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# Context modulates attention to social scenes in toddlers with autism

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## Abstract

**Background—**In typical development, the unfolding of social and communicative skills hinges upon the ability to allocate and sustain attention towards people, a skill present moments after birth. Deficits in social attention have been well documented in autism, though the underlying mechanisms are poorly understood.

**Methods—**In order to parse the factors that are responsible for limited social attention in toddlers with autism, we manipulated the context in which a person appeared in their visual field with regard to the presence of salient social (child-directed speech and eye contact) and nonsocial (distractor toys) cues for attention. Participants included 13- to 25-month-old toddlers with autism (AUT; n=54), developmental delay (DD; n=22), and typical development (TD; n=48). Their visual responses were recorded with an eye-tracker.

**Results—**In conditions devoid of eye contact and speech, the distribution of attention between key features of the social scene in toddlers with autism was comparable to that in DD and TD controls. However, when explicit dyadic cues were introduced, toddlers with autism showed decreased attention to the entire scene and, when they looked at the scene, they spent less time looking at the speaker's face and monitoring her lip movements than the control groups. In toddlers with autism, decreased time spent exploring the entire scene was associated with increased symptom severity and lower nonverbal functioning; atypical language profiles were associated with decreased monitoring of the speaker's face and her mouth.

**Conclusions—**While in certain contexts toddlers with autism attend to people and objects in a typical manner, they show decreased attentional response to dyadic cues for attention. Given that mechanisms supporting responsivity to dyadic cues are present shortly after birth and are highly consequential for development of social cognition and communication, these findings have important implications for the understanding of the underlying mechanisms of limited social monitoring and identifying pivotal targets for treatment.

### Keywords

autism; infants; toddlers; eye-tracking; visual attention; dyadic attention; scanning; naturalistic; dynamic stimuli

Young children with autism spend relatively little time monitoring other people and the facial expressions and gestures of others (Dawson et al., 2004; Swettenham et al., 1998). Given that the acquisition of language and the development of social cognition are highly experience-dependent processes (Greenough, Black, & Wallace, 1987), deficits in the ability to select for processing and to sustain attention on faces early in development are likely to

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have a detrimental effect on early socio-cognitive (Leppanen & Nelson, 2009; Pascalis et al., 2005) and language development (Kuhl, Williams, Lacerda, Stevens, & Lindblum,1992; Thiessen, Hill, & Saffran, 2007). Furthermore, given the role observational learning plays in the development of nonsocial cognition, atypical attention towards people is likely to result in collateral difficulties in other domains as well (Shic, Bradshaw, Klin, Scassellati, & Chawarska, 2011). Thus, it is essential to advance our understanding of the processes that underlie atypical social attention at the earliest ages when autism can be reliably identified. The benefit of such an approach is two-fold: it will advance identification of target skills for intervention, and will inform the design of methods for screening infants at risk for autism spectrum disorders (ASDs) in the first year of life.

In the past decade, studies utilizing eye movements as indices of perception and attention have shown great promise for identifying mechanisms underlying social disability in autism. A majority of studies have employed static images of faces and people, sometimes presented in isolation from their social context. This line of research has generated important insights into the attentional, perceptual, and learning strategies associated with autism in the first three years of life. Empirical evidence suggests that faces do not capture the attention of toddlers with ASD as readily as they capture the attention of non-affected toddlers (Coffman, Shic, Meltvedt, Bradshaw & Chawarska, 2011). When examining a novel face, toddlers with ASD exhibit atypical scanning patterns (Chawarska & Shic, 2009) and require more time to extract invariant face features necessary for recognition (Bradshaw, Shic, & Chawarska, 2011; Chawarska & Shic, 2009; Chawarska & Volkmar, 2007; Webb et al. 2010).

Although studies examining the processing of static faces are essential for parsing the nature of deficits in autism and reflect upon the atypical functioning of cortical networks involved in the structural analysis of faces (Haxby, Hoffman, & Gobbini, 2002), in real life faces present as dynamic stimuli. This aspect of face processing relies heavily upon multisensory brain areas involved in the perception of biological motion, speech, and social cognition such as the posterior superior temporal sulcus (pSTS) as well as the attentional network involved in selection of and sustained attention to these salient stimuli (Allison, Puce, & McCarthy, 2000; Calvert & Campbell, 2003; Haxby et al., 2002). Several eye-tracking studies have examined the attentional responses to dynamic faces embedded in complex naturalistic contexts in toddlers with ASD (Jones, Carr, & Klin, 2008; Shic, et al., 2011). These studies suggest that when toddlers with ASD view videos of adults trying to engage them through simple social games (e.g., peek-a-boo) (Jones et al., 2008) or observe parent-child dyads engaged in a shared activity (Shic et al., 2011), they tend to look at faces less than control participants, a pattern similar to that seen in high-functioning adolescents with ASD (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). The reasons for limited face monitoring in dynamic displays are not clear. It is possible that toddlers with autism spend less time attending to faces as means of regulating their arousal (Hutt & Ounsted,1966). It is also possible that they spend less time monitoring faces simply because faces are not prioritized in their attentional system for processing to the same extent as faces are in non-autistic individuals (Chawarska, Klin, & Volkmar,2003; Chawarska, Volkmar, & Klin, 2010). Finally, it is possible that limited attention to people is a direct result of increased salience of objects, whether it be due to high-level (e.g., cars) (Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008) or low-level (e.g., high contrast) attributes (Bertone, Mottron, Jelenic, & Faubert, 2005; McCleery, Allman, Carver, & Dobkins, 2007; Shic, Chawarska, Lin, & Scassellati, 2007).

In the present study we examine the effect of context on the regulation of attention in toddlers with autism (AUT) as well as developmentally delayed (DD) and typically developing (TD) controls using dynamic social scenes. To parse the factors that are responsible for limited attention to faces we manipulated context with regard to the presence of salient social (child-directed speech and eye contact) and nonsocial (distractor toys) cues. If toddlers with autism exhibit a generalized social attention deficit, they would spend, compared to non-ASD controls, less time examining the person's face in all contexts; instead we would expect their attention to be directed toward toys in the background. However, if they show elementary sensitivity to the context in which people appear in their visual field, then the atypical patterns should be condition-specific. In this case we would expect the smallest differences between groups in the condition with highly salient non-social distractors (moving mechanical toys) and the greatest differences in the condition containing explicit and prolonged social bids, including eye contact and child-directed speech.

## Methods

### Participants

Participants included 122 toddlers with: autistic disorder (AUT, n=54), developmental delays but no autism spectrum disorder (DD, n=20), and typical development (TD, n=48). Toddlers with AUT and DD were referred for differential diagnosis by their parents or professionals between 13 and 25 months and were assessed by a multidisciplinary team specializing in the early diagnosis of ASD. The assessment battery targeted verbal and nonverbal developmental skills (Mullen Scales of Early Development; Mullen, 1995), nonverbal communication (Communication and Symbolic Behaviors Scale, CSBS; Wetherby & Prizant, 2002), adaptive functioning (Vineland-II; Sparrow, Balla, & Cicchetti, 2005), and autism symptoms (ADOS-G, Module 1; Lord et al., 2000). Best estimate clinical diagnosis was based on a review of all standardized tests as well as medical and family history. Two expert clinicians assigned diagnosis based on all available evidence. In rare cases of discrepancy between clinicians, the case was further discussed until a consensus diagnosis was reached. The DD group included ten toddlers with global delays and ten with language delays; none of these toddlers exhibited autistic features or had a history of ASD in first- or second-degree relatives. 72% of the AUT sample had a confirmatory diagnosis at the age of 3-4 years, 14% relocated or were lost to follow-up, and 14% were too young for confirmatory assessment at the time when this manuscript was written. Previous work suggests a high stability of ASD diagnosis, in general, and autistic disorder, in particular, in this age range: in a study of 43 toddlers given a diagnosis of autism in the second year, only 25% improved enough to warrant a change of diagnosis to PDD-NOS at 3-4 years; none were considered to have a non-ASD disorder (Chawarska, Klin, Paul, Macari, & Volkmar, 2009). Given the sample size, shifts within the ASD category of this magnitude are unlikely to threaten the integrity of the analysis. Typically developing toddlers were recruited through online and newspaper advertisements and had no social or cognitive developmental delays and no family history of ASD in $1^{st}$ or $2^{nd}$ degree relatives. All parents provided informed consent in adherence to the University Human Investigation Committee requirements.

An additional 15 toddlers were tested but did not contribute any valid data to the experiment: seven (11%) in the AUT group, three (13%) in the DD group, and five (9%) in the TD group. There was no differential drop-out with regard to diagnosis (chisq (2) = .24, p=.884). The exclusions were primarily due to technical difficulties in calibration due to squinting, head positioning, motion artifacts, or negative affect precluding the child from beginning the session. Toddlers with autism excluded from the analysis did not differ significantly from the retained sample in terms of age, Mullen or ADOS scores.

Toddlers in all three groups did not differ in terms of age at the time of the experiment or in gender distribution (Table 1). As many as 79% of parents identified their child's race as

Caucasian, with the remaining 21% as African American (2.5%), Asian (3.3%), Other or not Specified (6.7%), or mixed racial heritage (8.3%); these distributions were not significantly different between groups. AUT and DD groups were comparable with regard to verbal and nonverbal mental ages. Given reports regarding atypical receptive and expressive language profiles (Chawarska, et al., 2009; Paul, Chawarska, Cicchetti, & Volkmar, 2008), as well as reports of potential associations between language ability and attention to the specific elements of the speaker's face in autism (Norbury et al., 2009), we computed an index of the discrepancy between Expressive and Receptive Language DQ scores: the Expressive-Receptive Language split (EL-RL split) was higher in the AUT group than in the TD group but not higher than in the DD group.

## Procedure

### Stimuli

The stimuli consisted of a 3-minute video of an actress filmed in a setting containing four toys and a table with ingredients for making sandwiches (see Figure 1a). The experiment consisted of four conditions, with each condition presented over multiple episodes, where each episode was an instance of the behavior associated with the condition. In the *DyadicBid* condition the actress engaged in child-directed speech while looking directly at the camera (11 episodes, total duration 69 s), resembling a bid for dyadic attention. In the *Sandwich* condition, the actress looked down at the table and made a sandwich; no direct gaze or speech cues were present (2 episodes, total duration 63 s). In the *Joint Attention* (*JointAtt*) condition the actress looked up briefly at the camera, and then exclaimed 'uh-oh' as she turned toward one of the toys and remained still for 4 s (4 episodes, total duration 30 s). Finally, in the *MovingToys* condition, after the actress looked up at the camera, a toy began to move and make noises; this was immediately followed by the actress turning to look at the toy on the opposite side of the moving toy (4 episodes, total duration 27 s). While the *JointAtt* and *MovingToys* conditions lent themselves to more specific hypotheses testing, here they are analyzed only for the purpose of examining the general distribution of attention across the key features of the scene. The entire experiment was designed to depict a woman making a sandwich, occasionally looking at the camera and trying to engage the viewer (e.g., saying, "Hi, baby, how are you today?") or looking at the toys positioned in four corners of the screen, with toys sometimes remaining still and sometimes moving. Episodes associated with conditions were interleaved throughout the video in order to provide variation and heighten interest. There were no breaks in the video to re-engage or re-center the child's visual attention. This type of display required the toddlers to adjust their viewing patterns depending on context, as they would in real life.

### Apparatus

Gaze trajectories were recorded at a sampling rate of 60Hz using a SensoMotoric Instruments IView X™ RED eye tracking system. Eye tracking data were processed using custom software written in Matlab (Mathworks, 2009). The software accommodated standard techniques for processing eye-tracking data including blink detection, data calibration, recalibration, and Region of Interest (ROI) analysis (Duchowski, 2003; Shic, 2008). Data reduction and analysis were carried through programs written in SAS (SAS Institute Inc., 2000-2004).

### Procedure

Toddlers were seated in a car seat in a dark and soundproof room 75cm in front of a 24" widescreen LCD monitor. Each session began with a cartoon video to help the child get settled. Subsequently, a five-point calibration procedure was initiated with calibration points consisting of dynamic targets presented simultaneously with sound (e.g. a meowing, walking cartoon tiger). Subsequently, each participant was presented with the video described in *Stimuli*.

## Analytic Strategy

### Data reduction

We divided the visual scene into several regions of interest (ROIs) (see Figure 1b). Regions of interest were dilated by 1.25 degrees on each side with no overlap between different regions to accommodate calibration error and eye-tracker noise. Dependent variables were based on the proportions of time spent examining each of the regions and include: (1) overall attention to the scene (%ValidTotal), (2) %Face, %Eyes (upper Face), %Mouth (lower Face), and %Hands/Activity area; and (3) %Toys and %Background. Proportion of the total valid looking time (%ValidTotal) was standardized by the total duration of the video display; the remaining variables were standardized by the total valid looking time at the scene. The scene subtended 27 × 21 degrees of visual angle, the Face 3.9 × 5.6, Mouth 3.5 × 2.0, and the Toys 5.8 × 6.4.

### Statistical analysis

Primary hypotheses regarding between- and within-group effects were tested using linear mixed models (SAS Proc Mixed) with diagnosis (3) as a between-group factor and condition (4) as a within-group factor. Whenever present, significant interaction effects were examined within each condition using planned contrasts comparing AUT to TD and AUT to DD groups; effect sizes (Cohen's *d* and Pearson's *r*) are reported whenever applicable. Post-hoc comparisons are reported with Tukey-Kramer correction for multiple comparisons. Associations between performance on the eye-tracking tasks and characterization features for toddlers with autism were examined using stepwise linear regression analysis.

## Total Looking Time at the Scene

Each child contributed data to at least one condition and a vast majority contributed to all four. Loss of eye tracking data was attributed to blinks as well as inattention. We excluded from the analysis all episodes in which the child contributed less than 20% of valid eye tracking, which was true for 36 out of 484 episodes (7.4%) from 18 toddlers (9 AUT, 5 DD and 4 TD). Exclusion rates were similar across conditions but toddlers with AUT and DD contributed fewer valid episodes (91% and 87%, respectively) than TD controls (96%) (*chisq* (2) = 7.93, p = .019), reflecting, most likely, non-specific attentional difficulties frequently encountered in children with developmental delays. A mixed models ANOVA performed on the average *%ValidTime* indicated a significant effect of condition, $F$ (3, 321) = 4.27, $p$ = .006, diagnosis, $F$ (2, 118) = 4.75, $p$ =.01, and a marginally significant condition × diagnosis interaction, $F$ (6, 321) = 2.06, $p$ =.057. Planned contrasts indicated that toddlers with AUT attended less to the screen in conditions involving direct dyadic cues (*JointAtt* and *Dyadic Bid)* than both DD and TD controls (Table 2). There were no diagnosis effects in the *MovingToys* or *Sandwich* conditions.

## Distribution of Attention within the Scene

### Face Ratio

A diagnosis × condition ANOVA on %Face indicated a significant effect of condition: $F$ (3, 321) = 636.46, p=.001, and a condition × diagnosis interaction: $F$ (6, 321) = 8.97, $p$ = .001. Planned contrasts revealed that in the *DyadicBid* condition attention to the *Face* was significantly lower in the AUT group compared to both DD and TD groups (Table 2). In the *JointAtt* condition, the AUT group spent less time looking at the face than the DD group, but not the TD group. Attention to the Face region did not differ by diagnosis in the *Sandwich* or *MovingToys* conditions.

### Eyes and Mouth Ratio

A diagnosis × condition ANOVA on %Eyes indicated a significant effect of condition, *F* (3, 321) = 108.59, *p* =.001, and no effect of diagnosis (*p*=.199) or interaction (*p*=.245). Post-hoc comparisons between conditions indicated that all groups looked more at the eyes in the *Dyadic Bid* (M=17%, SD=13) and *JointAttention* (M=20%, SD=16) conditions than in *Sandwich* (M=4%, SD=4) and *MovingToys* (M=6%, SD=7) conditions. An analogous analysis on %Mouth indicated a significant effect of condition, *F* (3, 321) = 313.68, *p*=.001, diagnosis, *F* (2, 118) = 7.12, *p* =.001, and a condition × diagnosis interaction, *F* (6, 321) = 8.75, *p* =.001. In the *DyadicBid* condition the AUT group spent *less* time looking at the mouth region than DD and TD groups (Table 2). The difference failed to reach statistical significance in the *JointAtt* condition, though the trend was in the same direction. There were no between-group differences in the *Sandwich* and *MovingToys* conditions.

### Hands/Activity Ratio

A diagnosis × condition ANOVA on %Hands/Activity indicated a significant effect of condition, *F* (3, 321) = 606.29, *p* =.001, and a condition × diagnosis interaction, *F* (6, 321) = 3.22, *p* =.004. Planned contrasts within each condition indicated no group differences in either *Sandwich* or *MovingToys* conditions (Table 2). However, in both *JointAtt and DyadicBid* conditions, toddlers with AUT spent more time looking at the *Hands/Activity* region than both DD and TD groups.

**Toys—**A diagnosis × condition ANOVA on %Toys indicated a significant effect of condition, *F* (3, 321) = 703.67, *p* = .001, and a diagnosis × condition interaction, *F* (6, 321) = 4.01, *p*=.001. Planned contrasts indicated that only in the *DyadicBid* condition did toddlers with AUT show greater attention to toys than the TD group (Table 2). There were no differences between other conditions or between AUT and DD groups.

**Background—**A diagnosis × condition ANOVA indicated significant effects of diagnosis, *F* (2, 118) = 7.77, *p* < .001, and condition, *F* (3, 321) = 8.21, *p* =.001. Planned contrasts indicated that the AUT group spent more time looking at the background (M=6%, SD=7) than the DD (M=3%, SD=3) (p =.006) and TD (M=3%, SD = 6) groups (p = .003). All groups looked the least at the Background in the *Sandwich* condition (mean=3%, SD=4) and the most in the *Moving Toys* condition (M = 6%, SD=9), with *JointAtt* (M=5%, SD=5) and *DyadicBid* (M=5%, SD = 4) conditions falling in between and not different from one another.

### Associations between Attention and Phenotypic Characteristics in Toddlers with Autism

Amongst all four conditions, the *DyadicBid* condition produced the most pronounced differences between AUT and control groups, particularly with regard to overall attention to the scene (%ValidTime), attention to the face of the speaker (%Face), and the speaker's mouth (%Mouth). Given inherent variability observed in autism, in this analysis we examine whether these performance features were associated with severity of clinical impairment within the autism group. A Pearson's *r* correlation analysis conducted between clinical measures (ADOS-G total score, verbal and nonverbal DQ and EL-RL split) and eye tracking measures (%Valid, %Face, and %Mouth) indicated significant (p<.05) correlations between %Valid and ADOS-G total score (r (50) = −.28), Nonverbal DQ (r (50) = .45), and Verbal DQ (r (50) = .33). A stepwise multiple regression analysis indicated that the Nonverbal DQ accounted for 19.9% of variance (*p*=.001) in the %ValidTime variable; no other predictors contributed significantly to the model (see Table 3). An identical set of predictors was tested for %Face and % Mouth. Only the EL-RL split showed a significant association with the two variables, accounting for 19% of variance in the %Face variable ($p$ =.002, $r$ (50) = −.43) and 14% of variance in the %Mouth variable ($p$=.008, $r$ (50) = −.38). Thus, within the autism sample, the lower-functioning toddlers attended less to the scene in episodes with dyadic cues. Moreover, regardless of the level of verbal or nonverbal skills, those with the most abnormal language profile exemplified by poor receptive relative to expressive skills spent less time monitoring the speaker's face and her mouth.

To examine whether the association between attention to the mouth in toddlers with autism was unique to this sample we conducted an analogous regression analysis for % Mouth in DD and TD groups. The analysis indicated that, in DD and TD groups, none of the characterization variables (VDQ, NVDQ, EL-RL split) contributed significantly to the model aimed at predicting the amount of time spent on the speaker's mouth. Given a small sample size in the DD group, we combined the DD and TD groups and found a marginally significant contribution of verbal DQ to the model (F (2, 52) = 3.94, p=.052; r (53) = .267, p =.052) suggesting that, in the non-autism group, higher verbal skills were associated with enhanced attention to the mouth, a pattern that was very different from that obtained in the AUT group.

## Discussion

The leading question in this study was, "What factors contribute to limited attention to people by toddlers with autism?" By decomposing the elements of the dynamic scene we were able to examine this question more deeply. Clearly, the mere presence of a person within the visual field (e.g., making a sandwich) did not perturb the toddlers' general looking patterns. Neither did the presence of toys and objects. It was only when dyadic cues consisting of child-directed speech and eye contact were introduced that differences between autism and control groups became apparent. In such a context, toddlers with autism showed diminished attention to the entire scene and spent less time monitoring the speaker's face in general and her mouth in particular. Instead, they directed their attention toward the toys as well as the sandwich making area. These effects appeared in an almost dose-dependent fashion: the differences were less evident when eye contact and speech were limited and short lived (*Joint Attention)*, but were pronounced when explicit and prolonged dyadic bids were present (*Dyadic Bid)*. These results do not support the hypothesis of a *generalized* preference for objects over people in toddlers with autism and provide no evidence for generalized difficulties in attending to people in this population. Instead, limited attention to faces appeared context-dependent and was linked to the presence of explicit cues for dyadic engagement. Given that gaze and speech cues were confounded in this study (as they often are in real life), their unique contributions need to be further investigated. However, together, they represent the prototypical bid for dyadic attention, the most elementary and perhaps most salient social behavior, to which a keen sensitivity is already present shortly after birth in typically developing infants (Farroni, Menon, Rigato, & Johnson, 2007; Johnson, Dziurawiec, Ellis, & Morton, 1991; Patterson & Werker, 2003; Sai, 2005). An attenuated attentional bias for this class of social stimuli early in life is likely to have a profound and debilitating effect on the development of social-cognitive skills and language in autism.

What mechanism might be responsible for the difficulty in attending to a scene containing bids for attention? The results showed that while toddlers with autism attended less to the actress' face in the *Dyadic Bid* condition when compared to controls, at the same time, they attended *more* to the actress's face in the *Dyadic Bid* condition than they did in the *Sandwich* condition. This suggests that while toddlers with ASD as a group exhibit an elementary sensitivity to dyadic cues, their attention to a person in such as context was not sustained. Are toddlers with autism perturbed by presence of dyadic cues or do they find them less engaging? Our experiment was not designed to directly test these hypotheses; however, we will discuss the two possibilities in turn based on the available evidence.

The appearance of a face in the visual field activates the fast-acting subcortical pathway including the amygdala, limbic brain regions that have been associated with the rapid categorization of faces and evaluation of expressions and personality traits (Adolphs, Baron-Cohen, & Tranel, 2002; Engell, Haxby, & Todorov, 2007; Todorov & Engell, 2008). Neuroimaging studies suggest that older individuals with ASD exhibit increased activation (Dalton et al., 2005) and/or decreased habituation (Kleinhans et al., 2009) of the limbic system in response to faces, which might lead to increased autonomic arousal and trigger self-regulatory strategies such as gaze aversion and, in the case of a failure to down-regulate arousal level, increases in negative affect and dropout from the experiment. We found very little evidence for the latter, though the first possibility needs to be further investigated.

An alternative hypothesis would suggest that child-directed speech and eye contact, while not aversive *per se*, may not attract or hold the attention of toddlers with autism to the same extent as in developmentally delayed and typical controls. Prior studies have shown that faces not only capture (Coffman et al., 2011) but also hold the attention of typically developing toddlers more than other classes of stimuli (Chawarska et al., 2003; Chawarska et al., 2010), reflecting a prepotent attentional bias within the dedicated neural system aimed at prioritizing faces for processing (Fox et al.; 2002; Langton et al., 2008; Ro et al., 2007). This aspect of face processing appears to be impaired in toddlers with ASD as indexed by faster disengagement of attention (Posner & Petersen, 1990) from dynamic faces than observed in DD and TD controls (Chawarska et al., 2003; Chawarska et al., 2010). The limited attentional bias for faces described here might represent a broader area of deficits extending to other types of social stimuli such as biological motion (Klin et al., 2009) or infant-directed speech (Kuhl, Coffey-Corina, Padden, & Dawson, 2005; Paul, Chawarska, Fowler, Cicchetti, & Volkmar, 2007). While speculative, limited attentional bias for faces and speech in toddlers with autism might be associated with the well-documented reports of decreased activation of cortical brain areas involved in the processing of gaze, facial expressions, biological motion, and speech in individuals with autism (Critchley et al., 2000; Gervais et al., 2004; Greene et al., 2011; Pelphrey et al., 2003; Pelphrey, Morris, Michelich, Allison, & McCarthy, 2005), and thereby represent a behavioral marker of abnormal activity in the social brain network in the second year of life in autism.

The limited ability to sustain attention on the speaker's face and her mouth was associated with an atypical language profile exemplified by a relative advantage of expressive single-word vocabulary over the ability to respond to and understand spoken language. This type of language profile is common amongst young children with autism (Charman, Drew, Baird, & Baird, 2003; Hudry et al., 2010; Luyster, Kadlec, Carter, & Tager-Flusberg, 2008), but not with other disorders such as Down or Fragile × syndromes or encephalopathy (Roberts, Mirrett, Anderson, Burchinal, & Neebe, 2002; Wolters, Brouwers, Moss, & Pizzo, 1995; Ypsilanti & Grouios, 2008), and reflects the emergence of echolalia (Kjelgaard & Tager-Flusberg, 2001) in a context of limited sensitivity to child-directed speech (Paul et al., 2007). Given that in typically developing toddlers, attention to child-directed speech facilitates the development of more sophisticated patterns of speech perception (Kuhl et al., 1992; Thiessen et al., 2007) and social interactions (Trevarthen & Aitken, 2001), the deficits observed in the second year of life in autism are likely to be highly consequential for language and communication development (Paul et al., 2007; Watson, Baranek, Roberts, & Perryman, 2010).

Our findings replicate and extend previous reports regarding limited attention to faces in dynamic contexts (Jones et al., 2008; Klin et al., 2002; Riby & Hancock, 2009; Shic et al., 2011), documenting that this effect is especially pronounced when explicit eye contact and child-directed speech are present. Consistent with findings both in typical (Rosenblum, Schmuckler, & Johnson, 1997; Teinonen, Aslin, Alku, & Csibra, 2008) and high-risk populations (Young, Merin, Rogers, & Ozonoff, 2009), more extensive attention to the speaker's mouth was associated with a less abnormal language profile. However, unlike the study by Jones and colleagues (2008), attention to eyes was similar across groups and, as a group, toddlers with autism showed *decreased* monitoring of the speaker's mouth. Several factors are likely to account for this discrepancy including the younger age of participants (1.8 years versus 2.3 years) and greater severity of symptoms amongst toddlers in the present study (autism versus autism spectrum disorder). Moreover, the speech episodes were presented for brief periods of time interspersed with other types of activity, forcing toddlers to respond and adapt quickly to the changing context. Such discrepancies between studies highlight the sensitivity of scanning patterns to the complex interplay between the context in which social stimuli are presented and the individual's clinical features including age, cognitive level, severity of social impairment, and language profiles.

### Conclusions

This is the first study to demonstrate context effects on scanning patterns in toddlers with autism. Focusing on the earliest age when the syndrome can be reliably diagnosed brings us closer to understanding which deficits are likely to be primary in autism. The findings lend little support to the hypothesis of a generalized deficit in attention regulation in response to complex social scenes in toddlers with autism. They also do not provide support for the hypothesis that, as a group, toddlers with autism prefer to look at objects compared to non-affected toddlers regardless of context. Instead, they point to speech and eye contact as key features likely to perturb attention in toddlers with autism. This study emphasizes that the very early deficits in autism are focused around the type of social stimuli that are absolutely essential for development of social cognition and language: the cues that typically prompt the child to attend, engage, reciprocate, and learn through an unfolding process. These findings have important implications for understanding the underlying mechanisms of limited social monitoring and identifying pivotal targets for treatment in infants.

### Limitations

Given that direct gaze and speech cues appeared simultaneously, their unique contributions to the regulation of attention in toddlers with autism remain to be clarified. Prospective longitudinal data from this cohort will be necessary to address questions of predictive validity of performance profiles in the toddlers with autism and developmental delays. The %ValidTime measure was affected by both blinks and inattention; further analyses will need to be conducted in order to separate these components. The causal relationship between abnormal language profiles and poor attention to the speaker in toddlers with autism needs to be further investigated. Finally, the effects reported here have been demonstrated at the group level; yet given the well-known variability in performance of toddlers with autism, it is possible that examining individual patterns of viewing may yield additional insights into understanding the nature of social disability in ASD. This work is in progress.

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## Key Points

1. Toddlers with autism exhibit particular difficulties in attending to people trying to engage them in dyadic interactions.
2. Decreased overall attention to a scene containing dyadic bids is strongly associated with lower nonverbal cognitive ability in toddlers with autism. However, decreased attention to the face and mouth of a speaker is associated with an atypical language profile consisting of greater expressive relative to receptive language ability.
3. Given that mechanisms supporting responsivity to dyadic cues are present shortly after birth and are highly consequential for development of social cognition and communication, these findings have important implications for understanding the mechanisms underlying limited social monitoring and for identifying pivotal targets for treatment in infancy.

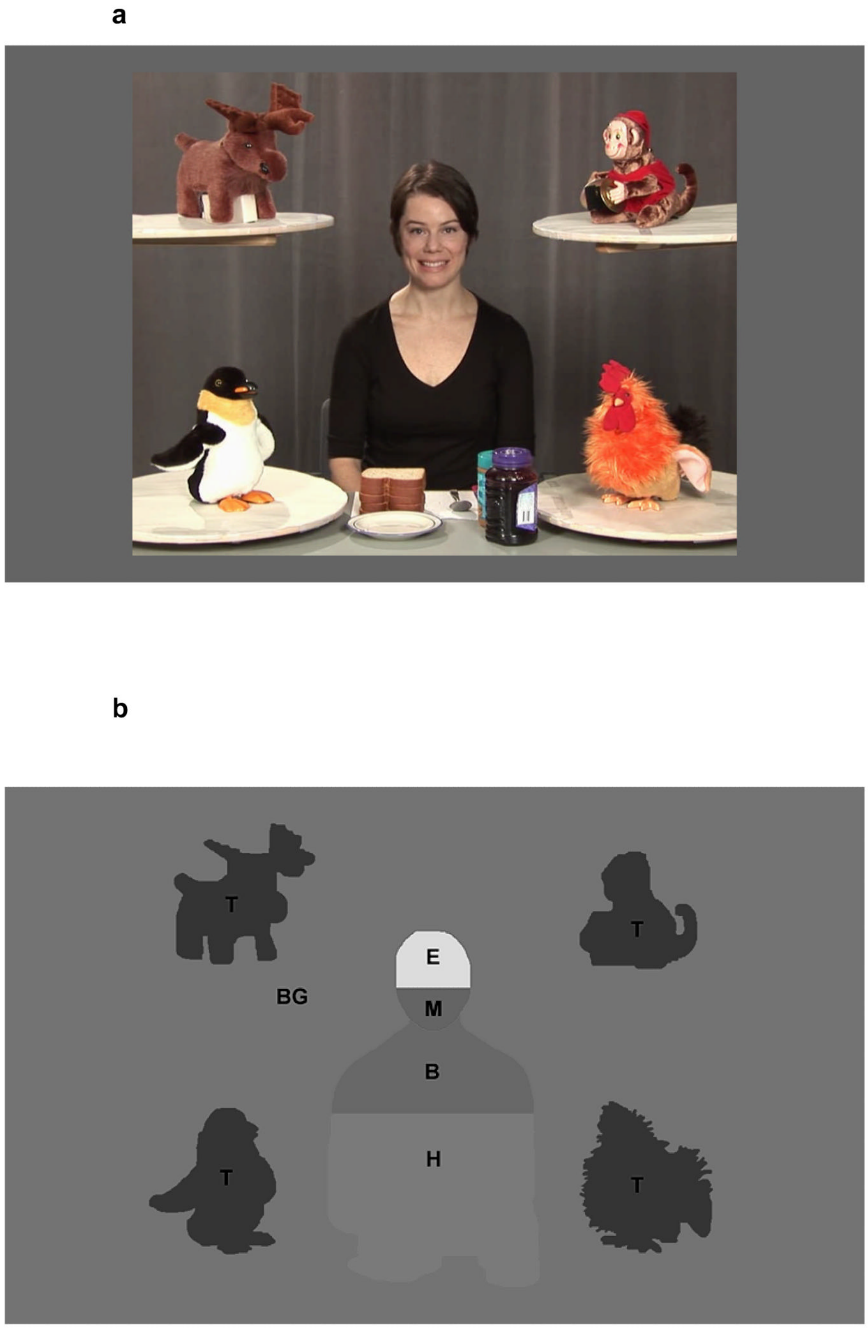


**Figure 1.**
(a) Frame from video stimulus used with (b) regions of interest (ROIs) used in analysis. Regions were: Eyes (E), Mouth (M), Body (B), Hands/Activity (H), Toys (T), and Background (BG). Face ROI consists of Eyes and Mouth combined.

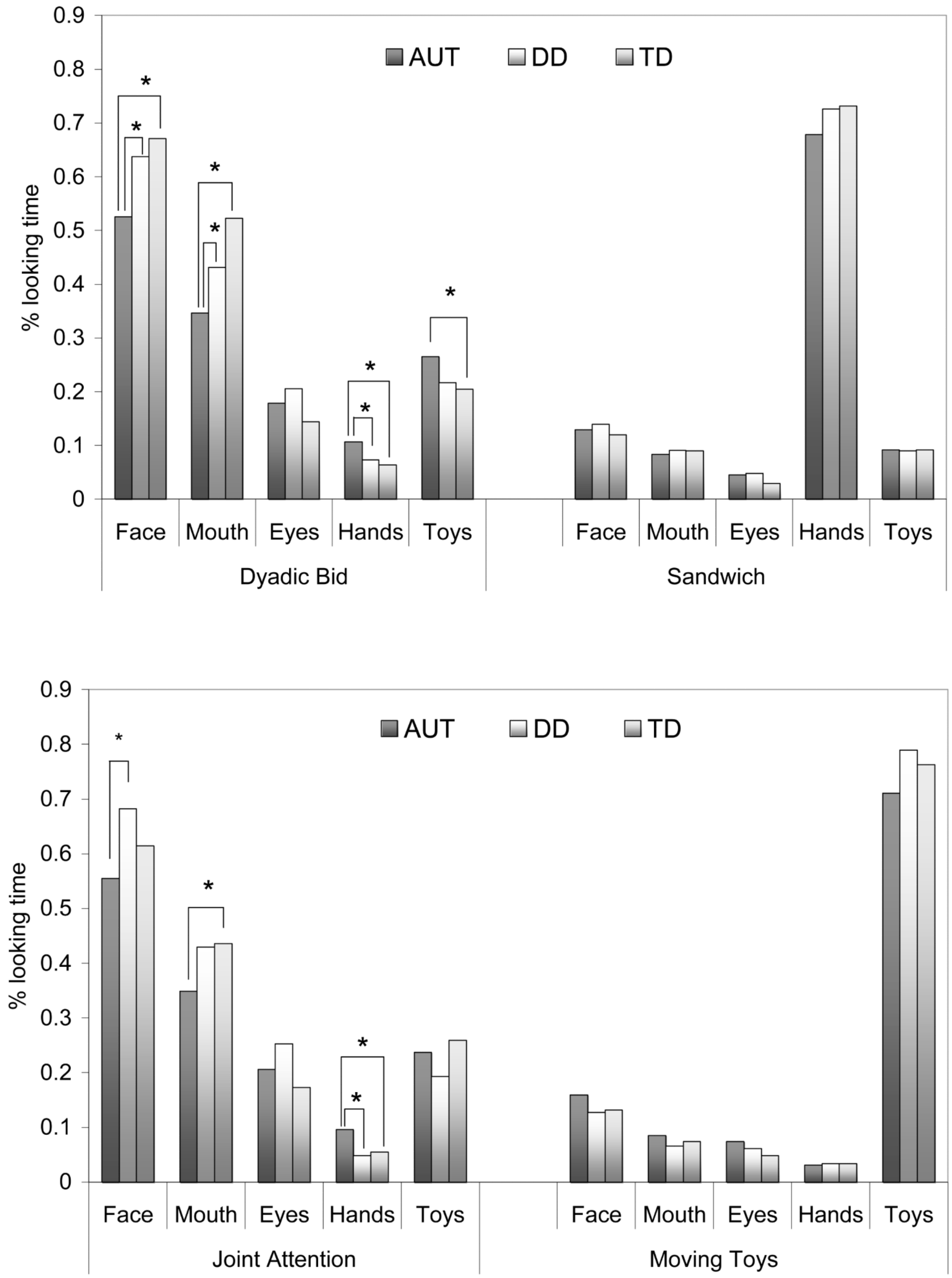


**Figure 2.**

Looking time ratios in the Dyadic Bid, Sandwich, Joint Attention, and Moving Toys conditions in the Autism (AUT), Developmentally Delayed (DD), and Typically Developing (TD) groups.

## Table 1

Sample Characterization

| | AUT | DD | TD | p-value |
|---|---|---|---|---|
| N | 54 | 20 | 48 | |
| Age | 21.6 (2.9) | 20.1 (3.5) | 20.5 (3.0) | ns |
| Gender (Male%) | 85% | 80% | 73% | ns |
| Mullen Nonverbal MA | 16.6 (4.5)[a] | 17.5 (5.1)[a] | 21.9 (4.07)[b] | .001 |
| Mullen Verbal MA | 9.1 (5.8)[a] | 11.7 (4.2)[a] | 22.0 (5.6)[b] | .001 |
| Mullen EL – RL split | 8.1 (23.4)[a] | −.35 (25.2)[ab] | −.4.9 (28)[b] | .05 |
| ADOS-G SA | 15.9 (3.3) | 7.9 (3.7) | -- | .001 |
| ADOS-G RRB | 4.7 (1.9) | 1.9 (1.6) | -- | .001 |
| ADOS-G Total | 20.6 (4.0) | 8.8 (4.8) | -- | .001 |
| Vineland Communication | 71 (13) | 84 (12) | -- | .001 |
| Vineland DLS | 78 (10) | 86 (8) | -- | .001 |
| Vineland Socialization | 76 (7) | 84 (7) | -- | .001 |

MA: Mental age, EL: Expressive language, RL: Receptive anguage. SA: Social affect, RRB: Restricted and repetitive behaviors, DLS: Daily Living Skills

Within each row, means with different superscripts differ at least at the p=.05 level

## Table 2

Mean (SD) percentages of time spent examining specific ROIs. Planned contrasts between Autism and Control groups for significant Diagnosis × Condition interaction effects in Dyadic Bid, Sandwich, Joint Attention and Moving Toys conditions.

| *Dyadic Bid* | *AUT M(SD)* | *DD M(SD)* | *TD M(SD)* | *F (2,111)* | *p-value AUT vs DD* | *p-value AUT vs TD* | *Cohen's d AUT vsDD* | *Cohen's d AUT vs TD* |
|---|---|---|---|---|---|---|---|---|
| %Valid Time | 71.7 (21.5) | 82.1 (19.1) | 81.5 (14.6) | 4.10* | .042 | .010 | .511 | .533 |
| %Face | 52.1 (19.3) | 63.7 (14.7) | 67.1 (12) | 10.45*** | .012 | .001 | .676 | .933 |
| %Mouth | 34.1 (16.8) | 43.2 (15.5) | 52.2 (14.2) | 15.48*** | .047 | .001 | .563 | 1.16 |
| %Hands/Act | 10.9 (7.5) | 7.4 (5.2) | 6.4 (4.2) | 6.40** | .047 | .001 | .542 | .740 |
| %Toys | 26.8 (14) | 21.6 (9.4) | 20.5 (9.4) | 3.37* | -- | .012 | -- | .528 |

| *Joint Attention* | *AUT M(SD)* | *DD M(SD)* | *TD M(SD)* | *F (2,107)* | *p-value AUT vs DD* | *p-value AUT vs TD* | *Cohen's d AUT vs DD* | *Cohen's d AUT vs TD* |
|---|---|---|---|---|---|---|---|---|
| %Valid Time | 69.1 (23.9) | 85.5 (15) | 81.7 (16.6) | 6.37** | .004 | .003 | .822 | .612 |
| %Face | 55.0 (23.2) | 68.2 (16.7) | 61.4 (14) | 3.08* | .019 | -- | .653 | -- |
| %Mouth | 34.3 (20.8) | 42.9 (20.1) | 43.6 (14.9) | 2.91~ | -- | .025 | -- | .514 |
| %Hands/Act | 9.9 (11.4) | 4.9 (5.3) | 5.5 (4.8) | 3.49* | .049 | .022 | .562 | .503 |
| %Toys | 23.8 (14.6) | 19.3 (14.8) | 25.9 (13.1) | ns | -- | -- | -- | -- |

| **Sandwich** | **AUT M(SD)** | **DD M(SD)** | **TD M(SD)** | **F (2,109)** | **p-value** |
|---|---|---|---|---|---|
| %ValidTime | 77.3 (17.5) | 85.7 (16) | 83.9 (15.6) | 2.62 | .-- |
| %Face | 12.9 (9) | 13.9 (7.4) | 12 (5.8) | .46 | -- |
| %Mouth | 8.3 (6.2) | 9.1 (5.5) | 9 (4.8) | .22 | -- |
| %Hands/Act | 68 (12.7) | 72.6 (14.6) | 73.1 (9.5) | 2.84 | -- |
| %Toys | 9.1 (6.7) | 9 (10.5) | 9.2 (7.1) | 0 | -- |

| **Moving Toys** | **AUT M(SD)** | **DD M(SD)** | **TD M(SD)** | **F (2,109)** | **p-value** |
|---|---|---|---|---|---|
| %ValidTime | 79.3 (19.4) | 87.3 (17.8) | 81.5 (16.7) | 1.25 | .-- |
| %Face | 15.7 (11.6) | 12.7 (9.7) | 13.1 (7.6) | 1.03 | -- |
| %Mouth | 8.4 (7.1) | 6.6 (6) | 7.4 (5.9) | .57 | -- |
| %Hands/Act | 3.2 (4.1) | 3.4 (3) | 3.4 (4.2) | .05 | -- |

| Moving Toys | AUT M(SD) | DD M(SD) | TD M(SD) | F (2,109) | p-value |
|---|---|---|---|---|---|
| %Toys | 71.1 (16.4) | 78.9 (10.6) | 76.2 (15.9) | 2.15 | -- |

~ .06

* .05

** .01

*** .001

**Table 3**

Stepwise multiple regression analyses in the Autism group based on performance in the Dyadic Bid condition

| Predicted Variable | Predictor | F (1, 49) | Intercept | Slope | Partial $R^2$ |
|---|---|---|---|---|---|
| Valid Time Ratio | Nonverbal DQ | 11.91*** | .57 | .004 | 19.9% |
| Face Ratio | Expressive-Receptive Split | 10.28** | .55 | .−003 | 18% |
| Mouth Ratio | Expressive-Receptive Split | 7.25** | .37 | −.002 | 13% |