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Early gesture provides a helping hand to spoken vocabulary development for children with autism, Down syndrome and typical development

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Abstract

Typically developing (TD) children refer to objects uniquely in gesture (e.g., point at cat) before they produce verbal labels for these objects ("cat"; Bates et al., 1979). The onset of such gestures predicts the onset of similar spoken words, showing a strong positive relation between early gestures and early words (Iverson & Goldin-Meadow, 2005). We ask whether gesture plays the same door-opening role in word learning for children with autism spectrum disorder (ASD) and Down syndrome (DS), who show delayed vocabulary development and who differ in the strength of gesture production. To answer this question, we observed 23 18-month-old TD children, 23 30-month-old children with ASD and 23 30-month-old children with DS five times over a year during parent-child interactions. Children in all three groups initially expressed a greater proportion of referents uniquely in gesture than in speech. Many of these unique gestures subsequently entered children's spoken vocabularies within a year—a pattern that was slightly less robust for children with DS, whose word production was the most markedly delayed. These results indicate that gesture is as fundamental to vocabulary development for children with developmental disorders as it is for TD children.

Introduction

The gestures typically developing (TD) children produce to indicate or request objects (e.g., point at chair) precede and predict the emergence of similar words in speech (e.g., "chair"; Iverson & Goldin-Meadow, 2005). Compared to TD children, children with autism spectrum disorder (ASD) and with Down syndrome (DS) show delays in producing their first words and produce words at lower rates (Tager-Flusberg, 2007; Tager-Flusberg et al., 1990). Interestingly, these two groups of children show different profiles of gesture use; children with ASD gesture at markedly lower rates—a pattern that is particularly pronounced for deictic gestures (Mundy, Sigman, & Kasari, 1990; Özçalışkan, Adamson, Dimitrova, 2016a). In contrast, gesturing remains largely intact in children with DS (Stefanini, Caselli, & Volterra, 2007). In this study, we ask how the delays observed in the vocabulary development of children with ASD and with DS are related to their use of gestures that identify referents at the early stages of language development. If gesture remains a robust aspect of vocabulary development across different language learners, we would predict that

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children with developmental disorders would identify referents in gesture before they do so with words—akin to TD children, but with parallel delays in both modalities. If, on the other hand, the route for vocabulary development is different in children with different developmental disorders, we would fail to observe gestural precursors of children's emerging vocabularies in speech, suggesting the possibility of an alternative developmental process for vocabulary development for either or both children with ASD or with DS.

Gesturing and vocabulary development across different learners

Typically developing children use gestures to indicate or request objects before they produce words for these referents (Bates, 1976; Iverson, Capirci, & Caselli, 1994; Özçalışkan & Goldin-Meadow, 2005a); and these early gestures predict the content and size of their emerging vocabularies in speech. A child who indicates a referent earlier in gesture with a deictic gesture also produces the word for that referent earlier in speech (Iverson & Goldin-Meadow, 2005). Moreover, individual variability observed in the early production of gestures that indicate or request objects serves as a reliable predictor of individual variability in speech. Specifically, children who convey greater number of referents in gesture at age 1 continue to develop more extensive vocabularies in speech at school entry (Rowe & Goldin-Meadow, 2009; Rowe, Özçalışkan, Goldin-Meadow, 2008). Thus, the early gestures TD children produce to identify referents appear to be closely linked to vocabulary development.

Compared to their TD peers, children with ASD and with DS both show difficulties in speech development (Rice, Warren, & Betz, 2005; Tager-Flusberg, 2007). However, they show contrasting patterns of gesture use, making them an ideal comparison pair to understand whether and how gesture is part of the process of vocabulary development across different learners. Children with DS show particular strengths in gesture use—producing gestures at rates comparable to or sometimes even higher than TD children, comparable in language ability or chronological age (Caselli et al., 1998; Franco & Wishart, 1995; Iverson, Longobardi, & Caselli, 2003; Singer Harris, Bellugi, Bates, Jones, & Rossen, 1997; Stefanini et al., 2007). Children with ASD, on the other hand, produce significantly fewer gestures (Landa, Holman, & Garret-Mayer, 2007; Loveland & Landry, 1986), particularly deictic gestures that indicate referents (Baron-Cohen, 1989; Camaioni, Perruchini, Muratori, & Milone, 1997; Mundy et al., 1990). Nonetheless, the use of deictic gestures by children with ASD—despite its lower rate—has been shown to be a good predictor of their productive spoken vocabularies one year later (Gulsrud, Helleman, Freeman, & Kasari, 2014; Özçalışkan et al., 2016a). However, apart from these few studies—mostly focusing on children with ASD— the link between early gestures that identify referents and vocabulary development in children with developmental disorders remains largely unexplored.

Current study

Gesture and speech form a closely integrated system in TD children; identifying a referent in gesture predicts not only when children will acquire the spoken word for that referent, but also the number of different spoken words they will eventually acquire. In contrast, children with ASD and with DS show delays in producing their first words and produce fewer words, accompanied by different patterns of gesture production, particularly in the production of gestures that convey information about objects. In this study, we ask whether the process of vocabulary development in children with ASD and with DS follows a trajectory akin to the one exhibited by TD children, with children using gestures to indicate referents before they do so with words. Earlier evidence from TD children that shows that gesture both precedes and predicts the content and size of children's emerging vocabularies in speech suggests that gesture might be integral to the process of vocabulary development across different learners. If so, then we should see precursors of emerging spoken language abilities in the gestures of not only TD children, but also children with ASD and children with DS, albeit with marked delays.

Methods

Participants

The participants came from a larger longitudinal project on the development of joint engagement (Adamson, Bakeman, & Deckner, 2004; Adamson, Bakeman, Deckner, & Romski, 2009). In this study, we focus on 23 children with ASD, 23 children with DS, and 23 TD children, observed longitudinally over a year in parent-child interactions. Children were just beginning to amass spoken vocabulary at initial observation and were comparable in expressive vocabulary size, both for word tokens (i.e., number of words; Kruskal-Wallis, $\chi^2(2)=2.42$, $p=.30$) and word types (i.e., number of different words; $\chi^2(2)=3.15$, $p=.21$) at initial observation (see rows 3-4 in Table 1). Children were predominantly Caucasian (TD: 74%, ASD: 83%, DS: 83%), and most had parents with at least college degrees (ASD: 65%, DS: 78%, TD: 78%). Attrition was relatively low; all of the TD children and children with DS, and the vast majority of the children with ASD (19/23) participated in at least four of the five observation sessions.

As part of the inclusion criteria in the original study (Adamson et al., 2009), children with ASD were referred by a clinician who had diagnosed the children with autism according to the DSM-IV-TR criteria for autistic disorder (American Psychiatric Association, 2000). Each clinician's diagnosis was confirmed with the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) 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.

Data collection

Children were videotaped 5 times over a year through two one-way mirrors in a laboratory playroom while they interacted with their mothers using the Communication Play Protocol (CPP; Adamson et al., 2004; manual available upon request). The CPP is designed to elicit semi-naturalistic observations of parent–child communication using a series of scenes applicable to a diverse group of young children; each scene involves the caregiver acting out a plot using props. Five sets of comparable props were used for each CPP; one was randomly assigned to each observational session with the constraint that no set was used more than once for a participant. We used 4 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), for a total observation time of approximately 20 minutes per child per observation session.[1]

Transcription and coding

All five observations were already transcribed for speech (Adamson & Bakeman, 2006). All sounds that referred to entities, properties, or events (e.g., "cat", "broken", "eat", "big"), including onomatopoeic (e.g., "meow") and conventionalized evaluative sounds (e.g., "yay"), were treated as words, following earlier work (Özçalışkan & Goldin-Meadow, 2005a). We used children's type and token frequency of word production at initial observation as the basis to select participants so that children with DS and with ASD would be comparable to TD children in their speech production. We further coded the initial observation for child gesture, using trained coders who were blind to the study's hypotheses. Gesture was defined as a communicative hand (e.g., pointing at ball, extending open palm towards ball) or body movement (e.g., shaking head sideways to convey negation; extending arms sideways to convey airplane) that was directed to the parent and that did not manipulate objects, such as hammering a peg. All gestures were empty-handed with the one exception of show gestures, during which the child brought an object to the parent's attention by holding it up. We considered these show gestures as serving the same function as the pointing gestures and coded them as deictic gestures, in line with earlier work (Özçalışkan & Goldin-Meadow, 2005a, 2005b).

In this study, we focused only on *deictic gestures* that indicated referents (e.g., pointing at or holding up a ball to refer to the 'ball') and *give gestures* that conveyed requests for objects (e.g., extending empty open palm towards a ball to convey 'give ball'), both of which conveyed information about referents and involved only hand movements. Given our focus on identification of referents initially in gesture and subsequently in speech in this study, we excluded all other gestures that did not indicate or request referents, including emblems (e.g., shaking head sideways for 'negation'; shrugging shoulders to convey 'lack of knowledge') and the few iconic gestures (n=14), most of which conveyed action information with no specification of the object involved (n=9; e.g., moving arm with empty palm forcefully forward to convey 'throwing'; for further details on children's production of these other gesture types, see Özçalışkan et al., 2016a; Özçalışkan et al., 2016b).[2]

We identified referents children expressed only in gesture but not in speech (i.e., *referents expressed uniquely in gesture)* and referents children expressed only in speech but not in gesture (i.e., *referents expressed uniquely in speech)* at initial observation, following earlier work (Iverson & Goldin-Meadow, 2005); we excluded the few items that children expressed both in speech and in gesture within the same initial observation session (M_{TD}=.17; M_{ASD}=.11; M_{DS}=.04), as we could not determine whether they initially appeared in gesture or in

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[1]Our previous work (Özçalışkan et al., 2016a, 2016b) that examined the predictive relation between overall vocabulary size in gesture and in speech separately in two communicative contexts, one designed to elicit declarative (commenting context) and one designed to elicit imperative gestures (requesting context), found no context-based differences in the way early vocabulary size in gesture (i.e., gesture tokens at initial observation) related to later vocabulary size in speech (i.e., word tokens at final observation). We therefore collapsed across communicative contexts in order to examine the relationship between the emergence of particular vocabulary items in gesture and then in speech (but see Colonnesi et al., 2010 and Harbison et al., 2017 for meta-analyses examining differential relation of declarative and imperative pointing gestures to overall child spoken vocabulary size in TD children and children with ASD, respectively).

[2]Children with DS—but not children with ASD or with TD—also produced a small number of baby signs that conveyed object information (e.g., tapping thigh to convey dog; *M*=0.83 [SD=1.80]); we excluded these few baby signs from our analysis as we were not sure whether they acted like spontaneous gestures or more like arbitrary symbols (i.e., signed words). However, if we included them, the patterns of results do not change.

speech. At initial observation, children occasionally used onomatopoeic sounds to identify referents in speech (e.g., meow for cat); we treated these onomatopoeic sounds as words as well. For the subsequent four observations, we assessed children's spoken vocabulary for the referents initially expressed uniquely in gesture to determine whether these referents appeared later as words. For the referents that later appeared as words, we estimated the time difference between the appearance of the referent in gesture and the appearance of the referent in speech to document the relative timing of the expression of the same referent in the two modalities.

Intercoder agreement was assessed with a second coder who independently coded a randomly selected 15% of the videorecords in each group. Agreement between coders was 89%, κ=.87 (TD: 91%, ASD: 86%, DS: 86%,) for identifying gestures, 92%, κ=.91 (TD: 93%, ASD: 93%, DS: 89%) for assigning meaning to gestures, 95%, κ=.93 (TD: 96%, AU: 98%, DS: 91%) for classifying gestures into types.

Analysis

Children showed considerable group differences in their production of unique gestures during the first observation (M_{TD}=8.91 [SD=4.10] vs. M_{DS}=7.74 [SD=4.79] vs. M_{ASD}=4.43 [SD=2.68]; $F(2,66)=8.12$, $p=.001$, $\eta^2_p=.20$). To compare the relative prevalence of referents conveyed uniquely in gesture or in speech, we calculated the proportion of referents that were produced uniquely in gesture and uniquely in speech for each child, conducted arcsine transformations, and analyzed them in two separate mixed ANOVAs: (1) *group* as between- (ASD, DS, TD) and *modality of expression* (uniquely expressed in gesture, uniquely expressed in speech) as within-subject factors, and (2) *group* (ASD, DS, TD) as between- and *modality shift from gesture to speech* (referent initially expressed uniquely in gesture and appeared later in speech, referent initially expressed uniquely in gesture but did not appear later in speech) as within-subject factors. In addition, for each child, we calculated how long it took to shift from gesture to speech for all referents that were conveyed uniquely in gesture at initial observation and later, during the next year, expressed in speech. We then examined differences with an additional mixed ANOVA, with group as between- (ASD, DS, TD) and *timing of modality shift from gesture to speech* (age of appearance in gesture, age of appearance in speech) as within-subject factors.[3] We also assessed the predictive relation between the age that we observed each child initially expressed referents uniquely in gesture (set by the child's age at initial observation) and the mean age for the same referents each child later expressed in speech, using Pearson correlations.

Results

We first focused on the preferred *modality of expression* in communicating about referents at the initial observation session. We asked whether children with ASD or with DS were as likely as TD children to indicate or request a greater proportion of referents uniquely in gesture than in speech. Children's production of unique referents showed no main effect of

[3]It is important to note that for children in all three groups the age noted for the use of a gesture for a particular referent was child age at initial observation. It is therefore possible that the child might have indicated any of the unique gesture referents earlier than specified in the current analysis.

group (F(2,66)=0.95, p=.39), but a main effect of *modality* (F(1,66)=53.07, p<.001, η^2_p =0.45). Children produced greater proportion of referents uniquely in gesture (.77) than they did so in speech—a pattern that remained robust in each of the three groups (see Fig. 1)—with no significant interaction between group and modality (F(2,66)=2.33, p=.11).

Next we focused on *modality shift from gesture to speech*. We asked whether the referents children expressed uniquely in gesture at the initial observation did or did not appear in children's speech as words within the next year and whether this pattern was similar across the three groups. The proportion of referents that were initially conveyed in gesture and appeared in speech during the following year showed no main effect of *group* (F(2,63)=1.06, p=.35), but a main effect of *modality shift from gesture to speech* (F(1,63)= 4.46, p=.04, η^2_p =.07), and more importantly, a significant interaction between *group and modality shift* (F(2,63)=6.45, p=.003, η^2_p =.17). Many of the referents conveyed uniquely in gesture entered children's spoken vocabularies as words for both TD children (.53) and children with ASD (.50) within a year—a pattern that was less pronounced for children with DS (.20), who differed significantly from both groups (*Bonferroni*, p_s≤.02).

Last we focused on the *timing of the modality shift from gesture to speech* for the referents that were conveyed uniquely in gesture at initial observation and later expressed in speech as words. We asked whether the time difference in the emergence of referents in gesture and later in speech was similar in each group. We found an effect of modality (F(1,48)=427.92, p<.001, η^2_p =.90)—with earlier onset of referents in gesture than in speech (M=26.16 months vs. M=33.96 months), an effect of group (F(2,48)=92.36, p<.001, η^2_p =.79), but more importantly a significant interaction between group and modality (F(2,48)=9.52, p<.001, η^2_p =.28). The average time interval between the initial observation of a referent in gesture and when it was observed in speech was similar in children with TD (M=6.54 months, SD=2.23) and with ASD (M=6.71 months, SD=2.64), but was significantly longer for children with DS (M=10.61 months, SD=2.87; *Bonferroni*, p_s≤.001; see Fig. 2). Nevertheless, there was a significant positive correlation between the age at which a child expressed referents uniquely in gesture and the mean age they were expressed later in speech both across the three groups (r=.93, p<.001) and within each group (ASD: r=.87, p<.001; DS: r=.81, p<.001), underscoring the tight link between early gestures and early words.[4]

Discussion

In this study, we asked whether gesture remains a robust aspect of vocabulary development process in children with ASD and with DS, who differ strongly in gesture production, as compared to TD children. More specifically, we asked whether children with ASD or with DS would initially indicate referents uniquely in gesture before they do so with words, and whether the relative delays in the expression of a particular referent first in gesture and then later in speech remains similar across different learners. We found that children in each group initially expressed a greater proportion of referents uniquely in gesture than they did so in speech. More important, the majority of these unique gestures subsequently entered

[4]We could not compute correlations for the age of initial observation of referents in gesture and the age when they were observed in speech for TD children because there was very limited variability for child age at the initial visit (see Table 1).

children's vocabularies as words, with an average time lag of 6 months—except for children with DS, whose word production remained more markedly delayed. Our findings show that gesture is a fundamental aspect of vocabulary development, remaining preserved even in children with ASD, who show relative weaknesses in gesture production.

How does gesture help with vocabulary development across different learners? One explanation could be that gesture serves as a signal to the caregiver that the child is ready for the relevant input. As shown in previous work (Marcos, 1991; Olson & Masur, 2013, 2015), parents are highly responsive to their children's gestures, routinely providing words for the majority of referents children convey uniquely in gesture. More important, the referents that children convey in gesture (e.g., point at bottle) when translated into words by the parent (e.g., "Want your bottle?"), are more likely to become part of children's verbal lexicons several months later, compared to the ones that are not translated (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). In fact, earlier work (Dimitrova, Özçalışkan, & Adamson, 2016) that examined the parental verbal responses to the unique gestures produced by the three groups of children in our sample showed that parents of children with ASD and with DS were as likely as parents of TD children to respond to and translate the gestures that their children produced. The gestures, when translated into words by their parents, were also more likely to enter children's speech vocabularies as words than gestures that were not translated, highlighting the critical role parents' timely input to child gesture might play in vocabulary development.

In addition to the effect of timely verbal input children receive from their parents to their gestures, another likely explanation—although not mutually-exclusive— is that the act of gesturing itself might also help children take the next step in language learning, largely by reducing cognitive load (Goldin-Meadow, 2014). Even though there is very little empirical work that has tested this possibility within the domain of language development, previous work that shows close temporal contingency between the achievement of different language milestones in gesture and in speech—from first words to first explanations (for reviews see Goldin-Meadow, 2014; Özçalışkan & Hodges, 2016)—supports its likelihood. On the road to mastery of different language milestones in speech, gesture offers children a cognitively easier communicative tool to practice their burgeoning knowledge of different linguistic abilities. For example, a child can share information about an object by pointing at it (e.g., point to bicycle) or convey propositional information related to the object by combining a word with a pointing gesture ("ride" + point to bicycle). Both of these options impose fewer memory demands, thus a lower cognitive load, than labeling the same object with a word ("bicycle") or sharing propositional information about the object in a sentence ("ride bicycle"), as all gesture requires is the extension of the index finger or the open palm towards a referent.

Our findings also showed more pronounced delays in children with DS in the transition from gestures to words. A likely explanation for this finding, also suggested by earlier work (Beeghly & Cicchetti, 1987; Miller, 1999), is that children with DS show markedly lower rates of speech production (even compared to children with ASD)—largely because of impairments in the phonological loop components of memory that feed into the articulation of meaningful sounds. However, their visual short-term memory largely remains unaffected, making the nonverbal modality a more accessible communicative tool (Broadley, MacDonald & Buckley, 1995; Jarrold & Baddaley, 2001). Children with DS, in fact, are often encouraged to retain use of the manual modality using both gestures and baby signs to compensate for the difficulties they experience in speech (Caselli et al., 1998; Franco & Wishart, 1995). Importantly, the children in our study were already conveying a substantial proportion of referents in gesture at initial observation, some of which entered children's vocabularies as words at the end of our observations, one year later. We predict that many of these unique gesture referents would have eventually become part of children's verbal repertoires as words, if we had the opportunity to observe their speech production for more than a year—a caveat that might be essential to take into account in future studies.

Our findings also show that the movement from gesture to speech in the emergence of particular vocabulary items found in TD children occurs in children with ASD as well, even though they produced significantly fewer unique gestures at initial observation. This similarity across different groups of language learners suggests that first identifying a referent in gesture could facilitate its subsequent acquisition in speech. As earlier work suggests, gesture might play a unique role in learning because of its status as "representational action"–a unique type of action that not only facilitates generalization beyond the specific context of use but one that also enhances retention of information over developmental time (Novack & Goldin-Meadow, 2016). As such, the act of indicating referents uniquely in gesture, even if it is only a few times, might still suffice to retain the information about the different referents and generalize expression of the referents from gesture to speech in subsequent observations. It is also important to note here that children with ASD, unlike children with DS or TD children, predominantly used give gestures when they identified referents uniquely in gesture, highlighting how ASD may alter the type of gesture by which children single out referents in their early communications while still preserving the way gesture provides a helpful hand to spoken vocabulary development.

Our findings also revealed an interesting diagnosis-specific difference between children with DS and with ASD in the way their early gestures related to their emerging vocabularies in speech. Children with DS produced significantly more referents uniquely in gesture than children with ASD; yet significantly lower proportion of unique gesture referents entered the spoken language vocabularies of children with DS compared to children with ASD. Unlike words, which are symbols that gain their meaning within a system of other symbols in a language (i.e., sign-sign relations), early gestures that identify referents almost always gain their meaning via indexical relations with entities that are physically or temporally available in the immediate environment (Peirce, 1955). Given the marked difficulties children with ASD show in sustaining joint engagement with adults around physically available objects—particularly compared to children with DS who show relative strengths in joint engagement (Adamson et al., 2009), it is not surprising that we found fewer number of referents uniquely identified in gesture in the early communications of children with ASD, compared to children with DS. However, more importantly, the advantage that children with DS show in the production of unique gestures (i.e., index-referent relations) was not reflected in their production of words to identify the same referents in speech, raising the possibility that children with DS might be more prone to difficulties in their use of symbols (i.e., symbol-referent relations), as compared to children with ASD.

The question still remains, however, whether there is a causal relation between early vocabularies in gesture and in speech across different learners. The observational nature of our study prevents us from attributing a causal role to gesture in spoken vocabulary development. However, an intriguing experimental study with TD children suggests that the relation may indeed be causal: 17-month-old toddlers who were instructed to point during a book reading task developed a larger repertoire of words 2 months than toddlers who were told not to point (LeBarton, Raudenbush, & Goldin-Meadow, 2015). Future studies that manipulate child gesture and document the effects of these manipulations on subsequent vocabulary development in children with developmental disorders could shed further light on a possible causal link between gestures and words in early language development of children with different developmental profiles.

In summary, our findings underscore the robustness of the gesture-speech system in language development across different learners. Children with ASD or with DS use gesture as readily as TD children to indicate referents that they cannot yet express in speech; these gestures then provide stepping stones for the appearance of words for the same referents, with parallel delays in both gesture and speech.

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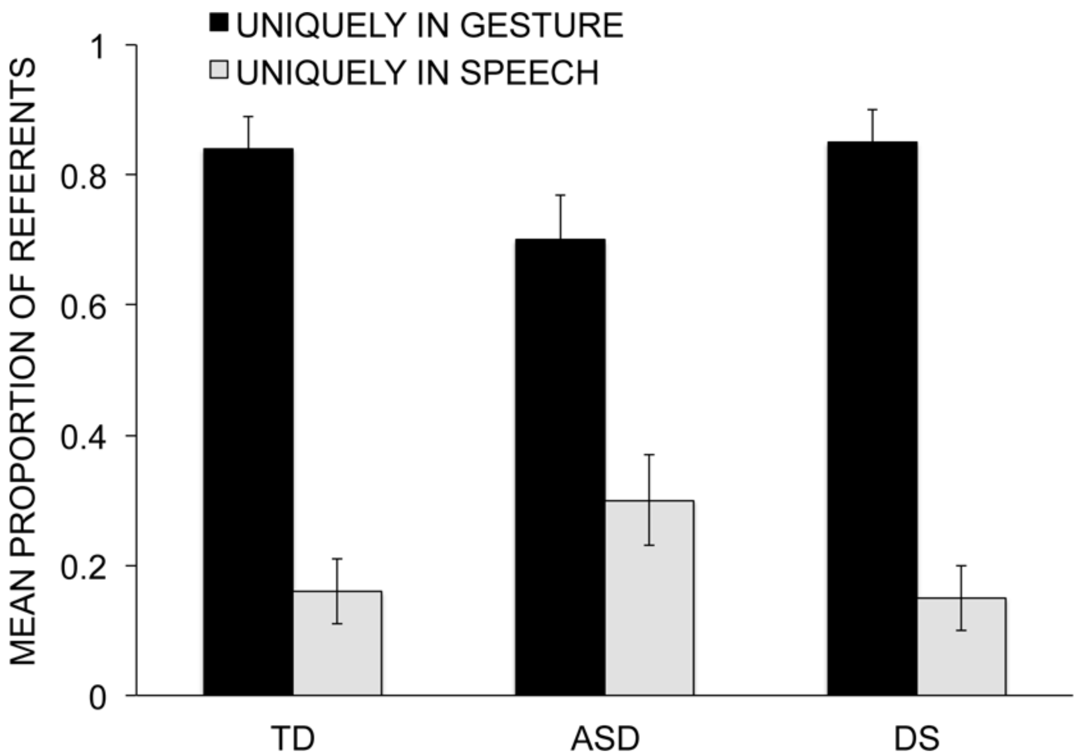

Fig. 1.

Mean proportion of referents children indicated uniquely in gesture but not in speech (dark columns) and uniquely in speech but not in gesture (light columns) in TD children, children with autism spectrum disorder (ASD) and children with Down syndrome (DS) at child mean age 18 months for TD children and 30 months for children with ASD and with DS; bars represent standard errors. The majority of the unique gestures that conveyed information about objects were requests for objects for children ASD (.59) but not for children with DS (.40), or for TD children (.40).

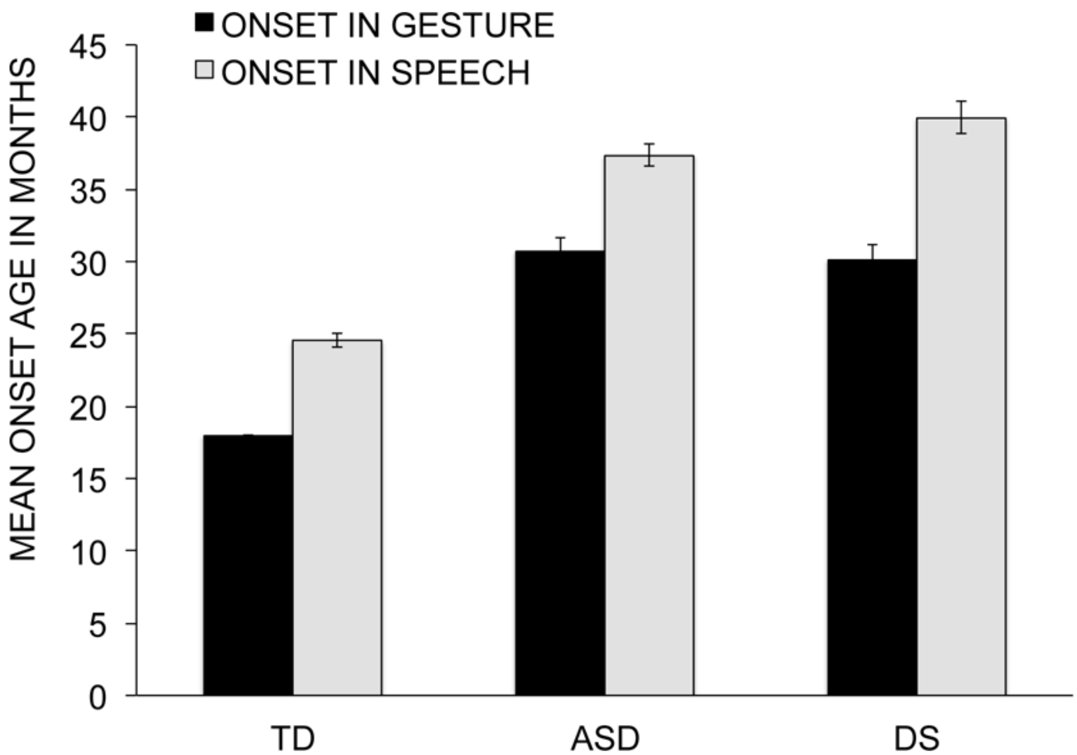

Fig. 2.

Mean age of observation of the appearance of referents conveyed uniquely in gesture (dark columns) at the initial visit and later in speech (light columns) in TD children, children with autism spectrum disorder (ASD) and children with Down syndrome (DS); bars represent standard errors. The age at the initial observation varied considerably for children with ASD (range =21.40-36.92 months) and with DS (range=24.0-40.54 months), but not for children with TD (range =17.56-18.28 months). Subsequent visits were scheduled at three-month intervals.

Table 1

Sample characteristics

	ASD (n=23)	DS (n=23)	TD (n=23)
Mean age in months at initial observation (SD)	30.81 (4.59)	29.87 (5.05)	18.05 (0.27)
Child Gender	20M, 3F	17M, 6F	18M, 5F
Mean word tokens at initial observation (SD)	172.91 (195.88) range=11-667	145.43 (88.78) range=35-381	168.26 (125.18) range=44-528
Mean word types at initial observation (SD)	39.65 (49.07) range=4-164	18.35 (22.78) range=4-116	28.43 (26.89) range=7-126
Mean word tokens at final observation (SD)	349.05 (226.51) range=13-699	284.95 (132.93) range=71-483	575.18 (228.75) range=229-1155
Mean word types at final observation (SD)[5]	103.16 (81.13) range=3-261	50.65 (32.89) range=4-117	166.14 (68.47) range=50-319

[5]We missed the final observations for a few of the children in our sample, including 4 children with ASD, 3 children with DS and 1 child with TD.