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Limited Activity Monitoring in Toddlers with Autism Spectrum Disorder

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Abstract

This study used eye-tracking to examine how 20-month old toddlers with autism spectrum disorder (ASD) (N=28), typical development (TD) (N=34), and non-autistic developmental delays (DD) (N=16) monitored the activities occurring in a context of an adult-child play interaction. Toddlers with ASD, in comparison to control groups, showed less attention to the activities of others and focused more on background objects (e.g. toys). In addition, while all groups spent the same time overall looking at people, toddlers with ASD looked less at people's heads and more at their bodies. In ASD, these patterns were associated with cognitive deficits and greater autism severity. These results suggest that the monitoring of the social activities of others is disrupted early in the developmental progression of autism, limiting future avenues for observational learning.

Keywords

activity monitoring; autism; eye-tracking; joint attention; social learning; observational learning

1. Introduction

Social and communicative difficulties, stereotyped behaviors, and restricted interests lie at the core of autism spectrum disorders (ASDs) (American Psychiatric Association, 2000). As our understanding of autism has increased, however, so too has our appreciation of its heterogeneity (Happé et al., 2006; Szatmari, 1999; Trikalinos et al., 2005). Some have argued that, in order to understand the complex genetic and epigenetic relationships in ASD, it is necessary to consider autism not as a reflection of singular deviations in specific functional cognitive or social modules, but as the emergent and recurrent property of atypical preferences, percepts, learning, and experience (Jones and Klin, 2009; Karmiloff-Smith, 2007; Klin et al., 2003; Johnson et al., 2005). In this study we examine how toddlers with ASD perceive and monitor people engaged in a shared activity. This simple act of activity monitoring is an expression not only of a person's experience-dependent

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understanding of the scene, but also provides access to new experiences as actions unfold. Thus activity monitoring may be related to both cause and consequence of atypical social and cognitive development in individuals with ASD.

In typical development, the ability to understand intentional and goal directed actions of others arises early in infancy (e.g. Baldwin et al., 2001; Biro and Leslie, 2007; Falck-Ytter et al., 2006; Woodward, 1998, 1999; for reviews see Aschersleben, 2006; Tomasello et al., 2005). However, less attention has been paid towards the relative salience of actions as compared to other salient constructs in ecological contexts. Amongst the exceptions is the work of Bahrick and colleagues (2000; 2008) who showed that when 5 ½ month old infants are presented with videos of people performing everyday tasks, such as brushing their teeth, actions are prioritized for memory over both the identities of the people and the objects those people employ. Furthermore, it is only when the presentation time of the scenes is extended, or the infants are older, that memory for faces and actions is achieved simultaneously (Bahrick and Newell, 2008). These results imply that when the attentional resources are constrained, even faces, one of the most privileged socially-relevant objects (Cohen Kadosh and Johnson, 2007; Farah et al., 1998; Haan et al., 2002; Halit et al., 2003; Hershler and Hochstein, 2005; Valenza et al., 1996), ultimately lose to actions.

Attention to the actions and activities of others is also a critical component of the learning and development of cognitive and social skills. For example, attention to others and their actions facilitates learning about affordances (Gibson, 1988; Huang and Charman, 2005; Loveland, 1991; Meltzoff, 1995), is a requisite for imitation and emulation (Abravanel et al., 1976; Carpenter, 2006; Heyes, 2001; Meltzoff and Moore, 1977; Tomasello, 1996; Want and Harris, 2002), and is crucial to the development of higher-level cognitive skills such as joint attention, social play, and the comprehension of intentions, goals, and motivations (Bakeman and Adamson, 1984; Carpenter et al., 1998; Moore and Dunham, 1995). The fact that skills such as affordance learning, imitation, and joint attention emerge in a regular fashion (e.g. see Carpenter et al., 1998; Trevarthen & Aitken, 2001), together with their relationships with later development of language and theory of mind skills (e.g. see Charman et al., 2000), argue for mutual interdependencies and suggest that common requirements, such as activity monitoring, may evolve together with the skills themselves.

Many of the skills outlined above have been found to be impaired in autism spectrum disorders. Children with ASD have been shown to use objects in an atypical manner, for example by spinning coins, shaking toy cars, or using a sock as a container (Bruckner and Yoder, 2007; Ozonoff et al., 2007). These unusual object manipulations may indicate self-stimulatory or regulatory behavior (Turner, 1997, 1999; Whitman, 2004); however, as noted by Loveland (1991), such behaviors might also indicate that they have not discovered the culturally appropriate affordances of objects via typical observation of adults and peers. In this case, attending to the behaviors of others would be a requisite to learning about those socially agreed upon conventions. Studies have also found deficits in imitation in ASD (Charman et al., 1997; Colombi et al., 2009; Rogers, Hepburn, Stackhouse, & Wehner, 2003; Vivanti, Nadig, Ozonoff, & Rogers, 2008; for reviews see Williams, Whiten, & Singh, 2004; Rogers & Williams, 2006). For example, Vivanti and colleagues (2008) showed that high-functioning children with autism were less precise in imitation than controls. Furthermore, greater attention to actions in children with autism corresponded to better imitation of certain types of gestures. Through eye-tracking, the authors were able to differentiate between attention to the actor, background, and the act itself, bringing into focus the possibility that a seemingly similar overall engagement in an experimental task may be comprised of very different internal patterns of selective attention. Finally, systematic deficits observed in joint attention suggest that reduced attention to the attentional focus of others may be a particularly striking characteristic of ASD (Bono et al., 2004; Bruinsma et al., 2004; Charman, 2003; Charman et al., 1997; Dawson et al., 2004; Hecke et al., 2007; Leekam et al., 2000; Leekam and Ramsden, 2006; Mundy and Vaughan, 2002; Mundy et al., 1990; Sullivan et al., 2007). Taken as a whole, these studies suggest that activity monitoring, a component of all these skills, may be affected by the developmental progression of the autistic syndrome.

In this study we examine to what extent toddlers with ASD attend to the activities of others as compared to chronologically matched typically developing (TD) toddlers and chronologically and mental-age matched toddlers with developmental delays (DD). Traditionally, in studies of phenomena such as joint attention and imitation, the child is explicitly included as an active participant in the ongoing social exchange. By contrast, in this study, we examine the gaze response of children to the activities of others during natural viewing. Also in contrast to other studies, there is no attempt to actively engage the child's attention socially at the onset of the experiment (e.g. through infant-directed motherese or direct gaze), there are no predefined instructions to the subjects, and the study is conducted via presentation of a naturalistic play interaction. The study targets toddlers at 20 months of age, the earliest age at which a stable diagnosis of ASD can be obtained (Chawarska et al., 2007), employing an ecologically valid paradigm in terms of what children may naturally encounter at any age.

Based on the extant literature, we hypothesize that that toddlers with ASD will spend less time attending to the actors of the scene and the area of shared activity. Instead, we expect they will spend more time looking at toys and objects in the background. Finally, given hypothesized relationships between social functioning and visual scanning patterns in ASD (Anderson et al., 2006; Jones et al., 2008; Klin et al., 2002; Speer et al., 2007; Chawarska and Shic, 2009), we expect that deviations from prototypical scanning behavior will correlate with measures of social deficits and impaired cognitive functioning in toddlers with ASD.

2. Results

To examine if the groups included into the study differed in their overall level of attention, we compared the toddlers on the total time spent looking at the movie. There were no between group differences: on average, toddlers with ASD viewed the scene for 23.5 s (SD = 5.6), the DD group for 24.6 s (SD = 5.1), and the TD group for 26.2 s (SD = 5.0) ($p>.13$ for all pairwise group comparisons).

To examine overall differences in scanning patterns between groups, a between-group ANOVA was performed on the proportion of time spent looking at each ROI (Table 2). This analysis indicated group differences for *Activity* and *Background* but not for *People* (Figure 2). Planned contrasts showed that toddlers with ASD attended less to the *Activity* area and more to *Background* areas than DD or TD controls.

We also considered a more fine-grained examination of looking at *People.* A between-group ANOVA followed by planned contrasts showed that although the overall level of attention to *People* was not different between groups, when looking at *People*, the ASD group attended more to *Body* areas and less to the *Head* of characters as compared to TD toddlers. We also compared whether the proportion of attention to the *People* region varied by person identity. However, no between-group differences were observed in attention towards the *Adult* or the *Child* in the scene.

To better understand the relationships between activity monitoring and clinical features of toddlers with ASD, we examined correlations between dependent measures obtained via eye-tracking and measures of social disability (ADOS-G) and cognitive performance

(MSEL) (Table 3). Greater difficulties with Social Affect were associated with increased attention to the *Background* and decreased attention to the *Activity*, *Heads*, and the scene as a whole (decreased total time looking at the scene). Lower levels of both verbal and nonverbal mental age (VMA and NVMA, respectively) were associated with increased attention to *People* and decreased attention to the *Activity*. A multiple regression on attention to the *Activity* and *People* was conducted to disentangle the effects of Social Affect and NVMA and indicated that for attention to the *Activity* both Social Affect (β=-.39, $p<.05$) and NVMA (β =.54, $p<.001$) contributed, but that attention towards *People* was primarily driven by NVMA (β=-.58, $p<.01$) as compared to Social Affect (β=.03). An examination of correlations in the DD group indicated that attention towards the *Activity* was likewise modulated by NVMA (r=.53, $p<.05$) but not VMA (r=.21) or Social Affect (r=-.10); attention towards *People* was modulated by NVMA (r=-.60, p<. 05).

3. Discussion

While a vast majority of studies of social perception in young children with autism have focused on attention to faces and facial cues, our study examined the ability of these children to attend to the shared activities of others. This is important because attending to what others do is the critical first step in understanding what they do: a deficit at this stage limits further learning, potentially reducing the relevance of others' activities to the observer and consequently depressing the salience of those activities in the future. The results show that 20 month-old toddlers with ASD attend less to the activities of others than typically developing or developmentally delayed toddlers, diverting their attention to elements of the background. This phenomenon appears to be specific to toddlers with ASD, as matched for CA and MA toddlers with developmental delays showed patters of attention similar to that observed in typically developing toddlers.

While in toddlers with ASD spent a similar amount of time looking at *People* as their comparison groups, a closer examination of the constituents of *People*-looking suggest that, similarly as in the Klin et al. (2002) study, toddlers with ASD attended more to *Bodies* and less to *Heads*. Diminished looking at *Heads* was also linked to increased difficulties in social-communicative function in ASD, suggesting that while overall attention to *People* as a whole was not different between groups, specific internal patterns of scanning the characters of the scene were predictive of social function. Of particular interest is whether looking at *Heads* could be further decomposed into looking at *Eyes* versus looking at *Mouths.* Previous work has suggested that toddlers with ASD attend more to mouths than eyes in comparison to control groups when viewing dynamic videos of actresses emulating dyadic interactions (Jones et al., 2008; though see Merin et al., 2007 and Young et al., 2009 for additional perspectives). In the current study, eye-looking versus mouth-looking was not a hypothesis and the face region was fairly small (approximately 1.5×2.5 visual degrees), and thus the breakdown of eye versus mouth was not attempted. Given the fundamental importance of internal face scanning strategies to the processing and recognition of faces (Chawarska and Shic, 2009), however, future studies will be conducted with this analysis in mind. Nonetheless, the overall lack of differences between groups in looking at *People* highlights the complex and often subtle interactions between different competitors for visual attention. It is possible that, in the absence of the activity in the scene, between-group differences for looking at *People* would be more pronounced, as would specific differences in looking at *Head* and *Body* regions.

Several, not necessarily exclusive, hypotheses could be advanced to explain decreased activity monitoring in toddlers with ASD. First, this deficit might be associated with atypical processing of perceptual aspects of the scene such as contrast and motion. A number of studies in older individuals suggest that low-level perception may be altered in ASD including enhanced sensitivity to spatial contrast (Bertone et al., 2005; McCleery et al., 2007; Sanchez-Marin and Padilla-Medina, 2008; Shic et al., 2007; though see Koh et al., 2010; for reviews see Mottron et al., 2006; Simmons et al., 2009). In this context, the decreased attention to activities may be secondary to increased preference for objects with certain perceptual characteristics within the scene (e.g. see Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008; Zwaigenbaum et al., 2005). Moreover, decreased sensitivity to and/or preference for biological motion has been documented both in toddlers (Klin et al., 2009) and older individuals with ASD (Bertone et al., 2003; Blake et al., 2003; Milne et al., 2002; Shic et al., 2007). A deficit in this area could help to explain the unequal distribution between groups to background elements as compared to activity area. This type of deficit could be detrimental to the child's development on several levels. Cues derived from biological motion are essential for regulating attention in early development. In fact, studies of typical development suggest that parents often demonstrate actions to infants and toddlers using exaggerated motions termed “motionese” (Brand et al., 2002; Brand and Shallcross, 2008). An early limited sensitivity to such biological kinetic cues could make it more difficult to process this didactic form of scaffolding and communication. The effects of atypical salience of certain features of the visual field could be further compounded by difficulties in executive functioning in ASD. Executive control functions are subserved by a distributed neural system (Newman et al., 2003; for a review, see Collette et al., 2006) which appear to be atypically activated and functionally underconnected in ASD (e.g. see Just et al., 2007; Kana et al., 2007; Shafritz et al., 2008). Deficits in this area may be at least partially responsible for inability to inhibit the draw of highly perceptually salient but irrelevant to a task at hand elements of the visual scene.

The second set of hypotheses draws upon a potential association between activity monitoring and the ability to understand various aspects of the scene under consideration. According to the moderate discrepancy hypothesis (McCall and McGhee, 1977) children will attend to those aspects of the environment that are only slightly outside their ability to comprehend, i.e. a child will preferentially attend to stimuli which are neither too simple, given his or her capabilities, nor too complex. The decreased attention to activities exhibited by toddlers with ASD with greater cognitive deficits and the similarity of these associations with toddlers with DD suggests that the salience of the shared activity might indeed be affected by the ability of the individuals with ASD to comprehend the significance of this type of interaction. However, it is unlikely that cognitive level of functioning alone would explain the phenomenon, as toddlers with ASD monitor the activity of others less frequently than MA- and CA- matched toddlers with developmental delays. As the primary characteristic differentiating ASD and DD groups is the level of autism symptomatology, most likely the activity monitoring in ASD is gated by social functioning, i.e. attending to the activities of others is a reflection of the salience assigned towards social aspects of a visual scene. This view is supported by the inverse relationship found between social deficits and the overall amount of time spent looking at the scene: the toddlers who exhibit the greatest degree of social deficits also look least at the scene as a whole, and, when they do, look least at the activity. Furthermore, those ASD toddlers who were excluded from analysis due to poor attention to the task were more impaired socially than the included toddlers, suggesting that the effects observed might represent the “tip of the iceberg” in relationship to the most severely impaired toddlers with ASD.

Finally, the observed deficit might be a manifestation of disturbed social development early in infancy. By 18 months of age TD infants show reliable coordinated joint attention with caregivers and accurate decoding of the target of gaze (Bakeman and Adamson, 1984; Butterworth and Jarrett, 1991; Carpenter et al., 1998). It is possible that in TD toddlers this sensitivity to the attentional focus of others bolsters the saliency of the shared activity area and, by contrast, limited joint attention skills result in toddlers with ASD having a limited appreciation for the significance of the shared focus of others. In typical development, age-related changes in joint attention behavior are supported by neurodevelopmental mechanisms that evolve throughout infancy (e.g. see Hoehl et al., 2008; Mundy et al., 2000, 2003; Striano et al., 2006; for reviews see Grossmann and Johnson, 2007; Hari and Kujala, 2009; Itier and Batty, 2009; Nummenmaa and Calder, 2009). By contrast, in individuals with ASD, brain activity in response to gaze appears abnormal or delayed (e.g. see Grice et al., 2005; Kylliäinen and Hietanen, 2006; Senju et al., 2005; for a review see Senju and Johnson, 2009). Thus, it is plausible that a combination of atypical neural activation by social stimuli coupled with the altered development of perceptual and cognitive sensitivity to actions leads to widespread depression of a network involved in processing, understanding, and attributing relevance to the activities of others. Though our study was not designed to directly disambiguate amongst these possibilities, future modifications of our paradigm, in conjunction with neuroimaging and electrophysiological techniques, will help clarify the contributors to our observed trends.

The current study has several limitations. First, the developmentally delayed group is small relative to the other two groups, limiting the statistical power of comparisons between DD and ASD groups. Second, the stimulus shown represents only a subset of possible shared activities, and further studies will need to consider the specific impact of particular content and context on the scanning patterns of toddlers. Third, the relationship of our results to eventual outcome is not yet known, and this information will be crucial in placing activity monitoring into the larger ecology of eye-tracking work on infants and toddlers with ASD.

This study demonstrates that prototypic attention towards shared activities is disrupted in ASD by 20 months of age. Though likely a reflection of an ongoing atypical developmental process, it is important to realize that this disruption, at an age where rapid development and skill acquisition is occurring in TD toddlers, may critically impact the content of their social experiences, specifically, and learning via observation, in general. A simple scene, such as a play activity between two individuals, necessarily entails a complex dynamic of turn-taking, synchronized verbal and non-verbal communication, and shared attention. To a typically developing infant, these ebbs and flows of the social milieu are fundamental, and, one might argue, instinctual—for the next step after a period of observing others play, after the rules have been comprehended, and the actors understood, is to join in on the exchange. This cycle of passive observation and active participation builds a foundation by which later social skills may be acquired, assembled, comprehended, and interpreted. The cycle also builds a common history, a point of unification by which the attention of typically developing toddlers may be directed. By comparison, it appears that toddlers with ASD are not engaged with activities to the same extent; they thus are limited in their exposure to this common experience, and this may impact the later scaffolding of their social development. It is an open question to what extent this atypical trajectory can be changed; however, enhancing attention early in development not only to other people but also to their activities may open new avenues for intervening and fostering the development of key cognitive and social skills.

4. Experimental Procedure

Participants

Three groups of 20-month old toddlers (N=78) were recruited for this study: toddlers with autism spectrum disorder (ASD) (N = 28), typically developing (TD) toddlers (N = 34), and toddlers displaying developmental delays (DD) but who did not meet criteria for ASD (N=16) (Table 1). Classification of developmental status was determined by clinicians on the basis of a review of medical and developmental history, diagnostic tests (Autism Diagnostic Observation schedule – Generic (ADOS-G) Module 1) (Lord et al., 2002), and developmental tests (Mullen Scales of Early Learning (MSEL)) (Mullen, 1995). Previous work in a similar setting and age range has shown the stability of the broadly-defined diagnosis of ASD to be excellent (Chawarska et al., 2007,2009). The ASD group was comprised of 20 toddlers diagnosed with autistic disorder and 8 toddlers diagnosed with pervasive developmental disorder - not otherwise specified (PDD-NOS) (American Psychiatric Association, 2000). The DD group included subjects who presented with global delays or language impairments based on clinical judgment and performance profiles on the same battery of tests as used in the ASD sample. Four subjects in the DD group were siblings of children previously diagnosed with ASD who exhibited language delays but no ASD features; their inclusion did not alter the significance of any of the reported findings. The status of TD toddlers was confirmed by direct observation of play and interaction skills, assessment of nonverbal cognitive skills, and medical and developmental history. None of the TD toddlers had a history of ASD in 1^{st} or 2^{nd} degree relatives. All toddlers in the study were born after 32 weeks gestation, suffered no major prenatal or perinatal insults, had no known visual or auditory abnormalities, and had no history of medical conditions associated with autism (e.g. tuberous sclerosis or fragile × syndrome) or any other identified genetic disorder.

All three groups were matched on chronological age (see Table 1 for sample characterization). ASD and DD groups were also matched on nonverbal and verbal mental age (NVMA and VMA, respectively) and developmental quotient (NVDQ and VDQ); as expected, the TD group had higher verbal and nonverbal skills. The ASD group exhibited greater deficits than the DD group on the ADOS-G in both Social Affect and Stereotyped and Repetitive Behaviors domains.

An additional 20 subjects were tested but not included in this study. One child's data (ASD: n=1) was not recorded due to technical problems. The remaining 19 toddlers were excluded due to non-optimal arousal state (upset or falling asleep; ASD: n=2, DD: n=2, TD: n=2), inattention (ASD: n=5, TD: n=3), or a high activity level resulting in failed calibration (ASD: n=1, DD: n=1, TD: n=3). Toddlers with ASD excluded for reasons other than technical problems (n=8), as compared to included toddlers with ASD (n=28), exhibited more severe autism symptoms (excluded group's ADOS total: M=21.9, SD=4.1; included: M=17.4, SD=5.6; $t(34) = 2.1$, $p < .05$) but did not differ in terms of mental age.

Apparatus and Stimuli

Apparatus—Gaze patterns were recorded with a SMI iView X™ RED dark-pupil 60Hz eye-tracking system (Sensomotoric Instruments, 2005). Data were processed using custom software written in MATLAB™ (MathWorks, 2009), which provided standard processing of eye-tracking data including blink detection, outlier detection, eye-tracking calibration and recalibration, measurements of experimental error, and region-of-interest analysis (Duchowski, 2003; Shic, 2008). Statistical analyses were accomplished through software written in Perl (ActiveState, 2009), SPSS (SPSS, Inc., 2006), and R (R Development Core Team, 2009).

Stimuli—The stimulus used in this study was a 30-second video of a female adult and a male toddler playing with an inset puzzle (Figure 1). The scene was extracted from an unscripted observational video and thus included natural referencing (e.g. the adult pointing to a slot on the puzzle) and vocalizations (e.g., the adult saying “Good!”). Toys were strewn about in the background; furniture, walls, and the doors were clearly evident. The displayed video was 800 × 600 pixels in size and displayed at a screen resolution of 1280 × 800 pixels, occupying an area 24.5 × 18.4 visual degrees at the center of a 24” wide-screen LCD presentation monitor when viewed from a distance of 75 cm. Sound for the video was emitted via a stereo sound bar attached to the monitor. The experimental task was programmed and displayed using the software Presentation® (Neurobehavioral Systems, 2006).

Procedure

Toddlers were seated in a car seat in a dark and soundproof room 75 cm in front of a 24" widescreen LCD monitor positioned so that their eyes were aligned with the center of the monitor. Except for the monitor and eye-tracking cameras, the room was covered in dark cloth, thus providing little or no visual distractions to the toddlers. The toddlers's parent sat 6 feet behind the child and the experimenter operating the experiment and eye-tracker was separated from the child by a curtain.

Experiments began with the presentation of children's videos to help put the toddlers at ease and to provide an opportunity for optimization of data acquisition by the eye-tracker. This was followed by a 5-point eye-tracking calibration procedure with targets consisting of small animated figures (radius 1 visual degree) presented together with contingent sound. Subsequent to calibration, the target activity monitoring video was presented for 30s.

Data Reduction

Standard region-of-interest (ROI) analysis techniques were adapted for the analysis of gaze patterns (Figure 1). The ROIs examined in the primary analysis were *Background* areas (toys and room elements of the scene such as walls, furniture, and the floor), *People* (the adult and child), and the *Activity* area (the focus of shared attention by the adult and child). In a secondary analysis, attention towards *People* was further decomposed into attention towards the *Head* and *Body* as well as the *Child and Adult*. Regions were overdrawn by 0.5 visual degrees in order to compensate for calibration drift. The video stimulus was designed such that no major movements of ROIs occurred. However, to accommodate the relatively minor motions that did occur (e.g. movements of hands while arranging puzzle pieces, head turns towards a person to respond to or initiate a verbal exchange), ROIs were adjusted every second.

Analytic Strategy—. In the primary analysis, we considered patterns of scanning over the entire scene. Dependent variables in this analysis were the total time spent looking at the scene and the percentage of total time spent looking at specific ROIs (*Activity*, *Background*, and *People*). In a secondary analysis, we considered patterns of scanning specific to looking at *People.* Dependent variables in this analysis were the time spent looking at *Head* and *Body* areas as well as the *Child* and the *Adult* as a percentage of time spent looking at *People.* Hypotheses regarding between-group differences were tested using an analysis of variance approach with a Holm-Bonferroni correction for multiple comparisons (Aickin and Gensler, 1996; Hochberg, 1988; Holm, 1979). Relationships between scanning patterns and cognitive and social functioning were tested using Pearson product-moment correlation analysis.

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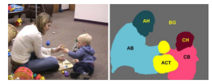

Figure 1.
An example frame from the start of the video stimulus (left) and the corresponding regions of interest (ROIs) (right). Regions are Activity (ACT; area of characters' shared focus), Adult Head (AH), Adult Body (AB), Child Head (CH), Child Body (CB), and Background (BG; comprised of toys and room elements).

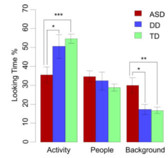

Figure 2.

Proportion of time spent examining the Activity, People, and Background regions of interest for ASD, DD, and TD children. * $p < .05$; ** $p < .01$. Error bars are ±1 SE.

Table 1

Sample Characterization (means and standard deviations)

Measure	ASD	DD	TD
N	28	16	34
Chronological age [months]	20.7 (3.0)	19.3 (2.6)	19.6 (2.8)
Male : Female	22:6	10:6	22:12
Nonverbal MA (NVMA) [months][1]	18.4 (4.1)[a]	18.0 (4.2)[a]	21.0 (2.9)[b]
Nonverbal Developmental Quotient (NVDQ)[1]	89.9 (17.3)[a]	93.7 (19.4)[a]	107.5 (10.8)[b]
Verbal MA (VMA) [months][1,2]	12.1 (5.9)[a]	12.5 (4.4)[a]	21.0 (4.4)[b]
Verbal Developmental Quotient (VDQ)[1,2]	59.7 (28.5)[a]	64.9 (22.1)[a]	106.7 (18.9)[b]
Social affect (SA)[3]	13.3 (4.3)[a]	7.9 (3.6)[b]	-
Stereotyped & repetitive behaviors (SRB)[3]	4.1 (2.1)[a]	1.6 (1.3)[b]	-
ADOS Total[3]	17.4 (5.6)[a]	9.6 (4.1)[b]	-

[1] One child in the ASD group was not administered the MSEL

[2] Two children in the TD group were not administered verbal components of the MSEL

[3] Two children in the DD group were not administered the ADOS

[a] Different superscripts indicate significantly different groups, $p < .05$

[b] Different superscripts indicate significantly different groups, $p < .05$

Table 2

Percentage of Time Spent Looking at Regions of Interest (ROIs) in 20-month old Toddlers.

	Looking Time, Mean (SD), % of Total					*Pairwise p value*[a]		
Region	**ASD**	**TD**	**DD**	$F_{2,77}$	**p value**	**ASD vs TD**	**ASD vs DD**	**TD vs DD**
Activity	35.5 (21.8)	54.6 (13.8)	50.5 (24.7)	7.79	.001	.001***	.032*	.486
Background	29.8 (20.9)	16.7 (9.6)	17.2 (10.6)	6.90	.002	.003**	.016*	.911
People	34.7 (14.7)	28.7 (10.2)	32.3 (18.8)	1.44	.243	.290	.786	.786

	Looking Time, Mean (SD) % of *People*							
Head	49.4 (25.6)	64.1 (22.6)	65.2 (15.5)	4.04	.021	.036*	.056~	.871
Body	50.6 (25.6)	35.9 (22.6)	34.8 (15.5)	“	“	“	“	“

	Looking Time, Mean (SD) % of *People*							
Child	46.0 (20.3)	45.9 (19.2)	56.7 (18.9)	1.94	.151	.980	.214	.214
Adult	54.0 (20.3)	54.1 (19.2)	43.3 (18.9)	“	“	“	“	“

[a] Holm-Bonferroni correction for 3 comparisons

*** p<.001

** p<.01

* p<.05

~ p<.10

Table 3

Correlations between dependent measures of scene scanning and social and cognitive functioning in ASD

	Social Disability[1]		Cognitive Functioning[2]	
Eye-tracking Measure	**SA**	**SRB**	**NVMA**	**VMA**
Total time	-.480**	-.328	.226	.049
Activity	-.403*	-.230	.557**	.570**
Background	.391*	.357	-.174	-.212
People	.041	-.168	-.581**	-.545**
Heads	-.432*	-.009	.153	.234

SA: Social Affect, SRB: Stereotyped & Repetitive Behavior; NVMA: Non-verbal Mental Age; VMA: Verbal Mental Age

[1]Autism Diagnostic Observation schedule – Generic (ADOS-G) Module 1 (Lord et al., 2002), N=28

[2]Mullen Scales of Early Learning (MSEL) (Mullen, 1995), N=27

*p<.05

**p<.01