7.44)	20.23 (7.83)
Age 24 months			
n	108	183	60
Age (months)	24.59 (0.73)	24.64 (0.69)	24.53 (0.78)
Mullen expressive	25.49 (4.99)	24.24 (5.29)	18.17 (5.50)
Mullen receptive	27.49 (3.98)	26.08 (4.37)	17.95 (7.77)
Early raw scores (*SD*)	16.44 (1.69)	16.04 (2.00)	12.33 (3.17)
Later raw scores (*SD*)	37.86 (5.53)	34.38 (6.84)	24.10 (8.22)

Note: Receptive and expressive languages are collected from Mullen Scales of Early Learning and are scores based on age of equivalence. Mullen measure was only collected at 12 and 24 months of age.
Abbreviations: HL-ASD, high likelihood for autism infants who were diagnosed with ASD at 24 months of age; HL-Neg, high likelihood for autism infants who were not diagnosed with ASD at 24 months of age; LL-Neg, low likelihood for autism infants who were not diagnosed with ASD at 24 months of age; SD, standard deviation.

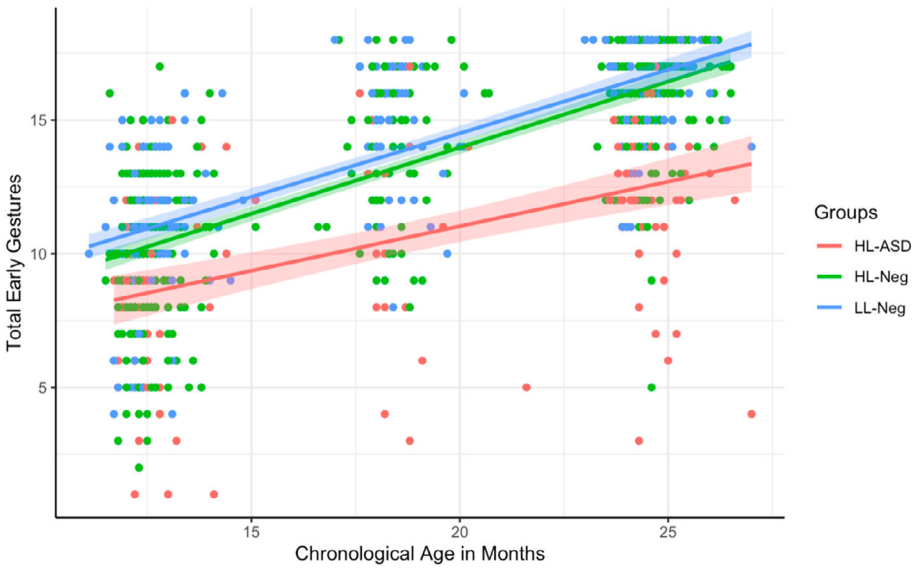

FIGURE 1 Early Gestures growth differed by diagnostic grouping. Interaction between chronological age in months and diagnostic grouping in Early Gestures of the MacArthur-Bates Communicative Developmental Inventory—Words and Gestures. HL-ASD, high likelihood for autism infants who were diagnosed with ASD at 24 months of age; HL-Neg, high likelihood for autism infants who were not diagnosed with ASD at 24 months of age; LL-Neg, low likelihood for autism infants who were not diagnosed with ASD at 24 months of age.

HL-Neg, and HL-ASD. Table 2 gives the means and standard deviations of the different groups per visit. Data S1 shows the voilin plots per time-point for Early and Later Gestures. Data S2 shows the full results of the general linear mixed models.

Early gestures

Figure 1 shows the longitudinal results of Early Gestures for which there was a significant interaction between diagnostic group and chronological age, $F(2,459) = 9.44$,

TABLE 3 ANOVA table. Type III F tests with Kenward-Roger (Kenward & Roger, 1997) degrees of freedom.

	F	*df*	$df_{residuals}$	*p*
Early Gestures				
Intercept***	1952.61	1	465.83	<0.001
Age***	424.23	1	543.19	<0.001
Diagnosis***	47.64	2	438.69	<0.001
DiagnosisAge***	9.44	2	524.47	<0.001
Maternal Ed	1.49	2	441.01	0.226
Sex***	11.19	1	448.72	<0.001
Site	2.62	3	442.87	0.050
Later Gestures				
Intercept***	1125.30	1	440.91	<0.001
Age***	1030.42	1	482.91	<0.001
Diagnosis***	48.42	2	341.57	<0.001
DiagnosisAge***	23.47	2	474.63	<0.001
Maternal Ed	0.87	2	431.34	0.421
Sex***	20.15	1	435.58	<0.001
Site	2.08	3	430.97	0.103

Note: References for each variable are Diagnosis as LL-Neg, Maternal Education as College Graduate, Sex as Female, Site as UNC-Chapel Hill; *df* indicates degrees of freedom; $df_{residuals}$ indicates residuals for degrees of freedom.

$p < 0.001$ (Table 3). Estimated marginal slopes (Table 4) for the interaction between diagnostic group and chronological age indicated that HL-ASD infants had slower growth for Early Gestures when compared to HL-Neg and LL-Neg.

Follow-up tests revealed significant main effects for the diagnostic grouping, with a medium effect size (η^2) at 12 months, a medium effect size at 18 months, and a large effect size at 24 months (Table 5). The main effect of age was significant only at 12 months ($\eta^2 = 0.03$, $p < 0.001$, CI [0.01, 0.07]). Group pairwise comparisons are presented in Table 6 for each time point. Across all time points, the HL-ASD group had significantly fewer Early Gestures when compared to the LL-Neg and HL-Neg groups. In contrast, the HL-Neg and LL-Neg groups did not significantly differ on the number of Early Gestures at any time point.

Later gestures

Figure 2 shows the longitudinal results of Later Gestures, for which there was a significant interaction between diagnosis and chronological age, $F(2, 451) = 23.47$, $p < 0.001$ (see Table 3). Estimated marginal slopes (Table 4) for the interaction between diagnostic group and chronological age indicated that HL-ASD infants had slower growth in Later Gestures when compared to HL-Neg and LL-Neg.

Cross-sectional results revealed significant main effects for diagnostic grouping, with a medium effect size (η^2) at 12 months and large effect sizes at 18 and 24 months (Table 5). In Later Gestures, the main effect of age was significant at 12 months ($\eta^2 = 0.10$, $p < 0.001$, 95% CI [0.04, 0.16]) and at 18 months ($\eta^2 = 0.01$, $p < 0.05$, 95% CI [0.00, 0.08]), but not at 24 months ($\eta^2 = 0$, $p = 0.25$, 95% CI [0.00, 0.03]). Group pairwise comparisons are presented in Table 7 by time point. Across all time points, the HL-ASD group had significantly fewer Later Gestures when compared to the LL-Neg group. The HL-ASD group also had significantly fewer Later Gestures when compared to the HL-Neg group at 18 and 24 months. The two groups were not significantly different from one another at 12 months ($d = 0.37$, $p = 0.06$, 95% CI [0.05, 0.69]). The HL-Neg group had significantly fewer Later Gestures when compared to the LL-Neg group at 12 and 24 months, but the two groups did not significantly differ at 18 months ($d = 0.39$, $p = 0.11$, 95% CI [0.00, 0.77]) (Table 7).

DISCUSSION

Previous prospective studies show that autistic children have challenges in symbolic gestures as early as 12 months of age; however, there are few longitudinal studies that track gestures from infancy to 2 years of age. The current prospective study used a large sample size ($N = 467$; 73 HL-ASD, 249 HL-Neg, and 145 LL-Neg) to assess whether communicative and symbolic gestures differ between autistic children and non-autistic children in the first 2 years of development. Using the MCDI–Words and Gestures, longitudinal and cross-sectional analyses show that HL-ASD infants acquired and used fewer deictic and symbolic gestures from 12 to 24 months when compared to the HL-Neg and LL-Neg infants.

The Early Gestures inventory from the MCDI–Words and Gestures includes deictic gestures, conventional gestures, and games and routines. These types of gestures represent the proficiency of skillsets in intentional communication and social interactions with others. As a group, infants and toddlers with ASD have been reported to display fewer gestures that involve intentional communication and social interactions with others than their non-ASD peers (Stone et al., 1997; Volkmar et al., 2005; Watson et al., 2013; West et al., 2020; Wetherby et al., 1998; Zwaigenbaum et al., 2005). Previous research with small samples ($n < 15$ in the HL-ASD group) found that HL-ASD infants have slower early gesture development from 8 to 14 months of age than HL-Neg and LL-Neg infants (Iverson et al., 2018; West et al., 2020). The current results support this previous work using a larger sample and extend the findings by showing that challenges with early gesture development persist until at least 24 months of age.

The Later Gestures inventory from the MCDI–Words and Gestures taps into behaviors that are indicative of representational skills and symbolic abilities. Items

TABLE 4 Estimated marginal slopes.

	LL-Neg (*a*)	HL-Neg (*b*)	HL-ASD (*c*)	
	EMS (SE)	*EMS* (SE)	*EMS* (SE)	Pairwise comparison
Early Gestures				
Interaction	2.75 (0.13)	2.80 (0.10)	1.93 (0.18)	*c* < *b*,*a*
Later Gestures				
Interaction	11.10 (0.35)	10.94 (0.26)	7.51 (0.47)	*c* < *b*,*a*

Note: Pairwise comparison indication is based on Tukey adjusted *p*-value of <0.05.
Abbreviations: HL-ASD, high likelihood for autism infants who were diagnosed with ASD at 24 months of age; HL-Neg, high likelihood for autism infants who were not diagnosed with ASD at 24 months of age; LL-Neg, low likelihood for autism infants who were not diagnosed with ASD at 24 months of age; EMS, indicates estimated marginal slopes; SE, indicates standard error.

TABLE 5 Effect sizes (eta-squared) for main effects of diagnostic grouping and age.

Gestures	Diagnostic group			Age		
	η^2	(95% CI)	*p*	η^2	(95% CI)	*p*
Early Gestures						
12 months	0.07	(0.03, 0.12)	<0.001	0.03	(0.01, 0.07)	<0.001
18 months	0.12	(0.05, 0.22)	<0.001	0.00	(0.00, 0.05)	0.182
24 months	0.32	(0.25, 0.39)	<0.001	0.00	(0.00, 0.03)	0.167
Later Gestures						
12 months	0.07	(0.03, 0.12)	<0.001	0.10	(0.05, 0.16)	<0.001
18 months	0.15	(0.06, 0.25)	<0.001	0.01	(0.00, 0.08)	<0.05
24 months	0.30	(0.23, 0.37)	<0.001	0.00	(0.00, 0.03)	0.253

Note: *p*-values are *p*-values for the main effects Diagnostic Group and Age at the different time points. CI: confidence interval; η^2 indicates generalized eta-squared: η^2 of 0.01 represents a small effect, η^2 of 0.06 represents a medium effect, η^2 of 0.14 represents a large effect.

TABLE 6 Effect size (Cohen's d; Cohen, 1988) for ANOVA contrast in diagnostic grouping of early gesture.

			Pairwise comparison for diagnosis				
Early Gestures	EMM	SE	*p*	Cohen's *d*	Cohen's *d* 95% CI	SE	*df*
12 months							
LL-Neg versus HL-Neg	0.77	0.35	0.073	0.27	(0.03, 0.51)	0.12	358
***LL-Neg versus HL-ASD	2.44	0.49	<0.001	0.86	(0.52, 1.20)	0.17	358
***HL-Neg versus HL-ASD	1.67	0.44	<0.001	0.59	(0.28, 0.90)	0.16	358
18 months							
LL-Neg versus HL-Neg	0.92	0.50	0.154	0.34	(0.02, 0.71)	0.19	144
***LL-Neg versus HL-ASD	2.98	0.71	<0.001	1.11	(0.57, 1.65)	0.27	144
**HL-Neg versus HL-ASD	2.05	0.66	0.006	0.77	(0.27, 1.26)	0.25	144
24 months							
LL-Neg versus HL-Neg	0.37	0.27	0.350	0.18	(0.08, 0.43)	0.13	341
***LL-Neg versus HL-ASD	3.83	0.36	<0.001	1.80	(1.44, 2.16)	0.18	341
***HL-Neg versus HL-ASD	3.46	0.33	<0.001	1.63	(1.30, 1.96)	1.96	341

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Pairwise comparison indication is based on Tukey adjusted *p*-value of $p < 0.05$; Cohen's d effect size index: 0.2 represents a small effect, 0.5 represents a medium effect, 0.8 represents a large effect.
Abbreviations: HL-ASD, high likelihood for autism infants who were diagnosed with ASD at 24 months of age; HL-Neg, high likelihood for autism infants who were not diagnosed with ASD at 24 months of age; LL-Neg, low likelihood for autism infants who were not diagnosed with ASD at 24 months of age; SD, standard deviation; EMM, estimated marginal means; SE, standard error; df, degrees of freedom; CI, confidence interval.

include knowledge of appropriate usage of items and actions, imitating adult actions, and using objects to represent other objects (symbolic play). Previous and current results show that autistic toddlers and preschoolers produce fewer symbolic gestures than their peers (González-Sala et al., 2021; Rogers et al., 2003; Williams-et al., 2001). This lack of production in symbolic gestures is most likely due to challenges in social communication

FIGURE 2 Later Gestures growth differed by diagnostic grouping. Interaction between chronological age in months and diagnostic grouping in Later Gestures of the MacArthur-Bates Communicative Developmental Inventory—Words and Gestures. HL-ASD, high likelihood for autism infants who were diagnosed with ASD at 24 months of age; HL-Neg, high likelihood for autism infants who were not diagnosed with ASD at 24 months of age; LL-Neg, low likelihood for autism infants who were not diagnosed with ASD at 24 months of age.

TABLE 7 Effect size (Cohen's d) for ANOVA contrast in diagnostic grouping of later gesture.

			Pairwise comparison for diagnosis				
Later Gestures	**EMM**	**SE**	***p***	**Cohen's *d***	**Cohen's *d* 95% CI**	**SE**	***df***
12 months							
***LL-Neg versus HL-Neg	3.33	0.83	<0.001	0.52	(0.26, 0.78)	0.13	331
***LL-Neg versus HL-ASD	5.70	1.14	<0.001	0.89	(0.53, 1.25)	0.18	331
HL-Neg versus HL-ASD	2.36	1.02	0.055	0.37	(0.05, 0.69)	0.16	331
18 months							
LL-Neg versus HL-Neg	2.76	1.38	0.115	0.39	(0.00, 0.77)	0.20	130
***LL-Neg versus HL-ASD	8.63	1.92	<0.001	1.21	(0.67, 1.77)	0.28	130
** HL-Neg versus HL-ASD	5.87	1.80	0.004	0.82	(0.31, 1.33)	0.26	130
24 Months							
***LL-Neg versus HL-Neg	3.32	0.87	<0.001	0.51	(0.25, 0.78)	0.14	318
***LL-Neg versus HL-ASD	11.78	1.15	<0.001	1.81	(1.44, 2.19)	0.19	318
***HL-Neg versus HL-ASD	8.46	1.04	<0.001	1.30	(0.97, 1.63)	0.17	318

Note: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Pairwise comparison indication is based on Tukey adjusted p-value of $p < 0.05$; Cohen's d effect size index: 0.2 represents a small effect, 0.5 represents a medium effect, 0.8 represents a large effect.
Abbreviations: HL-ASD, high likelihood for autism infants who were diagnosed with ASD at 24 months of age; HL-Neg, high likelihood for autism infants who were not diagnosed with ASD at 24 months of age; LL-Neg, low likelihood for autism infants who were not diagnosed with ASD at 24 months of age; SD, standard deviation; EMM, estimated marginal means; SE, standard error; df, degrees of freedom; CI, confidence interval.

skills and interests in demonstrating these actions rather than challenges in symbolic abilities (Ingersoll & Gergans, 2007; Jarrold, 2003; Smith & Bryson, 2007). Previous research supports this claim because autistic children are able to produce symbolic actions when prompted (Charman & Baron-Cohen, 1997; Hamilton et al., 2007; Jarrold, 2003; Wainwright et al., 2020). The current study contributes to this body of work and shows that a lack of participation in symbolic gestures can be assessed in the first year of development.

The MCDI–Words and Gestures is a parent-report measure that has consistently shown to be a reliable tool to assess gestures as an early behavioral indicator for later ASD, with multiple studies reporting group differences in the first year of life (Charman et al., 2003; Franchini et al., 2018; Iverson et al., 2018; Mitchell et al., 2006; Whitehouse et al., 2019). Data from our current study also shows that group-level differences in gesture use are apparent at 12 months of age, well before the infants were old enough for formal ASD evaluations. Overall, the MCDI–Words and Gestures contributes to the expanding research on early signs of ASD by showing that parental observations and concern for ASD arise before children are diagnosed with ASD (Ozonoff et al., 2009).

There is mounting evidence that the MCDI–Words and Gestures captures delays in gesture use before ASD diagnoses are established; hence, future efforts should

evaluate the measure as part of a suite of early screening measures. For example, Doyle et al. (2021) recruited a large community sample of parents of toddlers and collected parent-report measures of toddler repetitive behavior, reciprocal social communication, and word production and gestures (via the MCDI–Words and Gestures). Using a data-driven, RDoC-inspired approach, factor mixture models identified a five-class solution, of which two classes were "high-risk." Follow-up analyses indicated that these two classes also had elevated rates of externalizing symptoms and dysregulated behaviors. "Phenoscreening" addresses concerns around the generalizability of baby-sibling studies by providing a practical solution to community screening that is relatively low-cost and can be performed remotely.

Early intervention to support communication

Early detection of potential markers for ASD can provide important insight into targets for early intervention. As infancy is a time of high neuroplasticity and potentially a sensitive period for language acquisition, early intervention provided during this period of development may be more effective in supporting communication skills than intervention during the preschool years (Zeanah et al., 2011). For example, intervention programs such as the Early Start Denver Model are more effective when delivered during toddlerhood than interventions delivered during school age (Vivanti et al., 2016). Another study that focused on the timing of interventions found that toddlers who entered a parent-implemented intervention called the Early Social Interaction Model at 18 months showed greater gains in social communication, including gesture use, and language during the intervention than toddlers who entered the intervention at 27 months of age (Guthrie et al., 2023).

There is a small body of research showing that gestures and symbolic skills are an actionable intervention target for toddlers with ASD. In single-subject designs, autistic toddlers who participated in gesture interventions showed an increase in gestures and in overall language and communication (Ingersoll et al., 2007; Ingersoll & Gergans, 2007; Ingersoll & Lalonde, 2010). Similarly, interventions in social engagement improve spontaneous social behaviors, including imitation and play schemes (Ingersoll et al., 2007; Ingersoll & Walton, 2013; Kasari et al., 2006; Whalen et al., 2006). While these studies are not preemptive interventions, they do indicate that early intervention for autism that focuses on developmentally appropriate deictic gestures and symbolic skills may support later language skills. Future studies should determine whether early gesture interventions, before ASD diagnosis, can improve later communication skills.

LIMITATIONS

The current study used a contemporaneous parent report to quantify gesture inventories, but direct tests of gesture production may yield different information. Another limitation is that we considered the HL-Neg group as a whole and did not derive subgroups based on language ability or some other variable (Franchini et al., 2018; Iverson et al., 2018; Mitchell et al., 2006). Sub-grouping the HL-Neg may provide a better understanding of gesture production within this specific group.

Infant-sibling designs are unique and have limitations. The current study sample has restricted diversity in terms of race and ethnicity—a problem which could impact the generalizability of the results. Additionally, since the infants have an older sibling with ASD, parents' perceptions of their children's skillsets may differ from the perception of parents of typically developing children.

CONCLUSION

Gesture use is an important communicative tool for early social communication and language. As a group, HL-ASD infants have attenuated gesture growth compared to the control groups. In both Early and Later Gestures of the MCDI–Words and Gestures, the HL-ASD group had smaller inventories compared to the LL-Neg group. In contrast, HL-ASD had smaller inventories compared to HL-Neg at almost all time points in Early and Later Gestures, except for Later Gestures at 12 months. Infants in the HL-Neg group did not differ in rate of gesture growth compared to infants in the LL-Neg group. While the HL-Neg group did not statistically differ from the LL-Neg group in the number of Later Gestures at 18 months, the effect size for this comparison was small. Results from this study indicate that parent-report questionnaires are sensitive to developmental differences in gesture skills well before toddlers are diagnosed with ASD. Understanding the early behavioral traits of ASD before formal diagnosis provides valuable information for pre-symptomatic intervention programs.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

The study was conducted in accordance with the US Federal Policy for the Protection of Human Subjects by receiving formal approval from the Institutional Board Review.

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