



# Does autism affect gesturing during parent-child interactions in the early school years?



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## ABSTRACT

**Background:** Young children with autism spectrum disorder (ASD) have been shown to differ from typically developing (TD) children in their production of gesture, as well as the relationship between gesture and the content of their speech. In this study, we asked whether older children with ASD continue to differ from TD children in the types of gestures and gesture-speech combinations that they produce, and whether these differences reflect differences in parental gesture input.

**Method:** Our study examined the gestures and speech produced by 39 early school-age children (17 with ASD, 14 boys;  $M_{age} = 7;2$ , and 22 with TD, 13 boys;  $M_{age} = 5;4$ ), comparable in expressive vocabulary, and their parents, during a 10-minute play interaction. Gestures were coded for total amount, gesture type (deictic, conventional, or iconic), and gesture-speech relationship (complementary, disambiguating, or supplementary).

**Results:** Children with ASD were similar to TD children in the amount and types of gestures that they produced, but differed in their gesture-speech combinations, using gesture primarily to complement their speech. Parents did not show any group differences in their production of different types of gestures and gesture-speech combinations. There were no correlations between parent and child gesture patterns.

**Conclusions:** These findings suggest that differences in children's gesture use may reflect the child's own communicative intentions rather than parental input. These findings have important implications in understanding how older children with ASD use gesture in everyday interactive contexts, which can inform intervention or school-based practices to support learning.

## 1. Introduction

Gesture plays an important role in the early language acquisition of children with autism spectrum disorder (ASD). Like typically developing (TD) children (Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005b), young children with ASD use gestures (e.g., point at bike) and gesture-speech combinations (e.g., 'ride' + point at bike) before they produce similar words and sentences in speech (e.g., 'bike', 'ride bike'; Özçalışkan, Adamson, Dimitrova, & Baumann, 2017; Özçalışkan, Adamson, Dimitrova, & Baumann, 2018). Also like parents of TD children (Iverson, Capirci, Longobardi, & Caselli, 1999; Özçalışkan & Goldin-Meadow, 2005a), parents of young children with ASD provide models for the types of gestures and gesture-speech combinations that their children produce (Özçalışkan et al., 2018). Here we ask whether the gesture-speech system of older children with ASD remains similar to that of TD children as they develop more complex language abilities, and if so, whether children's gestures reflect the

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gestural input that they receive from their parents.

### 1.1. Gesture-speech system in TD children and children with ASD

TD children use gestures to communicate about referents before they do so with words (e.g., Bates, 1976). Initially they use *deictic* (e.g., point at book) and *give* gestures (e.g., extend open palm toward book) to indicate or request referents. These gestures are followed by conventional gestures that express culturally-prescribed meanings (e.g., nodding head for yes) and by a few iconic gestures that convey characteristic actions or features associated with referents (e.g., flapping arms for bird flying; Acredolo & Goodwyn, 1985; Iverson, Capirci, & Caselli, 1994; Özçalışkan & Goldin-Meadow, 2005a, 2011). Importantly, these early gesture-speech—particularly deictic gestures that indicate referents—precede and predict the emergence of similar vocabulary items in children's speech (Iverson & Goldin-Meadow, 2005).

TD children continue to use gesture even after they begin to produce words, producing gesture-speech combinations. They first produce *complementary combinations*, in which gesture conveys the same information as speech (e.g., 'dog' + point at dog), followed by *disambiguating combinations* in which gesture clarifies a pronominal referent in speech ('that one' + point at dog) and *supplementary combinations*, in which gesture adds information not found in speech ('pat' + point at dog). Importantly, these supplementary gesture-speech combinations precede and predict not only the time of onset but also the content of the word-word combinations TD children eventually produce in speech (Goldin-Meadow & Butcher, 2003; Özçalışkan & Goldin-Meadow, 2005b, 2010).

Even after the onset of two-word speech, TD children continue to use gesture to further expand their communicative repertoires in more extended speech contexts, including gains in their production of iconic gestures that convey unique meanings not found in speech, beginning around ages 2–3 (Özçalışkan, Gentner, & Goldin-Meadow, 2014). Gesture's contribution to communication continues at the later ages, with 4- to 10-year-old children using gesture to disambiguate or supplement the information in their speech. These gesture-speech combinations precede and predict their emerging abilities in producing narratives and explanations in speech (e.g., Church & Goldin-Meadow, 1986; Colletta, Pelleng, & Guidetti, 2010, 2015; Demir, Levine, & Goldin-Meadow, 2015; Stites & Özçalışkan, 2017; Özçalışkan, 2007).

Compared to their TD peers, children with ASD often show delays in achieving early language milestones (i.e., first words, first sentences; Tager-Flusberg, 2007), with 30% of children with ASD considered to be non- or minimally verbal; thus verbal children with ASD represent a subset of the greater ASD population (Tager-Flusberg & Kasari, 2013). Children with ASD have also been shown to have weaknesses in gesture production early in development (2;0-5;0), particularly for deictic gestures (Mundy, Sigman, & Kasari, 1990), even when compared to TD children and children with Down's syndrome with similar expressive speech vocabularies (Özçalışkan, Adamson, & Dimitrova, 2016; Toret & Acarlar, 2011). Despite differences in the *amount* of gesture production, young children with ASD (age 2;6) show a pattern akin to TD children in the *types* of gestures that they produce, using predominantly deictic and give gestures in their early interactions with their parents (Özçalışkan et al., 2016; Özçalışkan et al., 2018). Young children with ASD (2;6) also indicate referents first in gesture before conveying similar meanings exclusively in speech (e.g., point at cat before saying 'cat'); thus mirroring the pattern observed in TD children (Özçalışkan et al., 2017).

Like TD children, children with ASD also continue to use gesture after they begin to produce their first words. However, they differ in their production of gesture-speech combinations, producing notably fewer combinations compared to TD children similar in language ability (Özçalışkan et al., 2018). Despite these differences, young children with ASD (2;6) resemble language-comparable TD children (1;6) in the types of combinations that they produce and the way these combinations relate to their emerging abilities in sentence construction: they produce predominantly complementary gesture-speech combinations, followed by supplementary and disambiguating combinations—mirroring the patterns observed in language-comparable TD children (Özçalışkan et al., 2018). Furthermore, the types of semantic relations children with ASD convey in these early supplementary combinations also resemble the ones produced by TD children, primarily conveying simple relations between entities and/or actions (e.g., 'drink' + point to cup; 'baby' + point at bottle). More importantly, the majority of children with ASD produce such supplementary combinations at a point when they are not yet producing word-word combinations in speech, suggesting a trajectory similar to TD children in the emergence of different sentence-like constructions across modalities (Özçalışkan et al., 2018).

Research that examines the gesture production of children with ASD beyond the two-word stage is relatively sparse. However, the few existing studies suggest that verbal children with ASD during the earlier (ages 6–12) and later school years (ages 11–16) continue to gesture, but less so than their age or IQ-matched TD peers (Medeiros & Winsler, 2014; Silverman, Eigsti, & Bennetto, 2017; So, Wong, Lui, & Yip, 2015). Research on gesturing at the later ages also presents mixed findings on the similarities children with ASD show to TD children in the *types* of gestures that they produce. Some studies (de Marchena & Eigsti, 2010; Medeiros & Winsler, 2014; Morett, O'Hearn, Luna, & Ghuman, 2016) suggest that school age children with ASD (ages 6–12) use fewer conventional gestures during narrative or problem-solving tasks as compared to their age-matched TD peers, while others (Wong & So, 2018) found that children with ASD use more iconic gestures than their age- and IQ-matched TD peers during spoken narrative tasks.

Similarly, research on gesture-speech combinations in older children with ASD presents mixed results. Some studies (Morett et al., 2016) suggest that adolescents with ASD (ages 10–20) produce fewer supplementary gesture-speech combinations than TD children matched on age, gender, and verbal IQ, a pattern that becomes more pronounced when the listener is visible to the child compared to a condition where the listener is not visible. Other studies (Wong & So, 2018), however, show that school-age children with ASD (ages 6–12) use similar amounts of disambiguating and supplementary combinations as TD children, but produce more complementary gesture-speech combinations than their TD peers. Recent work has also shown that adolescents with ASD (ages 13–16) show difficulties in gesture use during social-communicative tasks (e.g., narration), a deficit that is not observed during executive function tasks where gesture serves a cognitive function, thus suggesting that lower amounts of gesturing in ASD may be driven by difficulties in

social communication (de Marchena & Eigsti, 2014). Less is known, however, about how verbal, school-age children with ASD compare to language-comparable TD peers in their spontaneous production of gesture types and gesture-speech combinations during parent-child interactions, particularly as their speech becomes more complex.

In summary, existing research on the gesture-speech system of children with ASD suggests that gesture is a robust aspect of the language learning process in children with ASD, particularly at the earlier ages (1;6-3;0). Children with ASD, even though they gesture less, nonetheless use gesture to convey their emerging abilities in speech—from first words to first sentences. They also continue to accompany speech with gesture—but still at lower rates—when producing more extended speech types (i.e., narratives) at the early school years. However, less is known about how early school-age children with ASD gesture, especially in comparison to language-comparable TD peers. Such research may shed further light on the patterns of similarities and differences in gesture production in ASD and in TD groups — patterns not driven by differences in speech production. Similarly, earlier work with older children with ASD has focused on speech and gesture production in narrative contexts, leaving gesture production during naturalistic interactions with a familiar partner, such as a parent, relatively unexplored. As such, the study of gesture production in a more naturalistic context might provide a fuller picture of relative weaknesses and strengths in gesture use among school-age children with ASD.

### 1.2. Gesture-speech system of parents

Parents of young TD children (1;0-3;0) gesture frequently when interacting with their children, providing models for the different types of gestures and gesture-speech combinations and tuning their gestures to their child's communicative needs (Bekken, 1989; Iverson et al., 1999; Özçalışkan & Goldin-Meadow, 2005a). Parents predominantly use deictic gestures, and gestures that complement what they convey in speech, and produce fewer iconic gestures and supplementary gesture-speech combinations (Iverson et al., 1999; Özçalışkan & Goldin-Meadow, 2005a, 2011; see Özçalışkan & Dimitrova, 2013 for a review). Importantly, research on parental gesture input has primarily focused on its role in early language development, leaving parent gesture input to older TD children unexplored.

Research on gesture input to children with ASD also remains relatively sparse. The few existing studies that focused on gesture input to younger children (1;0-3;0) with ASD or at high-risk for ASD show that parents of children with or at high-risk for ASD are comparable to parents of TD children in both the amount and the types of gestures and gesture-speech combinations that they produce (Mitchell, 2015; Özçalışkan et al., 2018). However, additional research has suggested that even if parents do not differ in the types of gestures that they produce, they do show differences in how often they produce different types of gesture. For example, Talbott, Nelson, and Tager-Flusberg (2015) compared the gestural input provided to infants at high vs low risk for ASD and found no difference in the types of gestures produced or their relative frequency. There were differences, however, in how often they produced each gesture type, with mothers of children with high risk for ASD using more of each gesture type than mothers of children with low risk for ASD.

To date, there have been only a few studies that observe parental nonverbal input to school-age children with ASD. Medeiros and Winsler (2014), using a collaborative problem-solving task, found that parents of TD children and children with ASD gestured at the same rate as their children. However, other studies that focused on a broader set of nonverbal parental behaviors (e.g., physical contact, social verbal approaches, directive statements) showed that parents of children with ASD used more high-intensity approaches and directive behaviors, including gestural prompts (Doussard-Roosevelt, Joe, Bazhenova, & Porges, 2003; Wan et al., 2012).

In summary, existing research on parental gesture input to children with ASD remains relatively sparse, and most of it focuses on young children. The overarching finding for the early gesture input is that parents of children with ASD show similar patterns to parents of TD children in the types and amounts of gestures and gesture-speech combinations that they produce. However, there are no studies that specifically focus on gesture input directed to older children with ASD—a point in development where children might be making important gains in their language development. The few existing studies focus on either a broader set of nonverbal behaviors (including but not limited to gesture) or a particular type of task, leaving parents' gesturing in more spontaneous everyday interactions unexamined. As such, examination of parent gesture input will not only provide important information about the nature of parental nonverbal input at the later ages, but it may also shed new light on how that input might reflect patterns of gesture production in children with more complex language skills.

### 1.3. Present study

Previous work has shown that gesture development and speech development go hand-in-hand in younger children with ASD and that parents contribute to this process by serving as models to their children for the types of gestures and gesture-speech combinations. However, we know little about the nature of the gesture-speech system in early school-age children with ASD in interactive contexts, particularly for children with more advanced expressive language skills, and whether parents continue to play a role in the development of the child's gesture-speech system. In this study, we focus on the speech and gestures produced by 17 early school-age children with ASD and 22 TD children, comparable in language ability, and their parents. The decision to form comparable groups based on language, and not chronological age or IQ, stemmed from our interest in identifying patterns of similarities and differences in gesture production not driven by differences in speech production. We first ask whether early school-age children with ASD differ from language-comparable TD children in the types of gestures and gesture-speech combinations that they produce. Based on previous research with both younger children and adolescents with ASD, we predict that early school-age children with ASD will produce

**Table 1**  
Children's and parents' characteristics.

	ASD		TD		<i>t</i>	<i>p</i>	<i>d</i>
	<i>M</i> (SD)	Range	<i>M</i> (SD)	Range			
<b>Children</b>							
Child Age (years;months)	7;2	5;2–9;1	5;4	5;0–6;2			
<b>Standardized Assessments</b>							
EVT-2 (age equivalent)	74.82 (22.55)	47–116	70.86 (9.43)	51–88	-.68	.50	.23
EVT-2 (standard scores)	96.35 (18.26)	70–129	119.55 (11.01)	96–139	4.63	< .001**	1.54
PPVT-4 (age equivalent)	74.82 (22.55)	41–111	66.73 (13.09)	45–83	-1.42	.17	.44
PPVT-4 (standard scores)*	96.82 (18.04)	65–135	112.77 (15.91)	61–133	2.93	< .01*	.94
KBIT-2 (raw)	51.94 (17.05)	22–71	45.30 (7.25)	32–55	-1.41	.17	.51
KBIT-2 (standard scores)	91.24 (20.43)	51–114	108.14 (10.08)	84–122	3.13	< .01*	1.05
<b>Parent</b>							
Parent education							
Mothers (% with college)	94%		88%				
Fathers (% with college)	65%		84%				
Household income > \$50,000	81%		89%				
Family racial background:							
Caucasian	53%		77%				
African American	18%		27%				
Multi-racial	29%		14%				

Note. *N* = 39 (17 with ASD, 22 TD). EVT-2 = Expressive Vocabulary Test, PPVT-4 = Peabody Picture Vocabulary Test, KBIT-2 = Kaufman Brief Intelligence Test, Second Edition.

fewer gestures, a difference that will be more pronounced for deictic gestures and supplementary gesture-speech combinations.

We also ask whether the group differences that we observe in child gesture reflect differences in the gestures and gesture-speech combinations that their parents produce. The existing evidence suggests two possibilities: parents of early school-age children with ASD will not differ from parents of TD children, thus following a pattern observed in studies of young children with ASD (Mitchell, 2015; Özçalışkan et al., 2018). An alternative possibility is that parents of early school-age children with ASD might gesture more than parents of TD children, while remaining similar in their proportional use of each gesture and gesture-speech combination type, as a way to provide additional communicative support (e.g., Talbot et al., 2015).

## 2. Methods

### 2.1. Participants

The participants included 39 children (17 with ASD, 22 TD)—all native English speakers, along with their parents. The gender ratio in the ASD group reflects the approximate 4:1 ratio of boys to girls in the greater population (Baio et al., 2018). The current sample size was based on a similar earlier study that compared gesture use in TD children and children with ASD and found that 16 subjects per group was adequate to detect reliable effects at  $p < .05$ ,  $\eta^2 = 0.44$  (So et al., 2015). The participants were part of a year-long longitudinal project on multi-modal communicative development (Özçalışkan et al.); our study focused on the third observation session, during which approximately 10-minute parent-child interactions were video-recorded,  $M_{TD} = 10.92$  min,  $SD = 1.41$ ;  $M_{ASD} = 11.04$  min;  $SD = .75$ ,  $t(37) = -0.31$ ,  $p = .76$ ,  $d = .11$ . The dyads included either the mother or father, with the majority of the dyads being mother-child (TD: 86%, ASD: 76%).

By design, the two groups were comparable in age-equivalent expressive (*Expressive Vocabulary Test*, EVT-2; Williams, 2007) at the first visit (Table 1). However, the groups differed on standard scores on the EVT-2, which was expected given that the group differences in the mean and variability of age. Groups were also comparable on receptive language (*Peabody Picture Vocabulary Test*; PPVT-4; Dunn & Dunn, 2007) scores, as well as their cognitive ability (*Kaufman Brief Intelligence Test, Second Edition*, KBIT-2; Kaufman & Kaufman, 2004), and on parents' education and household income (see Table 1 for demographic information). The children in each group were also comparable in their productive vocabulary during the observation session, for both word types and word tokens (Table 2).

All children with ASD received a clinical diagnosis of Autism Spectrum Disorder made by a licensed clinical psychologist after a comprehensive clinical evaluation. This evaluation included the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000)—a semi-structured interaction protocol that assesses social interaction, communication and restricted or repetitive behaviors. To further confirm the diagnosis of autism in the ASD group and its lack in the TD group, parents completed the *Social Communication Questionnaire* (SCQ; Rutter, Bailey, & Lord, 2003), a screening measure for symptoms of autism spectrum disorder. None of the scores in the TD group were above the autism cutoff,  $M_{TD} = 5.08$ ,  $SD = 3.12$ , autism cutoff = 15 + . Scores in the ASD group were all within the autism range,  $M_{ASD} = 21.47$ ,  $SD = 6.64$  except for one child who scored 11. Given the relative proximity of the child's score to the autism range, along with the documented diagnosis of ASD by a licensed clinician, we retained him in the ASD group.

**Table 2**  
Children's and parents' production of speech.

	Group		TD		F	p	$\eta_p^2$
	ASD						
	M (SD)	Range	M (SD)	Range			
<b>Children</b>							
Word Types	107.88 (45.03)	21–183	100.68 (42.67)	2–206	.26	.61	.01
Word Tokens	275.41 (167.71)	37–622	246.23 (142.49)	2–634	.35	.56	.01
Communicative acts with speech	88.29 (36.47)	14–143	77.59 (35.88)	2–164	.84	.37	.02
<b>Parents</b>							
Word Types	186.12 (47.53)	111–283	196.55 (41.26)	93–276	.54	.47	.01
Word Tokens	653.35 (226.86)	241–1032	626.86 (179.21)	222–986	.17	.69	< .001
Communicative acts with speech	163.29 (44.30)	104–231	149.36 (44.60)	60–269	.94	.34	.03

Note.  $N = 39$  (17 with ASD, 22 TD).

## 2.2. Data collection

All child-parent dyads were observed in their homes, except for two children with ASD who were observed in a laboratory playroom, following the parents' request. The observation consisted of a 10–12 min parent-child play with 3 age-appropriate objects (*Snow* by Uri Shulevitz, toy doctor's kit, puzzle) provided by the experimenter. The parents were asked to interact with their children as naturally as possible, playing with each toy for about 3–4 min. All sessions were video-recorded.

## 2.3. Data transcription and coding

Child and parent speech was transcribed using the Codes for Human Analysis Transcript (CHAT) system (CHILDES; MacWhinney, 2000). Onomatopoeic (e.g., 'vroom vroom') and conventionalized evaluative sounds (e.g. 'uh-oh') were also treated as words. The observations were also coded for child and parent gestures. Gesture was defined as a communicative hand movement that did not involve direct manipulation of an object (e.g. moving a toy truck back and forth) or a ritualized game (e.g. patty cake), following earlier work (Özçalışkan & Goldin-Meadow, 2005b). Transcripts were divided into communicative acts, defined as a sequence of words that was preceded and followed by a change in conversational turn, intonation or pause, following the CHAT system guidelines (MacWhinney, 2000). All communicative acts were further categorized as *gesture only* (utterances in which gestures are produced without speech; e.g. pointing to picture of snowflake), *speech only* (utterances in which speech is produced without gesture; e.g. 'It is snowing'), or *gesture + speech* (utterances that include both speech and gesture; e.g. 'It is snowing' + point to picture of snowflake).

### 2.3.1. Speech

All verbal responses produced by the children and their parents during the interaction were tallied for word tokens (i.e., number of words) and word types (i.e., number of unique words).

### 2.3.2. Gesture

All gestures produced by each child and their parent were coded into one of 3 types: *deictic gestures* that indicate referents (e.g., point to puzzle piece), *conventional gestures* that convey culturally-prescribed meanings (e.g., nodding head to mean yes), and *iconic gestures* that represent characteristic actions or features associated with objects (e.g., wiggling outstretched fingers to represent snowing). Give gestures, namely gestures that request referents (e.g. outstretched hand), were only produced by 2 children (1 TD, 1 ASD, 16 instances) and 5 parents (1 TD, 4 ASD, 9 instances), and thus were excluded from all analyses. Neither parents nor their children produced any beat gestures (i.e., meaningless hand movements that rhythmically relate to speech) during our observation.

### 2.3.3. Gesture + Speech

Each gesture-speech combination was further coded for the informational relation gesture held to the accompanying speech, defined as: (1) *complementary gesture + speech*, in which gesture conveys the same meaning as speech (e.g. 'It's snowing' + point at picture of snowflake), (2) *disambiguating gesture + speech*, in which gesture clarifies a pronominal referent in speech (e.g. 'that one' + point at picture of a snowflake, or (3) *supplementary gesture + speech*, in which gesture adds new information not found in speech (e.g., 'Look' + point at picture of snowflake).

### 2.3.4. Reliability

Intercoder reliability was assessed for gesture with additional coders who independently coded a randomly selected 20% of the videos in each group for gesture. For the children, agreement between coders was 82%,  $\kappa = .86$  (TD: 83%, ASD: 81%) for identifying gestures, 100%,  $\kappa = 1.00$  (TD: 100%, ASD: 100%) for classifying gestures into types, and 93%,  $\kappa = .90$  (TD: 94%, ASD: 92%) for classifying gesture-speech combinations into types. For the parents, agreement between coders was 87%  $\kappa = .91$  (TD: 88%, ASD: 87%) for identifying gestures, 99%,  $\kappa = .95$  (TD: 99%, ASD: 98%) for classifying gestures into types, and 87%,  $\kappa = .81$  (TD: 86%,

**Table 3**  
Summary of children's and parents' production of gesture.

	Group			
	ASD		TD	
	M (SD)	Range	M (SD)	Range
<b>Children</b>				
Gesture (All)	14.00 (13.07)	0–54	18.95 (15.50)	6–72
Communicative acts with gesture	12.53 (10.60)	0–45	17.27 (11.85)	6–56
Deictic Gestures	11.18 (12.10)	0–51	15.77 (14.32)	2–63
Conventional Gestures	2.41 (2.62)	0–9	2.09 (1.69)	0–5
Iconic Gestures	.18 (.53)	0–2	.68 (2.01)	0–9
<b>Parents</b>				
Gesture (All)	38.88 (23.54)	7–85	39.59 (24.14)	11–95
Communicative acts with gesture	38.35 (20.67)	9–77	37.45 (20.27)	11–81
Deictic Gestures	33.94 (21.57)	5–85	35.32 (23.57)	9–93
Conventional Gestures	3.35 (3.10)	0–9	3.23 (3.28)	0–15
Iconic Gestures	1.12 (1.58)	0–5	1.00 (1.38)	0–4

Note.  $N = 38$  (16 with ASD, 22 TD). One of the children with ASD did not produce any gestures.

ASD: 88%) for classifying gesture-speech combinations into types.

#### 2.4. Data analysis

The total number of words, gestures, and gesture-speech combinations were tallied for each participant, separately for the children and their parents. They were then analyzed, using one-way ANOVAs or Mann-Whitney  $U$ —where the assumption of homogeneity of variance or normality was violated—with group (TD, ASD) as a between-subjects factor. We next computed the total number of each type of communicative act (gesture-only, speech-only, gesture + speech), *gesture* (deictic, conventional, iconic), and *gesture + speech combination* (reinforcing, disambiguating, supplementary) produced by each child and parent. Children's production of different types of communicative acts, gestures and gesture-speech combinations showed considerable within- and between-group variability (see Tables 1–3). All raw frequencies of communications produced by each child and parent were converted into proportions by dividing number of a specific act the child produced (e.g., a gesture type or a specific type of gesture-speech combinations) by the total number of acts of that type the child produced (e.g., all gestures; all gesture-speech combinations). The proportions were arcsine transformed to attenuate any deviations from normality. Differences were then analyzed with mixed two-way ANOVAs, with *group* (TD, ASD) as between-subjects and *type of communication* as within-subject factors, separately for the children and their parents, using arcsine transformed scores. Where Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated, the Greenhouse-Geisser correction was used. We also examined correlations in parent and child gesture production using Pearson's correlations ( $r$ ), separately by group.

### 3. Results

#### 3.1. Speech

Children did not show group differences for either the amount (i.e., word tokens,  $F(1, 38) = .35, p = .56, \eta_p^2 = .01$ ) or the diversity of the words (i.e., word types,  $F(1, 38) = .26, p = .61, \eta_p^2 = .01$ ) that they produced (see Table 2, upper half), which was by design. The children also did not differ by group in their production of communicative acts with speech,  $F(1, 38) = .84, p = .37, \eta_p^2 = .02$ . All children in the sample were producing word-word combinations at the time of our observation, with the exception of one TD child who only used single words.

The parents of children with ASD and with TD were also comparable in their speech production, using similar number of word tokens,  $F(1, 38) = .17, p = .69, \eta_p^2 = < .001$ , word types,  $F(1, 38) = .54, p = .47, \eta_p^2 = .01$ , and communicative acts with speech,  $F(1, 38) = .94, p = .34, \eta_p^2 = .03$ , even though comparability of parent word production was not used as criteria for participant selection (see Table 2, lower half). In summary, neither children nor parents showed group differences in either the amount (word tokens, communicative acts with speech) or the diversity of the speech (i.e., word tokens) that they produced (Table 2).

#### 3.2. Gesture

All children, except for one child with ASD, produced at least one gesture during our observation (see Table 3, upper half). Children with ASD and with TD did not differ in their overall production of gesture, Mann-Whitney  $U = 137.5, p = .16, \eta^2 = .05$ , or in their production of communicative acts with gesture,  $U = 134.50, p = .14, \eta^2 = .06$ . We next looked at children's proportional use of different gesture types, excluding the one child with ASD who did not produce any gestures. Children's proportional use of each

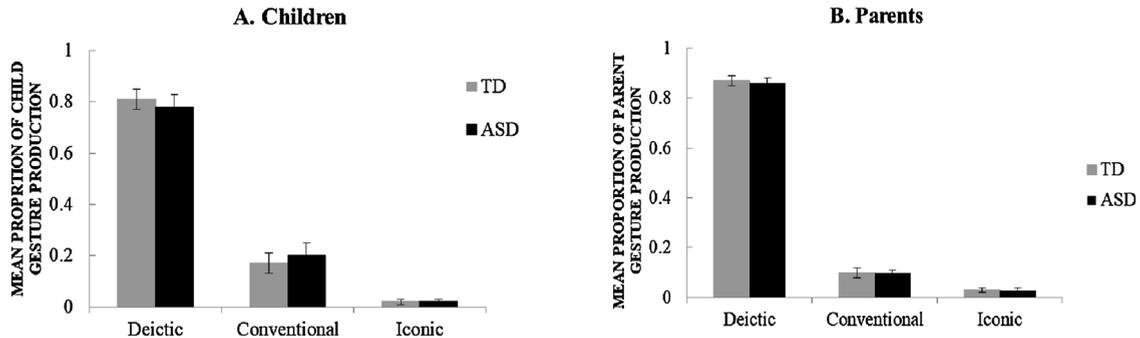


Fig. 1. Mean proportion of deictic, conventional and iconic gestures produced by typically developing (TD) children and children with autism spectrum disorder (ASD; 1A), and their parents (1B). Error bars represent standard error.

gesture type did not show an effect of group,  $F(1.23, 44.40) = .004, p = .95, \eta_p^2 = < .001$ , or a group x gesture type interaction,  $F(1.23, 44.40) = .27, p = .66, \eta_p^2 = .01$ , but did show a main effect of gesture type,  $F(1.23, 44.40) = 141.93, p < .001, \eta_p^2 = .80$  (see Table 3). The children in both groups produced a significantly greater proportion of deictic than conventional gestures (Bonferroni,  $p < .001$ ) and greater proportion of conventional than iconic gestures (Bonferroni,  $p < .001$ ; see Fig. 1, left panel).

All parents gestured during our observation (see Table 3, lower half). Similar to their children, parents of children with ASD did not differ from parents of TD children in their overall amount of gesture production,  $F(1, 38) = .01, p = .93, \eta_p^2 = < .001$ , or their production of communicative acts with gesture,  $F(1, 38) = .02, p = .89, \eta_p^2 = .001$ . This pattern was also evident in parents' proportional use of each gesture type, which showed no effect of group,  $F(1.65, 60.85) = .22, p = .64, \eta_p^2 = .01$ , and no interaction between group and gesture type,  $F(1.65, 60.85) = .03, p = .96, \eta_p^2 = .001$ , but an effect of gesture type,  $F(1.65, 60.85) = 412.00, p < .001, \eta_p^2 = .92$  (Table 3). Parents in both groups produced significantly greater proportion of deictic than conventional gestures (Bonferroni,  $p < .001$ ) and greater proportion of conventional than iconic gestures (Bonferroni,  $p < .001$ ; see Fig. 1, right panel).

In summary, neither children nor their parents showed group differences in their overall production of gesture and in their proportional use of each gesture type. Importantly, in addition, we did not find any reliable correlations between children and their parents for either the amount of gesture production (TD:  $r = -.09, p = .68$ , ASD:  $r = -.16, p = .54$ ) or the proportional use of deictic (TD:  $r = .02, p = .93$ , ASD:  $r = -.09, p = .73$ ), conventional (TD:  $r = -.14, p = .54$ , ASD:  $r = .06, p = .83$ ), or iconic gestures (TD:  $r = .15, p = .55$ , ASD:  $r = -.16, p = .56$ ).

### 3.3. Gesture + Speech

Almost all of the TD children (21/22) and children with ASD (15/17) were producing gesture-speech combinations during our observation (See Table 4, upper half). The groups did not differ in the number of gesture-speech combinations,  $U = 178.50, p = .81, \eta^2 = .002$ , or in the number of communicative acts with gesture + speech,  $U = 155.50, p = .38, \eta^2 = .02$ , produced. We next examined children's proportional use of each gesture-speech combination type, excluding the 3 children (1 TD, 2 with ASD) who did not produce any combinations. We found no main effect of group,  $F(2, 68) = 3.68, p = .06, \eta_p^2 = .10$ , but a main effect of gesture-speech combination type,  $F(2, 68) = 7.44, p < .01, \eta_p^2 = .18$ , as well as a significant interaction between group and combination

Table 4  
Summary of children's and parents' production of gesture-speech combinations.

	Group			
	ASD		TD	
	M (SD)	Range	M (SD)	Range
<b>Children</b>				
Gesture + speech (all)	11.18 (10.05)	0–39	14.00 (16.17)	0–73
Communicative acts with gesture + speech	8.65 (8.41)	0–33	12.32 (11.85)	0–54
Complementary gesture + speech	4.65 (4.65)	0–15	4.18 (5.93)	0–28
Disambiguating gesture + speech	3.41 (4.02)	0–16	5.68 (5.50)	0–20
Supplementary gesture + speech	1.88 (3.55)	0–13	4.82 (6.75)	0–25
<b>Parents</b>				
Gesture + speech (all)	36.94 (20.67)	7–78	36.86 (23.69)	9–100
Communicative acts with gesture + speech	33.94 (18.48)	7–73	32.05 (18.07)	8–75
Complementary gesture + speech	17.35 (10.92)	1–39	18.32 (15.21)	1–61
Disambiguating gesture + speech	11.65 (7.49)	0–28	12.27 (6.07)	4–26
Supplementary gesture + speech	7.88 (6.48)	1–27	5.50 (5.11)	0–21

Note.  $N = 36$  (15 with ASD, 21 TD). Two of the children with ASD and one child with TD did not produce any gesture + speech combinations.

type,  $F(2, 68) = 7.66, p < .01, \eta_p^2 = .18$ . Children with ASD used a significantly lower proportion of supplementary combinations than both complementary and disambiguating ones (Bonferroni,  $ps < .01$ )—a difference that was not evident in TD children, who produced comparable amounts of each gesture + speech type, with no reliable differences between types. The patterns also were evident for individual children. A majority in each group produced complementary (ASD: 15/17, TD: 18/22) and disambiguating (ASD: 13/17, TD: 21/22) gesture-speech combinations. However, less than half of the children with ASD produced supplementary gesture-speech combinations (8/17), while almost all of the TD children did (19/22).

All parents were combining gesture with speech during our observation, producing at least one instance of each of the three combination types (see Table 4, lower half). Similar to their children, parents did not show group differences in their overall production of gesture-speech tokens,  $U = 195.00, p = .83, \eta^2 = .001$ , or communicative acts with gesture + speech,  $F(1, 38) = .10, p = .75, \eta^2 = .001$ . The parents of children in both groups were also similar in their proportional use of each gesture-speech combination type—with no effect of group,  $F(2, 74) = 1.10, p = .30, \eta_p^2 = .03$ , and no interaction between group and combination type,  $F(2, 74) = 2.25, p = .11, \eta_p^2 = .06$ , but a main effect of combination type,  $F(2, 74) = 17.45, p < .01, \eta_p^2 = .32$ . Overall, parents produced a greater proportion of complementary than supplementary combinations (Bonferroni,  $p < .001$ ) and a greater proportion of disambiguating than supplementary ones (Bonferroni,  $p < .01$ ). Our analysis of gesture-speech combinations produced by each child and parent did not show any significant correlations for either the amount of gesture-speech combinations (TD:  $r = -.21, p = .36$ , ASD:  $r = -.10, p = .70$ ), or the proportional use of complementary (TD:  $r = -.05, p = .83$ , ASD:  $r = .16, p = .57$ ), disambiguating (TD:  $r = .30, p = .19$ , ASD:  $r = -.35, p = .20$ ), or supplementary gesture-speech combinations (TD:  $r = -.18, p = .44$ , ASD:  $r = -.11, p = .70$ ).

In summary, children's relative production of the different gesture-speech combination types varied by group—with lower production of supplementary gesture-speech combinations within the ASD, but not the TD group. However, unlike their children, parents in both groups were similar in their production of different gesture-speech combinations, relying primarily on complementary and disambiguating combinations over supplementary ones (Fig. 2).

#### 4. Discussion

Previous work shows that young children with ASD ( $M_{\text{age}} = 2;6$ ) and with TD ( $M_{\text{age}} = 1;6$ ), but *not* their parents, show group differences in their relative production of different types of gestures and gesture-speech combinations (Özçalışkan et al., 2018). In this study, we asked whether the patterns observed for younger children remain similar in older children with ASD ( $M_{\text{age}} = 7;2$ ) and with TD ( $M_{\text{age}} = 5;4$ ) and their parents. More specifically, we asked whether older children with ASD continue to differ from TD children in their gesture production, and if so whether we can find evidence of such differences in the gestural input that they receive from their parents.

In both groups, only a small proportion of utterances included gesture (TD = .14, ASD = .09), suggesting that, at early school-age, speech became the main communicative medium and gesture carried less of the communicative burden than it did at younger ages. Interestingly, although children with ASD *did not* differ from TD children with comparable language skills in either their overall use of gesture or in their relative production of different gesture types, they *did* differ in their use of gesture-speech combinations. Children with ASD used gesture primarily to complement their speech, whereas TD children also frequently used gesture to *supplement* what they expressed in speech. This finding suggests that gesture might be serving different informational roles in the two groups.

Parents in the two groups were similar to their children in the types of gestures and gesture-speech combinations that they produced, but, unlike their children, did not differ in their proportional use of different gesture-speech combination types. Moreover, the frequency of parents' gesture-speech combinations was not correlated with their children's production, suggesting that the children were not mirroring parent gesture input.

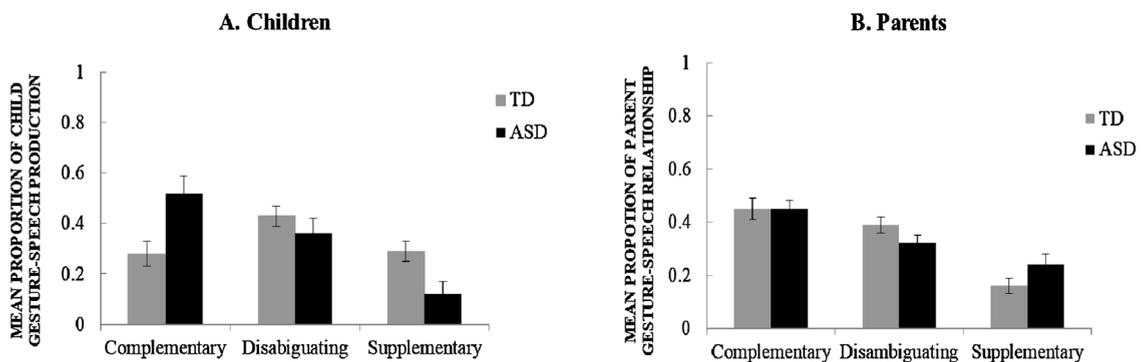


Fig. 2. Mean proportion of complementary, disambiguating and supplementary gesture-speech combinations produced by typically developing (TD) children and children with autism spectrum disorder (ASD; Panel A), and their parents (Panel B). Error bars represent standard error.

#### 4.1. Do early school-aged children with ASD differ from language-comparable TD children in their use of gesture?

In our study, we found that children with ASD did not differ from TD children in their overall production of gesture, a finding that differs from earlier work showing lower gesture production in children with ASD (Kjellmer, Hedvall, Fernell, Gillberg, & Norrelgen, 2012; Mundy, Sigman, Ungerer, & Sherman, 1986; Özçalışkan et al., 2016). Different sample selection is one plausible explanation for this discrepancy. All children with ASD in our study were verbal and already producing word-word combinations. This contrasts with most earlier work, which included children with more varied verbal abilities or matched samples based on age or IQ instead of language. Our selection of expressive language-similar groups reflects our interest in patterns of gesture production in groups who had similar levels of speech production, which is often not the case in age- or IQ-matched samples.

Children with ASD also did not differ from TD children in their proportional use of different gesture types. Across groups, children produced a greater proportion of deictic gestures (TD = .83, ASD = .76), followed by conventional (TD = .15, ASD = .22) and iconic gestures (TD = .02, ASD = .02). The prevalence of deictic gesture use might reflect, in part, different observational contexts. In our study, we used a play context with a set of concrete referents that might have elicited deictic gestures, which are the most commonly produced gestures to indicate a specific referent. In several previous studies with older children with ASD, gestures were observed during cartoon narration or conversational interaction contexts that did not include concrete referents; in these contexts, children with ASD rarely, if ever, used deictic gestures (Braddock, Gabany, Shah, Armbrecht, & Twymana, 2016; Capps, Kehres, & Sigman, 1998).

More importantly, children also showed diagnosis-specific group differences in their use of different gesture-speech combinations. Children with ASD primarily used gesture to complement speech (52%), and rarely used gesture to supplement speech (12%). TD children, in contrast, used gesture to supplement (29%), disambiguate (43%) or complement (28%) their speech at rates that were not significantly different from each other. This group difference follows a similar pattern to that found in older school-age children with ASD (ages 6–12), where children with ASD rarely used gesture to supplement the information in their speech (So et al., 2015). However, this finding contrasts with the finding that younger children with ASD ( $M_{age} = 2;6$ ; Özçalışkan et al., 2018), who were equally likely to use complementary and supplementary combinations in their communications with their parents.

One intriguing explanation for why verbal children with ASD are less likely to use supplemental gesture-speech combinations than TD children could be that these combinations depend on coordinating attention to both the partner and a shared referent—a skill that children with ASD find particularly difficult to initiate and sustain (Adamson, Bakeman, Deckner, & Romski, 2009; Loveland & Landry, 1986; Mundy et al., 1990). In contrast, complementary gesture-speech combinations are relatively simpler in that they convey similar information in speech and gesture so that their meaning can be conveyed in only one of the modalities. Thus, reliance on complementary gesture-speech combinations may also reflect the continued difficulty children with ASD show in integrating multi-modal information when the two pieces convey different semantic content, as shown in earlier work for older children with ASD (de Marchena & Eigsti, 2010).

#### 4.2. Do parents differ in their gestural input to their children?

Parents of children with ASD did not differ from parents of TD children in their use of gestures or speech, suggesting that children in both groups receive similar input across modalities. This finding is similar to previous research on parents of young children with ASD (Özçalışkan et al., 2018). Parents in both groups also did not differ in their proportional use of different gesture types, following a similar pattern to their children. They produced primarily deictic (TD = .87, ASD = .86), followed by conventional (TD = .10, ASD = .10) and iconic gestures (TD = .03, ASD = .03). This robust main effect of gesture type across both parents and children further suggests that the use of deictic gestures may be an easier form of communication when indicating or requesting concrete referents. The use of a variety of different gesture types by parents, a pattern also found with parents of young TD children (Özçalışkan & Goldin-Meadow, 2005a), also suggests that parents of older children continue to model different types of gestures for their children.

Unlike the group differences seen in children, parents showed no group differences in their use of different gesture-speech combinations, using mostly complementary combinations (TD = .45, ASD = .45), followed by disambiguating (TD = .39, ASD = .32), and supplementary ones (TD = .16, ASD = .24). This suggests that parents model the use of various gesture-speech combinations. At the same time, however, parents' production of gestures and gesture-speech combinations did not correlate with their children's—suggesting that children's relative production of each communication type might be largely driven by their own communicative needs.

Our finding that group differences in the child production of gesture-speech combinations were not observed in parental input suggests that gesture may serve a different function for older, verbal children with ASD than for TD children. In young children, the use of supplementary gesture-speech combinations has been shown to play an important role in language development, allowing the child to convey complex, additional information in gesture that they are not yet able to convey exclusively in speech, a finding that holds true for both younger TD children and children with ASD (Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005a, 2009; Özçalışkan et al., 2017). The fact that children with ASD in our study, unlike the TD children, used gesture most frequently to complement the information that they have already presented in speech may suggest that they are relying more heavily on the content of their verbal speech to provide communicative information.

### 4.3. Limitations

Recent studies suggest that roughly 30% of children with ASD are non-verbal or minimally verbal (Tager-Flusberg & Kasari, 2013). Our selected sample only included verbal children with ASD given our interest in the relation between gesture and speech, limiting the generalizability of our findings to a subset of children with ASD who are verbal. In addition, our relatively modest sample size ( $n = 39$ ) might have contributed to the lack of significance in some of the comparisons, particularly for children who show greater variability in their production. A power analysis (Faul & Erdfelder, 1992) indicated that a sample size of 28 per group was needed to reliably detect such effects 80% of the time, suggesting that our study may be underpowered. Our study also relied on parent-child interactions during a semi-naturalistic play context as the elicitation technique in identifying patterns of gesture and speech use in children with ASD and their parents. Future studies that extend data collection to other communicative contexts might shed further light on the effect of elicitation context in shaping the gesture-speech system of parent-child dyads. In addition, the observation period for our study was relatively short. Future studies that include a longer observation period might provide a broader representation of the gesture-speech production in parent-child interactions during early school years.

### 4.4. Implications

Due to the language delays and social development deficits that are often associated with the diagnosis of ASD, there is a growing need for early intervention and school-based services to support language development in this group. However, there is currently limited research that examines how early school-age verbal children use gesture when communicating with others in their immediate environment. Understanding how children and parents use gestures relative to speech, and the link between child and parent gesture, has the potential to inform intervention and school-based practices to encourage both expressive and receptive language development in children with ASD.

### 4.5. Conclusion

In summary, our study shows that early-school age, verbal children with ASD resemble TD children with comparable language and cognitive skills in their overall production of gesture and in their use of different gesture types, but differ in the way that they integrate gesture and speech. This difference may suggest that gesture serves a different communicative function for older, verbal children with ASD, who rely primarily on gesture to reinforce what they already express in speech. Parents of children with ASD, however, do not follow a similar pattern to their children, but instead show consistent similarities to parents of TD children in their production of gesture and use of different gesture types and gesture-speech combinations. Thus, any differences in children's gesture use is not a result of differing parental input, but rather suggests that diagnosis-specific differences may be driven by the communicative needs of the child. However, because this difference is only seen in children in their use of gesture-speech combinations children with ASD may be relying less on gesture than TD children to provide content to their communication, and rather rely more heavily on the informational content of their speech.

### Declaration of Competing Interest

Authors declare they have no conflict of interest.

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