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BRIEF REPORT

Brief Report: Gestures in Children at Risk for Autism Spectrum Disorders

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Abstract Retrospective video analyses indicate that disruptions in gesture use occur as early as 9–12 months of age in infants later diagnosed with autism spectrum disorders (ASD). We report a prospective study of gesture use in 42 children identified as at-risk for ASD using a general population screening. At age 13–15 months, gesture were more disrupted in infants who, at 20–24 months, met cutoffs for "autism" on the ADOS than for those who met cutoffs for "autism spectrum" or those who did not meet cutoffs for either, whereas these latter two groups displayed similar patterns of gesture use. Total gestures predicted later receptive and expressive language outcomes; therefore, gesture use may help identify infants who can benefit from early communication interventions.

Keywords Autism spectrum disorders · Early identification · Gesture · Infants

Introduction

Autism spectrum disorders (ASD) are characterized by deficits in social behavior, communication and repetitive and restrictive behaviors. Although definitive diagnosis often does not occur until 3 years of age or later (Autism and Developmental Disabilities Monitoring Network 2014), evidence indicates that intervention at the earliest possible age is highly beneficial (Roberts and Prior 2006; Rogers and Vismara 2008). Therefore, substantial research has focused on methods of early identification and characterizing indicators of ASD to facilitate early diagnosis. Disruptions in certain behaviors, such as gaze shifts, responding to name, and gesture use, serve as early ASD warning signs (Baranek 1999; Mitchell et al. 2006; Wetherby et al. 2007; Watson et al. 2013). Likewise, parental report screening instruments such as the First Year Inventory (FYI; Baranek et al. 2003) and the Modified Checklist for Autism in Toddlers (M-CHAT; Robins et al. 2001) have been developed to screen for at-risk children. The FYI is a screening tool designed for 12-month-old children containing items assessing behaviors indicating risk in two broad domains: sensory-regulatory and social-communication functioning. Approximately 44 % of 12-month-old children who meet cutoffs in both domains will receive a diagnosis of ASD at 3 years of age (Turner-Brown et al. 2013).

The use of gestures as an early identifier has been of considerable interest as gesture production is highly predictive of later communicative skills in typically developing children (Rowe and Goldin-Meadow 2009). "Gestures" is used here to refer to communicative gestures, or behaviors involving intentional movements that are interpreted by others as communicating meaning, which typically develop as early as 7–9 months of age (Crais et al. 2004; Guidetti and Nicoladis 2008; Iverson and Goldin-Meadow 2005). A widely accepted framework of the three earliest functions of intentional communication in young infants is Bruner's (1981) taxonomy. Behavior regulation (BR) gestures are defined as those used to control another person's behavior (e.g., requesting an out-

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of-reach object). Social interaction (SI) gestures are those that focus on the mutual interaction between the dyad (e.g., playing peek-a-boo). Joint attention (JA) gestures include those used to draw another person's attention to an object or event (e.g., showing, pointing).

Disruptions in both total gesture use and the communicative functions of gestures are characteristic of children with ASD (Carpenter et al. 2002; Loveland et al. 1988; Mundy et al. 1990; Wetherby and Prutting 1984). In fact, research using retrospective video analysis indicated that gesture disruption occurs as early as 9–12 months of age in infants later diagnosed with ASD, who use fewer JA and BR gestures and at 15–18 months were less likely to use all categories of gestures (Watson et al. 2013). Likewise, children later diagnosed with ASD also displayed less variation in SI gestures used at 9–12 months (Colgan et al. 2006). Prospective studies of at-risk infants with siblings with ASD also report altered gesture use as early as 12 months among infant siblings who are later diagnosed with ASD (Mitchell et al. 2006; Talbott et al. 2013; Veness et al. 2012). Specifically, at-risk infant siblings use fewer JA gestures at 12 months (Rozga et al. 2011).

Building on our previous work using retrospective home videos (Watson et al. 2013), the current study is a prospective study of gesture use in children 13–15 months old identified as at-risk for ASD. Unlike previous research using infant siblings, these at-risk infants have been identified from the general population using the FYI. The goal of this study was to compare early gesture use with later developmental and ASD symptom outcomes at 20–24 months old.

Methods

Participants

Participants included 42 children (30 male, 12 female) between 13 and 15 months old at the initial assessment. Eligibility criteria included that English was spoken in the home at least 50 % of the time. By parent report, 29 children (69 %) were identified as White, 8 (19 %) as African–American, 1 (2 %) as Asian, and 4 (10 %) of more than one race (3 as African–American and White, and 1 as American Indian and White). One child's ethnicity was Hispanic; all others were non-Hispanic. For comparison, in our catchment area in 2007, approximately 53 % of new mothers were White/non-Hispanic, 28 % African–American/non-Hispanic; and 19 % of other race/ethnicity combinations. The highest education level of the primary caregivers for the children (the mother for 41 of 42 children) was a high school diploma or less for 5 families (11 %); trade school, associate's degree, or some college coursework for 6 families (14 %), bachelor's degree for 15 families (36 %), and graduate/professional degree for 16 families (38 %). Due to response bias, our sample was more highly educated than expected in the catchment area, where in 2007, 41 % of new mothers had a high school education or less, 18 % had some college or trade school, and 41 % had a college degree or higher.

The children were identified from the general population as at-risk for ASD using the FYI (Reznick et al. 2007; Turner-Brown et al. 2013). The FYI was mailed to families in the catchment area for the study just prior to the child's first birthday, using birth records obtained from the state in which the study was conducted. Parents were invited to complete the FYI and return it to the project staff in a stamped, pre-addressed envelope, along with their contact information and permission for follow-up contact if their child's FYI scores indicated the child might be eligible for the study. Based off previous studies, cut-off criteria to identify children as at-risk for ASD required scores at or above the 94th percentile in the social-communication domain and at or above the 88th percentile in the sensory-regulatory domain.

General Procedures

As part of a larger intervention study, all children completed in-person evaluations between 13 and 15 months (Time 1). Gestures were coded from a 10-min videotaped session where children played freely with a set of toys with a parent (95 % with mother) during this visit. A battery of standardized assessments was given to the children during this evaluation, including the Mullen scales of early learning (MSEL; Mullen 1995). Following this assessment, consenting families were randomized to a parent-responsiveness intervention group or to a control group referred to community services; however the effects of intervention group are not tested in the analyses reported in the current paper. The children returned between ages 20–24 months for a second evaluation (Time 2). The primary outcomes from this time included in the current study are the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999) Module 1 and the MSEL (Table 1). It should be noted that while the ADOS was administered at this time, definitive clinical diagnoses were not made at 20–24 months as part of the standardized protocol of the larger study. For the purposes of this study, ADOS algorithm cutoffs were used to place the children into one of three groups: (a) "autism," or those who exhibit the most classic symptoms of ASD, likely to be associated with a clinical diagnosis of Autistic Disorder using DSM-IV-TR (American Psychiatric Association 2000, 2013) criteria; (b) "autism spectrum," or those with symptoms likely to be associated with clinical diagnoses such as Asperger's

Table 1 Ages and MSEL scores of participants at time 1 and time 2 (Non-ASD, $N = 13$; AS, $N = 15$; AUT, $N = 14$)

	Time 1 Mean (SD) Range			Time 2 Mean (SD) Range		
	Non-ASD	AS	AUT	Non-ASD	AS	AUT
Age in months	13.9 (.6)	13.9 (.7)	13.8 (.7)	21.9 (1.0)	22.2 (.6)	22.3 (.6)
	13–15	13–15	13–15	20–24	21–23	21–23
MSEL ELC	84.6 (9.6)	88.1 (17.3)	79.0 (18.1)	96.5 (15.1)	95.1 (22.0)	79.5 (23.4)
	70–106	55–117	56–115	70–122	63–135	49–121
MSEL RL T-score	32.9 (5.4)	38.9 (14.7)	30.6 (10.9)	52.3 (13.0)	49.3 (14.8)	35.6 (16.8)
	21–40	21–69	20–53	30–68	30–68	20–66
MSEL EL T-score	38.5 (11.5)	38.5 (12.7)	35.6 (13.4)	42.7 (6.1)	45.9 (14.0)	38.1 (15.6)
	20–61	20–56	20–65	33–52	22–70	20–68
MSEL VR T-score	46.9 (7.6)	46.7 (9.8)	40.1 (13.1)	50.0 (12.8)	49.1 (12.4)	44.1 (12.4)
	36–61	27–59	20–62	28–75	29–79	20–64
MSEL FM T-score	50.1 (7.4)	50.3 (11.9)	47.9 (10.7)	47.1 (8.1)	44.7 (12.0)	36.4 (14.1)
	38–59	22–64	22–63	36–62	27–66	20–60

MSEL Mullen scales of early learning, *Non-ASD* ADOS algorithm score in the non-autism spectrum disorder range, *AS* ADOS algorithm score in the "autism spectrum" range, *AUT* ADOS algorithm score in the "autism" range, *ELC* early learning composite, standardized score (mean of 100, SD of 15), *RL* receptive language, *EL* expressive language, *VR* visual reception, *FM* fine motor, *T-score* standardized score (mean of 50, SD of 10)

Disorder or Pervasive Developmental Disorder-Not Otherwise Specified using DSM-IV-TR diagnostic criteria; and (c) "non-ASD," or those whose symptoms would not likely meet the criteria for a diagnosis of a Pervasive Developmental Disorder using DSM-IV-TR. Our research spans a time of transition from DSM-IV-TR to DSM-5, and we will consider some of the associated issues in our discussion. In addition, Module 1 of the ADOS was used in this study because the Toddler Module had not yet been published. Current recommendations are to use the ADOS Toddler Module with 12- to 30-month-old children.

Coding Procedures

Gesture coding methods were based on Watson et al. (2013), and adapted for computerized use with Observer software (Noldus Information Technology). Gestures were coded using a checklist to make three judgments regarding the child's behavior. First, was the behavior among those listed as potential gestures? Options were: reaching, pointing, nodding or shaking head, clapping, representative gestures (e.g., talking on the phone), or conventional gestures (e.g., dancing, covering eyes for peekaboo). Second, was there evidence that the child was directing the behavior to another person? Options were: vocalizations, eye contact, touching a person, engagement in a social game. Third, did the behavior serve a communicative function of SI, BR, or JA? Finally, gestures could be initiated by the child or elicited by another person (e.g., "Wave bye–bye"), but were not counted if the child was physically prompted to use the gesture.

The first author and a research assistant both independently coded all videos. Coders completed a manualized training program on coding gestures, first, using home videos of infants not included in current dataset for practice and reliability, then with a second set of five video clips from the current dataset (training data were not included in the final dataset and the videos were re-coded with the full set). Reliability between coders across all videos was estimated with Type A intraclass correlations (ICCs), testing for absolute agreement. Mean ICCs were: .98 (95 % CI .97–.99) for SI, .91 (95 % CI .81–.95) for BR, and .49 (95 % CI .06–.72) for JA. The low frequencies of JA gestures impacted the ICCs for this category. Therefore, coders met regularly to discuss procedures, compare coding, and reach consensus on disagreements. Consensus codes were used for all data analyses. ICCs for Rater 1with consensus were: .99 (95 % CI .99–.99) for SI, .94 (95 % CI .89–.97) for BR, and .87 (95 % CI .76–.93) for JA. ICCs for Rater 2 with consensus were: .99 (95 % CI .98–.99) for SI, .96 (95 % CI .92–.98) for BR, and .78 (95 % CI .60–.88) for JA.

Results

Gesture Use

Across all 42 children, a total of 303 gestures were coded. Comparing Time 1 gesture use using Time 2 classifications on the ADOS, children who later met cutoffs for "autism" (AUT group, n = 14) produced a total of 62 gestures, children who later met cutoffs for "autism spectrum" (AS group, n = 15) produced 124 gestures, and children who did not meet cutoffs for AUT or AS (Non-ASD group, n = 13) produced 117 gestures.

On average, children in the AUT group used about half as many total gestures as those in either the AS or Non-ASD groups (see Table 2). The statistics for skewness (1.7, $SE = .4$) and kurtosis (2.1, $SE = .7$) indicated that our data departed substantially from a normal distribution. We thus completed a nonparametric Kruskal–Wallis analysis to compare the mean ranks for total gestures used across the three groups (mean ranks = 26.8, 23.9 and 14.1 for the Non-ASD, AS, and AUT groups, respectively), and found a significant difference, χ^2 $(2, N = 42) = 8.2$, $p = 0.017$. Post-hoc comparisons confirmed that the mean rank of the AUT group was significantly lower than both the Non-ASD and AS groups, which did not differ from each other.

The patterns of the communicative functions of gestures also tended to differ in the AUT group compared to the two other groups. Using Fisher's exact test (as our data contained expected cell values <5), the proportion of children in each group with no observed gestures to children with one or more observed gestures across gesture categories was compared. A significant association between SI gestures and ADOS classifications was found, $p = 0.039$. Only 7 of 14 children in the AUT group used one or more SI gestures, while 12 of 15 children in the AS group and 12 of 13 children in the Non-ASD group used one or more SI gestures. There were no significant differences in the proportions of children producing BR gestures across groups ($p = 0.19$), nor JA gestures ($p = 0.33$). Specifically, 7 of 14 children in the AUT group, 10 of 15 children in the AS group and 11 of 13 children in the Non-ASD group used one or more BR gestures. JA gestures were relatively infrequent across all groups: 2 of 14 children in the AUT group, 6 of 15 children in the AS group and 4 of 13 children in the Non-ASD group used one or more JA gestures.

Finally, in terms of the predictive power of early gesture use for later language development, linear regression analyses showed that total gesture use across all groups at Time 1 predicted both Expressive Language, $\beta = 0.34$, $t(40) = 2.3$, $p = 0.027$, and Receptive Language, $\beta = 0.36$, $t(40) = 2.4$, $p = 0.019$, on the MSEL at Time 2.

Follow-Up: Understanding ADOS Classification Groups

The at-risk children in the Non-ASD group and the AS group had very similar gesture use, both in terms of total gestures as well as the proportions of gestures falling within each category. In contrast, the AUT group produced only about half as many total gestures and used relatively fewer SI gestures. We wanted to better understand the relationship between the observed patterns of gesture use and ADOS scores. The algorithm for calculating ADOS scores includes a combination of points from the social/communication domains and repetitive/restrictive domains, such that higher scores represent more unusual behavior. Based on the higher use of gestures in the current study in the AS group compared to the AUT group, we considered two potential explanations. One possibility is that compared to children in the AUT group, those in the AS group had relatively intact social/communication behaviors and thus received few points on the ADOS in those domains, but had more unusual repetitive/restrictive behaviors resulting in higher points in those domains. Another possibility is that children in the AS group exhibited as many social/communication symptoms on the ADOS as children in the AUT group, but their symptoms were less severe in expression (e.g., mildly unusual in quality, represented by lower scores of "one" on the ADOS algorithm scores) while the AUT group exhibited more extreme

Table 2 Average gesture use across groups and gesture type

	Total Mean (SD) Range	JA Mean (SD) Range	SI Mean (SD) Range	BR Mean (SD) Range
Non-ASD group	9.0 (7.6)	1.0 (1.9)	4.7 (5.2)	3.3 (3.0)
	3–25	0–6	0–18	0–10
AS group	8.3 (9.4)	1.1 (1.6)	4.1 (4.3)	3.0 (4.3)
	0–33	0–5	0–16	0–14
AUT group	4.4 (7.1)	0.1 (0.3)	2.6 (4.6)	1.7 (2.8)
	0–23	0–1	0–13	0–10

Groups are children who met ADOS algorithm cutoffs for "autism" (AUT), "autism spectrum" (AS), and those who did not meet cutoffs (Non-ASD) on the Autism Diagnostic Observation Schedule

JA Joint attention gestures, *SI* social interaction gestures, *BR* behavior regulation gestures social/communication symptoms (e.g., often an absence of expected social/communication behaviors, represented by higher scores of "two" on the ADOS algorithm scores).

We analyzed the distribution of the points across domains on the ADOS to better understand these group differences. The points from the repetitive/restrictive behaviors domain as a proportion of the total ADOS score was similar across groups (AS = 28.9 %, AUT = 27.2 %), suggesting that both groups had closely comparable distributions of points from the social-communication domain and repetitive/restrictive behaviors domains. However, comparing the proportion of scores of zero, one or two (where two represents the most severe disruption) in the AS and AUT groups, we found a difference in the severity of the scores in the social/communication domain (Fig. 1). The AS group had a similar proportion of scores of one as the AUT group, χ^2 (2, $N = 29$) = 6.0, $p = 0.41$, but significantly fewer scores of two, χ^2 (2, $N = 29$) = 17.6, $p = 0.014$.

Discussion

In interpreting the differences or absence of differences among these three groups in this study, it is important to remember that all the infants had scored at-risk for later diagnoses of ASD based on parental responses on the FYI at 12 months. Their high-risk scores included elevated social-communication symptoms. Thus, it is not surprising that the mean receptive and expressive language scores on the MSEL for each group were greater than one standard deviation below the mean at the initial assessment. In fact, a careful examination of Table 1 reveals that all 13 infants in the Non-ASD group had receptive and/or expressive language scores on the MSEL that were one or more standard deviations below the mean at 13–15 months of age.

In light of the high risk status of the infants in all three groups, it is particularly notable that the use of gestures at 13–15 months of age were more limited in infants who later met ADOS cutoffs for autistic disorder (AUT) than for those who met the cutoffs for autism spectrum (AS) or those who did not meet cutoffs for either AUT or AS (Non-ASD), whereas these latter two groups of at-risk infants looked very similar to one another in their frequency and patterns of gesture use. The generally delayed language skills across all groups may help account for the fact that only less than half of the infants in any of the groups used JA gestures at 13–15 months. Research with typically developing infants has indicated that the use of gestures for JA tends to develop slightly later than the use of gestures for SI or BR (Crais et al. 2004). Although there were no significant differences in the proportion of children using JA gestures across groups, there were only two infants in the AUT group who used any JA gestures, and they only produced one JA gesture each. Thus, our data are in line with previous findings showing infrequent use of JA gestures by infants and toddlers who later receive diagnoses of ASD (e.g., Watson et al. 2013). However, because of the limited use of JA gestures among other at-risk infants at this young age, the lack of JA gestures is not as useful in identifying the infants most likely to develop the more classic symptoms of ASD.

Despite the at-risk status of all the infants in this study, however, a relatively low use of SI gestures was particularly evident among infants in the AUT group compared to those in the AS and Non-ASD groups. This pattern of gesture use fits with previous retrospective video analyses of infants later diagnosed with ASD as well as with prospective analyses of infant siblings of children with ASD (Colgan et al. 2006; Rozga et al. 2011; Watson et al. 2013). However, as disruptions in early gesture use were most evident for those who met cutoffs for AUT, the utility of early gesture use for predicting future ASD diagnoses may be limited to only those children whose symptoms are most "classic" or severe. Nevertheless, identifying such children early in life may be important, as these infants may especially benefit from early intensive and comprehensive interventions.

Evidence from our follow-up analysis suggests that the children who met cutoffs for AS differed from those who met cutoffs for AUT not in terms of the number of symptoms scored on the ADOS but rather in terms of the severity of their ADOS scores in the social/communication domain. The algorithm for calculating ADOS scores includes a combination of scores from the social/communication domains and repetitive/restrictive domains; algorithm scores on individual items range from 0 to 2, such that higher scores represent more extreme symptoms. Children in the AUT group received a higher proportion of scores of "two" in the social/communication domain relative to children in the AS group. This is particularly

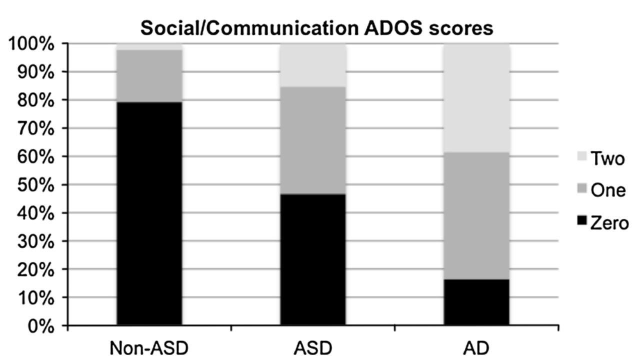

Fig. 1 The percentage of ADOS scores in the social/communication domain of zero, one or two in the children meeting diagnostic cutoffs for autism (AUT), autism spectrum (AS), and those who did not meet cutoffs (Non-ASD)

informative for understanding the relationship between gesture use in the current study and the social/communication domain on the ADOS. In the current gesture analysis, we simply evaluated whether or not the gesture occurred and what function it served, but did not go further to evaluate the qualitative appropriateness of the gesture in context. We suspect that children in the AS group likely exhibited gestures both in parent–child free play sessions and on the ADOS, but they may not have been used with the expected quality (e.g., failing to coordinate eye contact with gestures effectively), thus receiving scores of one, whereas children in the AUT group did not exhibit many gestures (or other social/communication behaviors) in either situation, leading to more scores of two. Future studies should evaluate more fully the social quality of gestures used by young children at-risk for ASD, as this may provide insightful differences for the less severe cases of ASD.

These results are particularly interesting considering the changes to ASD diagnostic criteria in DSM-5, which effectively collapses AS and AUT groups into one category, with further description of the severity of symptoms in both the social-communication and repetitive behaviors and interests domains. To date, the limited relevant research suggests conflicting conclusions about the proportion of at-risk toddlers meeting DSM-IV-TR criteria who would also meet DSM-5 criteria (e.g., Huerta et al. 2012; Matson et al. 2012). At this point, there is no research base examining the ability of early risk markers for ASD in infants to predict ASD diagnoses using DSM-5 criteria. Beyond predicting later diagnostic outcome, it will be interesting to see how well differences in gesture use by young children correlate with the new severity levels outlined in DSM-5.

Across all at-risk infants, early gestures were significantly associated with later receptive and expressive language outcomes on the MSEL. This suggests that as early as 13–15 months, gesture use may help identify infants who can benefit from early communication interventions. Getting at-risk infants enrolled in communication interventions early could be advantageous not only in improving language outcomes, but also in having opportunities to continue to monitor other aspects of their development for more specific symptoms of ASD.

We believe one of the strengths of this study is the generalizability of the findings because of the use of children at-risk for ASD from the general population. It is important to note that *all* children in this study had elevated FYI scores, meaning that they all exhibited risk factors for developmental disorders. A limitation of the current study is that we did not include a group of typically developing children who did not have elevated FYI scores. Keeping this in mind, although the children in the Non-ASD group did not meet cutoffs on the ADOS for "autism" or "autism spectrum" at Time 2, they did display characteristics that caused them to have elevated FYI scores at 12 months, indicative of ASD risk. In earlier research, 85 % of children who met risk cut-offs on the FYI exhibited developmental problems by age three, even if they did not show symptoms of ASD (Turner-Brown et al. 2013). This may help explain the lack of differences seen between the children in the Non-ASD group and the AS group. Likewise, the ADOS classifications should not be considered definitive diagnoses, particularly since the children were below 2 years of age at the time of ADOS administration and Module 1 of the ADOS is not the currently recommended module for children in this age range. Finally, a limitation of the current study is that, due to the preliminary nature of the data, we did not adjust *p*-values for multiple comparisons. In the future, our goal is to follow up with these children to obtain definitive clinical diagnoses, and to better understand the relationship between gesture use and language outcomes in developmental disorders.

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