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Early deictic but *not* other gestures predict later vocabulary in both typical development and autism

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Abstract

Research with typically developing (TD) children suggests a strong positive relation between early gesture use and subsequent vocabulary development. In this study, we ask whether gesture production plays a similar role for children with autism spectrum disorder (ASD). We observed 23 18-month-old TD children and 23 30-month-old children with ASD interact with their caregivers (Communication Play Protocol, CPP) and coded types of gestures children produced (*deictic, give, conventional, iconic)* in two communicative contexts *(commenting, requesting)*. One year later, we assessed children's expressive vocabulary, using Expressive Vocabulary Test (Williams, 1997). Children with ASD showed significant deficits in gesture production, particularly in deictic gestures (i.e., gestures that indicate objects by pointing at them or by holding them up). Importantly, deictic gestures—but not other gestures —predicted children's vocabulary one year later regardless of communicative context, a pattern also found in typical development. We conclude that the production of deictic gestures serves as a stepping-stone for vocabulary development.

Introduction

Children indicate objects with their hands (e.g., point at or hold up a bottle) before they can produce verbal labels for these objects ('bottle'; Bates, 1976). Importantly, the onset of such deictic gestures predicts the onset of similar spoken words in typically developing (TD) children (Iverson & Goldin-Meadow, 2005). Children with autism spectrum disorder (ASD) show difficulties in early gesture use, particularly in the production of deictic gestures (e.g., Mastrogiuseppe, Capirci, Cuva, & Venuti, 2015; Mundy, Sigman, & Kasari, 1990; Gulsrud, Hellemann, Freeman, & Kasari, 2014); they also often show prolonged delays in producing words and use fewer words than TD children (Tager-Flusberg, 2007). In this study, we ask how the delays and difficulties in the vocabulary development of children with ASD are related to different *gesture types* (deictic, give, conventional, iconic) produced in different *communicative contexts* (commenting, requesting). We predict that their production of deictic gestures in contexts that encourage commenting will be more affected than the production of other gesture types, compared to TD children. We also predict that the relation between early gesture production and later vocabulary could follow one of two paths. One possibility is that production of each gesture type will serve as a good predictor of later

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vocabulary development, (e.g., Luyster, Kadlec, Carter, & Tager-Flusberg, 2008; Rowe, Özçalışkan, & Goldin-Meadow, 2008). A more nuanced alternative is that variation only in deictic gesture production—but not other gesture types—will be related to later language in both ASD and TD groups, especially in commenting contexts for children with ASD (Colonnesi, Stams, Koster, & Noom, 2010; Gulsrud et al., 2014; Paparella, Goods, Freeman, & Kasari, 2011). Evidence that supports this alternative would help elucidate more specifically how early problems with gesture may impact language acquisition in ASD.

Gesture predicts vocabulary development in typically developing children

Typically-developing children use gesture to communicate before they produce their first words (Bates, 1976). They, for example, use *deictic* gestures to indicate objects, and do so several months before they refer to the same objects with words. In addition to deictics, children produce several other gesture types. These include *conventional gestures*, which convey culturally-shared meanings with prescribed gesture forms (e.g., nodding the head to mean 'yes'), and g*ive gestures,* which are hand extensions towards objects to request them (e.g., extending empty palm towards bottle to convey 'give bottle'; Özçalışkan & Goldin-Meadow, 2005a, 2005b). A third and relatively less frequent category of early gesture is *iconics*, which convey actions and attributes associated with objects. Unlike other gesture types, iconics provide a nonverbal tool to convey relational meanings, such as an object's shape or action (e.g., V-shaped fingers to indicate 'shape of rabbit 'sears'; tilting cupped hand toward mouth to indicate 'drinking'; Özçalışkan, Gentner, & Goldin-Meadow, 2014).

There is substantial evidence that one-year-old children use more gestures than words; they also convey a larger array of meanings with gestures than with words (Iverson, Capirci, & Caselli, 1994; Iverson, Capirci, Longobardi, & Caselli, 1999; Özçalışkan & Goldin-Meadow, 2005b, 2011). Gesture also signals upcoming changes in speech. The earlier children point at particular objects, the earlier they will label them, suggesting a tight positive relation between early deictic gestures and early words (Iverson & Goldin-Meadow, 2005). Moreover, gesture serves as a reliable index of individual variability. Children who produce more iconic gestures at 19 months have larger vocabularies at 24 months (Acredolo & Goodwyn, 1988). Similarly, children who convey more diverse meanings in gesture at 14 months show larger vocabularies at ages4 and 5 (Rowe et al., 2008; Rowe & Goldin-Meadow, 2009; see also Colonnesi et al.,2010 for a meta-analysis on pointing and vocabulary). The close coupling between gesture and speech is also evident in studies on sex differences in language development. Girls not only produce their first words and first word-word combinations earlier than boys, but also produce the gestural precursors for these milestones earlier than boys (Butterworth & Morissette, 1996; Özçalışkan & Goldin-Meadow, 2010). Thus the early gestures TD children produce predict upcoming changes in their speech: they signal the onset of first spoken words and predict individual variability in children's vocabulary development.

Does gesture predict vocabulary development in children with ASD?

In contrast to TD children who undergo each language milestone in a predictable fashion, children with ASD are at high risk for significant delays and/or deviations in language acquisition (Rapin & Dunn, 2003; Tager-Flusberg, 2007). Children with ASD also show diagnosis-specific variability across communicative contexts, with referential communication being affected the most (Adamson, Bakeman, Deckner, & Romski, 2009; Capps, Kehres, & Sigman, 1998; Capps, Losh, & Thurber, 2000; Loveland & Tunali, 1993; Stone, Ousley, Yoder, Hogan, & Hepburn, 1997; Tager-Flusberg, 1996, 1999).

Relatively few studies examined how children with ASD gesture and how the use of different gesture types relates to emerging language. Most studies focused instead on the *communicative function* of gestures, drawing a binary split between *proto-imperative* gestures that request objects versus *proto-declarative* gestures that indicate objects (Mundy, Sigman, & Kasari, 1990)—a distinction coined by Bates (1976). Their over arching finding was that children with ASD produce significantly fewer proto-declarative nonverbal behaviors (including gestures) than TD children and children with developmental delays matched on mental age or language level, suggesting that the deficits in proto-declarative gesture in ASD might be diagnosis specific (Baron-Cohen, 1989; Camaioni, Perucchini, Muratori, & Milone, 1997; Goodhart & Baron-Cohen, 1993; Dawson et al., 2004; Landry & Loveland, 1988; Loveland & Landry, 1986; Wetherby et al., 2004; Wetherby, Watt, Morgan, & Shumway, 2007). Furthermore, some of this work showed a positive relation between early proto-declarative gestures and later receptive or expressive vocabularies (Gulsrud et al., 2014; Mundy et. al, 1990; Paparella et al., 2011).

However, several key issues in early gesture production by children with ASD and how it links to vocabulary development still remain unanswered. Of particular note is that research that focuses on gesture types rather than the distinction between proto-declaratives and proto-imperatives is sparse (but see Mastrogiuseppe et al., 201 5 for an exception). This is due, in part, because most studies of gesture draw data from a standardized assessment, the Early Social Communication Scales (ESCS ; Mundy, Delgado, & Hogan, 2003) or parent report on the McArthur Communicative Development Inventory (MCDI; Fenson et al., 1993) that categorize gestures in terms of proto-declaratives or proto-imperatives, rather than on gesture production during on-going social interactions. This gap in the literature means that we lack important information about how ASD affects the production of different types of spontaneous gestures in different communicative contexts, particularly early in language acquisition, and how each gesture type might facilitate subsequent language development. The few available studies are inconclusive, with some suggesting that children with ASD produce fewer gesture types than TD children (Colgan et al., 2006; Wetherby & Prutting, 1984) or that they produce gestures that differ in hand shape form (Hobson, Garcia-Perez, & Lee, 2010), while others suggest that children with ASD show strengths in the production of iconic gestures, particularly in extended speech contexts (e.g., narratives; Capps et al., 1998). Moreover, there is some evidence that group differences between children with and without ASD in gesture frequency during social interactions dissipate after controlling for amount of speech (Attwood, Frith, & Hermelin, 1988; Capps et al., 1998; DeMarchena & Eigsti, 2010)—an important factor rarely accounted for in previous work.

Current study

Previous research suggests a strong link between early gestures that indicate objects and later vocabulary development in children with ASD. However, the question remains as to whether the process of vocabulary development is primarily driven by deictic gestures or whether it is also tied to other gesture types that are produced to either receive (give gestures) or characterize objects (iconic gestures), or to convey culturally-prescribed meanings (conventional gestures). Different from earlier work, we approach this question by focusing on both *gesture type* and *communicative function* by examining the different types of gestures produced by children with ASD in two communicative contexts that are designed to primarily afford either commenting or requesting functions. We ask how young children with ASD compare to TD children in the amount and types of gestures they produce in these communicative contexts and whether difficulties in the expressive language development of children with ASD can be traced back to earlier production of different gesture types in each communicative context. We expect that children with ASD will show marked deficits in their production of deictic gestures —particularly in commenting contexts —compared to TD children comparable in speech production. We expect either that variability in children's production of any gesture type will serve as a good predictor of later vocabulary development, regardless of communicative context, or alternatively, that the relation between gesture type and vocabulary development will be more nuanced such that variation in deictic gesture production—but not other gesture types—will predict variability in later vocabulary in children with ASD and in TD children, especially in commenting contexts for children with ASD.

Methods

Participants

All children were participants in a longitudinal project of early communication (Adamson et al., 2009). In this study, we focus on the 23 children with ASD (20 boys; M_{age}=31 months; range=21–37 months) and 23 TD children (18 boys; M_{age}=18 months; range=18–18 months) from this original sample, examining their speech and gesture production at initial observation and their expressive vocabulary size one year later. The 23 children in each group were selected so that the two samples were comparable—at the group level—in their mean productive vocabulary both for word tokens (M_{TD}=168.27 [SD=125.18] vs. M_{ASD}=172.91 [SD=195.80], Kruskal–Wallis, H(1)=2.26, p=.13) and for word types (M_{TD}=28.43 [SD=26.90] vs. M_{ASD}=39.65 [SD=49.08], H(1)=.96, p=.33) across the two communicative contexts. The two groups were also comparable in each communicative context both for word tokens (commenting: M_{TD}=86.57 [SD=68.26] vs. M_{ASD}=85.61 [SD=103.41], Kruskal–Wallis, H(1)=2.23, p=.13; requesting: M_{TD}=81.70 [SD=61.42] vs. M_{ASD}=87.30 [SD=96.10], H(1)=1.92, p=.16) and for word types (commenting: M_{TD}=15.65 [SD=15.90] vs. M_{ASD}=20.48 [SD=26.25], H(1)=1.07, p=.3; requesting: M_{TD}=12.78 [SD=11.61] vs. M_{ASD}=19.17 [SD=23.59], H(1)=.53, p=.47). Children with ASD were referred by clinicians in the metropolitan Atlanta area. We administered the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur,1 994) to confirm each clinician's diagnosis at 30 months ; 22 children scored above the cut-off for autism on all three of its scales and one child did so on two and within one point on the third. None of the TD children had developmental or health problems. Most children were Caucasian (TD=74%, ASD=83%), and all were learning English as first language.

Procedure for data collection

Video-recorded observations of semi-naturalistic parent-child interactions were made with the Communication Play Protocol (CPP; Adamson et al., 2009). We used4 five-minute CPP scenes: two that encourage requesting (getting toys from a high shelf, playing with complex toys) and two that encourage commenting (discussing pictures, discussing objects in container), resulting in 20 minutes of observation per child. [1] The parent was told that we were interested in how the child currently communicates. To facilitate the play, the caregiver was given a cue card for each scene that indicated its plot, a set of appropriate props, and directorial suggestions (e.g., ask what picture your child likes the most) but *not* a script. A manual for CPP is available upon request.

Procedure for data coding

Gesture coding—The video-recorded observations were coded for gesture by a trained researcher who was blind to the study's hypotheses and the children's language outcome. Gesture was defined as a communicative hand or body movement that was directed to the parent and that did not manipulate objects, such as twisting a jar open. All gestures were empty-handed with the one exception of show gestures during which the child brought an object to the caregiver's attention by holding up the object; these show gestures served the same function as the pointing gestures and thus were also treated as deictic gestures, following earlier work (Özçalışkan & Goldin-Meadow, 2005a; Özçalışkan, Levine, & Goldin-Meadow, 2013).

Each gesture was coded into one of five types based on its form and based on the perspective of the gesturer (in this case the child; McNeill, 1992; Özçalışkan & Goldin-Meadow, 2005a, 2005b):(1) *deictic* gestures indicated referents by either pointing at them (e.g., point to cat to indicate 'cat') or by holding them up to show to the parent (e.g., hold up bottle to indicate 'bottle'), (2) *give* gestures aimed at receiving objects by extending an empty palm toward them (e.g., extending open palm towards bottle to convey 'give me bottle'), (3) *conventional* gestures were hand and body movements with culturally-prescribed forms and meanings (e.g., flipping hands while shrugging shoulders to convey 'don't know'),(4) *iconic* gestures characterized an entity using an associated action or feature (e.g., thrusting empty hand to convey 'throwing'; pinching fingers to represent 'small'), and (5) *beats* were formless gestures with no semantic meaning that moved in rhythmic relationship to speech (e.g., flicking fingers to mark utterance boundaries).

Language measures—To ensure that children with ASD were comparable—as a group—to TD children in their speech production, we computed children's spoken vocabulary at the initial observation (TD:18-months, ASD:30-months) by counting the type

[1]The Communication Play Protocol (CPP) consists of a series of communicative contexts, each with 2 scenes. In Adamson et al. (2009), each child was initially observed in three contexts: *commenting* (discussing pictures, discussing objects in a container) *requesting* (getting toys from a high shelf, playing with complex toys), and *social interacting* (taking turns in playing a game, jointly playing with musical instruments); in subsequent visits, a fourth context, *narrating* (discussing past events, discussing future events) was added. The order of scenes was randomized across visits with the constraint that one of the scenes from each context always occurred during the first half of the CPP. Each scene lasted five minutes, resulting in 40 minutes of parent-child interaction across all 8 scenes and 4 communicative contexts. In our study, we only focused on four of these scenes, two that elicit commenting and two that elicit requesting, because previous research has shown these two contexts to reveal distinct patterns of weaknesses as well as strengths in the gesture production of children with different developmental disorders.

and token frequency of words children produced using previously prepared transcripts of the semi-naturalistic parent-child interactions observed during the CPP (Adamson & Bakeman, 2006). Sounds that referred to entities, properties, or events (e.g., 'doggie', 'open'), along with onomatopoeic (e.g., 'meow') and conventionalized evaluative sounds (e.g., 'oopsie') were counted as words. We computed *word token* as the total number of words and *word type* as the total number of different words each child produced (e.g., if the child said 'dog' twice it counted as one word type but two word tokens). The comparability of the two groups on word production—types and tokens—was particularly important, because we were interested in group differences in the production of each gesture type that were *not* driven by differences in speech production. One year after each child's CPP, vocabulary was assessed using the *Expressive Vocabulary Test* (EVT; Williams, 1997). We used EVT standard scores (instead of raw EVT scores) as our outcome measure because there was considerable variability in age at the final observation, particularly among children with ASD (range=34–49 months).

Statistical analysis—We computed the total number of each gesture type (deictic, give conventional, iconic) each child produced at initial observation by communicative context and children's spoken vocabulary—assessed by EVT, one year later. We analyzed differences in gesture production with one-way ANOVA and Kruskal-Wallis tests—where the assumption of homogeneity of variance or normality was violated—with group (ASD, TD) as a between-subjects factor, along with chi-squares. We assessed differences in gesture production by communicative context within each group using Wilcoxon signed-rank test, with context type (requesting, commenting) as a within-subject factor. We analyzed the relation between children's early production of different gesture types and their later vocabulary size with Spearman's zero-order correlations. EVT scores were missing for 2TD children and 5 children with ASD; these children were not included in the correlational analysis. In addition, we observed very few iconic gestures and no beat gestures in our data; we therefore focused our correlational analyses only on deictic, give, and conventional gestures.

Reliability—Intercoder agreement was assessed with two coders who were blind to the hypotheses and the outcome measures. Both coders were trained using video records with TD children and children with ASD that were not part of the current corpus until they reached 90% agreement on all coding categories. One coder then coded the entire current corpus and was blind to which participant sessions would be coded for reliability; the second coder independently coded a randomly selected 15% of the corpus. We first assessed agreement on detection of gesture in each group. We then compared coding of the gestures detected by both coders to estimate reliability on gesture *form* (i.e., type of gesture). Intercoder agreement scores were 88%(Cohen's kappa; κ=.86) for identifying gestures (TD: M=90%[SD= 3%], κ=.86; ASD: M=85%[SD= 4], κ=.86) and 97%[κ=.95] for assigning gesture types (TD: M=96%[SD= 3], κ=.94; ASD: M=97%[SD= 2], κ=.96).

Results

Do children with ASD differ from TD children in the amount and types of gestures that they produce in different communicative contexts?

First looking at gesture production *across the two communicative contexts,* we found group differences. As expected, children with ASD produced significantly fewer gestures than TD children (M_{ASD}=20.61 [SD=15.45] vs. M_{TD}= 46.78 [SD=25.03]; F(1,44)= 18.21, p<.001, η^2 =0.30). Importantly, this difference was *not* an outcome of the lower frequency of speech production by children with ASD. By design, the two groups were comparable in their spoken vocabulary production, both for word tokens (M_{TD}=168.27 [SD=125.18] vs. M_{ASD}=172.91 [SD=195.80], Kruskal–Wallis, H(1)=2.26, p=.13) and for word types (M_{TD}=28.43 [SD=26.90] vs. M_{ASD}=39.65 [SD=49.08], H(1)=.96, p=.33). Turning to differences in gesture types, we found that children in both groups produced similar types of gestures, including *deictic* (e.g., point to or hold up airplane to indicate 'airplane'), *give* (e.g., extend open palm toward airplane to convey 'give airplane'), *conventional* (e.g., shake the head to mean 'no'), and *iconic* (e.g., extend arms sideways to convey 'airplane's shape') gestures. However, the production of each gesture type across the two contexts showed group differences (Fig. 1). Compared to TD children, significantly fewer children with ASD produced deictic gestures during our session (ASD:70% vs. TD:96%, χ^2(1)=4.45, p=.02); and they produced them at significantly lower frequencies (M_{ASD}=9.22 [SD=11.96] vs. M_{TD}=27.96 [SD=23.96], Kruskal-Wallis, H(1)=11.45, p=.001, r=.50). The difference was less pronounced for give and conventional gestures, both of which were produced by 96% of the TD children and 91%of the children with ASD (χ^2(1)=.36, p=.55). Nonetheless, children with ASD produced significantly fewer give gestures than TD children (M_{ASD}=6.83 [SD=6.0] vs. M_{TD}=12.74 [SD=7.67]; H(1)=7.38, p=.007, r=.40), but the groups did not differ in their conventional gesture production (M_{ASD}=4.17 [SD=5.09] vs. M_{TD}=5.96 [SD=4.99]; H(1)=2.31, p=.13). The incidence of iconic gestures was extremely rare, but comparable across the two groups; 3 TD children and 5 children with ASD produced a total of 12 iconic gestures, which accounted for 1% of children's gesture production.

Next, looking at children's production of gesture *within each communicative context,* we found that children with ASD produced significantly fewer gestures than TD children in both the commenting (M_{ASD}=9.87 [SD=8.46] vs. M_{TD}=22.56 [SD=16.75], H(1)=7.26, p=. 007, r=.40) and the requesting (M_{ASD}=10.74 [7.95] vs. M_{TD}=24.22[11.65], H(1)=15.34, p<. 001, r=.58) contexts. This difference was particularly pronounced for *deictic* gestures, where children with ASD produced significantly fewer deictic gestures than TD children in both the commenting (M_{ASD}=5.13 [6.41] vs. M_{TD}=17.22 [16.70], H(1)=7.81, p=.005, r=.41) and the requesting (M_{ASD}=4.09 [6.23] vs. M_{TD}=10.74 [8.71], H(1)=10.20, p=.001, r=.47) contexts. The two groups did not differ in their production of either *give* (H(1)=0.17, p=.68) or *conventional* gestures (H(1)=0.42, p=.61) in the commenting context. However, compared to their TD peers, children with ASD produced fewer give (H(1)=10.32, p=.001, r=.47) and conventional (H(1)=3.44, p=.06, r=.27) gestures in the requesting context. Importantly, however, when we examine gesture production by communicative context *within each group*, we found no reliable differences in overall frequency of gesture use by context, either for children with ASD ($M_{COMMENT}$=9.87 [SD=8.46] vs. $M_{REQUEST}$=10.74 [SD=7.95], Wilcoxon-signed rank test, T=112.0, *p*=.43) or for TD children ($M_{COMMENT}$=22.56 [16.75] vs. $M_{REQUEST}$=24.22 [11.65], T=101.50, *p*=.42). However, as can be seen in Table 1, children in both groups produced significantly more give gestures in requesting contexts than in commenting contexts (ASD: $M_{REQUEST}$=4.30 [SD=4.03] vs. $M_{COMMENT}$=2.52 [SD=3.26], T=41.50, *p*=.03, *r*=.45; TD: $M_{REQUEST}$=:9.91 [SD=6.50] vs. $M_{COMMENT}$=2.83 [SD=3.42], T=7, *p*<.001, *r*=.76). In addition, TD children produced significantly more deictic gestures in commenting contexts than in requesting contexts ($M_{COMMENT}$=17.22 [SD=16.70] vs. $M_{REQUEST}$=10.74 [SD=8.71], T=59.00, *p*=.03, *r*=.46)—a difference that did not reach significance for children with ASD ($M_{COMMENT}$=5.13 [SD=6.41]vs. $M_{REQUEST}$=4.09 [SD=6.23], T=46.0, *p*=.25). There were no reliable differences in gesture production by context for either conventional gestures (ASD: T=75.5, *p*=.66; TD: T=62.50, *p*=.11) or for iconic gestures within each group (ASD: T=8.0, *p*=.89; TD: T=2.0, *p*=.56; see Table 1).

Overall, first summarizing children's gesture production *across the two communicative contexts*, children in both groups produced the same four types of gestures (deictic, give, conventional, iconic). Even though there was no group difference in the number of children producing give and conventional gestures, significantly fewer children with ASD produced deictic gestures, also at significantly lower frequencies compared to TD children. Children with ASD also produced significantly fewer give gestures than TD children, but were comparable in their production of conventional and iconic gestures. Turning next to *gesture production in each context*, the use of each gesture type differed by communicative context, with greater frequency of deictic gestures in commenting scenes within the TD group and greater frequency of give gestures in requesting scenes in both the TD and the ASD group. Gesture production in each context also showed group differences. Overall, children's production of deictic gestures showed the most pronounced group difference, with children with ASD producing reliably fewer deictic gestures in both contexts; children with ASD also produced fewer conventional and give gestures in the requesting, but not the commenting context, compared to their TD peers.

Does the individual variability in the production of each gesture type within and across communicative contexts predict children's spoken vocabulary one year later?

Next we asked whether the differences observed in the production of each gesture type were related to children's vocabulary one year later. First looking at relations between children's production of each gesture type *across the two communicative contexts* and later vocabulary, we found that the production of *deictic gestures* strongly predicted expressive vocabulary one year later for both children with ASD (*rho*=.72, *p*=.001) and TD children (*rho*=.64, *p*=.002; Figure 2); but no such predictive relation was found for either *give* or *conventional* gestures and later vocabulary for children with ASD (give: *rho*=.20, *p*=.43, conventional: *rho*=.16, *p*=.53) or TD children (give: *rho*=-.03, *p*=.92, conventional: *rho*=-.32, *p*=.17). [2],[3]

[2]The correlational patterns remain unchanged when we use raw EVT scores, showing a significant relation between deictic gestures and later vocabulary (ASD: *rho* =.73, *p*=.005, TD: *rho*=.62, *p*=.004), but no reliable relation between other gesture types and later vocabulary for children with ASD (give: *rho*=-.33, *p*=.26, conventional: *rho*=.06, *p*=.84) and TD children (give: *rho*=-.17, *p*=.48, conventional: *rho*=-.43, *p*=.06).

[3]Children's word production at initial visit also predicts their standard EVT scores one year later both for children with ASD (word tokens: *r*=.82, *p*<.001, word types: *r*=.73, *p*=.001) and for TD children (word tokens: *r*=.65, *p*=.001, word types: *r*=.63, *p*=.002); a

Next, examining relations between children's production of deictic gestures in each communicative context and later vocabulary, we found similar patterns. The number of deictic gestures children with ASD produced in both contexts served as reliable indices of their expressive vocabulary one year later (commenting: *rho*=.56, *p*=.02, requesting: *rho*=.74, *p*<.001)—a pattern that was also found in TD children (commenting: *rho*=.63, *p*=.002, requesting: *rho*=.47, *p*=.03). None of the other gesture types (i.e., conventional, give) produced in each context was related to later vocabulary (*p*'s>.15) both for children with ASD and TD children, suggesting a unique role to deictic gestures in predicting later vocabulary.

Discussion

In this study, we asked how young children with ASD compare to TD children in the amount and types of gestures that they produce in naturalistic parent-child interactions and whether variability in the type and token frequency of gestures in two communicative contexts (commenting, requesting) relates to later expressive language development of children with ASD. Children with ASD showed deficits in gesture production in both contexts even though they produced comparable amounts of speech, suggesting that lower rates of gesture production is not driven by either speech production or the demands of the communicative context. More importantly, it was only deictic gestures—but not other gestures types—that predicted vocabulary size one year later both for TD children and children with ASD, independent of communicative context, highlighting the important role deictic gestures assumes in spoken language development compared to other gesture types.

Our results extend earlier work on TD children to children with ASD, showing the unique role deictic gestures play in vocabulary development. Pointing serves as the child's first foray into referential communication before the onset of speech (Werner & Kaplan, 1963). It is through pointing that the child shows the initial ability to affect others' attention about referents (Bates, 1976), thus serving as the foundation for sharing intentionality and building joint engagement around objects—an essential step in the development of spoken language (Adamson & Dimitrova, 2014; Tomasello, Carpenter, & Liszkowski, 2007). In fact, the later speech delays in ASD could be closely related to the early difficulties these children encounter in building joint-attention frames in which gesture plays a crucial role (Adamson, Romski, & Barton-Hulsey, 2014; Dawson et al., 2004; Gulsrud et al., 2014; Mundy et al., 1990). However, even though children with ASD were less likely than TD children to produce deictic gestures (16 out of 23, 70% vs. 22 out of 23, 96%) and to do so at significantly lower frequencies, the individual variability in deictic gestures was a reliable predictor of later vocabulary in both groups. This finding suggests that deictic gesture might be the first sign of the child's emerging symbolic ability for spoken language across different learners (see Tomasello et al., 2007 for further discussion).

One important contribution of our study is that it showed—for the first time—that children with ASD gesture less than TD children even if they produce comparable amounts of

similar positive relation also holds between children's age at initial visit and standard EVT scores (*r*=.54, *p*=.02) one year later, but only for children with ASD who show variability in chronological age (21–37 months) at initial visit.

speech. Moreover, our findings indicate that children with ASD rely on the same types of gestures as TD children with similar gesture forms —including *deictic*, *give, conventional,* and *iconic* gestures. In fact, the two most commonly used gesture types in both groups were *deictic* and *give* gestures, accounting for 78% of the gestures produced by children with ASD (45% deictic, 33% give) and 87% of the gestures produced by TD children (60% deictic, 27% give). Conventional gestures were used less frequently (ASD:20%, TD:13%), and iconic gestures were rare (~1%) in both groups. These findings suggest that gesture deficits in ASD are not likely due to lower frequency of speech or less diversity of gesture types—two possible explanations provided for gesture deficits in children with ASD in previous work (e.g., Attwood et al., 1988; Colgan et al., 2006; Wetherby & Prutting, 1984). Future studies examining other possible contributors to gesture use are needed to further understand why children with ASD show deficits in early gesture production.

This study aimed to bring together two perspectives into the analysis of gestures produced by children with ASD—one focusing on gesture type (a framework more commonly used in studies with TD children) and one focusing on communicative function (an approach more commonly employed in studying children with developmental disorders). Importantly, our analysis both *by* and *across* communicative contexts showed the unique role deictic gestures play on subsequent vocabulary development of children with ASD and TD children. Pointing at objects or holding up objects to bring to the attention of others, but not other gesture types predicted children's emerging spoken vocabularies. At the same time, one important difference between the two groups of children was the relative strength with which deictic gestures predicted children's later vocabularies in the two communicative contexts. For TD children, deictic gestures produced in the commenting context was a stronger predictor of later vocabulary than the deictic gestures produced in the requesting context ($rho_{COMMENT}$=.63 *vs.* $rho_{REQUEST}$=.47). In contrast, for children with ASD deictic gestures produced in requesting context was a stronger predictor of their vocabulary one year later than deictic gestures produced in commenting contexts ($rho_{REQUEST}$=.74 *vs.* $rho_{COMMENT}$=.56). These differences in the strength of the link between early deictic gesture and later vocabulary suggest how autism may profoundly alter the way communication in various contexts may contribute to language acquisition (Adamson et al., 2009).

But why do only *deictic* but not other gesture types predict children's later vocabularies? Gesture can help with the process of spoken language development in two important ways that are not necessarily mutually exclusive of each other, namely by reducing cognitive load and by eliciting relevant input from the adults (Goldin-Meadow, 2003). Overall, the mapping between symbol and referent is more direct for deictic gestures than it is for other gesture types. Deictic gestures—like nouns —map onto the perceptual world in a clear-cut way; they refer to entities that naturally stand out as individuated wholes in the world (Özçalışkan et al., 2014). In contrast, conventional and iconic gestures choose referents from a diverse set of relational concepts that vary across languages. Existing work suggests that children growing up in linguistic environments with richer iconic and conventional gesture input, such as Italy, produce greater numbers and varieties of such gestures at an earlier age than children learning English in America (Capirci, Contaldo, Caselli, & Volterra, 2005; Iverson, Capirci, Volterra, & Goldin-Meadow, 2008). A pointing gesture, the form of which does not vary as a function of its referent, is easier to produce and to remember compared to a conventional or iconic gesture that represents a referent with a symbol—i.e., characteristic action or feature, and that shows variability in form for different referents. Accordingly, the child might face fewer cognitive demands to convey information about a wide range of objects by using deictic gestures, which involve using the same form (typically the index finger) for all referents.

In addition to reducing cognitive load, deictic gestures are strongly tied to the immediate context and consequently play a key role in building joint engagement. Parents of TD children rely heavily on their children's gestures to interpret their communicative acts: mothers are not only more likely to talk to their children following a gesture (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007), but they also often translate their children's gestures into words (Golinkoff, 1986; Goldin-Meadow et al., 2007; see Özçalışkan & Dimitrova, 2013 for a review). For example, a mother might translate her child's point at a bottle by saying, 'That is a bottle', thus exposing the child to the word bottle at a time when the child shows readiness for that concept. TD children benefit from this calibrated input, showing earlier production of referents labeled by their mothers in their expressive vocabulary (Goldin-Meadow et al., 2007). A similar process might be at work in maternal responses to the early deictic gestures children with ASD produce. As recent work suggests (Dimitrova, Özçalışkan, & Adamson, under review), mothers of children with ASD are equally likely as mothers of TD children to respond to their children's object-referring gestures and translate these gestures into words. More important, words for the referents of gestures mothers translate are more likely to enter children's later vocabularies than words for the ones that mothers did not translate. Similar beneficial effects of parents' verbal responses have been shown for children's focus of attention: parental responses that followed the child's focus of attention were associated with better language outcomes than responses that redirected child's attention (McDuffie & Yoder, 2010; Siller & Sigman, 2002, 2008). These earlier studies thus suggest that parents' calibrated responses to children's deictic gestures might play a mediating role between child deictic gesture and later vocabulary development, as these responses are finely tuned to the child's knowledge state. The type of parental responsiveness (e.g., prompting, questioning) and what it is directed at (child gesture *vs.* focus of attention) might also show different beneficial effects with children at different stages of vocabulary development. Future studies that examine the potential effects of individual variability evident in the types of parental responsiveness to child gesture on children's later vocabulary might shed further light onto the complex mechanism through which parental responsiveness might impact vocabulary development of children with ASD.

In summary, our results show that deictic gesture is a fundamental aspect of the language-learning process in children with ASD—as it is in TD children, predicting children's spoken language development. Our results further suggest that it is not *any gesture*, but the production of a particular gesture type, namely deictic gesture, that serves as a stepping-stone for subsequent vocabulary development independent of the communicative context in which the gesture is produced. Children's deictic gestures may play this important role by providing them with the opportunity to practice referring to objects before they have the verbal means to do so and by helping establish a joint focus that the caregiver can elaborate with language.

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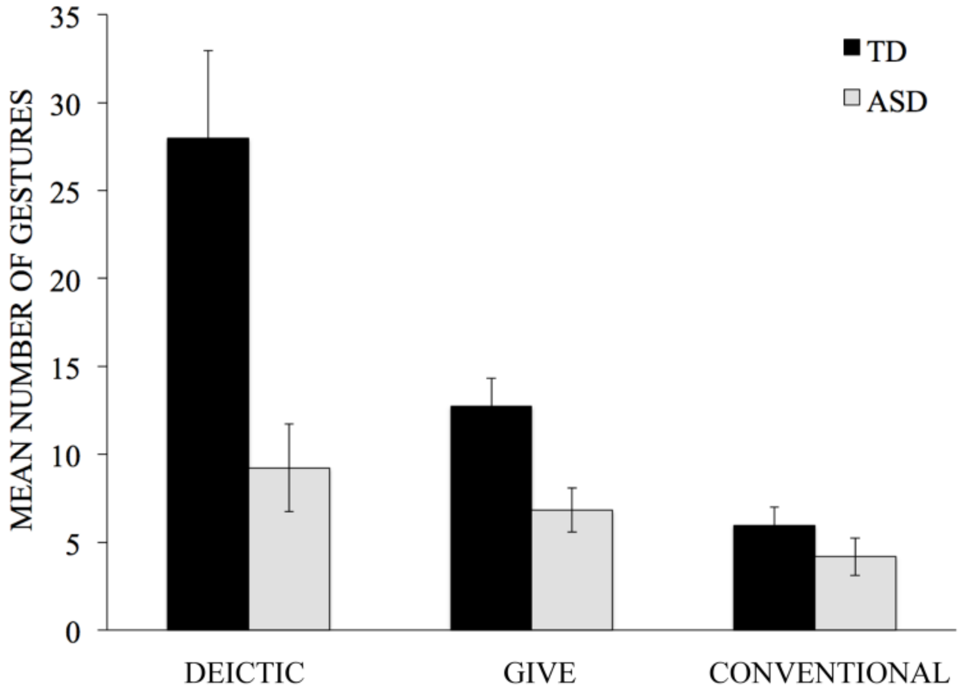

Figure 1.

Mean number of deictic, give, and conventional gestures produced by TD children (dark columns) and children with ASD (light columns); bars represent standard errors. Majority of the deictic gestures were points both for children with ASD (93%) and TD children (95%)

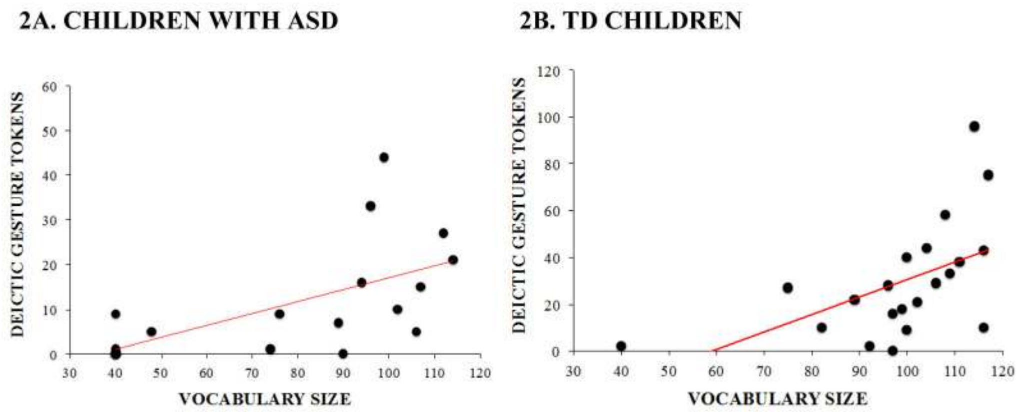

Figure 2.
Distribution of deictic gesture production by children with ASD (left panel) and TD children in relation to their later vocabulary (gesture production frequency was much lower for children with ASD compared to TD children as captured here by the different y-axis scales in Figures 2A and 2B).

Table 1

Children's mean production of gesture and speech by group and communicative context*

	Children with ASD			TD Children		
	Comment (C)	**Request (R)**	**C+R**	**Comment (C)**	**Request (R)**	**C+R**
Gesture at initial observation						
Deictic gestures	5.13 (6.41)	4.09 (6.23)	9.22 (11.94)	17.22 (16.70)	10.74 (8.71)	27.96 (23.96)
Give gestures	2.52 (3.26)	4.30 (4.03)	6.83 (6.0)	2.83 (3.42)	9.91 (6.50)	12.74 (7.67)
Conventional gestures	2.00 (3.29)	2.17 (2.61)	4.17 (5.09)	2.43 (2.97)	3.52 (3.12)	5.96 (4.99)
Iconic gestures	0.22 (0.67)	0.17 (0.58)	0.39 (0.84)	0.09 (0.29)	0.04 (0.21)	0.13 (0.34)
Gesture tokens	9.87 (8.46)	10.74 (7.95)	20.61 (15.45)	22.56 (16.75)	24.22 (11.65)	46.78 (25.03)
Speech at initial observation						
Word tokens	85.61 (103.41)	87.30 (96.10)	172.91 (195.80)	86.57 (68.26)	81.70 (61.42)	168.27 (125.18)
Word types	20.48 (26.25)	19.17 (23.59)	39.65 (49.08)	15.65 (15.90)	12.78 (11.61)	28.43 (26.90)
Speech at final observation						
Word tokens	177.11 (123.77)	171.95 (109.54)	288.35 (245.52)	287.27 (102.47)	287.91 (132.61)	550.17 (253.64)
Word types	57.63 (42.27)	45.53 (34.71)	85.22 (83.57)	90.77 (35.70)	75.36 (34.01)	158.91 (75.33)

ASD: Autism Spectrum Disorder; TD: Typically-developing; C: Commenting context; R: Requesting context

* Standard deviations are indicated in parentheses.