THE RELATIONSHIP BETWEEN ATTENTIONAL PROCESSES AND SOCIAL REFERENCING IN INFANTS AT HIGH AND LOW GENETIC RISK FOR AUTISM

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The present study investigated differences in social referencing and visual attention (e.g., attention to objects, attention to faces, and attention disengagement), and importantly, the extent to which variability in visual attention was related to social referencing among 11- and 16-month-old infants at high and low genetic risk for autism. Results indicate that HR infants referenced adults at a lower rate than did LR infants. Notably, 16-month-old infants later diagnosed with ASD referenced adults less frequently than typically-developing (TD) and non-typical (NT) infants, which suggests social referencing may be a promising early marker of ASD. When 16-month-olds were attending to the face, HR infants spent a smaller proportion of time looking at the top half of the face than LR infants. This finding indicates that HR infants distributed their attention within the face differently. In addition, associations between visual attention measures and variability in social referencing were found only among LR infants. Increased looking to the top half of the face was related to higher rates of social referencing in LR 16-month-olds. Conversely, LR 16-month-olds' increased looking to objects was related to lower rates of social referencing. Broadly, results support the idea that visual attention indices are related to successful social referencing. As the first study known to identify correlations between visual attention and social referencing, these findings suggest that further investigation

of the co-occurring development of visual attention and social-communicative behaviors in infancy is warranted.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Social referencing is a communication skill that emerges early in infancy and occurs when an infant recognizes the ambiguity of an object or event and looks to a person for presumed social information (Sorce, Emde, Campos, & Klinnert, 1985). By looking to an individual, social referencing allows infants to obtain important contextual information about events in the environment from people's facial expressions and voices which allows them to respond to events, often with approach or avoidance behaviors. Without complex language skills, infants rely on social referencing as an important tool for exploring their environment and processing information. Social referencing places a significant demand on the infant's ability to distribute attention within the environment. For example, the infant must (1) attend to the object, (2) attend to the person's face and (3) disengage attention between these two stimuli in the environment. Consequently, successful social referencing requires relatively mature and sophisticated attentional systems.

Given the importance of social referencing in guiding the social understanding of typically developing infants, it is critically important to understand the role social referencing may play for infants who are showing signs of atypical development. In particular, since autism is characterized as a disorder primarily involving social understanding and communication, it appears important to study the social referencing abilities of infants who develop autism or who are at-risk for developing autism. Surprisingly, however, there has been relatively limited research on the social referencing abilities of children with autism (Bacon, Fein, Morris, Waterhouse, & Allen, 1998). Also, since it is known that even infants and young children with autism display attentional differences or deficits (Chawarska, Volkmar, & Klin, 2010; Landry & Bryson, 2004; Sasson, Elison, Turner-Brown, Dichter, & Bodfish, 2011; Swettenham, Baron-Cohen, Charman, Cox, Baird, Drew et al., 1998; Zwaigenbaum, Bryson, Rogers, Roberts, Brian, & Szatmari, 2005), it is also important to understand how attentional differences may affect the social referencing abilities of young children with autism. Specifically, the attentional differences present in autism may reduce social information input early in development and disrupt typical behavioral development (Mundy & Neal, 2001), thereby impairing the development of social referencing.

Typically, information and behavioral responses that occur during social referencing become incorporated into the infants' knowledge and experiences, thereby influencing their future behaviors. Thus, disrupted or aberrant social referencing may result in infants having fewer opportunities to acquire social information, which in turn may decrease their propensity to develop various social communication skills, hinder their social functioning and further contribute to behavioral manifestations of autism. Therefore, the focus of the present study is on the emergence of social referencing in infants who are at genetic risk for autism and the possible relationships between attentional processes and social referencing.

Development of social referencing

Social referencing can provide infants with important information about the environment. During typical social referencing episodes, infants shift gaze between people and objects to see whether the person is attending to the object. This ability is demonstrated in infants by nine months of age (Bakeman & Adamson, 1984). Also, in a study comparing 7-month-old to 10-

month-old infants, Striano and Rochat (2000) found that when 10-month-old infants were presented with an ambiguous novel toy, they looked more towards the experimenter when the experimenter faced the infant compared to when the experimenter turned away from the infant. In contrast, infants seven months of age did not demonstrate a looking preference, which suggests that the 10-month infants, unlike the 7-month olds, had developed an awareness of the adult's gaze and engaged in social referencing behavior, as the older infants were looking to the experimenter's face in an ambiguous situation.

Once social referencing has emerged, research indicates that infants can utilize the social information they have obtained from other persons to guide their behavior. For example, positive emotional signals from a primary caregiver increased the probability of 12-month-old infants crawling across a visual cliff compared to when the primary caregiver provided negative emotional signals suggesting fear (Sorce et al., 1985). Similarly, research suggests that the effects of positive or negative emotional signals from a primary caregiver can influence 12-month-old infants' reactions to a novel, ambiguous toy (Stenberg & Hagekull, 1997).

Collectively, these findings indicate that infants attend to the facial and/or vocal cues in their environment and are behaviorally influenced by the social information they process in naturalistic settings. More broadly, they illustrate that social information is salient to the attention and subsequent behavior of humans from very early in development. Therefore, disruptions in social referencing may decrease infants' abilities in related social communication skills, like joint attention. That is, social referencing deficits may have detrimental cascading effects on early development by hindering the development of social skills that characterize autism symptomatology.

Autism spectrum disorders (ASD) are a class of neurodevelopmental disorders characterized by impairments in social interaction, communication and the presence of stereotyped behaviors and restricted interests (American Psychiatric Association, 2000). Since one of ASD's most notable features is social deficits, there has been a growing scientific interest in impairments in early skills and processes that hinder social development, including social referencing (Bacon et al., 1998; Campbell, Leezenbaum, & Fox, in preparation; Cornew, Dobkins, Akshoomoff, McCleery, & Carver, 2012). Preliminary research suggests that social referencing is deficient in preschool-aged children with autism (Bacon et al., 1998). Both high and low functioning children with autism displayed the lowest rates of responding to an ambiguous, loud sound by looking to an adult when compared to the rates of social referencing shown by typical, mentally retarded and language-delayed children. Interestingly, differences in cognitive level did not account for this finding. However, approximately one-third of both the high and low functioning groups of children with autism engaged in social referencing. This suggests that although there is a marked deficit in social referencing among children with autism, social referencing is not absent among all children with autism.

In addition to the social referencing deficits found among children diagnosed with autism, there is recent evidence that social referencing deficits are present in infants later diagnosed with autism and infants considered genetically high-risk (HR) for autism because they have an older sibling with an ASD (Campbell et al., in preparation; Cornew et al., 2012). Specifically, HR infants 18 months of age who received an ASD diagnosis at three years of age were less likely to spontaneously reference an adult within the first minute of noticing a novel toy and sought social information more slowly than low-risk (LR) infants (i.e., with a typically developing older sibling) and HR infants who did not meet ASD diagnostic criteria. This research indicates that latency to reference the facial expression of another may have predictive value for diagnosing ASD since this behavior distinguished HR infants who received an ASD diagnosis from those who did not. Furthermore, Cornew and colleagues (2012) found that HR infants who did not later meet ASD diagnostic criteria displayed marginally lower rates of spontaneous referencing to an adult than LR infants. This finding has been supported in 16 month-old infants as well (Campbell et al., in preparation). That is, regardless of diagnostic outcome, HR infants at both 16 and 18 months of age were less likely to spontaneously reference an unfamiliar adult or parent for social information in ambiguous situations (Campbell et al., in preparation; Cornew et al., 2012). Because these HR infants displayed similar social deficits to autism but were not yet diagnosed with ASD, these studies support the possibility that less frequent social referencing may be one sign of atypical development.

These recent findings collectively support the propositions that autism involves disruptions in the emergence of social referencing and that these disruptions occur early in development. It is known that a lower percentage of HR 16 and 18-month-old infants with or without ASD and children with autism exhibit social referencing (Bacon et al., 1998; Campbell et al., in preparation; Cornew et al., 2012). However, how social referencing emerges in ASD is not well understood and warrants further exploration. Investigating the onset and trajectory of social referencing may help to elucidate relationships between social and cognitive development in typical and atypical populations.

Proposed relationships between attention and social referencing

Although there is some recent evidence supporting the idea that social referencing deficits are associated with autism (Bacon et al., 1998; Campbell et al., in preparation; Cornew et al., 2012), whether a relationship exists between attentional processes and these disruptions in social referencing is unknown. To date, no studies have investigated the relationship between attentional skills and social referencing deficits. Mundy and Neal (2001) have established a developmental framework of autism that implicates impaired attention to social information as leading to disrupted brain and behavioral development, yet the relationship between attentional processes and social development has not been tested in regard to social referencing. While there may be several factors like motivation or interest in people that contribute to social referencing, it is clear that social referencing also requires that the infant be able to actively distribute attention among the individuals and objects within the contextual "scene." For example, social referencing involves looking at an object or event, and if the object or event is not understood (e.g, is it dangerous, harmless, pleasant), looking to the social partner for information to help the infant understand the situation. Thus, the infant's inability to actively distribute their attention among the relevant aspects of the social scene would be critical. Hence, the present study examined the social referencing abilities of infants who may develop autism, and whether there are attentional processes that are related to their social referencing abilities. Specifically, the study examined how social referencing may be related to the infant's ability to:

1. Attend to an object
2. Attend to a person's face
3. Disengage attention from both objects and faces

Attentional differences in typical and ASD populations

Visual attention to faces vs. objects. It is known that successful social referencing requires significant attentional demands. Therefore, it is proposed that the three attentional components described above are related to social referencing. The first two attentional processes focus on infants' ability to distribute their attention to (1) an object and (2) a person, especially the face.

The relative saliency of people and faces compared to non-social stimuli leads to visual attention preferences in infancy that have implications for how infants distribute attention in naturalistic settings. During typical development, newborn infants are more responsive to facial representations than equally complex non-social stimuli (Cassia, Turati, & Simion, 2004; Goren, Sarty & Wu, 1975; Johnson & Morton, 1991). This heightened response to faces was shown by infants' turning and following faces more than stimuli that had the same components as a face but were scrambled (Goren et al., 1975). This suggests that newborn infants display an attentional preference for faces in comparison to equally complex, non-social stimuli (Goren et al., 1975; Johnson & Morton, 1991; Cassia et al., 2004). An attentional preference for social stimuli, particularly for faces, persists beyond two months of age as well (Courage, Reynolds, & Richards, 2006; Johnson, Dziurawiec, Bartrip, & Morton, 1992; Turati, Valenza Leo, & Simion, 2005). For instance, three month-old infants display an attentional bias to faces over non-face patterns, as indicated by the larger proportion of time spent looking to the faces compared to the non-face patterns (Turati et al., 2005). This enhanced attention to faces continues from 14 weeks to 12 months of age, such that infants' look durations to faces increased in a quadratic fashion with age, whereas look durations to achromatic geometric patterns decreased linearly with age (Courage et al., 2006). Furthermore, infants displayed sustained attention for a greater proportion of time when presented with faces or dynamic social interactions from *Sesame Street* compared to achromatic geometric patterns (Courage et al., 2006). In summary, these findings show that there is an attentional bias to social information during infancy, thereby supporting the idea that there is a predisposition to visually seek out social information in the environment.

In contrast, research suggests that individuals with autism may not display a similar attentional bias to social information. Unlike typical and even schizophrenic populations, adults with autism fail to exhibit a faster speed of orienting to the facial region of social scenes when a face is present compared to when the face has been digitally erased (Sasson, Tscuchiya, Hurley, Couture, Penn, Adolphs, et al., 2007). Instead, adults with autism orient to the facial region at the same speed regardless of whether the face is present, which suggests that faces are less visually salient to individuals with autism than to other populations (Sasson et al., 2007). There is also evidence that children with autism orient less to faces than do typical children (Bernabei et al., 1998; Osterling & Dawson, 1994; Maestro et al., 1999; Zwaigenbaum et al., 2005) and spend comparatively more time looking at objects than typically developing and developmentally delayed toddlers (Swettenham et al., 1998). This attentional preference for objects rather than social stimuli is supported by young ASD children's performance on a visual exploration task in which they perseverated more on object stimuli than social stimuli (Sasson et al., 2011).

A similar attentional bias to nonsocial stimuli has been demonstrated during dynamic, more ecologically valid visual attention tasks as well. When presented with a simple preferential looking paradigm of dynamic social images and dynamic geometric images, toddlers with autism spent a greater proportion of time attending to the geometric images than to the social images compared to typical and developmentally delayed children. In other words, this lack of visual attention to people positively predicts autism diagnosis and supports an association between visual attention tendencies and autism early in development (Pierce, Conant, Stoner, & Desmond, 2011). Even in infancy, differences in visual attention to social versus nonsocial stimuli have been associated with autism. For example, infants at high-risk for autism exhibit slower looking responses to faces and faster looking responses to objects than do low-risk infants (McCleery, Akshoomoff, Dobkins, & Carver, 2009). Moreover, when viewing videotape clips of complex social situations that present faces and objects simultaneously, adolescents with ASD attended to objects twice as much as age and verbal IQ-matched controls, whereas typical individuals attended to the eye region of faces twice as much as individuals with ASD (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). In addition, these attentional differences were associated with individuals' social behavior. Analyses indicated that longer visual fixations to the mouth region of the face were related to higher levels of social competence and lower levels of ASD social impairment. In contrast, longer visual fixations to objects were associated with higher levels of ASD social impairment and lower levels of social competence.

Together, these findings suggest that individuals with ASD show different visual attention patterns to social and non-social stimuli. These attentional differences seem to emerge early in the development of autism, since young children and toddlers with ASD also display a limited attentional bias for faces (Chawarska et al., 2010). Furthermore, the salience of social and non-social stimuli for visual attention is related to how individuals engage socially in the environment (Klin et al., 2002). These attentional differences to faces and objects, particularly the relationship between a lower saliency of facial cues and higher social impairment, suggests that visual attention differences found in infancy may be related to the development of social-communicative behaviors like social referencing. Consequently, a developmental model of autism posits that this reduced saliency of orienting to faces may deprive infants with autism of important social information that further impairs brain and behavioral development (Mundy & Neal, 2001). These cascading effects likely disrupt social communicative behaviors (Zwaigenbaum et al., 2005) like social referencing.

Attentional disengagement. In addition to the ability to distribute attention to the object and a person's face, social referencing requires a third important attentional skill: disengagement. In two-month-old infants, attention is considered "obligatory" or "sticky," (Stechler & Latz, 1966) meaning that infants at this early age exhibit difficulty disengaging or shifting attention between two presented stimuli. Attentional disengagement is defined as the ability to direct one's attention to a second stimulus when the first stimulus remains, whereas attention shifting reflects one's ability to direct attention to a second stimulus once the first stimulus presented disappears. Infants typically develop the ability to disengage by three to four months (Hood & Atkinson, 1993; Johnson et al., 1991). Although the ability to disengage may emerge as early as three months of age, Frick, Colombo and Saxon (1999) found that four-month-old infants exhibited a significant improvement in their latency to disengage compared to three-month-old infants. Together, these findings suggest that "sticky attention" tendencies are lost with the early emergence and increasing ability to disengage attention within the first six months of life (Frick et al., 1999; Hood & Atkinson, 1993; Johnson et al., 1991).

However, "sticky attention" may persist beyond infancy in children with autism. Instead of developing the ability to disengage attention as early as four months of age, children with autism aged 3-7 years old continue to display "sticky attention" tendencies years after typical infants' disengagement skill has emerged. This significant attentional deficit in autism has been demonstrated with a basic visual orienting task (Landry & Bryson, 2004). After engaging on a central fixation stimulus, an additional stimulus was presented on either side such that there were two competing stimuli on the screen. Children with autism displayed a significantly longer latency to disengage with the central stimulus compared to typically developing children and children with Down syndrome, which suggests that a difficulty with attentional disengagement may be specific to autism (Landry & Bryson, 2004). The extent of this impairment in attentional disengagement is further illustrated by the result that the children with autism failed to disengage from the initial stimulus on 20% of the experimental trials (Landry & Bryson, 2004). Furthermore, this disengagement impairment appears consistent across IQ, such that children with autism of average or above average IQs tend to display “sticky attention” as do children with lower IQs (Landry & Bryson, 2004). However, Chawarska and colleagues (2010) found that toddlers with ASD did not differ from typically developing (TD) toddlers when disengaging from non-social stimuli based on saccadic reaction times, but they did exhibit faster saccadic reaction times when disengaging from a face than TD toddlers or those with developmental delays (DD). This finding suggests that the group differences in attentional preferences for social versus non-social stimuli may have facilitated a comparatively faster disengagement from faces in toddlers with autism, since faces are less salient to toddlers with autism. Due to the high saliency of faces to the visual attention of TD and DD toddlers, there is a higher cost of disengagement from faces among TD and DD than ASD groups.

Recent evidence suggests that 12 month-old infants’ difficulty disengaging visual attention in Landry and Bryson’s (2004) task predicts ASD symptoms and the number of social-communicative impairments present at two years of age derived from the Autism Diagnostic Observation Schedule (ADOS-G; Lord, Rutter, DiLavore, & Risi, 1999), a gold standard diagnostic tool for ASD that assesses ASD symptoms from semi-structured observations. Thus the research suggests the importance of investigating the relationships between attentional processes and disrupted behavioral development (Zwaigenbaum et al., 2005). This becomes a particularly important direction to explore given that the visual disengagement impairments present in Landry and Bryson’s (2004) task generalize to naturalistic interactions as well.

Specifically, infants with an ASD sibling displayed fewer gaze shifts to and from their parents' faces than infants without an ASD sibling, meaning that disengagement deficits are apparent in the parent-child interactions of infants at high genetic risk for autism (Ibanez, Messinger, Newell, Lambert, & Sheskin, 2008).

Due to this early difficulty with disengagement, high risk infants may process a different set of information than typical infants who are skilled at disengaging attention and incorporating more information from multiple sources, particularly social information obtained from parents' facial expressions. More broadly, infants with "sticky attention" may process information and respond differently behaviorally, such that they show different ways of exploring their environments. For the field of autism, this suggests that attentional preferences for faces versus objects in combination with disengagement deficits may be related to the disrupted development of social referencing that may also characterize autism.

The current study

Despite the importance of social referencing for infants' processing of information and exploration of their environment, few studies have investigated the social referencing deficits associated with autism (Bacon et al., 1998; Campbell et al., in preparation; Cornew et al., 2012). Given the detrimental cascading effects social referencing impairments may have on development previously discussed, it is imperative to consider how possible disruptions in autism may relate to other skills and processes.

Since there is much evidence suggesting that individuals with autism from infancy through adulthood exhibit differences in visual attention compared to controls (Chawarska et al., 2010; Ibanez et al., 2008; Klin et al., 2002; Norbury et al., 2009; Sasson et al., 2007; Sasson et al., 2011; Spezio et al., 2006; Swettenham et al., 1998; Zwaigenbaum et al., 2005), it is theorized that attentional differences early in development may reduce social information input and disrupt behavioral development (Mundy & Neal, 2001). The present study posited that three visual attention components are related to successful social referencing and has investigated the extent to which these attentional processes relate to social referencing behaviors at 11 and 16 months. Since the current focus is the development of social referencing, it was important to include an 11-month age point at the onset of typical social referencing behavior so the study may detect initial differences in social referencing and a later age point for examining development in this skill. By selecting 16 months as a second age point, the study could identify social referencing deficits and the attentional demands two months earlier in development than has been previously studied by Cornew and colleagues (2012).

The present study had four aims: (1) To determine whether HR infants can be distinguished from LR infants based on social referencing; (2) To determine whether the three attentional components of social referencing (attention to objects, attention to faces, and attention disengagement) distinguish HR from LR infants; (3) To assess the extent to which visual attention differences may be related to variability in social referencing; (4) To assess the visual attention and social referencing deficits specific to infants later diagnosed with ASD.

To understand the origins of the deficits children with ASD have regarding social referencing and distributing attention, it was necessary to investigate differences in social referencing and visual attention in infancy. Since children younger than two years of age cannot be reliably diagnosed with ASD, there has been a strong interest in the field of autism in assessing infants who have an older sibling diagnosed with ASD. Typically, these genetically high-risk (HR) infants are compared to infants characterized as low risk (LR) because their older siblings do not have ASD. Up to 20% of HR infants will later receive an ASD diagnosis according to current estimations (Ozonoff et al., 2011). Although the majority of HR infants will not receive an ASD diagnosis, research also indicates that HR infants tend to share many traits with diagnosed individuals due to genetic transmission of autism-like traits. For example, HR infants display delays and problems in basic areas of development like language and motor skills (for review, see Rogers, 2009). Hence, the present study may further our understanding of atypical development by focusing on HR infants. Therefore, the current study consisted of two groups based on risk status: infant siblings of children with ASD (HR) and infant siblings of typically developing children (LR).

Consistent with prior research, social referencing was measured using a well-established paradigm in which the infant is introduced to an ambiguous, novel toy in the presence of an experimenter and caregiver. Ideally, the study would use eye tracking to assess infants' social referencing during real world situations to examine the possible impacts of the attentional demands underlying social referencing. However, the technology for such an endeavor is not easily accessible and lacks an established program for data analysis. Instead, the study indirectly measured differences in how infants distribute their attention to a naturalistic social scene via dynamic video. Through eye tracking of infants' responses to naturalistic social scenes, more accurate representations of how infants observe and attend to their real environment were gathered (Sasson & Elison, 2012). With this approach, the visual attention processes were each measured from eye-tracking data collected from the presentation of a short video clip portraying a naturalistic social scene.

With this approach, it was expected that group differences in social referencing and visual attention would occur based on infants' autism risk status. It was hypothesized that HR infants would display less social referencing than LR infants at both 11 and 16 months of age, although 16-month-old infants would display more social referencing than 11-month-old infants. In regard to how infants visually distribute their attention, it was hypothesized that 11-month and 16-month-old HR infants would attend to the face for a smaller proportion of time and attend to the object for a larger proportion of time compared to 11-month and 16-month-old LR infants, respectively. In addition, it was hypothesized that HR infants would exhibit less attentional disengagement by displaying fewer total fixations than LR infants at both 11 and 16 months of age. Lastly, it was expected that disruptions in infants' ability to visually attend and disengage from various elements of the scene would be related to social referencing deficits displayed by infants at HR or those later diagnosed with ASD (Bacon et al., 1998; Campbell et al., in preparation; Cornew et al., 2012).

2.0 METHOD

Participants

As a part of an ongoing research protocol (Campbell et al., in preparation), participants consisted of infant siblings of children with ASD (high-risk infants; HR) and infant siblings of typically developing children (low-risk infants; LR). HR infants had at least one older sibling diagnosed with ASD, whereas LR infants did not have an older sibling, or other first or second-degree relatives diagnosed with ASD. Two age groups were included in the present study: 11-month-olds and 16-month-olds. Forty HR infants and 29 LR infants participated at 11 months of age. At 16 months of age, 32 HR infants and 29 LR infants participated. Twenty-one HR infants and 19 LR infants participated at both age points, yielding a longitudinal sub-sample.

Infants were recruited through advertisements and flyers. The ASD diagnosis of HR infants' older sibling was confirmed utilizing the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 1999) and the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & LeCouteur, 1994). A phone screen was used with LR infants' parents to ensure that older siblings did not have ASD diagnoses and that no first or second-degree relatives were diagnosed with ASD. In addition, any infant who had problems during labor and delivery, a birth weight less than 2500 grams or any form of brain injury or birth defect was excluded from the study.

At each time point (11 and 16 months of age), HR and LR infants were assessed with the Mullen Scales of Early Learning (MSEL; Mullen, 1995). The MSEL is a well-established measure of language and cognitive development with four subscales: visual reception, fine motor, receptive language and expressive language. A developmental quotient (DQ) was calculated by combining the receptive language, expressive language, visual reception and fine motor age equivalents. By studying HR and LR infants, the present study could explore differences in the development of social referencing and possible impacts of the underlying attentional demands in the context of typical and atypical development. Table 1 summarizes infant participants' demographic characteristics.

Lastly, in the cases in which infants reached three years of age by the end of data collection, infants were assessed for ASD on the ADOS-G (Lord et al., 1999) and ADI-R (Lord et al., 1994). Based on these assessment tools and clinical judgment, infants were assigned to one of three outcome groups: typically-developing (TD), non-typically developing (NT) or ASD. Infants diagnosed with ASD met at least spectrum cut-offs on the three ADOS-G total scores (Communication Total, Social Interaction Total and Combined Communication and Social Interaction Total) and the diagnosis was approved by a clinical psychologist's review. The NT group consisted of infants who displayed delayed global development, atypical language skills and/or social concerns. Delayed global development was characterized by Visual Reception and Reception Language MSEL (1995) scores at least 1.5 standard deviations below the normative mean and/or clinical opinion. An NT designation due to non-typical language skills was defined by MSEL (1995) scores at least 1.5 standard deviations below the normative mean for only Expressive and/or Receptive Language. Alternatively, infants may have had MacArthur-Bates Communicative Development Inventory (CDI; Fenson, Bates, Dale, Marchman, Reznick, &

Table 1. Participants' demographic characteristics

	HR (N = 40)		LR (N = 29)	
	M	*SD*	*M*	*SD*
11-month-olds				
Mullen DQ	103.94	15.82	106.47	17.07
Gender (M/F)	(26/14)		(16/13)	
Ethnicity	34 Caucasian, 2 Black, 3 Hispanic White, 1 More than one race		27 Caucasian, 1 Black, 1 Hispanic White	
16-month-olds	HR (N = 32)		LR (N = 29)	
Mullen DQ	97.45	15.33	104.90	17.54
Gender (M/F)	(21/11)		(15/14)	
Ethnicity	30 Caucasian, 2 Hispanic White		27 Caucasian, 1 Black, 1 Hispanic White	

Thal, 2007) Words Produced below the 10th percentile and/or received the classification due to clinical opinion. Lastly, infants were classified as showing social concerns if they demonstrated at least spectrum cutoffs on the ADOS-G Social Interaction total only or scored within 2 points of spectrum cutoffs on the combined Communication and Social Interaction Total and/or clinical opinion. Infants who did not meet any of the criteria described above were designated as TD.

Social Referencing Study

Stimulus

Social referencing measure. As conducted by Campbell and colleagues (in preparation), infants and their primary caregivers were brought to a playroom (approximately 10x12 feet) containing one adult-size chair and a floor mat. After a period of free play, an experimenter presented infants with a novel, battery-operated moving toy elephant with a primary caregiver present. Specifically, the experimenter placed the toy on the floor and said the following script: "[Infant's name], look at what I have." The experimenter directed the toy towards the infant by using the touch pad attached to the toy that controls the elephant's movements and sounds. The remote-controlled elephant was considered novel but ambiguous due to the toy's movements and noises, thereby meant to elicit social referencing. Mothers were told to interact with their child as they normally would.

Coders viewed each infant's videotape and recorded the frequency of social referencing to the experimenter and the primary caregiver in five-second intervals for the entire three-minute session. An act of social referencing was defined by the following distinct behavioral sequences: (1) an infant looking at the toy, looking to the face of either the experimenter or primary caregiver, and then looking back to the toy, (2) an infant looking to the experimenter or primary caregiver, looking to the toy, and then looking back to the experimenter or primary caregiver, or (3) an infant looking at the toy, looking to the face of either the experimenter or caregiver, looking to the face of the other individual, and then looking back to the toy. Coders were blind to infant risk status. Furthermore, two coders independently coded 20% of the videos and maintained at least 80% coding agreement.

Procedure

Infants and their primary caregivers were brought to a playroom and given a period of time for free play. The experimenter entered the room and presented infants with the remote-controlled toy elephant, thereby starting the social referencing paradigm and initiating interaction with the infant and primary caregiver. The session duration was three minutes unless the infant became markedly upset, at which time testing was discontinued.

Data Reduction

The total number of social referencing acts, which included the number of social referencing acts toward the caregiver and the number of social referencing acts toward the experimenter, served as a social referencing frequency. Since the duration of the session may be shortened in some cases due to marked upset, all social referencing frequencies were converted into proportions by dividing social referencing frequencies by the length of timed interaction. These proportions will be referred to as rates of social referencing.

Eye Tracking/Visual Attention Study

Apparatus

For the portion of the study examining visual attention, infants were seated in a high chair located in a dark, quiet room 162 cm from a large rear projection movie screen measuring 69 x 91 cm. A Tobii X120 stand-alone eye-tracker was placed on a table between the infants and the projection screen. This position was 81 cm from the screen. A Dell Dimension 9200 and Tobii Studio software (Version 2.0.6) was used to rear project the video clip stimulus onto the projection screen and record eye movement and behavioral accuracy data. At a sampling rate of 60 Hz, the eye-tracker recorded eye movements with a 0.2 degree spatial resolution, 0.5 visual angle degree accuracy and 0.3 degree drift.

Stimulus

Dynamic social scene video clip. To assess visual attentional patterns to naturalistic social scenes, infants viewed a 30-second video clip from the television show, *Mister Rogers' Neighborhood*. In the video clip, Mr. Rogers shows and talks about a wooden toy airplane and several wooden blocks. During the scene, he makes eye contact with both the airplane when he describes it and looks directly at the camera when addressing the audience. Mr. Rogers is seated in a chair in front of a static background. The video clip provided both visual and auditory information. The entire scene was approximately 26 x 17 degrees of visual angle. While the filming camera had minor changes in its focal distance, on average, Mr. Rogers was 11 x 15 degrees, his face was 5 x 4 degrees, and the airplane (the main object of interest) was 9 x 5 degrees.

Procedure

Infants first sat in a high chair and viewed a cartoon to attract their attention to the projection screen. After infants oriented to the screen, the cartoon was replaced by a picture of a red rattle that made noises and oscillated hence attracting the infants' attention so that eye-tracking calibration could be conducted. This picture served as the calibration stimulus. The experimenter used the live view of infants' eye movements during the calibration to assess when infants had oriented to the rattle. Once infants had oriented to the stimulus, the experimenter pressed a button to shift the rattle to a different location on the screen. Successful calibration was achieved by repeating this sequence until infants accurately oriented to the stimulus for a total of five different positions.

After the calibration task, infants viewed one 30-second video clip from the *Mister Rogers' Neighborhood* television show. Eye-tracking data was recorded during the viewing, after which infants and caregivers were led to a separate room to participate in the aforementioned social referencing study.

Data Reduction

In regard to the eye-tracking data collected during the *Mister Rogers' Neighborhood* television clip, the amount of time infants spent looking at the face (Mr. Rogers') or the objects (the toy airplane and wooden blocks) was determined by creating regions of interest (ROIs) with Tobii Studio software for Mr. Rogers' the top half and bottom halves of the face, objects, and the total video viewing area (see Figure 1). To adjust for motion during these dynamic video clips, ROIs were shifted in position and size across each frame as needed. To account for individual variability in infants' total looking times, proportions were analyzed. The proportion of time spent looking at the face was calculated by dividing the amount of time spent looking at the face by each infant's total looking time. This formula was also applied to calculating looking time proportions to objects. The proportion of looking time to the top half of the face was calculated by dividing the amount of time spent looking at the top half of the face by the amount of time spent looking at the whole face. In addition, the extent to which infants disengaged attention was measured by the total number of fixations, since this measure approximates the frequency of eye movements. A higher total number of fixations indicated a higher number of eye movements during the presentation of the video clip.

Figure 1. Example of ROIs for video stimulus

3.0 RESULTS

Social Referencing

Risk Status Analyses. One primary aim was to assess whether infants displayed different rates of social referencing based on risk status. Due to the inclusion of both cross-sectional and longitudinal participants, separate analyses were conducted for each age group for all cross-sectional analyses. For all following risk status analyses, one-way ANOVAs were conducted with risk status (HR vs. LR) as the between-subjects factor. At 11 months of age, infants did not differ significantly in their rate of social referencing based on risk status ($F(1,60) = .45$, p = ns). At 16 months of age, HR infants referenced the adults less frequently (M=1.47, SD=1.34) than did LR infants (M=2.62, SD=2.22) ($F(1,52)$=5.36, p=.03) (see Figure 2).

An additional analysis was conducted on the subsample of infants for whom there was longitudinal data in order to explore whether developmental changes emerged between 11 and 16 months of age. This longitudinal subsample consisted of 15 HR infants and 17 LR infants. A two-way ANOVA was conducted on the rate of social referencing per minute with risk status (HR vs. LR) as the between-subjects factor and age (11 months vs. 16 months) as the within-subjects factor. Two-way ANOVAs were conducted for all longitudinal analyses reported below. Only the main effect of risk status was marginally significant ($F(1,30) = 3.71$, $p = .06$). As shown in Figure 3, HR infants at both age points referenced adults less frequently (M=1.49, SE=0.45) than did LR infants (M=2.66, SE=0.42).

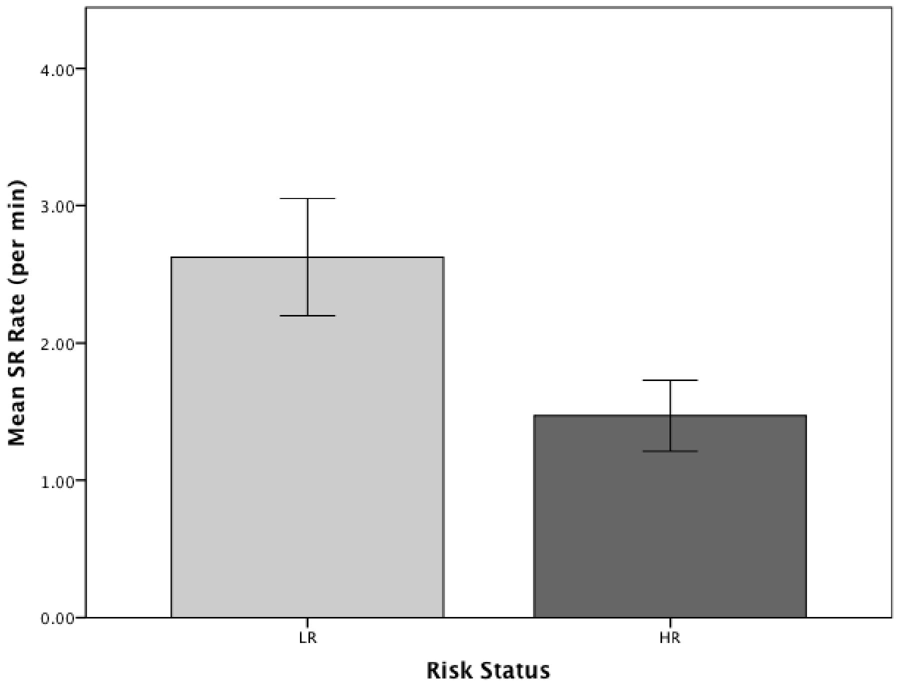

Figure 2. Social referencing by risk status in 16-month-old infants

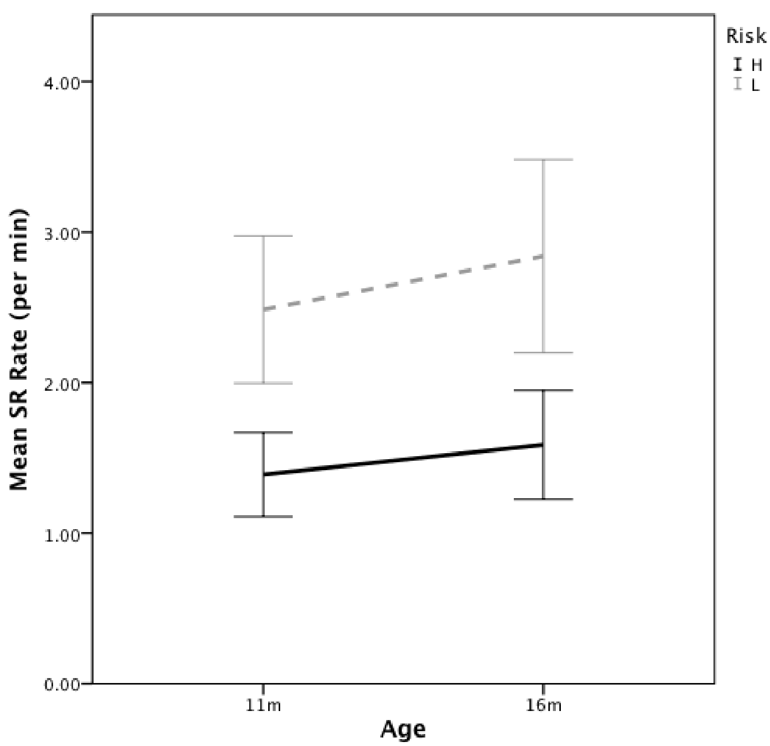

Figure 3. Social referencing by risk status in longitudinal subsample

Outcome Group Analyses. It is also of interest whether infants showed different rates of social referencing based on their diagnostic outcome status as TD, non-typical (NT) or ASD at follow-up. All outcome group analyses consisted of one-way ANOVAs with outcome group (TD vs. NT vs. ASD) as the between-group factor. At 11 months of age, infants did not significantly differ in rate of social referencing based on outcome group ($F(2,50) = 2.16$, p = ns).

In contrast, the 16-month-old infants significantly differed in rate of social referencing based on outcome group ($F(2,48) = 3.25$, $p < .05$). Post-hoc independent *t*-tests indicated that TD 16-month-old infants did not significantly differ from NT 16-month-old infants ($t(42) = 1.34$, p = ns). However, as shown in Table 2, ASD infants referenced adults significantly less frequently (M=.65, SD=.49) than both TD infants (M=2.49, SD=2.17; $t(35) = 4.22$, $p < .01$) and NT infants (M=1.64, SD=1.34; $t(18.1) = 2.47$, $p = .02$).

Table 2. 16-month-olds' social referencing by outcome group

	16-month SR Rate (per min)	
	M	*SD*
TD (N=30)	2.49	2.17
NT (N=14)	1.64	1.34
ASD (N=7)	0.65	0.49

Visual Attention

Risk Status Analyses.

Another primary aim was to assess whether infants distributed their attention differently to various elements of dynamic social scenes (e.g., objects and facial regions) based on risk status. An initial analysis was conducted to determine whether total looking time to the social scene differed between HR and LR infants. At both 11 and 16 months of age, no significant results were found regarding total looking time at the scene based on risk status ($F(1,67) = .003$, p = ns; $F(1,59) = 2.51$, p = ns).

A two-way ANOVA was conducted on the subsample of infants who participated at both 11 and 16 months to explore possible changes in how these infants distribute their attention with age. This ANOVA yielded no significant findings, indicating that infants (regardless of both risk status and age) looked at the video stimulus for statistically comparable lengths of time.

Objects. No significant differences emerged at 11 or 16 months of age, indicating LR and HR infants spent comparable proportions of time looking at objects ($F(1,67) = .06$, p = ns; $F(1,59) = .25$, $p < .01$) (see Table 3).

Table 3. Infants' visual attention by risk status

	HR (N = 40)		LR (N = 29)	
	M	*SD*	*M*	*SD*
11-month-olds				
Total Looking Time (s)	23.36	10.16	23.24	8.79
Object Looking (%)	31.12	16.19	32.07	14.30
Whole Face Looking (%)	22.64	16.80	17.29	17.93
Top-Half Face Looking (%)	30.30	27.47	29.82	34.58
Fixation count (#)	43.85	15.10	43.48	12.91
	HR (N = 32)		LR (N = 29)	
	M	*SD*	*M*	*SD*
16-month-olds				
Total Looking Time (s)	25.57	11.18	21.20	10.29
Object Looking (%)	40.05	18.35	37.68	18.79
Whole Face Looking (%)	12.02	11.74	14.73	14.41
Top-Half Face Looking (%)*	11.75	22.57	29.30	27.99
Fixation count (#)	44.34	14.19	45.00	19.10

In examining possible changes in visual attention to objects between 11 and 16 months, the two-way ANOVA on the longitudinal subsample yielded only a significant main effect of age ($F(1,38) = 18.81$, p = ns), indicating that infants (regardless of risk status) increased the proportion of looking time at objects from 11 months (M=0.31, SD=0.16) to 16 months (M=0.41, SD=0.18).

Faces. Results regarding whether infants spent more or less time attending to the face and top vs. bottom facial regions based on risk status can be seen in Table 3. Analyses of both 11-month-olds and 16-month-olds indicated no significant differences based on risk status in the proportion of time spent looking at the face ($F(1,67) = 1.62$, p = ns; $F(1,59) = .65$, p = ns). No significant difference was also found based on risk status in the proportion of time 11-month-olds spent looking at the top half of the face compared to the bottom half of the face ($F(1,63) = .004$, p = ns). However, when attending to the face, HR 16-month-olds spent a significantly smaller proportion of time looking at the top half of the face (compared to the bottom half) of the face (*M*=.12, *SD*=.23) than LR 16-month-olds (*M*=.29, *SD*=.28; $F(1,51) = 6.39$, $p = .02$).

Additional analyses were again conducted using only the longitudinal subsample. The first analysis yielded only a marginally significant main effect of age ($F(1,38) = 2.86$, $p = .10$), indicating that infants (regardless of risk status) decreased the proportion of looking time at the whole face from 11 months (*M*=0.16, *SD*=0.16) to 16 months (*M*=0.11, *SD*=0.09). Interestingly, as shown in Figure 4, a marginally significant main effect of risk status ($F(1,32) = 3.23$, $p = .08$) and a significant interaction (risk X age) was found on the proportion of looking time to the top half of the face ($F(1,32) = 4.05$, $p = .05$). When looking at the face, LR and HR infants demonstrated similar proportions of looking time to the top half of the face at 11 months (*M*=.27, *SD*=.31; *M*=.26, *SD*=.29); however, from 11 to 16 months, HR infants displayed a decrease in the proportion of looking time to the top half of the face (*M*=.06, *SD*=.09), whereas LR infants remained consistent between the two time points (*M*=.30, *SD*=.28).

Disengagement. Separate analyses for 11-month-olds ($F(1,67) = .01$, p = ns) and 16-month-olds ($F(1,59) = .02$, p = ns) did not yield any significant differences in total number of fixations, suggesting similar performance in attentional disengagement (see Table 3). The lack of significant results was replicated in the longitudinal analysis as well.

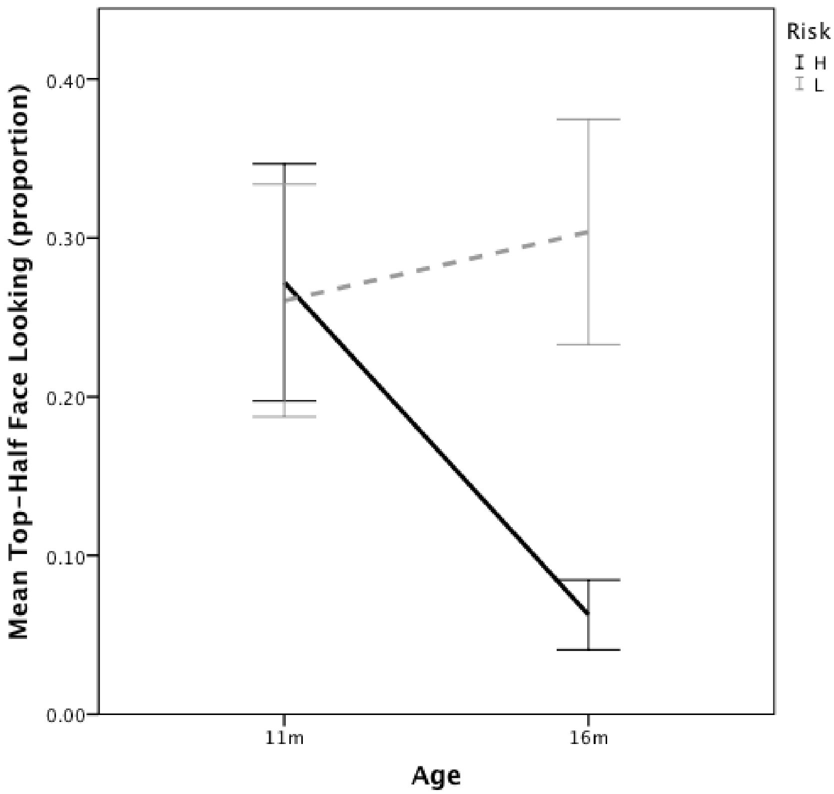

Figure 4. Top-half face looking by risk status in longitudinal subsample

Outcome Group Analyses.

In addition to risk status, it was also important to investigate whether infants' proportion of looking to various elements (e.g., objects, faces) and the total number of fixations differed based on outcome group (TD, NT or ASD). One-way ANOVAs for both 11 and 16-month-olds did not yield significant differences in their total looking time to the scene ($F(2,56) = 2.44$, p = ns; $F(2,52) = 1.83$, p = ns).

Objects. To determine whether infants' attention to objects differed based on outcome group, a one-way ANOVA with outcome group (TD, NT or ASD) as the between-group factor was conducted on the proportion of time spent looking at objects. At 11 months of age, a significance difference in the proportion of time spent looking at objects was found based on outcome group ($F(2,56) = 4.55$, $p = .02$). Post-hoc independent *t*-tests were conducted indicating that at 11 months of age, NT infants spent a smaller proportion of time looking at objects (M=.22, SD=.14) than TD infants (M=.35, SD=.15; $t(51)= 2.88$, $p < .01$). In addition, NT infants did not differ from ASD infants at 11 months of age in the proportion of time spent looking at objects ($t(18)= .39$, p = ns).

At 16 months of age, no significant differences were observed in the proportion of time spent looking at objects based on outcome ($F(2,52) = .25$, p = ns).

Faces. At 11 months of age, infants did not significantly differ in the proportion of time spent looking at the whole face based on outcome group ($F(2,56) = .21$, p = ns). At 16 months of age, differences in infants' proportion of time spent looking at the whole face based on outcome group approached significance ($F(2,52) = 2.66$, $p = .08$). Only a marginally significant trend was found between TD and ASD 16-month-old infants ($t(38) = 1.85$, $p = .07$), in which ASD infants spent a smaller proportion of time looking at the face (M=.05, SD=.09) than TD infants at 16 months (M=.16, SD=.14).

Analyses were also conducted to determine how infants distributed their attention within the face based on outcome group but results indicated no significant differences in the proportion of time spent looking to the top half of the face at either age ($F(2,52) = 1.39$, p = ns; $F(2,45) = .02$, p = ns).

Disengagement. Similarly, one-way ANOVAs examining infants' attentional disengagement via the total number of fixations at 11 and 16 months of age yielded no significant results based on outcome group ($F(2,56) = 1.43$, p = ns; $F(2,52) = 1.38$, p = ns).

Relations between Visual Attention & Social Referencing

Correlational Analyses Based on Risk Status. Another aim was to investigate to what extent these various measures of visual attention (e.g., attention to faces, objects, disengagement) relate to social referencing behavior based on risk status. Pearson's *r* correlations were conducted between the aforementioned visual attention measures and rate of social referencing. Separate analyses were conducted for each age group. First, Pearson's *r* correlational analyses were conducted using only the LR 11-month-old infants. Only a significant negative correlation was observed between the proportion of looking to the top half of the face (compared to the bottom half) and rate of social referencing (r=-.41, p=.04), indicating that increased looking to the top half of the face was related to lower rates of social referencing among LR 11-month-olds. Pearson's *r* correlational analyses were conducted also on the HR 11-month-old infants, but no significant associations were found between visual attention measures and social referencing.

As for the LR 16-month-olds, a significant positive association was found between the proportion of looking to the top half (vs. bottom half) of the face and rate of social referencing (r=.54, p=.01) (see Figure 5). This result suggests that increased proportion of looking to the top half of the face was related to higher rates of social referencing among LR infants at 16 months of age. In addition, a significant negative association was observed between proportion of looking at objects and social referencing (r=-.44, p=.02), indicating that increased looking to objects was related to lower rates of social referencing (see Figure 6). For HR 16-month-olds, no significant associations were found between visual attention measures and rate of social referencing, so visual attention indices were not shown to be predictive of social referencing behavior for HR 16-month-olds.

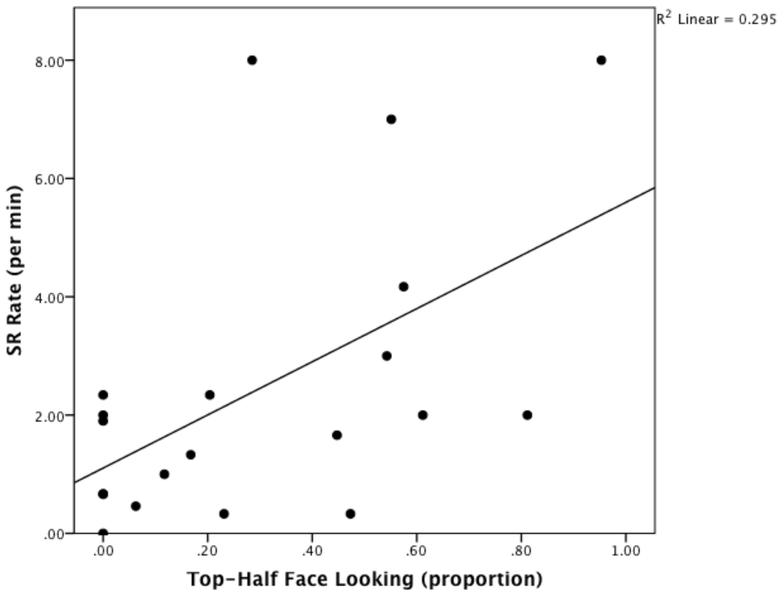

Figure 5. Top-half face looking by social referencing rate in LR 16-month-olds

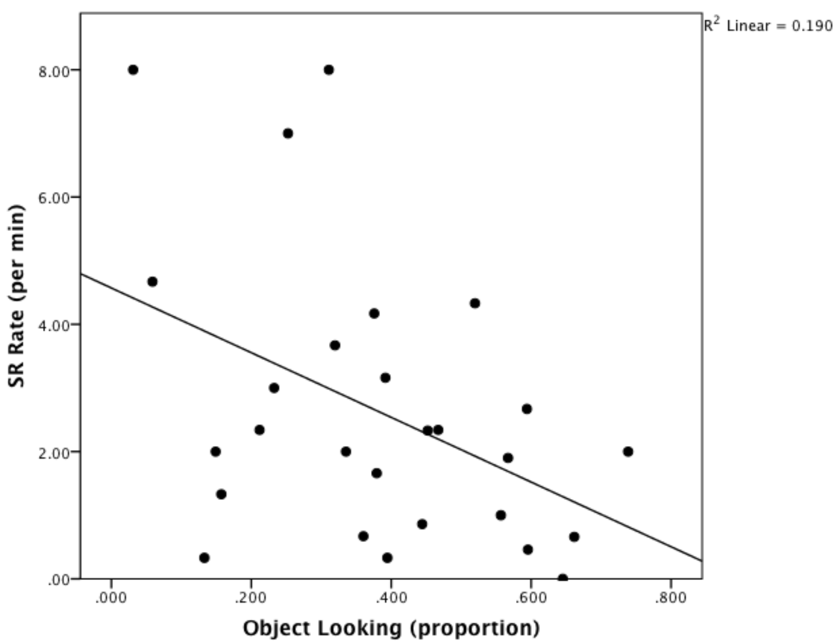

Figure 6. Object looking by social referencing rate in LR 16-month-olds

4.0 DISCUSSION

A primary objective of the present study was to identify differences in social referencing and visual attention (e.g., attention to objects, attention to faces, and attention disengagement) among 11 and 16-month-old infants based on autism risk status and outcome group. As hypothesized, results indicate that HR infants referenced adults at a lower rate than did LR infants, and importantly, 16-month-old infants later diagnosed with ASD referenced adults less frequently than infants classified as TD and NT at follow-up assessments. These findings provide additional support to previous studies showing social referencing deficits among at-risk infants, infants later diagnosed with ASD and preschool-aged children with autism (Bacon et al., 1998; Campbell et al., in preparation; Cornew et al., 2012). These results suggest a social referencing deficit in HR infants emerges after the first year of life (Campbell et al., in preparation; Cornew et al., 2012). Moreover, results suggest social referencing may be a promising early marker of ASD since it is possible to distinguish 16-month-old infants later diagnosed with ASD from infants who demonstrate non-typical development (in addition to TD infants).

Visual attention differences between LR and HR infants emerged at 16 months of age as well. Mainly, when infants were attending to the face, HR infants spent a smaller proportion of time looking at the top half of the face than LR infants. This suggests that, despite infants looking at the whole face for comparable amounts of time, HR infants distributed their attention within the face differently. On average, LR infants continued attending to the top half of the face over 25% of the time from 11 to 16 months of age, whereas HR infants had a similar attention pattern at 11 months but displayed a substantial decrease to a mean of 6% by 16 months.

Although previous literature supports a limited attentional bias to faces among toddlers with ASD (Chawarska et al., 2010) and children with ASD (Bernabei et al., 1998; Osterling & Dawson, 1994; Maestro et al., 1999; Zwaigenbaum et al., 2005), the current study suggests that atypical visual attention to faces may not be present before the first year of life in at-risk infants but rather may emerge by 16 months of age. It may be that variability among typical 11-month-old infants hinders the identification of early attentional differences in HR infants. Nonetheless, faces presented in the context of a dynamic social scene seem to be equally salient to HR and LR infants during early development, but the within-face attentional difference (less attention to the eye or upper region of the face) found among HR 16-month-olds in the present study is consistent with attentional differences observed among adolescents with ASD when compared to controls (Klin et al., 2002). When similar types of stimuli were used across studies, as was the case between the present study and Klin and colleagues' (2002) work, both of which utilized dynamic, naturalistic social scenes, less attention to the upper face was associated with ASD or autism risk. Therefore, it may be that methodological differences (such as stimulus characteristics) between the current study and the extant literature on children with ASD may have contributed to the within-face attentional difference found in the present study and the lack of attentional bias to objects over faces described in previous research (Chawarska et al., 2002; Sasson et al., 2011). For example, the audiovisual synchrony of the present study's dynamic social scene (e.g., Mr. Rogers' mouth movements and sounds) may have facilitated increased looking by HR infants to the bottom half of the face. It would be valuable for future studies to systematically assess stimulus characteristics (e.g., audiovisual synchrony, motion) in order to compare studies with different methodologies and improve identification of distinct developmental phenomena.

Another primary aim of the present study was to assess the extent to which visual attention differences were related to variability in social referencing. Significant associations were found only among LR infants. Notably, increased looking to the top half of the face was related to higher rates of social referencing in LR 16-month-olds. Conversely, LR 16-month-olds' increased looking to objects was related to lower rates of social referencing, which parallels previous associations reported between longer fixations to objects and lower social competence among adolescents with ASD (Klin et al., 2002). Few studies have examined associations between visual attention to naturalistic scenes and social behavior (Klin et al., 2002), such that the present study provides valuable support for the idea that the attentional salience of social and non-social stimuli relates to how individuals engage socially in their environment. As the first study known to identify associations between visual attention measures and social referencing, results indicate that attentional preferences for faces and objects predict social referencing behavior and suggests that further investigation of the co-occurring development of visual attention and social-communicative behaviors in infancy is warranted.

However, the lack of significant associations between visual attention measures and social referencing among HR infants may reflect more limited variability in social referencing skills and visual attention indices, given that this group showed deficits in both domains. Thus, floor effects may have reduced the variability in performance required to detect cross-task correlations. In addition, given the limitation of a small sample size in the present study, it was not feasible to analyze the developmental trajectories of HR infants based on outcome group

(TD, NT or ASD). It would be beneficial for future work to recruit larger samples with the statistical power to detect associations between visual attention and social referencing in NT infants and infants later diagnosed with ASD, as the extent to which these processes relate in these populations remains unclear.

In summary, results of the present study support deficits in social referencing as a promising early marker of ASD. Based on the limited research on social referencing and ASD (Bacon et al., 1998; Campbell et al., in preparation; Cornew et al., 2012), it will be important for future research to continue investigating the development of social referencing and its potential implications for ASD early detection efforts. Given the associations found in the current study between attentional preferences for faces and objects and social referencing behavior in early typical development, it also appears important to examine social referencing in the context of early cognitive processes, particularly visual attention. As the first study to identify these relationships, results support the idea that visual attention indices are related to successful social referencing. Furthermore, the finding that 16-month-old HR infants distribute attention within the face differently than LR infants implicates early atypical attentional processes, but the extent to which early atypical attention is related or contributes to social referencing performance in NT infants and infants later diagnosed with ASD requires further investigation.

	HR (N = 40)		LR (N = 29)	
	M	*SD*	*M*	*SD*
11-month-olds				
Mullen DQ	103.94	15.82	106.47	17.07
Gender (M/F)	(26/14)		(16/13)	
Ethnicity	34 Caucasian, 2 Black, 3 Hispanic White, 1 More than one race		27 Caucasian, 1 Black, 1 Hispanic White	
16-month-olds	HR (N = 32)		LR (N = 29)	
Mullen DQ	97.45	15.33	104.90	17.54
Gender (M/F)	(21/11)		(15/14)	
Ethnicity	30 Caucasian, 2 Hispanic White		27 Caucasian, 1 Black, 1 Hispanic White	

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