Published in final edited form as:

J Autism Dev Disord. 2012 April ; 42(4): 487–498. doi:10.1007/s10803-011-1262-5.

Selective Visual Attention at Twelve Months: Signs of Autism in Early Social Interactions

Ted Hutman,

UCLA Center for Autism Research & Treatment, Semel Institute for Neuroscience & Human Behavior, David Geffen School of Medicine at UCLA, 760 Westwood Plaza, Room 68-237, Los Angeles, CA 90095-1759, USA

Mandeep K. Chela,

Department of Psychology, UCLA, Los Angeles, CA 90095-1563, USA

Kristen Gillespie-Lynch, and

Department of Psychology, UCLA, Los Angeles, CA 90095-1563, USA

Marian Sigman

UCLA Center for Autism Research & Treatment, Semel Institute for Neuroscience & Human Behavior, David Geffen School of Medicine at UCLA, 760 Westwood Plaza, Room 68-237, Los Angeles, CA 90095-1759, USA

Ted Hutman: thutman@mednet.ucla.edu

Abstract

We examined social attention and attention shifting during (a) a play interaction between 12-month olds and an examiner and (b) after the examiner pretended to hurt herself. We coded the target and duration of infants' visual fixations and frequency of attention shifts. Siblings of children with autism and controls with no family history of autism were tested at 12 months and screened for ASD at 36 months. Groups did not differ on proportion of attention to social stimuli or attention shifting during the play condition. All groups demonstrated more social attention and attention shifting during the distress condition. Infants later diagnosed with ASD tended to continue looking at a toy during the distress condition despite the salience of social information.

Keywords

Autism; Broader autism phenotype; Visual attention; Attention shifting; Early identification

Introduction

One conceptual model of autism proposes that the disorder may be rooted in the failure to attend preferentially to social stimuli (Dawson et al. 1998). Atypical social attention may reflect impairment in the social reward circuitry (Dawson et al. 2001). Difficulty anticipating social reward may be attributable to the unpredictable nature of social interactions relative to non-social sources of information. If infants later diagnosed with autism attend to social stimuli such as faces less than typically developing infants (Osterling and Dawson 1994), they are unlikely to attain the expertise that results from practice (Sasson et al. 2008). This lack of experience may exacerbate atypical brain development early in life

(Mundy and Neal 2001) and thereby compound deficits in social understanding and social reciprocity that are associated with autism. The social reward theory of autism is supported by studies involving infants later diagnosed with autism, which consistently report atypical patterns of social attention and responsiveness by 12 months of age (Baranek 1999; Maestro et al. 2002; Osterling and Dawson 1994; Osterling et al. 2002; Ozonoff et al. 2010; Rozga et al. 2011; Werner et al. 2000; Yoder et al. 2009). Cumulatively, these studies indicate that reduced social attention and social responsiveness are among the earliest signs of autism.

Retrospective analyses of home video recordings report that, relative to control infants, infants later diagnosed with autism are less responsive to their own name (Baranek 1999; Osterling and Dawson 1994, 2002; Werner et al. 2000) and pay less attention to faces (Maestro et al. 2002; Osterling and Dawson 1994, 2002). Consistent with the retrospective studies, prospective studies indicate that 12-month olds later diagnosed with autism look to faces less (Ozonoff et al. 2010) and are less responsive to their name (Zwaigenbaum et al. 2005) than low-risk controls. By 12 months of age, infants later diagnosed with autism differ from controls in many social behaviors including social smiling (Adrien et al. 1993; Zwaigenbaum et al. 2005); initiating (Rozga et al. 2011) and responding to an examiner's bids for joint attention (Rozga et al. 2011; Yoder et al. 2009); imitation (Young et al. 2010; Zwaigenbaum et al. 2005); socially directed vocalizations (Ozonoff et al. 2010); and responding to another person's signals of distress (Hutman et al. 2010). The 12-month old who will later be diagnosed with autism is less likely to initiate social engagement or respond to social stimuli than infants who are not subsequently diagnosed with autism.

The social reward theory of autism (e.g., Dawson et al. 1998) could explain the observed failure to prioritize or specialize in social phenomena. Preliminary evidence of failure to specialize in social relative to non-social information processing during the first year comes from studies comparing infant siblings of children with autism to infants with no family history of autism. Prior to the age at which high-risk infants with ASD can be distinguished from high-risk infants not on the autism spectrum, comparisons of high- and low-risk infants provide useful clues regarding the divergence of development in autism relative to typical development. Given the genetic basis of autism (e.g., Bailey et al. 1995), findings of atypical responses to social stimuli in high-risk infants who do not go on to develop autism provide evidence of a broader autism phenotype (BAP), wherein first-degree relatives of people with autism demonstrate subclinical symptoms of autism (e.g., Piven et al. 1997). An ERP study comparing responses to images of faces and objects in 10-month-old siblings of children with autism found evidence of faster responses to objects by high-risk infants relative to low-risk infants and faster processing of objects than faces by high-risk but not low-risk infants (McCleery et al. 2009). The study also found evidence of faster processing of faces relative to objects by low-risk but not high-risk infants. Although not specific to infants later diagnosed with autism, this study is important for identifying an early disadvantage in processing social information coupled with advantages in processing non-social stimuli in a sample of infant siblings of children with autism. Heightened ability to process non-social stimuli may inhibit the development of social information-processing skills.

Alternatively, disadvantages in face processing may lead to advantages in processing non-social stimuli. Consistent with this claim, high-risk 9-month olds exhibited superior working memory for non-social stimuli relative to low-risk infants (Noland et al. 2010). The high-risk group's advantage in processing non-social information was not yet evident at 6½ months, suggesting that the differences between groups emerge during the second half of the first year. Follow-up research incorporating diagnostic outcomes would be required to determine whether differences between high- and low-risk participants in the preceding two studies were driven by ASD itself or represent aspects of the BAP.

A recent eye-tracking study shed new light on differences in processing social and non-social stimuli by presenting both classes of stimuli simultaneously. Three groups of toddlers (ASD, DD & TD) did not differ in saccadic reaction time when shifting attention from a non-social central fixation stimulus to a peripheral target (Chawarska et al. 2010). Saccadic reaction time from a social central fixation stimulus to a peripheral target was significantly shorter for toddlers with ASD than those in both comparison groups. The authors did not describe this effect as a heightened skill in toddlers with autism, but concluded that “the cost of disengagement of attention from a face was higher in TD and DD groups than in toddlers with ASD” (Chawarska et al. 2010, p. 182). In this study, accelerated processing of non-social information was attributed to limited attentional bias for faces.

Other studies have addressed the question of selective attention to social and non-social stimuli by evaluating where participants look during interactions with caregivers and/or examiners. In face-to-face parent–child interactions at 6 months, siblings of children with autism demonstrated fewer shifts of attention to and from the parent’s face and longer duration of looking toward non-social targets than low-risk infants (Ibañez et al. 2008). An investigation of spontaneous looking by toddlers with autism reported less looking to people overall, shorter duration of looks at people, and longer looks at objects than TD and DD comparison groups (Swettenham et al. 1998). Toddlers with autism shifted attention less frequently overall, but more frequently from one object to another than DD and TD toddlers. These results suggest that differences in patterns of looking at social and non-social targets cannot be explained by a general impairment in attention shifting.

The studies summarized above indicate that children with autism and their siblings attend preferentially to non-social stimuli as early as 6 months of age, perform better on tasks involving non-social stimuli as early as 9 months, exhibit decreased attention to social stimuli by 12 months, and respond atypically to social relative to non-social stimuli as toddlers. There is some evidence of developmental continuity of these observations in that older individuals with autism also perform better than typically developing peers on some tasks involving complex non-social stimuli. For instance, individuals with autism determined whether arrays of identical geometric shapes contained a unique component faster than typically developing individuals (Plaisted et al. 1998).

The current study explores selective attention to social versus non-social stimuli during play interactions between an examiner and 12-month olds at high and low risk for autism. Infant siblings of children with autism and infants with no family history of neurodevelopmental disorders were enrolled in the study at 6 or 12 months of age and they were tested regularly until at least 36 months of age. Twin studies indicate that autism is highly heritable (Bailey et al. 1995; Steffenburg et al. 1989). Accordingly siblings of children with autism are at heightened risk for diagnosis (Fombonne 2003; Ritvo et al. 1989; Sumi et al. 2006). Infant sibling studies report rates of autism recurrence within families ranging from 11% (Rozga et al. 2011) to 29% (Zwaigenbaum et al. 2005). A prospective longitudinal design permits implementation of structured, controlled, and unbiased evaluations of infants at high and low risk for autism prior to the age at which autism can be diagnosed reliably. Behaviors were compared among four groups that were formed on the basis of developmental and diagnostic evaluations at 36 months. One group met criteria for ASD at 36 months according to criteria outlined in the *Diagnostic and Statistical Manual of Mental Disorders* (DSM; American Psychiatric Association 2000). Children judged to be developing typically on the basis of cognitive, language, and social skills were split into two groups, one with a family history of autism (High-Risk Typical) and one with no family history of neurodevelopmental disorders (Low-Risk Typical). A fourth group (Other Concerns) did not meet criteria for ASD, but had significant cognitive, language, or social deficits that did not reflect typical development.

This study investigated social attention by documenting the precise visual targets of infants with and without ASD during interactions with an examiner. We sought to understand whether and how infants' looking patterns toward social and non-social stimuli differ between two social contexts. Our analysis of looking patterns explored the targets of infants' fixations, the duration of fixations, and the frequency of shifts among targets in the testing room. In the first social context, the examiner engaged the infant in play with a toy xylophone. This condition was characterized by the examiner's use of verbal communication and her display of positive affect. Next, the examiner pretended to hit her finger with the toy mallet and, in the second condition, she quietly tended to her feigned injury. This condition was characterized by the examiner's withdrawal from interaction and display of negative affect.

Our previous research indicates that 12-month olds later diagnosed with autism orient their attention toward and demonstrate changes in affect in response to an examiner's display of distress, though they do so to a lesser extent than low-risk controls (Hutman et al. 2010). The current study builds on our previous work in three important ways. First, the current study employed a micro-analytic approach to yield precise continuous measures of infants' gaze to all possible visual targets in the testing room whereas our earlier report used a global rating of attention to the examiner. This approach allows us to evaluate duration of looks to social and non-social targets as well as the frequency of shifts among targets. Secondly, we aimed to determine whether variations in the allocation of attention might be related to, and thus a potential substrate for, the reduced global ratings of responsiveness to distress by infants later diagnosed with ASD reported previously. Finally, we compared infants' gaze patterns during a play condition to those demonstrated during a distress condition. The inclusion of a comparison condition is designed to ascertain the effect of a change in the examiner's affective state on infants' attention. Whereas the previous study indicated that infants later diagnosed with autism attended less to an examiner feigning distress than infants who were not on the autism spectrum, this study seeks to determine precisely where infants look and how they gather information in the context of naturalistic social interactions. To our knowledge, the current study is the first to examine whether infants subsequently diagnosed with autism differ from typically developing infants in the distribution of attention to social and non-social stimuli in the context of a social partner's displays of positive versus negative emotions.

Because toddlers with ASD looked more to objects than people relative to DD and TD controls (Swettenham et al. 1998), we expected that infants later diagnosed with ASD would also look less to social targets than comparison infants in both the play and the distress conditions. Based on previous studies examining the behavior of children with autism in different social contexts, we expected that the infants' looking patterns would change between the two conditions described above (Dawson and Adams 1984; Dawson and Galpert 1990; Lewy and Dawson 1992). Given that infants consistently orient their attention to another person's distress at and after 10 months of age (Zahn-Waxler and Radke-Yarrow 1982), we predicted that all four groups studied here would increase duration and number of looks to social targets in the distress condition relative to the play condition. Because the infants with ASD who participated in the current study demonstrated reduced responsiveness to distress as assessed by a global rating (Hutman et al. 2010), we hypothesized that the increase in attention to the examiner during the distress condition relative to the play condition would be smallest in the ASD group compared to the three comparison groups.

This study contributes to the characterization of the autism phenotype during infancy in several ways. It explores infants' social attention during one-on-one interactions in two distinct social conditions. The prospective design, the laboratory setting, and the use of the

same toy for all participants enhance our ability to compare behaviors between conditions and groups. Social attention was evaluated at 12 months of age and participants were classified at 36 months as typically developing, on the autism spectrum, or otherwise developmentally delayed at 36 months. Dividing infants into a clinical group, a sub-clinical group, and a typically developing group clarifies the relevance of 12-month looking behaviors as they relate to outcomes. Associating early behaviors with later diagnosis may improve early screening for autism, help identify infants who will benefit most from receiving treatment, and support the development of early intervention programs.

Methods

Participants

The sample and design of the UCLA Infants at Risk for Autism study have been described elsewhere (Hutman et al. 2010; Rozga et al. 2011). Participants included in the analyses reported here enrolled in the study prior to 12 months of age and returned for developmental and diagnostic evaluation at 36 months. High-risk participants ($n = 81$) had an older biological sibling with autistic disorder and no other known genetic or medical conditions. These participants were recruited from the UCLA Autism Evaluation Clinic and other autism research studies at the UCLA Center for Autism Research & Treatment. Low-risk participants ($n = 48$) had no family history of neurodevelopmental disorders and were recruited by means of a mass mailing to families on the basis of records indicating that they had a baby in the target age range. Family history of developmental disorders was ascertained prior to enrollment in the study by means of a screening interview with parents. Siblings of all participants were also screened for social symptoms associated with ASD using the Social Responsiveness Scale (Constantino et al. 2003).

Comparison groups were formed on the basis of standardized measures and clinicians' judgment when participants reached 36 months of age. The four comparison groups were: ASD ($n = 15$); Other Concerns ($n = 12$); High-Risk Typical (HRT; $n = 59$); and Low-Risk Typical (LRT; $n = 43$). Children were considered to be developing typically if no single scale score from the Mullen Scales for Early Learning (MSEL; Mullen 1995) fell more than 2 SD below the mean of the normative sample; if no more than one MSEL scale score was more than 1.5 SD below the mean; and if the summed social-communication algorithm score from the ADOS (Lord et al. 2000) fell more than 1 point below the ASD cut-off. These criteria were ratified by a consortium of researchers who specialize in the onset of autism during infancy (Baby Sibling Research Consortium 2007). Children who did not meet the criteria for typical development or for ASD were assigned to the Other Concerns group. Thus, Other Concerns was a broad category including moderate delays in multiple scales of the MSEL, severe delays on at least one scale of the MSEL, or ADOS social-communication scores within one point of the ASD cut-off. Of the 12 children in the Other Concerns group, 8 came from the high-risk group. Characteristics of the four groups are summarized in Table 1.

Autism Diagnosis

Diagnostic status of older siblings with autism (probands) and infant siblings was confirmed by means of a clinician's judgment on the basis of direct observation and parent report regarding early development and the child's behavior in a variety of contexts. In determining their diagnostic judgments, clinical psychologists had the opportunity to interact with participants, and they had access to children's scores from the ADOS (Lord et al. 2000), ADI-R (Lord et al. 1994), a standardized measure of cognitive development such as the MSEL, and the Vine-land Adaptive Behavior Scales (Sparrow et al. 1984). Ultimately, ASD diagnoses were made in accordance with the criteria in the *DSM* (American Psychiatric

Association 2000). All participants were screened and judged to be on autism spectrum, in the Other Concerns group, or typically developing at 36 months of age. Of the 15 children who met criteria for ASD at 36 months, 14 came from the high-risk group.

Measures

- *The Autism Diagnostic Observation Schedule—Generic* (ADOS; Lord et al. 2000) is a structured observational measure comprised of play-based activities that elicit behaviors relevant to a diagnosis of autism spectrum disorders. Diagnostic classification on the ADOS is generated by means of an empirically derived algorithm, using score thresholds in social reciprocity, communication, and a combination of these two domains. Research assistants who administer the measure achieved reliability with authorized trainers from the University of Michigan Autism and Communication Disorders Center.
- *The Mullen Scales of Early Learning* (Mullen 1995) are comprehensive measures of cognitive functioning for young children from birth through 68 months. The MSEL yields standard scores in five developmental domains including gross and fine motor skills, visual reception skills, and receptive and expressive language. Verbal and non-verbal cognitive skills at 12 months were evaluated as covariates in models comparing looking behaviors between groups. For the analyses reported below, verbal ability is the average of t-scores from the receptive and expressive language scales of the MSEL. Non-verbal ability is the average of t-scores from the visual reception and the fine motor scales. Combining the scales aimed at reducing the number of parameters tested.
- *Examiner-Child Interaction.* The examiner and the infant sat on opposite sides of a low table and took turns playing with a toy xylophone during the play condition. Examiners coordinated turn-taking in a calm manner that aimed at sustaining the infant's engagement with the activity. The infant's face was filmed from behind the examiner with a side-view of the examiner in the frame with the infant. Remote camera operators also captured a picture-in-picture view of the examiner's face to facilitate coders' determination of infants' looking target. Caregivers were seated out of the direct site line between the infant and the examiner. The examiner pretended to hit her finger with the toy mallet and withdrew from play. She neither made eye contact nor spoke to the child. After the feigned injury, the examiner held her hand still at chest level for a period of 15 s. The examiner neither made eye contact nor spoke to the child during this withdrawal period. After the 15 s elapsed, s/he assured the child that s/he was not hurt.

In our previous work with this measure, we reported differences in global ratings of infants' attention and affective response to the negative change in the examiner's emotional state (Hutman et al. 2010). Here, we test the relationship between discrete looking patterns during the distress condition and the global rating of attention to the examiner that were a focus of the previous study. The global rating of attention was based on the amount of time the child spent looking at the examiner. The scale was conceptually derived to reflect levels of attention to the distressed examiner, i.e. very little attention (<1 s looking to examiner, score of 0); brief attention (1–4 s looking time, score of 1); clear attention (5–8 s looking time, score of 2); and sustained attention (>8 s looking time, score of 3). Single-measure reliability was .92 for the attention scale.

For the current study, undergraduate volunteers watched infants' responses to the examiner's distress during the 15.0-s play interaction prior to the feigned injury and for the 15.0 s after the examiner pretended to hurt her finger. Based on pilot data, we determined that extending the distress condition beyond 15 s was neither credible nor comfortable for

participants. The 15-s play condition was chosen to match the distress condition. Using behavioral coding software (The Observer 9.0 XT, NOLDUS), coders indicated where the infant was looking at all times. Social looking targets were the examiner's face and hand and the caregiver. Non-social targets were the xylophone or mallet, and "other targets". The catch-all category of "other" targets was considered non-social and included any looking target not previously mentioned. Two undergraduate research assistants, unaware of the hypotheses of this study, double-coded 22 instances of the distress-response task, representing 17% of the current sample. Judgments were considered to be in agreement if both coders scored changes in the target of gaze to or away from the same location within one second of each other. Coders' decisions regarding looking targets among the five target categories listed above were in agreement 92% of the time (Cohen's $\kappa = 0.82$).

In this study, we evaluated the number of visual targets fixated as a proxy for attention shifting. In order for an infant to fixate on 10 visual targets during the distress condition, she would need to shift her attention away from one visual target and to another target 9 times. Eight- and 9-month-old infant siblings of children with autism demonstrated longer latencies to disengage visual attention relative to low-risk comparisons (Elsabbagh et al. 2009) and 12-month olds later diagnosed with autism demonstrated longer latencies to disengage relative to their own performance at 6 months (Zwaigenbaum et al. 2005). Based on these findings, we interpreted more discrete looks to all visual targets as evidence of flexible distribution of attention, which supports global processing of visual information (Frick et al. 1999). Accordingly, we hypothesized that the ASD group would demonstrate fewer fixations on social targets and non-social targets than the other groups.

Results

We hypothesized that infants later diagnosed with autism would look less at social targets in both the play and distress conditions. We expected that looking to the face would increase for all three groups in the distress condition relative to the play condition, but that the increase would be smallest in the ASD group. To test these hypotheses, we ran a 4 (Group: ASD, Other Concerns, HRT, LRT) $\times$ 2 (Condition: play vs. distress) mixed-design analysis of variance (ANOVA), with percentage of looking time to social targets as the dependent variable. Ratio of social looking was total duration of infants' looks to the examiner and the caregiver divided by total looking time to all targets. Since this value is complementary to the ratio of looking to non-social targets, we evaluated only the former variable and not the latter. Planned comparisons were run to explicate results of the mixed-design analyses of variance.

Looking time to all targets and the number of looking targets for each group in both the play and distress conditions are summarized in Table 2. Twelve-month olds spent very little time looking at their caregiver. Therefore, the proportion of social looking during the distress condition is highly correlated with the global rating of attention to the examiner's display of distress reported previously (Hutman et al. 2010; Pearson's $r(118) = 0.85, p < 0.001$). The proportion of social looking during the play condition was not related to the global rating of attention to the examiner ($p = 0.59$). Change in proportion of social looking from the play condition to the distress condition was strongly related to the global rating of attention to the examiner, Pearson's $r(118) = 0.82, p < 0.001$. Thus, the proportion of social looking during the distress condition and the degree to which social attention increased between conditions corresponds with a rating of interest, awareness, and curiosity about the social partner. Higher social looking ratios are expected to correspond with more favorable developmental outcomes.

Proportion of Time Looking to Social Targets

A significant group $\times$ condition interaction, $F(3, 124) = 5.81, p < 0.001$, confirms different patterns of social attention among the three groups, between the two conditions. (See Fig. 1.) Using analyses of covariance (ANCOVAs), we tested the group $\times$ condition interaction effect while controlling for a verbal skills $\times$ condition interaction and a non-verbal skills $\times$ condition interaction. The group $\times$ condition interaction was robust to the inclusion of both cognitive skills interaction terms, $F(3, 122) = 4.03, p < 0.01$. Verbal skills at 12 months were related to the proportion of time that infants looked to social targets, $F(1, 122) = 4.28, p < 0.01$. Non-verbal skills at 12 months were not related to looking patterns, $F(1, 122) = 1.74, p = 0.19$.

Planned Comparisons Within Condition

A one-way analysis of variance indicated significant differences between groups in the ratio of looking to social targets during the baseline play condition, $F(3, 126) = 2.90, p < .05$. In accordance with our predictions, the ASD group produced the lowest social looking ratio. However, significant differences among groups were not evident in post-hoc tests using a Bonferroni correction, suggesting marginal differences in attention to people during the play condition.

During the distress condition, there were no differences between the LRT and the HRT groups ($p = 0.79$). The ASD group ($t(115) = 4.66, p < 0.001$) and the Other Concerns group ($t(83) = 3.05, p < 0.01$) looked to social targets significantly less than the combined LRT and HRT groups. The ASD and Other Concerns group did not differ significantly from each other ($p = 0.31$). These results partially support our first hypothesis. (See Table 2.) Looking patterns to the examiner's face and hand mirrored overall social looking patterns. Looks to the caregiver occurred too infrequently to be tested for group differences.

Planned Comparisons Between Conditions

All four groups increased the ratio of looking time to social targets between conditions (ASD: $t(14) = 3.17, p < 0.01$; Other Concerns: $t(11) = 3.73, p < 0.01$; HRT & LRT combined: $t(101) = 18.30, p < 0.001$). Mean change in social looking was significantly less for the ASD group than all other groups combined, $t(127) = 3.23, p < 0.01$, but not less than the Other Concerns group by itself, $p = 0.55$. The Other Concerns group increased the ratio of looking time to social targets less than the HRT ($t(69) = 2.33, p < 0.05$) and LRT ($t(53) = 2.61, p < 0.05$), but the TD groups did not differ from each other ($p = 0.62$). These results partially support our second hypothesis.

Attention Shifting

Next, we examined frequency of infants' shifts in attention from one target to another. For the analyses reported below, the dependent variable was a count of all infant gaze fixations regardless of category rather than a count of the number of members of the category targeted. As above, we ran 4 (Group) $\times$ 2 (Condition) mixed-design analyses of variance. We tested two models, one for number of social looking targets and one for number of non-social looking targets. These data are summarized in Table 3.

Social Targets

For number of looks to social targets, the condition $\times$ group interaction was significant, $F(3, 125) = 4.3, p < 0.01$. Groups did not differ on the number of looks to social targets during the play condition, $p = 0.17$. The ASD group looked at fewer social targets than the combined typical groups across conditions ($t(115) = 3.9, p < 0.001$) and during the distress condition ($t(115) = 4.1, p < 0.001$). The Other Concerns group did not differ from any of the

other three groups in number of looks to social targets. All four groups increased the number of looks to social targets between conditions (ASD: $t(14) = 1.93, p < 0.05$; Other Concerns: $t(11) = 5.9, p < 0.001$; combined typical groups: $t(101) = 12.5, p < 0.001$). Change in number of social looking targets was greatest for the combined typical groups and least for the ASD group (Typical > Other Concerns: $t(112) = 1.92, p < 0.05$; Other Concerns > ASD: $t(25) = 2.2, p < 0.05$).

In an ANCOVA with verbal skills as a covariate, verbal skills were related to number of social targets viewed, $F(1, 125) = 4.98, p < 0.05$, significant differences between groups persisted, $F(3, 125) = 3.85, p < 0.05$, but the group $\times$ condition interaction was no longer significant, $p = 0.15$. In an ANCOVA testing non-verbal skills as a covariate, the group $\times$ condition interaction was no longer significant ($p = 0.08$), but the differences between groups persisted, $F(3, 125) = 5.07, p < 0.01$. Non-verbal skills were not related to the number of social targets fixated, $p = 0.45$. The number of social targets viewed was strongly correlated with the proportion of time participants fixated on social targets during the play, $r(129) = .83, p < .001$, and the distress conditions, $r(129) = 0.67, p < 0.001$.

Non-social Targets

There was no main effect of group or condition and no group $\times$ condition interaction for number of looks to non-social targets. The number of non-social targets to which infants looked during the play condition was positively correlated with proportion of time participants fixated on social targets during the same condition, $r(129) = 0.51, p < 0.001$. A negative correlation between number of looking targets viewed during the distress condition and proportion of time looking at social targets in the same condition was marginally significant, $r(129) = 0.17, p = 0.06$. In general, infants who referenced the xylophone more frequently during the distress condition also tended to spend a higher proportion of the distress condition looking at social stimuli. Those who made more discrete looks to the toy during the play condition looked for a marginally smaller proportion of the play condition to social stimuli.

Discussion

This study sought to determine whether variation in attention to social stimuli across contexts distinguishes 12-month olds later diagnosed with autism from 12-month olds with subclinical delays and typically developing infants. Our observation that infants later diagnosed with autism look more frequently and longer to social targets while an examiner feigns distress relative to a one-on-one play condition suggests that the social attention deficit associated with autism varies with context. In this study, infants later diagnosed with autism did not differ from infants with developmental delays and typically developing infants in the proportion or frequency of looking to social targets during a play condition involving a toy and an unfamiliar examiner. In the play condition, the apparent preference for toys among infants later diagnosed with ASD did not distinguish them from other participants, who also allocated the majority of their attention to the toy. All four groups demonstrated a significant increase in looking time to social targets in the distress condition relative to the play condition, but the increase and the resulting proportion of attention to social targets during the distress condition were significantly greater among children who were not on the autism spectrum at 36 months.

Groups did not differ on the duration or proportion of time they looked around the testing room ("other targets") and to their accompanying caregiver. Infants in all four groups predominantly divided their attention between the examiner and the toy. Therefore, the observation that infants later diagnosed with autism did not attend to social stimuli indicates a tendency to continue looking at the toy with which they had been engaged during the play

condition. Children with cognitive, language, or social delays who were not on the autism spectrum demonstrated an intermediate level of social attention in the context of the examiner's feigned distress. Decreased attention to social stimuli distinguishes a group of 12-month olds with subclinical impairments related to autism from typically developing infants. This finding echoes our previous report of a lower global rating of attention to the examiner's display of distress among infants later diagnosed with ASD. Not surprisingly, we found that the measure of looking time to the examiner was strongly correlated with the global rating of attention to the examiner during the distress condition. Although the mean proportion of social attention was greater for the Other Concerns group than for the infants later diagnosed with ASD, these groups did not differ significantly in the proportion of looking to social targets during either the play or the distress condition.

The increase in looking to social targets during the distress condition may reflect (a) infants' awareness that something is wrong with the examiner, (b) a lack of experience with adults' expression of negative affect (Nelson and de Haan 1996), or (c) the detection of a qualitative change in the examiner's contribution to the interaction. We favor the first two explanations over the third because repeated looks and increased attention to the examiner following the feigned injury suggest that interest in the examiner outlasts the transition between conditions.

The ASD group looked more to social stimuli during the distress condition than the play condition. This change in behavior suggests some level of awareness of the change in the social environment. We would expect that the examiner's encouraging verbalizations and display of positive affect during the play condition would make engagement with the examiner more rewarding in that context than during the distress condition. The observation that attention to the examiner was greater during the distress condition than the play condition implies that curiosity, interest, or the perception of an informational benefit compensates for the lack of social reinforcement in attending to the face of a person in distress. Although infants in the ASD group increased looking to the examiner in the distress condition relative to the play condition, they and the infants in the Other Concerns group still looked less to the examiner and more to non-social targets during the distress condition and increased their attention less from the play to the distress condition relative to typically developing infants. Infants in the high- and low-risk TD groups looked more to the examiner than to non-social targets during the distress condition. The Other Concerns group did not differ from the ASD group in the proportion of time they looked to social targets or the change in proportion between conditions, but they looked less to social targets during the distress task and changed less between conditions relative to the TD groups.

Looking behaviors of the infants later diagnosed with ASD may be driven by preference for toys over people, a reduced bias toward social information, or impairment in the cognitive faculties that underlie adaptation to a change in social environment. The tendency to continue looking primarily at the toy from one condition to the next may be driven by the desire to continue an enjoyable activity or to avoid having the activity curtailed. Staying focused on the toy may stem from an inability to inhibit attention to an interesting event when presented with a competing stimulus, even one that was almost uniformly ratified as salient by typically developing infants.

Infants in the ASD group may perceive the examiner's display of negative affect to be more aversive than participants in the other three groups. An earlier study from our lab tested this hypothesis and found that preschoolers with ASD demonstrated more interest in displays of negative affect than neutral affect and that their heart rates did not increase in response to the examiner's display of negative affect (Corona et al. 1998). The authors interpreted these

results to indicate that children with autism do not find other people's displays of negative affect to be aversive.

The data did not support our hypothesis that infants in the ASD group would look less to social targets than TD infants during the play condition. This result was surprising because 12-month olds later diagnosed with ASD looked significantly less frequently to the face of an examiner during cognitive testing than typically developing 12-month olds (Ozonoff et al. 2010). A subset of the current sample provided data for the Ozonoff study. The rate of looking to the examiner by TD participants in the current study is lower than we would expect given the rates reported by Ozonoff et al. during cognitive testing, given what is known about the development of infants' interest in faces (Frank et al. 2009), and given what is known about the development of joint attention.

Initiating joint attention by alternating gaze between a social partner and an object or event of interest emerges between 9 and 12 months in low-risk samples (Carpenter et al. 1998; Moore and Corkum 1994; Mundy et al. 2007). Although typically developing infants would be expected to share their interest in an enjoyable activity by 12 months, the TD groups did not share interest in the toy xylophone more frequently than infants who were later diagnosed with ASD. The low rate of looking to social targets by TD participants in this sample may be related to the brevity of our play condition (15 s), a factor that must be considered a limitation in the current study. Presumably, a longer behavioral sample would increase variability and thereby magnify differences among groups. The low rate of looking to social targets may be driven by heightened attention to a toy that holds strong appeal for most participants. The xylophone is colorful, interactive, and generates an impressive magnitude of sound. While the short duration of the assessment and the attractive toy used may have influenced the amount of attention to the examiner observed in the current study, variations in the social behavior of infants later diagnosed with ASD and typically developing infants across interactive contexts affirm the importance of considering context when evaluating the social behavior of young children at risk for ASD.

Looking data from the play condition suggest that most children focused solely on the toy, even though the infant and the examiner took turns playing with it. Transferring the toy between the examiner and the infant may have drawn infants' attention to the toy and away from the examiner and other stimuli in the testing room during the play condition. However, calm turn-taking was coordinated by the examiner with the goal of sustaining infants' engagement with the activity. The introduction of negative affect and the disruption of the rhythmic play routine elicited the attention of infants in all groups to the examiner and corresponded with more shifting of attention among looking targets in all groups and especially among typically developing infants.

Results regarding duration and number of looks to social targets are consistent with evidence that young children with autism and high-risk infants shift attention toward and away from people less frequently than controls (Ibañez et al. 2008; Swettenham et al. 1998). Relative to TD infants, infants in the ASD group looked at fewer social targets. The Other Concerns group demonstrated an intermediate number of gaze fixations. The number of looks to social targets was related to verbal skills. When we controlled for verbal skills, the group $\times$ condition interaction was no longer evident, but significant differences between groups persisted across conditions. Non-verbal skills were not related to the frequency of attention shifts involving social visual targets.

The frequency of attention shifting increased significantly in the distress condition relative to the play condition among the three groups of infants who were not diagnosed with ASD at 36 months, but not among infants later diagnosed with ASD. Less flexible distribution of

attention has been explained by longer latencies to disengage from one stimulus before shifting attention to a competing stimulus and when a second stimulus was presented following a gap between stimuli in 8–9-month-old siblings of children with autism (Elsabbagh et al. 2009). Longer latencies to disengage have also been related to longer fixation durations and localized information-processing strategies in low-risk 3-month-old infants (Frick et al. 1999). By 4 months, global processing, faster disengagement, and more flexibly distributed attention took precedence over local processing strategies (Frick et al. 1999). Infants who demonstrate higher rates of attention shifting also tend to process information more rapidly (Rose et al. 2004). In the current study, fixation on fewer visual targets across conditions suggests that infants later diagnosed with autism rely on bottom-up, localized information-processing strategies.

In this sample, higher rates of attention shifting across conditions corresponded with better diagnostic outcomes. The 11 infants who demonstrated the highest rates of attention shifting, fixating on 18–24 targets in the 30 s of coded interaction (rate = 0.6–0.8 targets/s), were all judged to be free of developmental delays at 36 months. Further research should explore the possibility that the relationship between frequency of attention shifting and developmental outcomes is not linear and that the highest rates of attention shifting may not be adaptive.

Our observation that infants who go on to develop autism display some sensitivity to changes in their social environment echoes the finding that emotion recognition is not universally impaired in older children with autism (Ozonoff et al. 1990; Pelphrey et al. 2002; Wang et al. 2004). The increase in looking to the examiner following her feigned injury suggests that emotion recognition is intact in infants who later develop autism, but that the emotional value of the information appears to be less salient for infants later diagnosed with autism. Despite the increase in looking to the examiner in the distress condition, infants in the ASD group did not look to the examiner as long as participants in the three other groups, suggesting that they did not have the same opportunity to glean information from the experience of their social partner as members of the other groups. In order to maximize the benefit of the intact ability to selectively orient to emotional information, increasing responsiveness to other people's emotional signals is proposed as a target for early intervention. Given that the frequency of gaze to faces during cognitive testing decreased significantly between 6 and 24 months in infants later diagnosed with autism (Ozonoff et al. 2010), the first and second years of life appear to be a critical time to bolster skills present early in development before these skills decline. This study suggests that skills to be targeted include the ability to orient to faces and to respond to variations in emotion across contexts.

Our previous work has found few differences between non-autistic siblings of children with autism and low-risk controls in joint attention (Rozga et al. 2011), responsiveness to another person's distress (Hutman et al. 2010), and functional play skills (Christensen et al. 2010). The current study employs a different grouping strategy in which participants judged neither on the autism spectrum nor typically developing were compared to children who met criteria for ASD and children whose cognitive, language, and social development are in the normal range. The Other Concerns group, 67% of whose members have a family history of autism, attended to social targets for a significantly shorter segment of the distress condition than the high-risk and low-risk TD groups. These results did not change when we excluded the 4 participants in the Other Concerns group who did not have a family history of autism. Therefore, duration of interest in social targets during an interaction with a person feigning distress distinguishes the combined group of infants later diagnosed with ASD and infants who show signs of the broader autism phenotype from typically developing children with and without a family history of autism. Group differences in social attention and distribution

of attention are largely independent of delays in verbal or other cognitive skills. The identification of sub-clinical features of autism in the relatives of individuals with autism greatly increases the pool of potential participants in research about the genetics of autism and thereby facilitates efforts to identify genes associated with autism (e.g., Geschwind 2008).

The short segments of social interaction coded for this study and the single implementation of social interaction tasks are limitations that argue for a cautious interpretation of these results. In the interest of maximizing ecological validity, we would not recommend repeating the distress task or extending it for more than 15 s, but longer segments of free play may reveal differences in social attention patterns among the groups of infants studied here. The sample of infants later diagnosed with autism is small and the volunteer sample may not be representative of the general population. Familial autism, the target of the infant sibling research design, may have a different genetic basis than sporadic autism (Sebat et al. 2007). Therefore, phenotypic presentation and onset patterns may differ, too.

We sought to characterize attention to social and non-social stimuli and attention-shifting patterns among infants later diagnosed with ASD, infants with Other Concerns, and typically developing infants. The results confirm that the behaviors of infants later diagnosed with autism do not differ from those of typically developing infants across all social contexts. Infants later diagnosed with ASD may be less attentive to changes in the affective state of social partners than infants with other developmental delays and typically developing children, but infants later diagnosed with ASD demonstrate some awareness of changes in others' affect. Infants later diagnosed with ASD attend more to non-social stimuli during interactions with an unfamiliar examiner and they shift attention among visual targets less frequently than high- and low-risk typically developing infants. Attenuated social attention at the end of the first year appears to be a useful early indicator of autism as well as a potential target of early intervention.

Acknowledgments

Funding for this project comes from Grants #U54 MH068172 (Sigman), #P50 HD055784 (Bookheimer), #5 T32 HD007032 (Hutman). Additional support from the Friends of the Semel Institute (Hutman). The authors extend special thanks to the families who participated in this study and the research team who collected, managed, and coded the data: Stephany Cox, Mithi del Rosario, James Earhart, Lovella Gomez, Stephanie Marshall, Joanna Mussey, Amanda Nekoud, Nuri Reyes, and Agata Rozga.

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Fig. 1.

Ratio of looking time to social targets by group and condition. *ASD group change between conditions, $p < 0.05$. **Other Concerns, HRT, LRT groups change between conditions, $p < 0.001$

Table 1

Sample characteristics

	(1) ASD n = 15	(2) Other concerns n = 12	(3) High-risk TD n = 59	(4) Low-risk TD n = 43	Groups differ	p values
Gender (% male)	73%	58%	44%	59%		
12-month assessment						
Verbal t-score	40.6 (7.5)	45.4 (7.5)	49.2 (6.6)	47.6 (8.2)	1 < 3, 4	+
Non-verbal t-score	57.1 (5.6)	58.0 (8.7)	60.7 (5.8)	59.5 (6.2)		
36-month assessment						
Verbal t-score	43.3 (13.8)	48.1 (9.0)	55.6 (6.5)	55.3 (7.4)	1 < 3, 4	+
Non-verbal t-score	46.3 (16.6)	51.1 (8.5)	61.8 (9.5)	61.5 (8.4)	2 < 3, 4	*
					1 < 3, 4	+
					2 < 3	+
					2 < 4	*
ADOS scale scores						
Communication + social	12.6 (2.6)	5.0 (2.8)	2.1 (1.4)	1.8 (1.3)	1 > 2 > 3, 4	+
Restricted & repetitive behavior	1.9 (1.4)	1.2 (1.0)	0.4 (0.7)	0.6 (0.8)	1, 2 > 3, 4	+
					1 > 2	†

Assessment-related data are presented as Mean (Standard Deviation). Statistically significant differences between groups are indicated as follows:

† $p < 0.05$,

* $p < 0.01$,

+ $p < 0.001$

Table 2

Looking times and proportions by group and condition

Condition	Looking target	ASD concerns n = 15	Other TD n = 12	High-risk TD n = 59	Low-risk TD n = 43
Play	Examiner's face	0.6 (0.7)	1.0 (1.4)	1.5 (1.7)	0.5 (0.9)
	Examiner's hand	0.2 (0.4)	0.3 (0.7)	0.4 (0.7)	0.6 (0.9)
	Caregiver	0.0 (0.0)	0.0 (0.0)	0.1 (0.4)	0.0 (0.1)
	Toy	13.6 (1.6)	13.7 (1.9)	12.1 (3.0)	13.6 (1.4)
	Other targets	0.6 (1.1)	0.1 (0.2)	1.0 (2.4)	0.2 (0.7)
Distress	Proportion of looking to social targets	0.05 (0.06)	0.08 (0.12)	0.13 (0.13)	0.08 (0.08)
	Examiner's face	2.0 (2.7)	2.9 (3.3)	4.4 (2.9)	3.7 (2.8)
	Examiner's hand	1.7 (2.1)	2.3 (2.4)	3.8 (3.0)	4.5 (3.3)
	Caregiver	0.0 (0.2)	0.0 (0.0)	0.4 (1.1)	0.2 (0.8)
	Toy	10.8 (4.1)	9.7 (3.8)	5.8 (3.9)	6.3 (3.8)
	Other targets	0.5 (1.4)	0.2 (0.4)	0.7 (1.4)	0.3 (0.6)
	Proportion of looking to social targets	0.25 (0.24)	0.34 (0.25)	0.57 (0.25)	0.56 (0.26)

Looking times for each target are presented in seconds. Times and proportions are listed as Mean (Standard Deviation)

Table 3

Number of looks to targets by group and condition

Condition	Looking target	ASD n = 15	Other concerns n = 12	High-risk TD n = 59	Low-risk TD n = 43
Play	Social targets	1.0 (1.2)	1.0 (1.3)	1.7 (1.5)	1.3 (1.2)
	Non-social targets	2.4 (1.5)	2.1 (1.5)	2.7 (1.8)	2.3 (1.3)
	All targets	3.4 (2.6)	3.1 (2.8)	4.4 (2.9)	3.6 (2.3)
Distress	Social targets	2.7 (1.8)	3.8 (2.2)	6.1 (3.3)	5.7 (3.2)
	Non-social targets	2.6 (1.2)	2.8 (1.4)	3.0 (1.5)	2.8 (1.2)
	All targets	5.3 (2.7)	6.5 (3.2)	9.1 (3.9)	8.5 (3.4)

Number of looks to targets are presented as Mean (Standard Deviation)