

Relating Infants' Social Engagement Profiles to Individual Differences in Language Outcomes

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ABSTRACT

Social engagement has been clearly associated with socio-developmental outcomes in clinical and at-risk populations of infants, who show deficits in gaze following, face processing, and joint attention. Importantly, these are all skills related to language learning. This is most prominently illustrated by individuals with autism, for whom social engagement and language are markedly dysfunctional. In contrast, for typically developing infants the parameters of social engagement and language learning have only been generally defined. The present study was designed to relate infants' social attention to later language outcomes. In this longitudinal study, 11-month-old infants participated in social attention tasks (distracter, gaze following and face scanning tasks); at 14 months, infants returned to participate in language (word/object association) and joint attention (Early Social Communication Scales) tasks; at 18-20 months, caregivers reported on language (vocabulary size) and autistic symptomatology (developmental screening measures). Overall, the results indicated that measures of social attention predict later language outcomes. In particular, joint attention accounted for 13% of the variance in infants' word/object association performance at 14-months. More frequent response to the joint attention bids of an adult female tester (e.g., looking in the direction of her pointing) was associated with better word/object association learning. With regard to vocabulary size, two tasks emerged as significant predictors, the distracter and joint attention tasks, which together accounted for 38% of the variance in language at 18-months. Specifically, longer latencies (i.e., less distractibility) to look away from the face when an adult female was speaking (distracter task) and more frequently responding to the attention bids of the tester were associated with a larger productive vocabulary size.

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Chapter 1

Introduction

Social engagement can be broadly characterized as the ability to attend to social information and engage in productive interactions with others. Social engagement has been studied under a variety of names, including social referencing, joint attention, and social cognition, or precursor behaviors such as gaze following, face processing, imitation and social attention. In terms of the early development of social engagement, research has largely focused on single components of social engagement, such as joint attention, or gaze following and imitation behaviors (see Mundy & Acra, 2006; Mundy & Sigman, 2006). This literature has documented that clinical and at-risk populations of infants show deficits in social engagement; furthermore, these social engagement skills have been related to language learning (Mundy, Kasari, Sigman, & Ruskin, 1995; Mundy & Willoughby, 1996; Sheinkopf et al., 2004). Such deficits in social engagement can have drastic consequences for the development of language, most prominently illustrated by children with severe autism, in whom social engagement is markedly dysfunctional, and who often fail to develop language at even rudimentary levels (Tager-Flusberg, Paul, & Lord, 2005). Thus, there appears to be a fairly strong link between clinical-level deficits in social engagement and deficits in language outcomes. However, the relationship between social engagement skills and language learning in more typically developing infants has only been generally defined.

Typically developing infants (i.e., infants with no known clinical symptomatology) may show significant variability in social engagement, or social attention, and still fall within the range of typical language development as toddlers. On the other hand, typically developing

infants may also show variability in social engagement and subsequently display specific delays/deficits in language-related skills. The nature of the relationship between social engagement and language outcomes can be better understood by connecting variable profiles of social engagement in individual infants with their subsequent language development. Although studies have documented an association between components of social engagement (e.g., gaze following) and language development in atypically developing infants, to date, there is no evidence available on the same infants' performance across early components of social engagement behaviors and their developmental trajectory towards language outcomes. In order to better understand the relationship between social engagement and language learning, the fine-grained microscope ordinarily applied to atypical development can be used to examine the processes and profiles falling within the parameters of 'typical' development. Thus, it is the aim of this study to compare the development of social engagement skills (e.g., social attention, face processing, gaze following) in the same (non-clinically referred) infants, and then relate these individual differences to language outcomes. The selection of early social engagement skills relevant to language development will be guided by previous studies that have investigated patterns of attention to social sources of information in typically developing infants, as well as investigations of social engagement deficits in young children with autism. The logic of this design flows directly from the conceptualization of language as an explicitly social process during early human development.

Language Development as a Social Experience

The impact of social experience has been strongly argued in the field of language learning (e.g., social learning theories Bruner, 1983; Vygotsky, 1962). Research has demonstrated associations between infant joint attention, theory of mind, and imitation and later

language development outcomes (Baldwin, 1995; Brooks & Meltzoff, 2005; Bruner, 1983; Tomasello & Farrar, 1986). In particular, joint attention (i.e., shared attention) behaviors are considered to be an especially crucial factor in language development for both typically (Baldwin, 1995; Carpenter et al., 1998; Dunham & Dunham, 1992; Dunham, Dunham, & Curwin, 1993; Morales, et al., 2000a, 2000b; Mundy & Gomes, 1998; Sigman & Kasari, 1995; Smith & Ulvund, 2003; Tomasello & Farrar, 1986) and atypically developing children after controlling for cognitive development (Mundy et al., 1990; Mundy & Gomes, 1998; Sigman & Ruskin, 1999; Ulvund & Smith, 1996). Joint attention is thought to reflect the development of social cognition, as well as early social attention regulation, and emotional and motivational processes, which all impact the individual variability observed in language development (for a discussion see Mundy & Acra, 2006).

Long before the onset of joint attention, infants are actively processing many different aspects of their native language structure. This requires segmenting and categorizing speech sounds from the language stream, learning the particular sounds which distinguish the native language, parsing words and applying meaning, ultimately producing sounds and words, and then stringing words together to create meaningful communication. Although the details of this developmental process are not yet entirely clear, recent research on the mechanisms by which infants learn language has advanced our understanding considerably. For example, infants are ‘statistical language learners.’ In other words, infants are sensitive to the distributional frequencies of sounds they hear in ambient language (Saffran, Aslin, & Newport, 1996). As young as 6 months of age, infants show sensitivity to distributional properties of their native language input (Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992), and show phonetic learning when distributional properties of speech are manipulated (Maye, Werker, & Gerken,

2002). At first glance this research suggests language development is a largely automatic process requiring only input. However, recent research suggests that social interaction may constrain the computational abilities of the infant (Kuhl, 2007). That is, although infants may acquire lexical knowledge by using statistical learning abilities, the social context in which such learning occurs is essential. This ‘social hypothesis’ of language learning, the proposition that social interaction is necessary for language development, is supported by studies demonstrating limitations in speech learning and language development when social interaction is absent.

For example, Kuhl, Tsao and Liu (2003) compared two groups of American infants who either experienced a live social interaction with a native female Mandarin speaker (playing with toys) or passively watched a video of this same speaker playing with the infants in the live group. In this way, both groups of infants were given the same ‘information’, except that in one case it was active and in the other passive. Subsequently, all infants were tested for their ability to discriminate a Mandarin (i.e., non-native) phoneme contrast that occurred in the female’s vocalizations. Only infants exposed to the live social interaction condition discriminated the Mandarin contrast.

Other evidence for the importance of social experience for language learning comes from research describing the role of contingency in social interaction. Goldstein, King and West (2003) compared the vocalization of 8-month-old infants interacting with their mothers in either a contingent or non-contingent condition. In this study, mothers were asked to respond to their infants’ (by smiling, moving closer and touching their infant) either immediately after their infants vocalized (contingent condition), or when cued by the experimenter (non-contingent condition). Responding in the non-contingent condition was determined on the basis of the response schedules of the contingent mothers; in other words, non-contingent mothers were

yoked to the control condition and received the same amount of social stimulation (same number of responses), although the interaction was not contingent. Infants in the contingent condition significantly increased the number and quality of vocalizations, producing more phonologically advanced sounds, compared to infants in the non-contingent condition.

Key evidence for social influences on language development also comes from studies of atypical language development. While most children eventually acquire language that falls somewhere within the ‘typical’ range, in specific clinical populations language processes are deficient. Among those with clinically significant deficits in language are individuals with Williams syndrome, Specific Language Impairment and Autism Spectrum Disorders. The degree of language impairment in these cases ranges from mild to severe (i.e., the absence of language). Williams syndrome (WS) is a rare disorder (1 in 20,000 live births) with a known genetic cause (microdeletion of several genes on chromosome 7). Although WS is characterized by severe cognitive deficits (performance IQ in the 40s-70s), language abilities are unusually spared (see Singer Harris, Bellugi & Bates, 1997). In fact, individuals with WS display remarkable proficiencies in language, including extraordinarily rich and complex grammar. Interestingly, individuals with WS appear to be very social, and have been shown to pay an unusual amount of attention to social information (i.e., greater attention to people’s faces and voices) (Karmiloff-Smith et al., 1997). Language Impairment (SLI) is a disorder of language acquisition, with otherwise typical development occurring in all other cognitive and physical domains (i.e., nonverbal intelligence is in the normal range, at least 85). SLI occurs in approximately 5-7% of the total population, and is characterized by impairment in specific areas of comprehension and/or production, most commonly in subtle aspects of grammar (Tomblin et al., 1997). Although differences have been reported for the social profiles of individuals with SLI compared

to typically developing children, these differences are thought to be generally within the normal ranges of social development (see for example McCabe & Marshall, 2006).

In contrast to WS and SLI, where social processes seem to be comparatively intact, autism stands as the most prominent example of social engagement gone awry, illustrating the developmental implications of marked deficits in social experience for language outcomes. In other words, autism seems to represent the extreme impact of atypical social processes on atypical language outcomes. Individuals with autism fall on a spectrum of dysfunction in the domains of social development, communication, and repetitive and stereotyped behaviors and interests (DSM-IV). This spectrum of disorders affects approximately 1 in 110 individuals (CDC, 2009). Although prognosis is highly variable among individuals with autism, it is clearly a life-long condition with outcomes ranging from poor to good (Howlin, 2005). Autism spectrum disorders (ASDs) are characterized by a pattern of social disengagement, ranging from severe to mild (for a discussion see Klin, Paul, Schultz, & Volkmar, 2005), that stands in marked contrast to typical patterns of social development - difficulty in social interaction, lack of interest in relating to and communicating with others, poor eye contact, poor empathy, repetitive behaviors and interests, sensory sensitivities, and lack of peer relationships.

Klin and colleagues have suggested that the deficits in social engagement observed in autism result from a lack of necessary foundational social experiences (Klin, Jones, Schultz, & Volkmar, 2005). Early social (or perhaps *less* social) dispositions may be particularly important for children with ASD. These areas of dysfunction include early social orienting responses and early motivational dispositions to respond to social stimuli. For infants who will be later diagnosed with autism, the process of social engagement may be derailed from the beginning, by an early lack of preferential orienting and lack of salience for social stimuli. Importantly,

developmental skills implicated in the emergence of atypical social engagement are also strongly implicated in the emergence of atypical language development in individuals with autism. Early dysfunction in social attention/orienting, face processing and gaze following/joint attention are perhaps the earliest identified deficit areas associated with autism (see Mundy & Sigman, 2006).

In general, individuals with autism demonstrate a failure to orient to social stimuli, spending less time looking at people, and more time looking at objects (Dawson et al., 1998). Compared to typically developing counterparts, children with autism more often do not orient to their name at their first birthday party (Osterling & Dawson, 1994), do not show a preference for human speech (Klin, 1991), and typically fail to respond to the emotions of others (Sigman et al., 1992). Children with autism display markedly dysfunctional, or absent, joint attention behaviors, which constitutes the DSM-IV operational definition for social deficits in autism (e.g., lack of eye contact, showing, gestures, bringing or pointing out objects of interest, sharing attention with others). The relationship between joint attention and autism has been widely examined (for reviews see Charman, 1998; Leekam, Lopez, & Moore, 2000; Sigman & Kasari, 1995). In comparison to typically developing children, children with Down syndrome, and children with developmental delays, children with autism initiate and respond less to joint attention (Loveland & Landry, 1986; Mundy, Sigman, Ungerer, & Sherman, 1986; Mundy, Sigman, & Kasari, 1990). Furthermore, deficits of early joint attention in children with autism appear to strongly implicate later adaptive outcomes and degree of impairment in language.

Importantly, compared to other populations with atypical language development, for which social engagement is relatively intact (e.g., specific language impairment, Williams syndrome), individuals with autism stand as the striking example of atypical social engagement and deficient language development. Drawing from outcomes observed in autism, it can be

expected that when social engagement is absent (i.e., lack of social attention), language is also likely to be absent. In contrast, the implications of variability in features of social engagement are relatively unknown for infants with no known clinical symptomatology. Individual variability may be present among typically developing infants, although these differences may not have the same implications for the infants' capacity for so-called 'normal' development. The parameters of language development are wide (Fenson et al., 1994). At 12 months, infants in the bottom 10% on language produce no speech and those in the top 10% use 26 words or more; at 16 months, children in the top 10% have productive vocabularies of 180 words, while children in the lowest 10% have productive vocabularies of less than 10 words, or even no words at all. Two toddlers with productive vocabularies of thirty-five spoken words and two hundred words will both fall within typical developmental ranges. Consequently, it is reasonable to expect that for non-clinical infants, the more deviant the pattern of social engagement, the greater the likelihood of impairments in language outcomes. Thus, the present study aims to describe individual profiles of non-clinically referred infant's social engagement, and then to link this variability to differences in language outcomes. Following a developmental psychopathology perspective (Cicchetti, 1984), the components selected for individual social engagement profiles will be guided by research that has identified behaviors that are dysfunctional among individuals with autism.

Components of a Social Engagement Profile

Social engagement has been operationalized in various ways, most prominently including gaze following, joint attention, and imitation behaviors as paradigm processes. In the present study, infant social engagement is conceptualized and empirically defined by presenting social attention tasks derived from literature on typical and atypical infant development. Specifically,

social attention/orienting, face processing, gaze following, and joint attention are described as pivotal skills in early emerging social engagement processes related to language development. In the following discussion, information on the typical (non-clinical) and atypical course of each of these component processes is presented. Finally, the application of these social engagement processes to tasks in the present study will be introduced.

Social Attention

Social attention/orienting will be described here as the infant's pattern of attention towards information that is social in nature, compared to non-social information. The developmental course of typical and atypical attention in this domain will be reviewed below.

Typical Development. From the first days after birth, infants actively orient to perceptual information in their environments, information that is both of a non-social and social origin. Newborns prefer to look at human faces (Johnson & Morton, 1991; Valenza, Simion, Macchi Cassia, & Umiltà, 1996), and also at geometric patterns that are high in visual contrast (Fantz, 1964). Infants also prefer to look more at moving (versus stationary) stimuli (Slater, Morison, Town, & Rose, 1985), such as moving heads and blinking eyes (Samuels, 1985). Infants recognize their mother's voice within a few days of birth (DeCasper & Fifer, 1980), and prefer infant-directed speech over adult-directed speech (Cooper & Aslin, 1990). Coordinated, or synchronized perceptual information also seems particularly salient for infants. For example, 3-month-olds looked longer at videos of a toy hammer striking a surface when the sound and video image were coordinated, than when they were not synchronized (Hernandez-Reif & Bahrick, 2001). Similarly, 4-month-olds looked longer at video images of a female producing vowel sounds when the image was accompanied by the appropriate sound track (Kuhl & Meltzoff, 1984). The infant's duration of looking time to dynamic, interactive, and complex stimuli

increases with age (Courage, Reynolds, & Richards, 2006; Ruff & Capozzoli, 2003), and infants are increasingly orienting their attention to the face and voice.

While initially the newborn has little voluntary control of their visual attention, developmental changes (e.g., changes in the visual system, see Atkinson, 1992) allow the infant to achieve this ability (Rothbart, Ellis, & Posner, 2004). This, in turn, is followed by increasing capacity for attentional control with age (Ruff & Rothbart, 1996). Ruff and Rothbart (1996) capture this developmental progression by suggesting that infants possess two attention control systems, an early emerging attention system which is guided by novelty of objects and a later developing system which is self-generated and goal-oriented to allow sustained, focused attention.

At first, infants have difficulty disengaging visual attention ('obligatory looking' or 'sticky fixation') (Hood, Willen, & Driver, 1998; Hunnius & Geuze, 2004b; Johnson & Morton, 1991). Then around 2- to 3-months of age, infants begin to develop the ability to disengage attention. Between 3 and 9 months, attention seems to be guided by relative novelty, and this attention increases with age (Bakeman & Adamson, 1984). By 9 months, most infants are adept at initiating, shifting, and disengaging attention, and are also learning to direct the attention of others. At around 12 months of age, novelty becomes less salient as a determinant of attention (as infants begin to habituate much more quickly), while sustained, focused attention becomes increasingly influential. The ability to maintain focused attention increases with age (Ruff & Lawson, 1990). Importantly, infants are less distractible when they are focused in attention towards object or play, compared to when they are casually engaged (Kannass, Oakes, & Shaddy, 2006; Ruff & Capozzoli, 2003). Typically, it takes about twice as long for infants to shift their gaze towards a distracting stimulus (i.e., a stimulus presented in the periphery) during

focused attention (Richards, 1989). Also, infants show an increase in heart-rate defined attention toward dynamic faces (compared to other dynamic displays) between 3 and 9 months of age (McIlreavy, Panneton, Bhullar, & Aslin, 2006).

Atypical Development. Although atypical social attention patterns have been reported for children and adults with autism, our understanding of the attention patterns of infants with autism is limited. Diagnoses are not typically reliably made until children are around 2 years old (Lord, 1995). Perhaps most well examined are differences in patterns of attention towards social and nonsocial information displayed by individuals with autism. The ability to detect human-specific biological motion is an early emerging form of socially relevant information thought to support later developing social skills (e.g., the ability to perceive what others are doing, understand body language, facial expressions). Research using point-light displays indicates that human infants can detect biological motion and discriminate this from other forms of motion as early as 4 months of age (Fox & McDaniel, 1982). Children (age 8 to 10 years) and adults with autism display significant impairments (compared to typically developing children) in their ability to detect biological motion (Blake, Turner, Smoski, Pozdol, & Stone, 2003; Klin & Jones, 2006). In addition, children with autism also do not show a preference for human speech (Klin, 1991) and do not demonstrate a preference for infant directed speech. When given the choice between 5 seconds of “motherese” speech and nonspeech, only children with ASD (compared to children with developmental delay and typical development) chose the nonspeech analogue (Kuhl, Coffy-Corina, Padden & Dawson, 2005).

Atypical attentional control may be also present among individuals with autism, in particular, difficulties in attention shifting (the ability to disengage from one stimulus in order to attend to another stimulus) (Ozonoff, 1997; Ozonoff & Jensen, 1999). At least one prospective

study has found that infants later diagnosed with autism display a prolonged latency to disengage visual attention and a tendency to fixate on particular objects in the environment (Bryson et al., 2007; see also Landry & Bryson, 2004). In a prospective study of infant siblings of children diagnosed with autism (considered an “at risk” for autism population), Zwaigenbaum and colleagues (2005) presented “at risk” infants (at 6 and 12 months of age) with a dynamic, colorful central stimulus, followed by a distractor stimulus; the manipulation was whether or not the central stimulus was turned off or remained on during the distractor presentation. Compared to other infants (infants without siblings diagnosed with autism), at-risk infants had difficulty disengaging from two competing stimuli (i.e., both stimuli remained on), showing abnormally long latencies to disengage attention. In addition, diagnoses of autism at 24 months were predicted based on disengagement of visual attention and visual tracking patterns (among other behaviors). This attention profile in autistic children has been compared to the “sticky attention” (or obligatory attention) observed in younger, typically developing infants (Hood, et al., 1998).

Individuals with autism have been suggested to show deficits in holistic encoding of information (i.e., weak central coherence) (Frith, 1989). Individuals with autism typically display superior performance on certain tasks, such as enhanced discrimination on visual search and perceptual learning tasks (e.g., O’Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O’Riordan, & Baron-Cohen, 1998), better performance when identifying shapes embedded within a complex design (Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983), and perform better on the Block Design subtest of the Wechsler intelligence scales (Shah & Frith, 1983; 1993). When copying line drawings of objects, children with autism are more likely to begin copying the local details rather than the overall features of the object (Mottron, Belleville, & Menard, 1999).

Research using retrospective analyses of home videotapes has provided additional information about attention patterns in infants later diagnosed with autism. Osterling and Dawson (1994) examined videos of first birthday parties and found that infants' lack of "looking at other people" was the best single predictor of later diagnosis of autism. Dawson and colleagues (1998; Osterling, Dawson, & Munson, 2002) compared children with autism to developmentally matched children with Down syndrome and typically developing children, on their visual orienting to social stimuli (e.g., having their name called, hands clapping) and nonsocial stimuli (e.g., rattle, musical jack-in-the-box). Children with autism more often failed to orient to all stimuli, but the strongest effect was for social stimuli. Those children with autism who did orient to social stimuli took longer to do so compared to other groups of children. Maestro and colleagues (2002; 2005a) examined social attention by comparing retrospective videotapes of infants later diagnosed with autism and typically developing children during the first year of life. Significant differences in attention towards people and objects were found between the two groups at 6-months of age (e.g., differences on looking, smiling, and vocalizing towards people versus objects). At 12 months of age, children with autism also displayed significant differences in their nonsocial and social attention (i.e., attention to objects versus attention to people).

Social Attention in the Present Study. In general then, typically developing newborns increasingly display social attention preferences. Infants gradually develop the ability to control and direct attention, particularly to social aspects of the environment. Attention may be differentially directed towards social versus nonsocial information, and similarly, distractibility may be differentially influenced as well. In contrast, atypical development implicates social attention difficulties in the areas of attention preferences and attention shifting. To examine

individual differences in infant's social attention in the present study, infants will be presented with a task designed to measure infants' distractibility when visually focused on a face (social stimulus). In other words, infants' latency to look away from a social target stimulus during distraction will be measured. Social attention will be operationally defined as the latency to look away when visually focused on the target face, when presented with a peripheral distracter.

Face Processing

A second major ability central to social engagement is an infant's face processing/scanning ability. Face processing is an early emerging skill central to social engagement, which includes behaviors such as looking at faces, processing features of faces (e.g., eyes and mouth) and recognition of faces. In the following section, typically and atypically developing face processing will be presented.

Typical Development. The capacity to perceive features of faces, to recognize familiar faces, and to discriminate emotional information are all pivotal skills for infant development in multiple domains (e.g., cognitive development, language, social cognition, etc). The human face provides an abundance of information - about the identity of the individual, emotional and attentional state, and communicative intent. Infants at first scan the edges of faces and during the first month of life will look most at the contours of the face (i.e., the hairline and chin), and largely ignore the inner features of a stimulus (Salapatek, 1968). Around two months of age, infants begin to look more at the eyes and mouth, and at moving, talking faces than at moving, silent faces (Haith, Bergman, & Moore, 1977; Maurer & Salapatek, 1976; Pascalis, De Schonen, Morton, Deruelle, & Babregrenet, 1995). By 3 months of age, developing visual abilities allow more controlled visual fixation, and as a result, more strategic scanning abilities (see Atkinson, 1992). Between 6 and 26 weeks, infants were shown to increase their amount of looking time to

their mother's mouth region from 39.98% to 57.19% (Hunnius & Geuze, 2004a). Around 3-months of age, the eye region becomes more salient than the mouth for infants' visual attention, although by 5 months of age this difference is no longer discernable (Caron, Caron, Caldwell, & Weiss, 1973). Also around 3 months of age, as increasingly adult-like scanning develops, infants have the ability for efficient and accurate eye movements (Bronson, 1994).

Initially then, infants are processing internal and external features of the face separately. However, between 3 and 10 months, infants shift to processing these features together (Cashon & Cohen, 2003), an ability which has major implications for the infant's ability to process and recognize faces, and ultimately attend to and learn language. Infant scanning patterns to dynamic faces have been less explored in the face processing literature. In a longitudinal study of face perception (6 to 26 weeks of age), infants' scanning patterns to a dynamic moving image of their mother's face and to a dynamic stimulus stabilized around 18 weeks of age (slightly later than the literature reports for static stimuli) (Hunnius & Geuze, 2004a). In this study, there was no scanning preference for facial contours; infants looked most often at the mouth and eye region.

An important development of face processing abilities involves the infants' specialized processing of eyes and eye-gaze direction. Within the face, the information contained in the eyes functions as a salient and powerful channel for the infant to detect and process. Newborns and infants show evidence of sensitivity to eye information and gaze direction of others. Infants prefer to look at a picture of a face with eyes open rather than the same picture with eyes closed (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000). Farroni and colleagues have demonstrated that newborns and infants prefer to look at faces that can be engaged in mutual gaze (i.e., for eye contact). Newborns 2- and 5-days-old look longer and reorient more often to faces with direct/mutual gaze, compared to faces with averted gaze (Farroni, Csibra, Simion, &

Johnson, 2002; Farroni, Massaccesi, Pividori, & Johnson, 2004). Infants' at 4-months of age display enhanced neural processing (event-related potentials) of faces that engage them in mutual gaze, compared to faces with averted gaze. Infants also show an emotional response to perception of eye gaze information. Hains and Muir (1996) manipulated adult eye direction (direct versus averted), while maintaining contingent social interaction (live or televised) with the infant under all conditions. Infants' smiling (at 3- and 6-months-old) declined whenever the adult looked away, and visual attention decreased across trials. In contrast, infants who experienced only interactions with direct eye gaze engaged longer and smiled more often. Similarly, newborns have been shown to imitate the facial behaviors of others (Meltzoff & Moore, 1977).

Face processing skills allow infants to also learn about specific faces. Hours after birth, infants show a visual preference for their mother's face over unfamiliar female faces (Bushnell, 2001; Bushnell, et al., 1989; Pascalis, et al., 1995). Newborns are capable of basic recognition of stranger's faces. After being habituated to a stranger's face, four-day old infants will look longer to a new face than to the familiar one (indicating recognition of the familiar face) (Pascalis, et al., 1995). Typically developing infants can detect facial gestures, and expression of emotion in the first year of life (cf. Bernier, Webb, & Dawson, 2006). Importantly, infants also begin to interpret and respond to the affect conveyed in the face. Research suggests that experience may play a role in the development of face processing. Pascalis and colleagues (2005) demonstrated that 6- and 9-month-old infants, who had experience viewing non-native faces (Barbary macaques) over the course of a three-month training period, were able to discriminate the familiar faces from unfamiliar faces on testing. Direction of gaze (mutual versus averted gaze)

has been shown to modulate recognition of faces in 4-month-old infants (Farroni, Massaccesi, Menon, & Johnson, 2007)

Atypical Development. Further evidence for the necessary role of experience comes from studies of atypical development. In general, children and adults with autism show atypical patterns of looking and recognition for faces (although this is a matter of debate in the literature; for reviews see Sasson, 2006 and Schultz, 2005); however, the face processing patterns of infants with autism are largely unknown. In retrospective analysis of children's first birthday parties, children later diagnosed with autism have been shown to spend less time looking at faces, compared to infants who were not later diagnosed with autism and children who were mentally retarded (Osterling & Dawson, 1994; Osterling et al., 2002). Several studies have also found that children with autism processed faces feature by feature, rather than using the holistic encoding strategies used by typically developing children (Davies, Bishop, Manstead, & Tantam, 1994).

Children and adults with autism also display atypical looking patterns to features of the face. While typically developing individuals orient to the eyes for information, individuals with autism do not seem to utilize such eye gaze cues (Pelphrey et al. 2002; Baron-Cohen, Wheelwright, & Joliffe, 1997; Ristic, et al., 2005). Eye-tracking studies have attempted to clarify the looking patterns of individuals with autism. Adults with high functioning autism have been shown to demonstrate less attention to eyes, compared to the amount of attention to mouth, body parts and objects, during a video of a social scene (Klin et al., 2002a, b). Klin and colleagues (2003) illustrate two cases of visual fixation patterns from their eye-tracking studies. In the first example, an adult with autism is shown to visually fixate on the room's light switch, rather than on the social interaction occurring between the actors in the scene. In the second example, a 2-year-old boy with autism visually focuses on the objects and details of shelves in the corner of

the frame, rather than on the popular character in the children's television show. In other eye-tracking studies, when presented with a film of a social interaction, adults (normative IQ) with autism visually orient to the mouth region or the periphery of the face, spending twice as much time on the mouth region and 2.5 times less time on the eye region of faces compared to age-, IQ- and gender-matched typical controls (Klin et al., 2002b). Similarly, high-functioning adults and adolescents with autism display visual scan patterns focused on non-feature areas of the face (i.e., cheeks, chin, side of face), compared to the amount of time focused on features of the face (i.e., eyes, nose, mouth) (Pelphrey et al., 2002).

Individuals with autism are reported to frequently avoid eye contact (e.g., Pelphrey et al., 2002). It may be that individuals with autism dislike eye contact, and may even use avoidance of eye contact as a strategy to modulate arousal. It has been suggested that gaze aversion may provide the arousal modulation necessary for self-regulation and early social interactions among children with autism (Field, 1981). When presented with the task of viewing the eye region of the face, individuals with autism showed more avoidance and arousal (greater neural activity in the fusiform gyrus and amygdala, and greater galvanic skin response) compared to controls (Dawson et al., 2005). Similarly, children with autism less often engage in mutual gaze (Sigman, Mundy, Sherman, & Ungerer, 1986). In addition, compared to typically developing children who more quickly detect mutual/direct eye gaze, children with autism show no difference in their ability to detect direct and averted gaze (Senju, Yaguchi, Tojo, & Hasegawa, 2003). Adults and children with autism do poorly on recognizing emotions based on eye region information (Baron-Cohen, Wheelwright, Jolliffe, 1997). Evidence also exists for anatomical brain differences between individuals with autism and typically developing individuals in areas associated with gaze following (see Frieschen, Bayliss, & Tipper, 2007).

Individuals with autism also show atypical face identification of familiar people (Sasson, 2006). Children with autism rarely look at another person's face for information or assurance, typically have difficulty recognizing emotional facial expressions, and fail to respond to the emotions of others. When presented with the still face paradigm, children at-risk for autism (i.e., younger siblings of children diagnosed with autism) show a markedly atypical response. When an adult presents the still face (i.e., mother interacts with the infant, then freezes and presents a neutral, expressionless face), typically developing children respond with precipitous decreases in smiling, increased gaze aversion and distress (Tronick, Als, Adamson, Wise, & Brazelton, 1978). In contrast, 4-month-old infant siblings of children with autism (i.e., sibling sample was considered at-risk for autism) were less likely to display distress during the still face (Yirmiya, et al., 2006). When exposed to a distressed adult or familiar caregiver (pretending to be hurt), children with autism were more likely to ignore the adult after a fleeting glance, playing with the toy in front of them, compared with normally developing children, who could not shift their attention from the "injured" adult (Sigman, et al., 1992). Similarly, when adults demonstrated either fear or amusement in response to the appearance of a robot, most children with autism did not look at either the parent or the experimenter (Sigman, Kasari, Kwon, & Yirmiya 1992).

Face Processing in the Present Study. Overall, failure to demonstrate a visual orienting response to faces, and failure to orient to salient features of faces (e.g., eyes) and emotional information presented therein, are clear indicators of basic and early impairment of social engagement. Atypical face processing thus represents a basic component of dysfunctional social engagement strongly implicated in developmental psychopathology (e.g., autism). In contrast, variability in face processing abilities among typically developing populations has not been similarly mapped onto developmental outcomes such as language abilities. In the present study,

face processing will be assessed by using an eye-tracking device to capture the eye gaze patterns of infants. Infants will be presented with dynamic videos of the face of an unfamiliar adult female and the face of their own mother. Infants' patterns of gaze towards familiar and unfamiliar faces will be compared.

Gaze Following

Gaze following requires increasingly more sophisticated social engagement abilities. The infant must process face information, perceive eye gaze direction, disengage attention to faces, and appropriately shift attention to re-orient to the focus of another person's gaze. Gaze following is considered a major milestone of development, paving the pathway for increasingly sophisticated social interaction and referential communication (e.g., Adamson, 1995). Typical and atypical development of gaze following is presented below.

Typical Development. Gaze following has been operationally defined as the ability to follow the gaze of another person (for a review see Frieschen, Bayliss, & Tipper, 2007). Even though infants show an early sensitivity to eye gaze direction (Batki et al., 2000; Hains & Muir, 1996; Farroni et al., 2002), the ability to use (or act on) gaze information is slower to develop. In 1975, Scaife and Bruner first reported that during the first year of life infants are able to follow the direction of gaze and head turn of a caregiver. Following this seminal study, researchers have attempted to document the specific cueing information and context necessary for the developmental progression of gaze following behavior.

When then does gaze following first emerge? Infants have been shown to discriminate and follow an adult's direction of gaze shift as young as 3 or 4 months (Hood et al., 1998). Hood and colleagues presented images of an adult female face and a target object, with eye gaze either congruent or incongruent with the direction of the target. Infants' orienting reaction times (i.e.,

time to make a saccade to the peripheral target) to the target were faster for congruent than incongruent trials. On incongruent trials, 87.5% (14/15) of infants made errors in looking to the target, compared to 56.3% (9/16) of errors made during congruent trials. Furthermore, infants made more gaze shifts away from the target during incongruent trials. However, during trials when the face was visible (i.e., the face remained visible when the target appeared), gaze following only occurred on 25.9% of the trials, and most infants continued to fixate on the face.

Building on this research, Farroni and colleagues explored parameters of eye gaze perception and gaze following by examining the role of eye motion in gaze following. Neonates (2- and 5- days old) and 4-month-old infants were tested on their ability to gaze follow when presented with images of a face slightly shifted to one side, without the information provided by pupil movement (Farroni, Massaccesi, Pividori, & Johnson, 2004). Newborns and infants both followed adult gaze, but only when the pupils could be seen to move. Similarly, when 4- and 5-month-old infants were presented with contradictory eye and face movement information (e.g., the pupils are stationary but the head movement is to the side), infants oriented to the direction of the head movement rather than to the side cued by eye gaze (Farroni, Johnson, Brockbank, & Simion, 2000). In other words, the ability to follow gaze when eyes are statically looking to the left or right, or to preferentially follow eye gaze information, seems to be a later developing ability. Several other lines of research have confirmed the importance of motion for developing gaze following abilities. In one study, 9-month-old infants who had not yet demonstrated spontaneous gaze following were only able to do so when viewing the motion of a head turn; in contrast, infants who were already spontaneously gaze following, could demonstrate this ability when presented with static images depicting a gaze shift (Moore, Angelopoulos, & Bennett, 1997). Other research has demonstrated that the infant must experience eye contact with an

upright face prior to viewing gaze shift, in order to respond to gaze cueing (Farroni, Johnson, & Csibra, 2004; Farroni, Mansfield, Lai, & Johnson, 2003).

Although research in more naturalistic contexts is quite limited, research indicates that infants may process dynamic information differently with developmental time. Younger infants appear to require the stronger perceptual information provided by a head turn. Infants are capable of gaze following in response to an adult's head turn as early as 3 months of age, when the target is in the infant's immediate visual field (D'Entremont, et al., 2000; D'Entremont, Hains & Muir, 1997). Between 9 and 10 months of age, infants can follow head turns and gaze shifts to locate a target outside of their immediate visual field (Butterworth & Jarret, 1991; Corkum & Moore, 1998; Scaife & Bruner, 1975). By 10 months of age, infants have been shown to be most likely to follow a head turn when the adult's eyes were open, compared to when the adult's eyes were closed (Brooks & Meltzoff, 2005). In this study, individual differences in gaze following were related to language at 18 months. Generally then, gaze following becomes more reliable across contexts by the end of the first year (Corkum & Moore, 1995).

Compared to other components of social engagement, gaze following has been most often theoretically and empirically related to language development. Gaze following may provide an important foundational experience that is necessary for an infant to correctly pair an object with its spoken name and thus learn word-object associations (Baldwin, 1995). Furthermore, early gaze following (as young as 6 months) has been associated with vocabulary size at 18 months of age (Morales et al., 2000a; Morales, Mundy & Rojas, 1998). Although it is not clear at precisely what age infants understand the exact referent of the adult's attention, some evidence suggests that infants may possess this discriminative gaze following ability by 9 months of age. For example, 9-month-old infants oriented to the correct focus of an adult's gaze

shift when nearby distractor objects were also presented (Flom, Deak, Phill, & Pick, 2004). Also, 12- and 18-month old infants will crawl to look around a barrier in order to see what an adult is looking at (Moll & Tomasello, 2004). Gaze following and later more sophisticated joint attention abilities (i.e., triadic attention) are thought to underlie the development of language development and social cognition (e.g., Mundy, 1995; Tomasello, 1995). Typically developing infants display a significant range of individual differences in gaze following (Carpenter et al., 1998; Corkum & Moore, 1998; Morales, Mundy, & Rojas, 1998; Mundy & Gomes, 1998; Scaife & Bruner, 1975). Gaze following behaviors emerge infrequently at first and are highly context dependent, showing a marked increase during the first year of life and into the second (Morales et al., 2000a). Even after mastery of this skill, most children display significant individual differences in the frequency and consistency of its use. In further support of this perspective, gaze following behavior and joint attention have been related to social cognitive outcomes. For example joint attention at 20 months has been related to theory of mind ability at 44 months (Charman et al., 2001). Other evidence comes from studies of gaze following outcomes in atypical development.

Atypical Development. Deficits in gaze following have been most clearly documented in individuals with autism (for a review see Nation & Penny, 2008). Young children with autism show deficits in gaze following behavior, although in older children these deficits may not be observed (Leekam et al., 1997; Leekam, Hunnisett, & Moore, 1998; Leekam, Lopez, & Moore, 2000). Gaze following abilities are relatively unexplored among infants with autism. Leekam et al. (1997) have demonstrated that children with autism can determine where others are looking; in other words, failure to follow gaze does not seem to be because individuals with autism are functionally incapable of understanding direction of gaze. Leekam et al. (1998) found that mental age (verbal and nonverbal age above 4 years) predicted spontaneous gaze following

among children with autism. In some children with autism, basic gaze following abilities have been observed by 2 years of age (Chawarska, Klin, & Volkmar, 2003). It may be that gaze following abilities can catch up with development in those with higher mental ages (Leekam & Moore, 2001; Sigman & Ruskin, 1999). (This is similar to the predicted relationship between mental age and joint attention abilities; see Landry & Loveland, 1988; Mundy, Sigman, & Kasari, 1994).

Gaze Following in the Present Study. Gaze following will be operationally defined as a shift in visual attention toward the direction of eye gaze of another individual, and will be measured based on performance across two tasks in the present study. First, a gaze following task will assess infants' looking patterns to static video images. This image will consist of an image of an adult female in mutual gaze with the infant, followed by an image of the female gazing towards or away from a visible object. Infants' ability to act on the social information (gaze follow) using socially congruent and incongruent information will be measured. Second, joint attention tasks will measure infants' successful gaze following (along with other joint attention behaviors which are described below) when interacting with their own mother and with a female experimenter. These tasks will allow measurement of the infants' gaze following using dynamic, naturalistic information during the context of an interaction with their own caregiver and with an unfamiliar experimenter.

Joint Attention

Building upon these developing social attention abilities, infants ultimately attain the capacity for triadic joint attention. Joint attention is conceptually defined as a social interaction in which two individuals simultaneously coordinate visual attention to an object or event, with both individuals aware of the shared attention. A simple example of joint attention would be as

follows: a toddler watches an interesting wind-up toy moving across the table in front of her, the toddler looks at her mother in excitement, and then looks back at the toy. The goal of this form of communication is to share attention and experience with others. Fully developed joint attention represents a transition from dyadic (face-to-face) to triadic (infant-other-object) interactions involving shared intentions and goals. Joint attention has been divided into two processes of attention sharing (Mundy et al., 2003): (1) responding to joint attention (RJA), or gaze following, discussed in the previous section: following direction of gaze, head turn and/or pointing gesture of another person; and (2) initiating joint attention (IJA): the infant's use of eye contact and/or pointing or showing to spontaneously initiate attention coordination with another person. Importantly, RJA and IJA may have different associations with developmental abilities and seem to have differential predictive associations in both typical and atypical populations.

Typical Development. By the time of their first birthday, children typically follow and direct (with pointing) the visual attention of an adult. More sophisticated and elaborated joint attention episodes (e.g., integrated pointing, triadic attention) appear during the second year. The primary period for the development of triadic joint attention appears to be from 9- to 12-months of age, with consolidation of joint attention skills occurring around 18 months of age (Carpenter, et al., 1998; Tomasello, 1995).

Processes of early joint attention are thought to allow the later development of social engagement abilities. However, early stages of joint attention may not reflect social-cognition, or the awareness that others have intentions and actions (e.g., Carpenter et al., 1998). Instead, this may only be reflected in later stages of joint attention development (Brooks & Meltzoff, 2002). Gaze following and other basic joint attention skills may appear as early as 3 months of age (D'Entremont, Hains, & Muir, 1997; Hood et al., 1998; Morales, Mundy & Rojas, 1998; Scaife

& Bruner, 1975), which is long before social-cognitive processes are thought to be operational (Mundy & Sigman, 1989). In fact, some research suggests that joint attention (gaze following/RJA) before 2 years of age does not adequately support social-cognition (Brooks & Meltzoff, 2002). When the first joint attention behaviors emerge (e.g., gaze following), the infant is likely not playing an active role in establishing joint visual attention, and may not even recognize that the episode occurred (Corkum & Moore, 1998).

However, during the 9- to 12-month period, infants begin to display more complex triadic interactions, so much more complex that Tomasello (1995) has called this the “social-cognitive revolution.” It is thought that this shift reflects a change in the infant’s understanding of others’ actions and intentions (Bretherton, 1991; Carpenter et al., 1998; Tomasello, 1999). Joint attention is thought to reflect an underlying understanding of other persons as intentional agents (Tomasello, 1999). This interpretation is based upon assumptions about the intentions of the infant, for example, assuming that the infant follows an adult’s direction of gaze in order to share the experience with the adult or to examine what the adult is viewing (for alternative interpretations, see Baldwin & Moses, 1996; Corkum & Moore, 1995). It has also been suggested that triadic joint attention allows the development of intentional understanding of others’ actions (Corkum & Moore, 1995).

Individual differences in joint attention show a predictive relationship with language development, and in fact, RJA and IJA are thought to be critical for language development (Baldwin, 1995; Mundy & Neal, 2001). Associations between measures of RJA (in the second year) and later receptive language development have been reported in typical and atypical populations, after controlling for cognitive development (Mundy & Gomes, 1998; Mundy, Kasari, Sigman, & Ruskin, 1995). Infant RJA seems to predict long-term language outcomes as

well. Morales and colleagues have shown that individual differences as early as 6 months may be predictive of outcomes at 12, 24, and 30 months of age (Morales, Mundy, & Rojas, 1998; Morales et al., 2000a, b). The primary period for predictive RJA associations with language development seems to be between 6 and 18 months of age (Morales et al., 2000). Overall, RJA seems to be the strongest predictor of language outcome. However, IJA has also shown some associations with receptive and expressive language development (Ulvund & Smith, 1996).

Individual differences in joint attention are thought to reflect the extent to which social engagement is reinforcing and rewarding to the infant, in both typically and atypically developing populations (Mundy, Kasari, Sigman & Ruskin 1995; Trevarthen & Aitken, 2001). IJA is thought to reflect “social motivation”, or the tendency to express agreeableness and interest in others, while RJA is thought to serve more instrumental purposes for the infant (e.g., requesting assistance). Regardless of the theoretical explanations of joint attention and the relationship with outcomes (i.e., language and social development), this process seems to represent the juncture of social, cognitive, self-regulatory and motor abilities for the purpose of coordinated attention sharing (Mundy, 1995).

Atypical Development. Importantly, deficits in these processes of social attention engagement and language converge in atypical development. Deficits in joint attention have been shown to be a valid method for detecting autism as early as 12 months of age and older (Lord, 1995; Osterling & Dawson, 1994; Osterling, Dawson, & Munson, 2002). Similar studies have been attempted during the first year of life as well, although to a limited extent, and with less clear results (Zwaigenbaum et al., 2005). Retrospective analyses of home videotapes has demonstrated that infants who were later diagnosed with autism look at others and oriented to their names less than infants with mental retardation (Osterling & Dawson, 1994; Osterling,

Dawson, & Munson, 2002). Compared to typically developing infants, infants later diagnosed with autism and mental retardation use fewer gestures, look less often at objects others are holding, and use more repetitive motor actions. Children with autism experience deficits in both RJA and IJA skills. Although it has been suggested that children with autism do not use RJA at all (Baron-Cohen, Baldwin, & Crowson, 1997), RJA has been shown to have strong associations with later language development (Sigman & Ruskin, 1999). Among children with autism, RJA ability appears to moderate the effectiveness of treatment interventions (Bono et al., 2004). RJA has been associated with parent-child interaction factors that are typically associated with attachment (Capps, Sigman & Mundy, 1994). Children with autism (ages 3 to 6 years) who were classified as securely attached displayed more frequent social interaction with their mothers, compared to children who were insecurely attached. On the other hand, IJA has been associated with impairments in the expression of positive affect (Kasari, Sigman, Mundy & Yirmiya, 1990), parent's report of social impairment (Mundy et al., 1994), and long-term social outcomes in autism (Sigman & Ruskin, 1999). Overall then, children with autism who use better joint attention skills seem to be more likely to learn language skills than those who do not (Sigman & Kasari, 1995), and are more likely to have more adaptive longitudinal social outcomes (Sigman & Ruskin, 1999).

Eye-tracking studies shed some light on the joint attention processes of individuals with autism. When viewing a scene from a movie, individuals with autism fail to follow the joint attention gestures of the characters. In contrast to gesture following displayed by typically developing adults, an adult with autism failed to follow the pointing gesture of a character in the film (i.e., a point towards a painting on the wall), using instead the conversation of the characters in the scene (i.e., a question about the painting, asked after the pointing gesture) as a prompt to

then inefficiently locate the object in question (Klin et al., 2002b). Incidentally, when later questioned about the meaning of the pointing gesture, the autistic individual was able to define the meaning of the gesture. Klin and colleagues point out that for individuals with autism, the world is not the social world that is experienced by typically developing (socially engaged) individuals. In other words, there is a relative lack of saliency for social stimuli as sources of information to be attended to (Dawson et al. 1998).

Joint Attention in the Present Study. Joint attention will be operationally defined as the frequency and duration of time infants spend in shared attention, where the infant and adult are focused on the same object or task. This will be assessed during two tasks, first during infants' live interaction with their own mother (during an unstructured interaction) and second, with an unfamiliar female experimenter (in a structured series of play tasks designed to assess joint attention skills).

Language Outcomes

The present study is concerned with mapping infant's performance on tasks of social attention onto their language outcomes and performance on language tasks. Language assessment typically involves presenting standardized tests, parent-completed questionnaires, or lab based language tasks. The present study will use 1) a word association learning task and 2) a parent report measure of language outcome. By 6-months of age, infants associate highly frequent words with familiar objects (Tincoff & Jusczyk, 1999). Drawing on this developing ability, the 'switch task' is designed to study word (associative) learning by presenting infants with sound-image pairings and then testing their ability to learn the word (Werker et al., 1998). Performance on this task has also been associated with language outcomes, up to two and a half years later (Bernhardt, Kemp, & Werker, 2007). Language outcome will also be assessed by

parent-report of receptive and productive language (i.e., parents will complete a questionnaire measure by reporting on words that infants recognize and use).

Present Study

The developmental cascade of social attention observed in typically developing infants likely serves an important function in facilitating language development (see for example Bruner, 1983; Kuhl, 2007; Mundy & Acra, 2006; Tomasello & Farrar, 1986; Vygotsky, 1962). The overarching interest of the present study is to explore individual variability in social attention profiles and to subsequently relate these differences to language outcomes. Individual differences in social attention will be assessed based on performance across a range of tasks that vary in their social aspects. A non-clinical longitudinal sample of infants will be presented with the social attention tasks at Time 1, with language and joint attention tasks at Time 2, and their mothers will provide reports of their developing language and social development (i.e., autistic symptomatology) at Time 3. The specific aims of the present study are the following: (1) systematically examine individual differences in social attention in infants; (2) examine the predicative relationship of individual variability in social attention for language, joint attention and autistic symptomatology; and (3) examine the predictive relationship of joint attention for language and autistic symptomatology.

Specific Hypotheses

Hypothesis 1: Prediction of Language by Social Attention. Social attention at 11-12 months (performance on distractor task, gaze following task and face scanning task) will predict language perception at 14-months (switch task) and parent-report of receptive/productive language at 18-20 months (MacArthur-Bates Communicative Development Inventory).

- a. On the distractor task, latency to disengage attention from a face will account for a significant portion of the variance in language outcome.
- b. On the gaze following task, latency to look at the target object and an accurate first look will account for a significant portion of the variance in language outcome.
- c. On the face scanning task, the proportion of time spent looking at the face compared to other visual fixations will account for a significant portion of the variance in language outcome.

Hypothesis 2: Prediction of Joint Attention by Social Attention. Social attention at 11-12 months (performance on distractor task, gaze following task and face scanning task) will predict joint attention performance at 14 months (Early Social Communication Scales).

- a. On the distractor task, latency to look away from the social target toward the distractor will account for a significant portion of the variance in joint attention.
- b. On the gaze following task, latency to look at the target object and an accurate first look will account for a significant portion of the variance in joint attention.
- c. On the face scanning task, the proportion of time spent in visual fixation towards the face compared to other visual fixations will account for a significant portion of the variance in joint attention.

Hypothesis 3: Prediction of Autistic Symptomatology by Social Attention. Social attention at 11-12 months (performance on distractor task, gaze following task and face scanning task) will predict parent-report of autistic symptomatology at 18-20 months of age (Modified Checklist for Autism in Toddlers, Parents Evaluation of Developmental Status).

- a. On the distractor task, latency to look away from the social target toward the distractor will account for a significant portion of the variance in autistic symptomatology.
- b. On the gaze following task, latency to look at the target object and an accurate first look will account for a significant portion of the variance in autistic symptomatology.
- c. On the face scanning task, the proportion of time spent in visual fixation towards the face compared to other visual fixations will account for a significant portion of the variance in autistic symptomatology.

Hypothesis 4: Prediction of Language and Autistic Symptomatology by Joint Attention. Joint attention at 14 months (on the Early Social Communication Scales) will predict language perception at 14-months (switch task) and parent-report of language at 18-20 months (MacArthur-Bates Communicative Development Inventory); joint attention at 14 months will also predict parent-report of autistic symptomatology at 18-20 months (Modified Checklist for Autism in Toddlers, Parents Evaluation of Developmental Status).

Chapter 2

Method

Participants

Mothers and their infants were invited to participate in the study by letter and a follow-up telephone call (see Appendices A and B) when the infant was between the ages of 11 to 12 months (Time 1), again at 14 months (Time 2), with their mothers completing additional surveys when the infants were between 18-20 months (Time 3). Prenatal and postnatal health of the infants was confirmed with their parents, and infants with acute or chronic pre- or perinatal medical complications were excluded from analyses. A total sample size of 52 infants was planned, based on accepted criterion for the number of predictor variables in the regression analyses (Cohen, Cohen, West & Aiken, 2003). Importantly, because the goal of this study was to examine the relationship between various aspects of infants' social attention and subsequent language learning skills, it was desirable to include a sample with considerable individual variation. To accomplish this, infants were recruited from the Developmental Research database that is maintained in the Department of Psychology, and also by placing flyers at local retail outlets, day care centers, and family physician waiting rooms, across a wide range of counties (Montgomery, Giles, Pulaski, and Roanoke), with racial and ethnic demographics representing availability within each of these geographic regions.

Participant Characteristics

A cohort of 53 (19 males and 34 females), 11-month-old infants and their mothers were recruited for this experiment at Time 1. Of these dyads, 52 returned for the Time 2 tasks (one family was unable to be contacted for the Time 2 visit), and 47 mothers completed and returned

by mail the Time 3 follow-up questionnaires. Demographic information, including prenatal and postnatal health of the infants, family structure (whether single parent homes or married homes), formal education and average combined annual household income of the parents was obtained directly from the parents (demographic data presented below).

The demographics of the longitudinal cohort ($n=53$) were as follows: 85% ($n=45$) of infants were white/Caucasian, 9% ($n=5$) were African American, and 6% ($n=3$) identified as Bi-racial/Other. Average combined family income was as follows: 34% \leq 50,000 ($n=18$), 45% 50-95,000 ($n=24$), 19% $>$ 95,000 ($n=10$), and 2% unreported ($n=1$). Four per cent of mothers ($n=2$) reported having a high school education, 13% ($n=7$) attended some college, 41% ($n=22$) held a college degree, 31% ($n=16$) reported a graduate degree, 8% ($n=4$) completed professional/doctoral degrees, and 2% ($n=2$) were not reported. Eight per cent of fathers ($n=4$) reported a high school education, 10% ($n=6$) attended some college, 30% ($n=16$) reported a college degree, 23% ($n=12$) held a graduate degree, and 23% ($n=12$) completed professional/doctoral degrees, with 6% unreported ($n=3$). Eighty-nine percent ($n=47$) of infants were from married homes and 11% ($n=6$) from unmarried/single homes. Eighty-three percent of infants were full-term ($n=44$), 4% were postmature ($n=2$) and 13% premature ($n=7$). The home language was English for 92% ($n=49$) of infants, Hebrew for 2% ($n=1$), and Spanish/English for 6% ($n=3$) of infants. One family reported a sibling diagnosed with a developmental disability.

Procedures

Infants and their mothers participated in two laboratory sessions, conducted at the Infant Perception Laboratory in the Department of Psychology at Virginia Tech. Upon arrival at both Time 1 and 2, parents were given informed consents and an anonymous family demographic sheet (Time 1 only; see Appendices C through E). The study timeline is presented in Table 1.

Questionnaires and Tasks: Time 1

At the first visit (Time 1), parents completed the following surveys: the Ages and Stages Questionnaire (ASQ; Bricker & Squires, 1999), the Ages and Stages Questionnaire: Socio-emotional (ASQ:SE; Squires, Bricker, & Twombly, 2002).

The Ages and Stages Questionnaire (ASQ; Bricker & Squires, 1999) is a parent-completed measure used to screen for developmental concerns among children 4 months to five years of age, across five developmental domains (communication, gross motor, fine motor, problem-solving, and personal/social development). Further evaluation for areas of concern is indicated if the child falls two standard deviations or more below the mean in these domains. The ASQ contains approximately 30 items describing specific behaviors that are either observed or easily elicited by parents in the home. The ASQ has been widely used for screening purposes, with an overall specificity of 86%, and an average sensitivity of 72% (Squires, Bricker & Potter, 1997). The ASQ has a test-retest reliability of 94% and interrater reliability of 90%.

The ASQ: Socioemotional questionnaire (ASQ:SE; Squires, Bricker, & Twombly, 2002) is also a parent-completed screening measure (companion to the ASQ) used to identify social-emotional difficulties in children between 3 months and 63 months of age. The ASQ:SE is divided into socio-emotional competence and problem behaviors (e.g., “does your baby let you know when she is hungry, hurt, or wet” and “does your child have eating problems”). The ASQ:SE has a specificity ranging from 82% to 96%, with an overall specificity of 92%; sensitivity ranges from 75% to 89%. Internal consistency for the ASQ:SE is generally high, with an overall alpha of 0.82, and test-retest reliability between parents is 94% (Squires, Bricker, Heo & Twombly, 2001).

In addition to these questionnaires, infants participated in a variety of tasks at both Times

1 and 2, each of which was designed to measure some specific aspect of infants' social attention and/or sensitivity to social cues. These various tasks are described below according to their time of administration, with each task description followed by procedural details related to that specific protocol.

Time 1: Distracter Task. The distracter task is designed to measure individual infants' ability to engage attention to a central visual event as well as their likelihood of disengaging attention in the presence of a peripherally located visual distracter. Each infant was presented with a central visual event consisting of a moving adult female speaker who was either (1) silent or (2) accompanied by her natural voice track. The distracter (a flashing black and white checkerboard in silence) was presented 26° to the right of the infant, in the upper right-hand sector of the viewing area. Each infant received four blocks of two trials, such that each target–distracter pairing was presented four times, for a total of 8 trials for each infant (counterbalanced across trials for order).

Procedure for Distracter Task: Infants were seated on their mother's lap, facing a 32" color LCD monitor, surrounded by black material (making the screen prominent in the infant's visual field). Two small loud speakers were located directly adjacent to the right and left of the screen, with a remotely controlled dome camera (Panasonic WV-CS574) positioned directly above. The infant and mother were seated in line with the remote camera so that head/eye position of the infant was clearly distinguishable to the observer. The observer watched and recorded the infant on a colored television monitor, in an adjacent, sound-attenuated control room (this observer is blind/deaf to the events presented to the infant). When the infant was calm and alert, he or she was brought into the testing room by the mother, who remained with the infant during the entire session. Once the infant was judged to be looking at a pretrial attention

getter, the target event began. After the target event has been played for 5 consecutive seconds, the distracter appeared in the periphery, and the latency of the infant's first fixation to the distracter (or 20 sec, whichever occurred first) was recorded. After the end of a trial, the attention-getter reappeared on the screen until the infant fixated, and then the next trial ensued. Of primary interest were individual differences in latencies to look at the distracter (with silence/with voice).

The dependent variable on this task was latency to look away from the target (i.e., face with silence/face with voice) to the distracter. Latency was measured from the onset of the presentation of the distracter until the infant fixated on the distracter.

Time 1: Gaze Following Task. The gaze following task was designed to assess individual infants' likelihood of looking at an object when an adult female is also looking at that object compared to when she is looking away from the object, and when her visual image is silent compared to when it is accompanied by her voice. On each trial, infants were first presented with a static video image of an adult female looking directly ahead (i.e., at the infant), followed by a frame in which she either directs her gaze toward an object to her right, or toward empty space to her left. Both types of trials (looking at object/looking away from object) occurred with silence and also with speech (a female voice saying "Look at that!"), counterbalanced within block, for four blocks of trials (8 trials total).

Procedure for Gaze Following Task: The same general procedure as that described above was employed for this task. As in the Distracter Task, trials began when the infant was attending to a pre-trial attention-getter. An image of an adult smiling female face was then presented, with her gaze directed at the infant. Once the infant looked at the female face, her image changed such that her gaze shifted either toward or away from an object (that appeared on either her left or

right). The latency of the infant's first fixation toward the target was recorded (or 20 sec, whichever occurred first). Of primary interest was the latency and direction of the infant's first look after the gaze shift by the adult female as a function of the kind (gaze toward/gaze away) and composition (with silence/with voice) of the event.

The dependent variable on this task was direction and latency of the first look towards the object as a function of the kind of social information (gaze congruent/gaze incongruent and with silence/with voice). Latency was measured from the onset of the presentation of the image with the object visible until the infant looks away from the face. Direction of first look was measured by judging the infant's object location as either 'correct' (in the direction of the female's gaze shift) or 'incorrect.'

Time 1: Face Scanning Task. The face scanning task was designed to assess individual infants' patterns of visual fixation to video presentations of either a familiar face (the infant's own mother) compared to an unfamiliar face (some other infant's mother), when both are silent, and when both are accompanied by their natural voice tracks. Infants' mothers were recorded after their arrival at the laboratory, looking into a camera as they imagined interacting with their infant. Mothers were instructed to say the phrases "Hello sweetie! Are you having a good time? What a beautiful day! I love you so much!" looking into the camera as if they were talking to their infant. The recordings were approximately 15 sec in length. Using an eye-tracking system, digital movies of mother and stranger were presented silently and with their natural voice tracks (4 combinations in one block), for two blocks (8 trials in total).

Procedure for Face Scanning Task: Infants were seated on their mother's lap as in the previous two tasks, but now facing a 17" color TOBII T60 eye-tracking system, surrounded by black material (making the screen prominent in the infant's visual field). The T60 system has the

infrared light source and dual cameras mounted below the monitor, which is composed of thin film transistor technology (TFT). The TFT monitor has a resolution of 1280x1024 pixels, and also has built-in audio speakers and a front mounted digital camera for presenting sound and filming the session. The T60 measures the gaze direction of each eye separately and from these measurements makes an evaluation of where the infant is looking on the TFT screen. The cameras are capable of handling fairly large head movements, and as a result, no equipment is necessary on the infant. The eye tracker (mounted on an adjustable arm) was positioned so that the TFT screen was fronto-parallel to the infant's face at a viewing distance of approximately 60 cm.

Before the task, the eye tracker was calibrated individually for each participant, using five separate calibration points (see von Hofsten et al., 2005). Calibration was considered successful if measures from four or more calibration points were obtained; otherwise, the procedure was repeated. Light levels were kept constant during the calibration procedure to reduce recording errors resulting from differences in pupil size. Once calibrated, the infant was presented with a series of dynamic faces (stranger or mother), either in silence or accompanied by the woman's natural voice track. Each dynamic face was presented for as long as it took the speaker to say all four sentences. A brief (500 ms) blank screen separated each trial. Infants were presented with each trial combination twice, for a total of 8 trials. Of primary interest was the total number of fixations and total amount of gaze time infants' spend fixating in a pre-determined face area of interest, as a function of type (mother/stranger) and composition (with silence/with voice) of the events.

The dependent variables on this task was the duration of visual fixation towards the face in videos of the infants' own mother and an unfamiliar speaker (another infant's mother).

Questionnaires and Tasks: Time 2

Time 2: Switch task. The Switch task was designed to assess infants' ability to associate words with objects between 8 and 20 months of age (Werker et al., 1998). Each infant was habituated to repeated pairings between moving Object A + Word A and moving Object B + Word B. After habituation, the infant was presented with one "same" trial, consisting of a familiar object-word pairing (e.g., Object A + Word A), followed by a "switch" trial, which had a novel object-word pairing (e.g., Object A + Word B). If the infant learned to associate specific objects with their accompanying labels, attention on "switch" trials would be higher compared to attention on "same" trials.

Procedure for Switch Task. The same general procedure as that used in the Distracter and Gaze Following tasks (described above) was also employed here. As soon as the infant fixated to the attention-getter, one moving object+word event was presented for as long as the infant fixated to the screen. When the infant looked away for at least 1 sec, the event terminated, and the attention-getter came on again. The two object+word events alternated across habituation trials until the mean looking time on two consecutive trials fell below 50% of the mean from the first two trials of the session. Each soundtrack that accompanied a given moving object consisted of seven exemplars of one of two nonsense consonant-vowel-consonant (CVC) words: *neem*, and *boog*. These nonsense words were chosen because they are from different vowel categories, and have different consonant dimensions of nasality, voicing, and place dimensions. The words were recorded by a female speaker, instructed to imagine that she was talking to an infant (to ensure infant-directed speech and prosodic contours). Visual stimuli were two attractive moving objects that the infant had never seen before. Immediately following the habituation phase, the two test trials began. During test trials, infants were presented with a "same" pairing (same word-object

pairing used in habituation, e.g., Object A/*neem*) and a “switch” pairing (familiar word and object in a new combination, e.g., Object B/*neem*). The order of test trials was counterbalanced across participants.

The dependent variable on this task was duration of looking time during “switch” versus “same” trials (longer duration of looking during “switch” compared to “same” trials indicates the infant has learned the word-object association). Looking time was measured from the onset of the test trial until the infant’s first visual fixation away from the image. Differences as a function of trial type were analyzed initially (habituation trials, same test trials, switch test trials). Next, novelty scores (switch ratios) were calculated for individual infants (looking time for switch trials / switch trials + same trials).

Time 2: Early Social Communication Scales (ESCS): This structured joint attention task was designed to assess the frequency and duration of infants’ non-verbal social communication behaviors (Mundy et al., 2003). The ESCS is widely used as a structured method of coding individual differences in early nonverbal social communicative development (e.g., Mundy et al., 1998, 1995; Ulvund & Smith, 1996).

Procedure for ESCS: The infant was seated on mother’s lap, at a small table, facing the tester. A video camera was positioned to record a three-quarter to full-face view of the child, while also capturing a profile view of the tester. A set of toys was visible, but out of reach of the infant (toys and other materials, and the task procedure follow Mundy et al. 2003). The infant was presented with three small wind-up mechanical toys (three trials each); three hand-operated toys (three trials each), turn-taking games (two trials), turn-taking toys (hat, toy comb and glasses; three trials), opportunities for a tickle game (two trials) and opportunities to look at a book with the tester (one trial). The tester also presented the infant with two sets of four gaze

following trials. The tester calls the infant's name, to gain attention, and then turns and visually fixates on a poster in the room. While looking at the poster, the tester also points and says the infant's name. A constant order of left, left-behind, right and right-behind was presented (two trials each). Of primary interest were behavioral frequencies along two dimensions, based upon whether they are initiated by the child, or were the child's response to a social partner: (1) initiating joint attention, the frequency of the infant's pointing and alternating gaze and (2) responding to joint attention, the infant's attention to bids of a social partner, by following the direction of eye gaze, head turn, or pointing gestures.

The dependent variables on this task were frequency counts of infant behaviors (eye contact, alternating eye contact, pointing, showing, following the pointing gesture of the experimenter, following the gaze direction of the experimenter) calculated separately for the purpose of either initiating joint attention (IJA) and responding to joint attention (RJA),

Questionnaires: Time 3

The Time 3 Follow-up was completed with caregivers only, using parent-report questionnaire measures for language evaluation (MCDI), and social engagement/autism screening (MCHAT and PEDS), all completed at home, and then returned by mail (see Appendix F).

Time 3: Language Assessment. Measures of language productivity were obtained from parent report using the MacArthur-Bates Communicative Development Inventory, short form version (MCDI; Fenson et al., 2000). The MCDI is designed to provide a measure of productive vocabulary. From a series of word lists ("Words Children Use"), including nouns, action lists, and animal sounds, parents choose the words that their child uses. This instrument has been typically used in clinical and research settings to quickly assess language production and has

demonstrated high internal consistency and test-retest reliability; the MCDI has also been suggested to assess a more complete range of vocabulary production than either laboratory observation or structured laboratory measures (Fenson et al., 1994).

Time 3: Social Engagement/Autism Screening. Parent-report screening measures were used to screen for the presence of autistic symptomatology in infants. The Modified Checklist for Autism in Toddlers (MCHAT; Robins, Fein, Barton, & Greene, 2001) is designed to screen for Autism Spectrum Disorders in toddlers between 8 and 30 months of age. The MCHAT has adequate sensitivity and specificity (.95 and .98 respectively) (Robins et al., 2001). The MCHAT contains 6 critical items (querying protodeclarative pointing, response to name, interest in peers, bringing things to show parents, following a point, and imitation) and a total of 23 items. Failure on any 3 of the 23 total items, or any 2 of the 6 critical items indicates a risk for an ASD.

The Parents Evaluation of Developmental Status (PEDS; Glascoe, 1998) is a broad developmental screening instrument for children from birth to 8 years of age. The parent-completed screener contains 8 open-ended items, to which parents indicate areas of concern. The PEDS shows sensitivity ranging from 74% to 79%, and specificity ranging from 70% to 80% (Glascoe, 2000).

On the MCHAT, autistic symptomatology was quantified by the number of failed items endorsed (clinical level symptom screening is indicated when two or more critical items are failed, or when any three items are failed). On the PEDS, developmental problems were quantified as the number of symptom areas on which parents report concerns (two or more predictive concerns indicates a higher risk for developmental problems; one area of predictive concern indicates a moderate risk of serious difficulty).

Chapter 3

Results

The primary interest in this longitudinal study was in whether infants' performance on social attention tasks would significantly account for variation in their emerging linguistic skills. For this study it was expected that as individuals, infants would perform consistently across tasks, but that as a group, there would be a considerable amount of variation within each task. In order to examine these expectations, descriptive summaries of each performance measure are provided by way of examining whether sufficient variance emerged for ultimate inclusion in the regression analyses (i.e., regressing measures of social attention onto measures of linguistic competence).

Social Attention and Language Outcome Measures (see Table 2 and 3 for descriptive summaries)

Social Attention Measures (Table 2)

Distracter Task. In this task, it was conceptualized that infants who were slower to disengage from the female speaker were higher in social attention, but also that social attention would be modulated by whether the speaker's voice was present or absent. A total of 51 infants (33 females, 18 males) completed the distracter task (data from two infants were not collected due to technical problems). Two measures of interest were considered: (1) latency was timed (in seconds) starting at the onset of the trial until the infant's first fixation towards the distracter or away from the face (maximum latency was the trial length); and (2) duration of total looking time to the face during the 10-second trial was coded offline (including return looks to the face after the look away). Interobserver reliability for latencies and duration of looking time across individual trials was 0.96 (determined by calculating Pearson's correlation coefficient for the

latency and duration of all individual trials, as recorded by coders for approximately 10% of the participants). In preliminary analyses, no order or gender effects were found on these measures and sufficient group-level variance warranted the inclusion of these measures in subsequent analyses (see Appendix G). However, it was clear from the coding of the infants' sessions (offline) that after the first two trials, many began to orient to the location of the distracter prior to its appearance, given that the distracter always appeared in the same quadrant of the screen. Thus, means were calculated for the first two (of the four) latency and duration trials in order to increase the internal validity of this measure.

Gaze Following Task. Gaze following data were obtained for 50 infants (data were not obtained from 3 infants due to technical problems). Two measures of interest were considered: (1) latency (in seconds), starting at the onset of the trial until the infant's first gaze shift after the adult female's gaze shift; and (2) gaze accuracy was coded as correct if the infant's direction of first gaze was in the same direction as the adult female's gaze shift. Trials in which the infant was not fixating on the target stimulus when the gaze shift occurred were excluded from the analysis. Interobserver reliability across individual trials was 0.89 (determined by calculating Pearson's correlation coefficient for the latency and accuracy of all individual trials as recorded by coders for approximately 10% of the participants). Unlike the distracter task, group level variance on the gaze following task was minimal. There was virtually no variance in latency to first look (see Table 2), and in terms of accuracy, infants looked at the object when it appeared on the screen, independently of where the female actor was looking (47 out of 50 infants received accuracy scores of 100% on congruent trials; 44 out of 50 infants received accuracy scores of 0% on incongruent trials). Given the low level of performance variance on this task, although there were no gender or order effects these are not reported and these measures were not included in subsequent analyses (a critique of this task will be provided in the Discussion).

Face Scanning Task. Face scanning data were obtained for 24 infants, with the reduction in sample size primarily due to technical difficulties with the eye tracker ($n=27$), but also due to infant fussiness ($n=2$). The measure of interest was look duration to the face of the speaker. To determine whether infants showed differences in this measure as a function of speaker familiarity (mother, other) and speech condition (voice, silent), a trained coder defined the face region as the area of interest (AOI) for each speaker in Tobii Studio software (v 2.0). No significant differences as a function of gender or order were obtained (see Appendix H). Moreover, preliminary analysis of the speaker condition (mother vs. other; see Appendix H) showed that infants' scanning patterns did not differ on this dimension. Thus, for regression analyses, scanning patterns for silent and voice trials were collapsed across the speaker manipulation. Given the statistical limitations created by the restricted sample size for this measure ($n=27$), all regression analyses for the face scanning task were performed separately (as described below).

Joint Attention Task. A total of 51 infants completed the joint attention (ESCS) task at their second visit (32 females; 19 males); data from 1 infant was unusable due to technical error. Infants' joint attention behaviors were coded by trained observers along two dimensions, following the ESCS coding procedures (Mundy, 2003): (1) initiating joint attention (IJA; the frequency of the infant's pointing and alternating gaze); and (2) responding to joint attention (RJA; the frequency of the infant's attention to bids of a social partner, by following the direction of eye gaze, head turn, or pointing). Interobserver reliability for IJA and RJA was 0.98 (determined by calculating Pearson's correlation coefficient for all behaviors as recorded by coders for approximately 10% of the participants); *t*-tests revealed no significant differences between the means of ESCS scores generated by the testers for joint attention behaviors. Also, there were no differences in either initiating or responding joint attention behaviors as a function

of gender (see Appendix I). Given that there was substantial variance in these measures, they were included in subsequent analyses.

Language Outcome Measures (Table 3)

Switch Task. A total of 44 infants (of the 52 who returned) successfully completed the switch task at their second visit (26 females; 17 males). Data from 8 infants were not available for analyses (2 were excluded for fussiness/looking times were too short to code, and 6 for experimenter error and technical problems). Infants' duration of looking time during "switch" and "same" trials was coded online by trained observers from the onset of the test trial until the infant's first visual fixation away from the image. Novelty scores were then calculated for individual infants (looking time for switch trials / switch trials + same trials). There were no differences in looking times to same and switch trials as a function of gender or order (see Appendix J).

MacArthur-Bates Communicative Development Inventory (MCDI). Parent-report questionnaires measures were completed after the second visit, when infants were between 18 and 21 months of age ($M=18.5$ months, $SD=.76$), reporting on language skills for a total of 47 infants (29 females; 18 males). Infants' productive vocabulary size as reported on the MCDI was on average 31.8 words ($SD=17.74$). Infants' mean and modal grammatical complexity level (not yet/sometimes/often combining words) was "sometimes combining words." There were no significant differences in language as a function of gender (see Appendix K). A total of 7 infants were below the 10th percentile of the sample (productive vocabulary sizes of 11 words or less in this sample), while 5 infants were above the 90th percentile (vocabulary sizes of 59 words or more in this sample). In comparison to normative data, at the 10th percentile infants have between 4 and 12 words (for boys and girls, respectively) and at the 90th percentile infants have

between 46 and 59 words in their productive vocabularies (boys and girls, respectively) (Fenson et al., 2000).

Developmental Screening Measures (see Table 4 for descriptive summaries)

Ages and Stages Questionnaire (ASQ). Caregivers completed the ASQ for 46 infants, across five developmental domains (communication, gross motor, fine motor, problem-solving, and personal/social development). In total, 12 infants scored in the clinical ranges on these subscales: 5 were clinical on one subscale, 5 were clinical on two subscales, and 2 were clinical on three subscales.

Ages and Stages Questionnaire: Socio-emotional (ASQ:SE). Questionnaires were completed by caregivers for 46 infants. Three infants were reported in the clinical range (none of these are the same infants as those listed above for the ASQ).

Modified Checklist for Autism in Toddlers (MCHAT). On the MCHAT (completed for 46 infants, by their mothers), autistic symptomatology was quantified by the number of failed items endorsed (clinical level symptom screening is indicated when two or more critical items are failed, or when any three or more items are failed). Caregivers on average reported that infants failed 0.26 items overall ($\underline{SD} = 0.49$), and 0.11 critical items ($\underline{SD} = 0.38$). Of the 46 infants with completed MCHAT data, 72% ($n=33$) did not fail any items. Of the 13 infants who failed items, 8 infants failed only 1 item, 4 infants failed 2 items, and 1 infant failed 2 critical items (indicating a positive screening). There were no differences as a function of gender [$F(2, 43)=.46, p=.63$], with the number of failed items for females ($\underline{M}=.21, \underline{SD}=.49$) not differing from males ($\underline{M}=.35, \underline{SD}=.49$), and the number of critical items failed not differing for females ($\underline{M}=.10, \underline{SD}=.41$) and males ($\underline{M}=.12, \underline{SD}=.33$). However, it should be noted that the sample was disproportionately female (29 females; 17 males).

Parents Evaluation of Developmental Status (PEDS). On the PEDS, developmental problems were quantified by the number of symptom areas in which parents report concerns (two or more predictive concerns indicate higher risk for developmental problems; one area of predictive concern indicates moderate risk of serious difficulty). Of the 46 infants with completed PEDS data, 35% (n=16) of caregivers reported concerns in one or more areas, although most of these concerns related to behavioral concerns (i.e., shyness, problem behaviors). However, predictive concerns (i.e., those that may indicate a risk for developmental problems) were only reported for 2 infants in the sample, with caregivers reporting concerns about language development for both infants. Both of these infants also had 1 failed (non-critical) item on the MCHAT. Because of the low number of reported developmental concerns on the PEDS, this measure was not included in any subsequent analyses.

Data Screening for Regression Analyses

In order to assess the degree of correlation between the various measures of social attention at Times 1 and 2 of the study, the following task measures were entered into a correlation matrix: distracter task (voice latency, silent latency, voice duration, silent duration), face scanning task (voice duration, silent duration), and joint attention (initiating joint attention, responding to joint attention; see Table 5). Coefficients $>.70$ resulted in the elimination of one of the two associated measures in order to minimize redundancy in the regressions. Given that the correlation between silent latency and silent duration on the distracter task was $.77$, only silent latency was maintained for further analyses. The intercorrelations and tests for multicollinearity on all other measures rendered them suitable for further analyses (i.e., distracter task (voice latency, silent latency, voice duration), face scanning task (voice duration, silent duration), and joint attention (initiating joint attention, responding to joint attention)).

Next, all data were screened for normality and linearity, as well as for potential outliers. Continuous variables were centered before being entered into the regression model (i.e., the sample mean was subtracted from each individual score, creating a new sample mean of zero; this does not change the significance of potential interactions or the values of the simple slopes¹). The number of predictors in each regression was within the 1:10 variable-to-participants ratio recommended for regression analyses (Cohen, Cohen, West & Aiken, 2003). This was accomplished by considering the face scanning task predictors separately from the other social attention tasks. That is, face scanning task analyses will be presented in a separate exploratory section given their restricted sample size. Thus, the distracter task and joint attention task were considered the primary social attention measures.

The general regression strategy was two-part: First, each social attention task was examined separately in a regression analysis to explore the predictive ability of the measure for the outcome. At this initial level of analysis, predictors with a significant coefficient at the 0.10 level were retained for an overall model. This less stringent significance level was chosen given the exploratory nature of the study (the strength of the relationships between predictors and outcome are generally not known) and the relatively small sample size for the number of predictors. Although this liberal significance level (together with a small sample size) increases the likelihood of type 1 error, subsequent analyses employed more rigorous criteria. Second, the overall model was tested including all predictors that were retained, with a more stringent significance level of .05.

¹ Note that by centering variables the regression coefficients can be interpreted in terms of standard deviations. In other words, for every one standard deviation increase in the predictor, the outcome is expected to have an associated standard deviation increase/decrease equal to the predictor's regression coefficient.

Regression Analyses

Again, the primary interest in this study was to examine whether indicators of infants' social attention would significantly predict emerging language competence.

Hypothesis 1: Prediction of Switch Outcome by Social Attention. The first regression analysis examined the relationship between social attention predictors (distracter and joint attention tasks) and performance on the switch task (a measure of word/object association learning; Table 6). Standard multiple regressions were performed for each social attention task separately in order to examine the predictive ability of each measure for capturing variance in word/object association. Performance on the distracter task did not significantly predict switch task performance. In contrast, the joint attention task significantly predicted switch outcome ($p=.04$) and accounted for 12% of variance, with responding to joint attention (RJA) emerging as the significant predictor. Therefore, the overall model of social attention tested only RJA (all other coefficients $p>.10$). This model (switch ratio = RJA) significantly accounted for 13% of the variance in switch performance. More frequent response to the tester's bids for joint attention was associated with better word/object association ($\beta=.38$). These results support the hypothesis that better social attention at 11-months is associated with better language outcome at 14-months. Specifically, the percent of time infants responded to the tester's joint attention bids (RJA) accounted for 13% of the variability in word/object association learning.

Hypothesis 2: Prediction of Vocabulary by Social Attention. The second analysis examined the relationship between social attention predictors (distracter and joint attention tasks) and language outcome as measured by productive vocabulary size on the MCDI at 18-months of age (Table 7). Standard multiple regressions were performed for each social attention task separately in order to examine the predictive ability of each measure for capturing variance in

vocabulary size. The distracter task significantly predicted language outcome on the MCDI ($p=.003$), accounting for 24% of the variance in vocabulary size. Of the distracter task measures, latencies to look away from the face during both silent trials and voiced trials displayed significant coefficients and were retained for the overall model. The joint attention task overall also significantly predicted vocabulary ($p=.04$), accounting for 12% of the variance in vocabulary. Percent of responding to the tester's joint attention bids (RJA) displayed a significant coefficient ($p=.02$) and was retained for the overall model.

The overall model of social attention (vocabulary = distracter silent latency + distracter voice latency + RJA) was significant ($p=.001$), accounting for 38% of the variance in vocabulary size. Only distracter voice latency and RJA were significant predictors. More specifically, longer latency to look away initially during voice trials on the distracter task ($\beta=.44$) and more frequent response to joint attention bids ($\beta=.30$) were associated with larger vocabulary size. These results support the hypothesis that better social attention at 11-months predicts better productive vocabulary at 18-months of age.

Hypothesis 3: Prediction of Autistic Symptomatology by Social Attention. The third regression analysis examined the relationship between social attention predictors (distracter and joint attention tasks) and autistic symptomatology as measured by parent-report on the MCHAT at 18 months of age (Table 8). Two groups were defined for analyses by logistic regression, based on either the presence or absence of failed items: no-fails group, fails group (at least 1 critical or non-critical failed item).

The initial logistic regressions were performed for each social attention task separately in order to examine the ability of each measure to predict MCHAT outcome (failed items, no failed items). The distracter and joint attention tasks did not significantly predict MCHAT status.

Therefore, these results fail to provide support for the hypothesis that better social attention at 11-months predicts autistic symptomatology at 18-months of age.

Exploratory Face Scanning Analyses

Additional regression analyses were conducted to examine the predictive ability of face scanning measures of social attention (voice duration and silent duration; see Table 9). The regression strategy was identical to that presented above for the same outcome measures. In terms of language outcomes, these face scanning measures did not significantly predict switch performance. However, the silent duration was related to MCDI at the $p < .10$ level of significance, so retained for the next regression step. However, silent duration ($\beta = -.39$) did not account for a significant amount of variance in vocabulary size when entered alone in the regression ($p = .07$; a post-hoc power analysis indicated a sample size of 108 infants would be necessary for this to be a significant effect). A nonsignificant outcome was obtained when evaluating the ability of face scanning measures to predict MCHAT. Overall, these results do not provide evidence for the predictive utility of the face scanning task for language and autistic symptomatology outcomes.

Clinical Profiles (see Tables 10-12)

As a subsidiary and preliminary interest, the task performances of infants who were classified as clinical risks were considered separately. First, the descriptive relation between ASQ (including both ASQ and ASQ:SE) scores and MCHAT scores reveal no consistent pattern (see Table 10). With regard to maternal ratings on the ASQ, 15 infants were above the clinical cutoff on at least one domain (Table 11). If sorted by MCDI, it appears that as vocabulary size decreases, RJA, switch ratio scores, and distracter latency scores also tended to decrease (with respect to group standard deviations). Likewise, for the 13 infants who failed at least 1 item on

the MCHAT (see Table 12), it appears that as vocabulary size decreases, RJA, switch ratio scores, and distracter latency scores also tended to decrease (with respect to group standard deviations). Thus, the low correspondance between scores on the ASQ and MCHAT screeners is most likely due to the presence of different types of risk factors that were not consistent across individual infants.

Chapter 4

Discussion

The primary aim of this study was to examine individual differences in emerging social engagement skills to later language outcomes in a non-clinical, longitudinal sample of infants. Social engagement was broadly characterized as the ability to attend to social information (i.e., social attention) and engage in productive interactions with others (i.e., joint attention, communication). Although previous research has associated joint attention with language development in clinical and at-risk populations (Mundy et al., 1995; Mundy & Willoughby, 1996; Sheinkopf et al., 2004), the relationship between early social attention and emerging language in typically developing infants has not been described, even though infants are actively processing information relevant for language learning long before they are participating in triadic joint attention episodes (Morales, et al., 2000a; Senju, Csibra, & Johnson, 2008). It was predicted that variability in typically developing infants' social attention (distracter latency, distracter duration, face scanning duration, and response to joint attention (RJA)) would be significantly related to emerging language skills (switch ratio, vocabulary size). Additionally, the relationship between measures of clinical risk and social attention was also explored. Overall, the results indicated that measures of social attention predicted later language outcomes. Data supporting this prediction for object/word association learning and vocabulary size will be discussed first, followed by a discussion of the relationship between developmental screeners for clinical risk and social attention. Next, a critique of the social attention tasks themselves will be presented, as well as some limitations of the current study and suggestions for future work in this area.

Relationship between Social Attention and Language Outcomes

The two primary measures of language outcome were the object/word association (switch) task and vocabulary size (MCDI). Regarding the former, only RJA accounted for a significant amount of variance in object/word learning. In particular, how often infants responded to the joint attention bids of the tester accounted for 13% of the variance in the ratio of infants' attention to novel:familiar trials in the switch task. In general, ratios above .50 indicate the infant successfully learned object/word pairings (ObjectA/WordA and ObjectB/WordB), and detects violations of these pairings by paying more attention on novel trials (ObjectA/WordB). With regard to vocabulary size, two factors emerged as significant predictors, average distracter voice latency and RJA (accounting for a total of 38% of the variance). In particular, longer latencies (i.e., less distractibility) on the distracter task when the woman was speaking were associated with higher MCDI scores. Likewise, higher levels of responding to the attention bids of an adult female tester (e.g., looking in the direction of her pointing) were associated with higher MCDI scores.

Taken together, both the word/object association and vocabulary findings reflect two important aspects of the relationship between social engagement and language learning. First, the relationship between RJA and language outcomes (both switch performance and vocabulary size) may arise developmentally because being socially engaged with adult interactors affords important opportunities for infants to process adult referential activity (e.g., looking at and naming new objects). As mentioned earlier, there appears to be a well-documented relationship between joint attention and language outcomes (e.g., productive/expressive vocabulary; Morales et al., 2000a), with the current study replicating this effect. Moreover, at least one other study (with 17- to 20-month-olds) found that infants who showed more attention to the switch also

showed higher performance on language measures at later ages (Bernhardt, Kemp, & Werker, 2007).

Second, in addition to joint attention, the ability of infants to maintain focused attention on speakers in spite of potentially distracting events around them further supports language growth in terms of vocabulary size. Interestingly, the ability to maintain focused attention to a dynamic female even in the presence of a peripheral distractor was not observed for silent trials, suggesting that vocal dynamics are a necessary component in promoting attention during interaction, but there is substantial variability in this process across infants. Across a wide range of ages, infants and young children are consistently found to be more likely to attend to dynamic auditory streams when presented with visual+auditory compounds (Robinson & Sloutsky, 2007; Sloutsky & Robinson, 2008). This is consistent with psychophysiological evidence that as infants age, focused attention is enhanced by dynamic visual+auditory sources (Courage, Reynolds, & Richards, 2006), with dynamic *facial+vocal* events being the most effective at modulating attention (McIlreavy et al., 2006; Panneton & Richards, 2004). Recently, work in our lab found that a facial+vocal display enhanced infants' ability to discriminate a change in a speech sound in the presence of distracting background noise (Versele, Panneton, & Polka, 2008), but only when the voice was highly exaggerated (i.e., infant-directed). Therefore, infants showing higher levels of social attention (RJA and voice latency) also had larger productive vocabularies because they are more likely to have their attention regulated by those components of natural interactions most relevant to language learning.

One interpretation is that RJA is predictive of switch performance because both tasks are measuring a more general aspect of associative learning. That is, in the joint attention protocol, infants were scored on their ability to attend to locations (e.g., posters on the wall) and objects

(e.g., pictures in a book) as guided by the actions of an adult female. In essence, this protocol is tapping infants' association of social gestures with ways in which their attention should be shifted. So, part of joint attention requires associative learning in that gestures become meaningful cues to interesting events. Although switch performance (i.e., increased attention to novel object/word pairings) does not require joint attention, infants who are higher in RJA can be considered more practiced in associative learning.

A second interpretation of the relationship between RJA and switch performance is that although switch performance does not require social attention (i.e., there is no demand for focused attention on face+voice events), infants who are high in RJA have experienced more episodes of specific associative learning involving objects and labels (in natural caretaking situations). This is supported by evidence that infants are sensitive to the referential intent of a speaker who is labeling objects. Baldwin (1996) demonstrated that infants (15-20 months-old) were more likely to make word-object associations when they observed the speaker looking at the object (as opposed to only hearing a speaker label the object). One limitation of the current study is that the joint attention protocol was structured, and did not involve the infants' own mothers. If both structured and naturalistic (i.e., with caregiver) joint attention phases had been included, it is predicted that infants who displayed high RJA in *both* would perform best on the switch task. From this view, it is likely that there are multiple pathways along which good associative learning may emerge. However, the kind of associative learning most relevant for *language* development may be critically dependent on social engagement skills.

If this proposition is correct (that social engagement is a necessary concomitant of associative learning that is related to language), then it seems to follow that performance on the switch task would account for significant variance in vocabulary size at a later age. Interestingly,

this was not the case in the current study, in that switch performance did not predict MCDI vocabulary [$F(1,37)=.00, p=.99$]. Given that productive vocabulary can be considered social in the sense that infants learn words predominantly via interactions with others, a significant relationship between switch performance and vocabulary size may be mediated through social engagement (e.g., joint attention). That is, some infants who perform well on the switch task also engage in more joint attention and have higher productive vocabularies. However, other infants who do well on the switch task evidence lower joint attention and lower productive vocabularies, with the important link between associative word/object learning and vocabulary size being social engagement.

In light of this possibility, it is reasonable to reconsider the usefulness of the switch task as a measure of language outcome. Given that there was a relationship between infants' attention to face+voice and vocabulary size, but no relationship between attention to dynamic face+voice and switch performance, it may be that good object/word association learning is not enough to predict language outcome. That is, word/object association alone will not allow strong language skills because although the ability to learn words that are associated with objects/events is critical, the skill of attending to other social agents is equally critical.

Another goal of the present study was to consider profiles of social attention as they relate to subsequent language-related skills and autistic symptomatology/social engagement. The results showed that social attention measures did not account for a significant amount of variance in whether or not infants had failed MCHAT items. This is likely a function of both the restricted variability on the MCHAT and the nature of the behaviors assessed on the MCHAT. In part, this was expected given that the sample of infants was not clinically referred and it was not expected that we would identify a large number (or any) infants who would screen positive for the

potential presence of autism spectrum disorder (ASD) on the MCHAT. A total of 13 (of 46) infants failed at least one item (which is not necessarily clinically meaningful), with only one of these infants screening positive (two critical items were failed). The infant who screened positive on the MCHAT displayed an overall profile which fell above the group means (with the exception of switch ratio performance which was -1 standard deviation below the group mean). It should be noted that the current version of the MCHAT is designed to maximize sensitivity (to identify as many children with ASD as possible), which will result in false positive cases. Therefore, not all children who fail the checklist will meet criteria for an ASD diagnosis. For 18-24 month-olds however, there is currently a lack of standardized parent-report measures designed to assess autistic symptomatology. The Social Responsiveness Scale (Constantino, 2002) is a measure of social behaviors characteristic of the autistic spectrum across the entire range of severity that occurs among the general population beginning at 4 years of age, however there are no similar standardized measures designed to assess social engagement behavior within the typical range of development in infancy or toddlerhood.

In contrast to the results on MCHAT profiles, infants who scored in the clinical range on the ASQ and ASQ:SE appeared to also perform lower on multiple measures of social attention and language outcome. As described above, the MCHAT is a screener for ASD (querying behaviors such as protodeclarative pointing, response to name, interest in peers, bringing things to show parents, following a point, and imitation). In contrast, the ASQ is a broad screener for general developmental concerns (in the areas of communication, gross motor, fine motor, problem-solving, and personal/social development) and the ASQ:SE is a screener for socio-emotional competence and problem behaviors (e.g., “does your baby let you know when she is hungry, hurt, or wet” and “does your child have eating problems”). Among this group of infants,

their vocabulary skill at 18 months of age was the factor that best differentiated their performance across tasks in that lower vocabulary size was related to lower social attention (i.e., RJA and distracter voice latency). Again, it may be that social attention/joint attention and word/object association abilities develop somewhat independently. However, for infants who display limited skill in one or both of these areas, there appears to be a risk for later language challenges in terms of their vocabulary development.

Overall then, language learning seems to require a specialized kind of social attention. Simply paying attention to people is not enough (this does not predict associative learning). Likewise, the ability to learn word/object associations is not sufficient (this does not predict vocabulary size). The critical feature of social attention modulation may involve sensitivity to particular aspects of what others are doing (e.g., pointing and naming) *with respect to the infant's own attention* that is most relevant for learning language ('social agency'). Infants who are most sensitive to social agency would be better poised for language learning, while infants who attend to people regardless of social agency would be more limited in opportunities for language specific information.

There is some evidence suggesting the importance of the social context for associative learning. When 14-month-old infants shared mutual gaze with an adult female labeling two different objects using minimal pair words (e.g., "bif" and "dif") – words which are typically impossible for them to differentiate at this age – those infants who shared more frequent mutual gaze learned the different word/object associations (Fais, 2009; Fais, Helm et al. 2009). In contrast, for some infants the presence of social domains of information may pose a challenge in terms of their differential attentional/learning/processing abilities. Although infants and children generally attend more to dynamic visual information when paired with an auditory component, in

some cases the social nature of the auditory stream may actually compromise learning abilities. For example, when presented with an visual/auditory association task, linguistic labels interfere with the ability of 10-month-old infants (but not 16-month-olds) to process a change in the visual stimuli (Sloutsky & Robinson, 2008). This suggests that for at least some infants who performed poorly on the switch, their particular attention allocation may have been a function of differential attention to the voice over the visual information that was provided (i.e., they did not recover attention during the novel word-object pairing, but looked longer during the familiar trial). Therefore, full consideration must be given to the degree of social information that is adaptive and accessible for the contextual demands and the individual characteristics of the infant.

Task Considerations and Suggestions for Future Work

The social attention tasks developed for this study were designed to provide an assessment of individual infants' social skills that logically relate to emerging language proficiency (regulation of attention, eye gaze following, face scanning, and joint attention engagement). In the final analysis, the distracter, face scanning, and joint attention tasks were more informative in terms of characterizing variability in infants' attention patterns to a dynamic speaker under various conditions (e.g., silent vs. voiced; familiar vs. novel; sharing attention to objects).

In contrast, the gaze following task failed to capture sufficient variability in infants' performance, most likely due to task parameters, rather than to the fact that all infants engage in gaze following to the same extent. In fact, at least one other study with 11-month-olds identified individual variability in the accuracy of gaze following behavior relative to the performance of the overall sample (Brooks & Meltzoff, 2005). Similarly, a study examining 9-month-old infants' attention to adult gaze direction and object location found substantial individual

variation in spite of significant group-level performance (Senju, Csibra, & Johnson, 2008). One way in which variance was constrained most likely resulted from the sequencing of events. After the female gaze shift occurred, she disappeared, and an object appeared either to the left or right of the screen. If the infant was in the process of looking where she was looking, but that information was no longer available, they would be more inclined to simply look at the object on the screen (and no longer be guided by her initial gaze). This appears to be the best explanation for the pattern of results that was obtained in that infants' accuracy of looking to the side where she looked was 100% on congruent trials, but close to 0% on incongruent trials (i.e., they looked at the object, not in the direction of her gaze).

A second parameter of this task that warrants consideration is the length of time infants saw the female gazing directly at them (1 second duration) prior to seeing her gaze shift (1 second duration). Given that eye to eye contact appears to be a critical component of social engagement (Farroni et al, 2002; Senju, Csibra, & Johnson, 2008; Senju, & Hasegawa, 2005), these time intervals may have been too brief to fully engage infants' social attention. Direct (mutual) gaze is a powerful event that appears to have important implications for development. For example, in adults, direct gaze holds attention and makes it difficult to disengage from the face when attempting to detect a peripheral target (Senju & Hasegawa, 2005). In children, direct gaze facilitates detection of the target in a visual search paradigm (Senju et al., 2008). Newborns and infants prefer to look at images of faces with direct gaze and display enhanced neural processing when viewing these images (Farroni, Csibra, Simion, & Johnson, 2002; Farroni, Massaccesi, Pividori, & Johnson, 2004). Infants (at 3- and 6-months-old) also show increased smiling and engagement when interacting with an adult with mutual eye gaze (Hains & Muir, 1996). Neuroimaging and lesion studies have suggested that the superior temporal sulcus (STS)

region is involved in this specialized processing of eye gaze information (Campbell, Heywood, Cowey & Regard, 1990; Pelphrey, Morris, Michelich, Allison, & McCarthy, 2005), showing enhanced activation of the STS to viewing shifts of eye gaze. In contrast, atypical patterns of looking are reported for individuals with autism (Sasson, 2006; Shultz, 2005; Klin et al., 2002b; Pelphrey et al., 2002). Thus, it is possible that the brief frontal eye view presented in the current gaze task did not sufficiently engage the attentional system of infants in this task.

Currently, we are in the process of redesigning this gaze following task in some important ways in order to re-introduce this measure in future studies. For example, the duration of mutual gaze has been lengthened, such that infants view the image of the adult female with direct gaze for 5 seconds. This is followed by the image of shifted gaze (either to the right or the left), which has also been lengthened to 3 seconds. In addition, the face remains visible as the target object appears (rather than disappearing prior to the appearance of the object). This allows detecting gaze shifts between the eyes and the target object, including anticipatory gaze shifts prior to the appearance of the object on the screen. This task is being presented on an eye-tracker, which greatly enhances the ability to examine gaze patterns, including precise measurement of when gaze shifts occur, as well as durations of looking and order of eye gaze movements.

Although the distracter task was a successful measure in terms of characterizing variability in latency to look away from a dynamic speaking face, this task has been modified to address limitations of the design as well as to capture differences attention to social versus non-social events. To begin with, in the present study it was necessary to consider only the first two of the four trials (for each trial type), because infants began to anticipate the appearance of the distracter (the flashing checkerboard located in the right upper quadrant of the screen). For this

reason the timing and placement of the distracter has been adjusted, such that the onset of the distracter as well as the placement are both random. In addition, the nature of the distracter has also been modified, with some trials including the same non-social dynamic distracter (i.e., flashing checkerboard) and other trials including a social distracter (i.e., a silent dynamic speaker).

It is expected that infants will differ in terms of their latency to look away from the social target as a function of the distracter type and placement. Infants who are high in social attention should have the longest latency to look away from the speaker in the context of the non-social distracter, but would be expected to have a comparatively shorter latency in the context of a social distracter. Infants who are low in social attention are expected to be equally distractible in the presence of both. In addition, it is expected that differences in attention may be identified as a function of the placement of the distracter. A distracter that appears close to the mouth (in the lower right and left quadrants of the screen) would be expected to compromise the focused attention of the majority of infants, whereas a distracter that is in the periphery (upper right and left quadrants of the screen) may only disrupt attention for a subset of infants. The goal with these and other modifications will be to differentiate and compare general attentional abilities with social attention patterns for individual infants. This will include considering individual and contextual differences in sustained attention versus the ability to disengage and shift attention. Given differences in context it is expected that there would be differing levels of optimal social attention.

Although the face scanning task produced sufficient variability in gaze patterns, the ability to associate this social attention measure with language outcomes was limited. One explanation for this lack of predictive ability is the restricted sample size (approximately half of

the larger longitudinal sample), primarily the result of technical difficulties with the eye-tracking equipment. While the ability to track infant visual fixation patterns is an important and useful tool, eye-tracking poses a number of challenges in general, as well as more particular challenges for infant research (for a recent discussion see Oakes, 2010). For example, one of the primary challenges involves accuracy in calibration, which is a function of the quality of information that the system collects (how well pupil/corneal reflections are captured), but is also dependent on the (infant) participant looking at the calibration stimuli. Additional considerations include how missing data are handled and the filtering of data from the eye-tracker. In the present study, the primary challenge was initially with regards to collecting calibration data (in the absence of calibration, testing cannot be conducted), which precluded collecting data on the complete longitudinal sample.

In spite of the challenge of obtaining sufficient data when using eye trackers with infant samples, a second possibility is that this particular methodology is less likely to generate variability in performance across infants. This seems unlikely given several published studies using eye-tracking methods with infants. For example, eye-tracking has been used with typically developing 12-month-olds to demonstrate that infants spend more time looking at an object when an adult female is also gazing in the direction of the object (compared to when she is pointing at the object and looking directly ahead), with most of their looking time focused on the face during both conditions (von Hofsten, Dahlstrom, & Fredriksson, 2005). In addition, children with ASD (4-year-olds) and typically developing peers (1- and 3-year-olds) have different patterns of fixation to movies of a conversation, but similar tracking patterns to movies of objects (von Hofsten, Uhlig, Adell, & Kochukhova, 2009). Given that a post-hoc power analysis for the regression of face scanning measures on vocabulary size indicated a sample size of 108 infants

would be necessary for this effect size, it is likely that the particular events that were used in the current study (and not eye-tracking per se) limited the power of this sample size to account for variance in other measures.

Finally, the switch task was used to characterize one aspect of language skill, word/object associative learning *in the absence of a social agent*. Given the pattern of relationships observed in this study, the switch task is currently being modified to incorporate consideration of social and non-social contributions to associative learning. Thus, a social version of the switch task has been created, with a person appearing on the screen. An adult female first engages the infant in mutual gaze, and then shifts her gaze (i.e., to the right) as a dynamic object appears, while her voice labels the object (i.e., “boog”). The same sequence is completed in a second movie with the gaze shift occurring in the opposite direction (i.e., to the left) towards a second object with a different label (i.e., “neem”). In the non-social version, the adult female’s image is fragmented, such that she is not identifiable as a person, although all the components of her face are still present. Thus, in the non-social switch task, all of the same information is present but not available for use in terms of social agency.

It is expected that infants who are high in social attention (specific to social agency) will perform well on the social version of the switch. However, infants who are non-specifically high in social attention (i.e., differentially attentive towards faces without respect to social agency) are not expected to perform well on the switch, given that they would be more attentive to the female than to the word/object information she is providing. Infants who are low in social attention are not expected to perform differently on the social and non-social versions of the switch, in that they would not capitalize on the socially relevant information, compared to the non-social information, for associative learning. In this way, future work can begin to differentiate the

contributions of social attention modulation, as well contextual parameters that may influence the word/object associative learning abilities that are brought to bear on language development.

New Directions in Conceptualizing Social Attention and Language Learning

In conclusion, the pattern of results from the present study provide evidence that social attention, as a developmental construct, is related to our understanding of the nature of language learning in infants and young children. Generally, deficiencies in language ability found in severe autism are taken as *prima facie* evidence of this relationship (Mundy, Kasari, Sigman, & Ruskin, 1995; Mundy & Willoughby, 1996; Sheinkopf et al., 2004), with the explicit assumption that low social attention compromises language acquisition in this population. More recently, one of the first prospective longitudinal studies of infants at high-risk for autism (i.e., the infant siblings of children diagnosed with autism) failed to detect differences in the frequency of gaze to faces, shared smiles, and vocalizing to others in 6-month-olds who later received a diagnosis of autism (Ozonoff et al., 2010). One interesting interpretation of this disconnect between early social communication and autism is that poor language learning contributes to low social attention such that children who are not skilled communicators forego important opportunities to be socially engaged with others, resulting in poor social skill development (Norbury et al., 2009). In other words, it may be that difficulties with language learning constrain the extent to which infants are engaged by others, thus impacting their social engagement as well as future language learning.

However, this same study (Ozonoff et al., 2010) did find a significant relationship between social communication and autistic diagnosis when infants were first tested as 12-month-olds. This is more consistent with results from the present study which found differences in social attention at 11-months of age that were related to vocabulary size at 18-months of age.

Given the nature of the sample, it is not clear whether the measures of social attention in the current study would also predict risk for autism in a more clinically-relevant group of infants. Although the present study was not a clinically referred sample, it stands to reason that more divergent patterns of social attention would be present in infants who later receive a diagnosis of autism. Ozonoff et al. measured social communication behaviors during administration of a developmental assessment measure (the Mullen Visual Reception subtest) and via examiner ratings of social engagement (i.e., behaviors rated as rare, occasional or frequent). The tasks and measures employed in the current study add to this array of protocols in which the relationship between social attention (including communication) can be assessed as indicators of developmental risk in atypical, as well as typically developing, populations.

In the end, it may be futile to try and resolve the temporal sequence of this language – social attention relationship, given that throughout the first postnatal year, infants are actively perceiving language (e.g., Vouloumanos & Werker, 2003; 2007) as they attend to communicative partners. The ongoing interplay between language perception and social attention is likely mediated by social agency. In other words, it is within the context of interaction infants gain experience with dynamic faces and voices. In interaction with infants, adults tend to exaggerate the prosodic features of both visual speech and auditory speech. This particular infant-directed style not only elicits differential attention in infants (Cooper & Aslin, 1990), but feeds back onto adults' behavior in important ways. For example, when mothers were recorded singing to their imagined infants and then again in the actual presence of their infants, their voices were distinctly different (Trainor, 1996). When infants were given the opportunity to listen to both kinds of recordings, they preferred the latter, showing the reciprocal nature of influence that is so typical of adult-infant exchanges. The importance of this kind of contingency

in social exchange is apparent in the finding that infants vocalize more in response to contingent dynamic, voiced feedback from their mothers compared to the same feedback delivered non-contingently (Goldstein et al., 2003). From this view, future studies that stand to benefit our explanation of the complex emergence of language (or lack thereof, as in autism) will capture social agency in ways that make clear the dynamic, reciprocal, and real-time nature of interactions between infants and others.

References

- Adamson, L. (1995). Joint attention, affect, and culture. In C. Moore & P.J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 205-221). Hillsdale, NJ: Erlbaum.
- Atkinson, J. (1992). Human visual development over the first 6 months of life. A review and a hypothesis. *Human Neurobiology, 3*(2), 61-74.
- Bakeman, R., & Adamson, L. (1984). Coordinating attention to people and objects in mother infant and peer-infant interactions. *Child Development, 55*, 1278-1289.
- Baldwin, D.A. (1995). Understanding the link between joint attention and language. In C. Moore & P.J. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 131-158). Hillsdale, NJ: Erlbaum.
- Baldwin, D. A., Markman, E. M., Bill, B., Desjardins, R. N., Irwin, J. M., & Tidball, G. (1996). Infants' reliance on a social criterion for establishing word-object relations. *Child Development, 67*, 3135-3153.
- Baldwin, D.A. & Moses, L.J. (1996). The ontogeny of social information gathering. *Child Development, 67*, 1915-1939.
- Baron-Cohen, S., Baldwin, D., & Crowson, M. (1997). Do children with autism use the speaker's direction of gaze strategy to crack the code of language? *Child Development, 68*, 48-57.
- Baron-Cohen, S., Wheelwright, S., & Jolliffe, T. (1997). Is there a "language of the eyes"? Evidence from normal adults, and adults with autism or Asperger syndrome. *Visual Cognition, 14*(5), 311-331.
- Batki, A., Baron-Cohen, S., Wheelwright, S., Connellan, J., & Ahluwalia, J. (2000). Is there an innate gaze module? Evidence from human neonates. *Infant Behavior and Development, 23*, 223-229.
- Bernier, R., Webb, S.J., & Dawson, G. (2006). Understanding impairments in social engagement in autism. In P. Marshall & N.A. Fox (Eds.), *The development of social engagement: Neurobiological perspectives* (pp. 304-328). New York, NY: Oxford.
- Bernhardt, B.M., Kemp, N., & Werker, J.F. (2007). Early word-object associations and later language development. *First Language, 27*(4), 315-328.
- Black, M.M., & Matula, K. (1999). Essentials of Bayley Scales of Infant Development II Assessment. San Antonio, TX: The Psychological Corporation.

- Blake, R., Turner, L.M., Smoski, M.J., Pozdol, S.L., & Stone, W.L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science, 14*(2), 151-157.
- Bono, M., Daley, T., & Sigman, M. (2004). Joint attention moderates the relation between intervention and language development in young children with autism. *Journal of Autism and Related Disorders, 34*, 495-505.
- Bretherton, I. (1991). Intentional communication and the development of an understanding of mind. In D. Frye & C. Moore (Eds.), *Children's theories of mind: Mental states and social understanding* (pp. 49-75). Hillsdale, NJ: Erlbaum.
- Bricker, D., & Squires, J. (1999). *Ages and Stages Questionnaire: A Parent-Completed Child Monitoring System*. Baltimore, MD: Paul H. Brookes Publishing.
- Brooks, R., & Meltzoff, A. (2002). The importance of eyes: How infants interpret adult looking behavior. *Developmental Psychology, 38*, 958-966.
- Brooks, R. & Meltzoff, A.N. (2005). The development of gaze following and its relation to language. *Developmental Science, 8*(6), 535-543.
- Bronson, G.W. (1994). Infants' transitions toward adult-like scanning. *Child Development, 65*, 1243-1261.
- Bruner, J.S. (1983). Education as social invention. *Journal of Social Issues, 39*(4), 129-141.
- Bryson, S.E., Zwaigenbaum, L., Brian, J., Roberts, W., Szatmari, P., Rombough, V., & McDermott, C. (2007). A prospective case series of high-risk infants who developed autism. *Journal of Autism and Developmental Disorders, 37*, 12-24.
- Bushnell, I.W., Sai, F., & Mullin, J.T. (1989). Neonatal recognition of the mother's face. *British Journal of Developmental Psychology, 7*(1), 3-15.
- Butterworth, G., & Jarrett, N. (1991). What minds have in common is space: Spatial mechanisms serving joint attention in infancy. *British Journal of Developmental Psychology, 9*, 55-72.
- Campbell, R., Heywood, C. A., Cowey, A., Regard, M., & Landis, T. (1990). Sensitivity to eye gaze in prosopagnosic patients and monkeys with superior temporal sulcus ablation. *Neuropsychologia, 28*, 1123-1142.
- Capps, L., Sigman, M., & Mundy, P. (1994). Attachment security in children with autism. *Development and Psychopathology, 6*(2), 249-261.
- Caron, A.J., Caron, R.F., Caldwell, R.C., & Weiss, S.J. (1973). Infant perception of the structural properties of the face. *Developmental Psychology, 9*(3), 385-399.

- Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social Cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, 63, No. 4 (Serial No. 255).
- Cashon, C.H., & Cohen, L.B. (2003). The construction, deconstruction, and reconstruction of infant face perception. In O. Pascalis & A. Slater (Eds.), *The development of face processing in infancy and early childhood: Current perspectives* (pp. 13-25). New York: Nova Science Publishers.
- Center for Disease Control and Prevention. Prevalence of ASDs [Online]. (2009) Autism and Developmental Disabilities Monitoring (ADDM) Network. Available from: URL: <http://www.cdc.gov/ncbddd/autism/data.html>. [Cited 2010 May 1].
- Charman, T. (1998). Specifying the nature and course of joint attention impairment in autism in the preschool years. *Autism*, 2(1), 61-79.
- Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2001). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development*, 15, 481-498.
- Chawarska, K., Klin, A., & Volkmar, F. (2003). Automatic attention cuing through eye movement in 2-year-old children with autism. *Child Development*, 74, 1108-1123.
- Cohen, J., Cohen, P., West, S.G., & Aiken, L.S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences* (3rd ed.). New Jersey: Erlbaum Associates.
- Cooper, R.P., & Aslin, R.N. (1990). Preferences for infant-directed speech in the first month after birth. *Child Development*, 61, 1584-1595.
- Corkum, V., & Moore, C. (1995). Development of joint visual attention in infants. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origin and role in development*. Hillsdale, NJ: Erlbaum
- Corkum, V. & Moore, C. (1998). The origins of joint visual attention in infants. *Developmental Psychology*, 34(1), 28-38.
- Courage, M.L., Reynolds, G.D., & Richards, J.E. (2006). Infants' attention to patterned stimuli: Developmental change from 3 to 12 months of age. *Child Development*, 77(3), 680-695.
- Davies, S., Bishop, D., Manstead, A., & Tantam, D. (1994). Face perception in autistic children. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 35, 1033-1058.
- Dawson, G., Meltzoff, A.N., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. *Journal of Autism and Developmental Disorders*, 28(6), 479-485.

- Dawson, G., & Lewy, A. (1989). Arousal, attention, and the socioemotional impairments of individuals with autism. In G. Dawson (Ed.). *Autism: Nature, diagnosis, and treatment* (pp. 49-74). New York: Guilford.
- Dawson, G., Osterling, J., Meltzoff, A., & Kuhl, P. (2000). Case study of the development of an infant with autism from birth to two years of age. *Journal of Applied Developmental Psychology, 21*(3), 299-313.
- DeCasper, A.J., & Fifer, W.P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*(4448), 1174-1176.
- D'Entremont, B. (2000). A perceptual-attentional explanation of gaze following in 3- and 6-month-olds. *Developmental Science, 3*(3), 302-311.
- D'Entremont, B., Hains, S., & Muir, D. (1997). A demonstration of gaze following in 3- to 6-month-olds. *Infant Behavior and Development, 20*, 569-572.
- Dunham, P.J., & Dunham, F. (1992). Lexical development during middle infancy: A mutually driven infant-caregiver process. *Developmental Psychology, 28*, 414-420.
- Dunham, P.J., Dunham, F., & Curwin, A. (1993). Joint attentional states and lexical acquisition at 18 months. *Developmental Psychology, 29*, 827-831.
- Fais, L. (2009). Looking at looking time: Word-object association in 14-month-old infants. Invited talk, Second International School of Speech Science, Federal University of Minas Gerais, Belo Horizonte, Brazil, October.
- Fais, L. (2009). Fais, L., Helm, S., & Werker, J. F. (2009). The effects of social interaction on word-object association. Poster, Annual Meeting of the Cognitive Development Society, San Antonio, Texas, October.
- Fantz, R.L. (1964). Pattern vision in newborn infants. *Science, 140*(3564), 296-297.
- Farroni, T., Csibra, G., Simion, F., & Johnson, M. H. (2002). Eye contact detection in humans from birth. *Proceedings of the National Academy of Sciences, 99*(14), 9602-9605.
- Farroni, T., Johnson, M.H., Brakbar, M., & Simion, F. (2000). Infants' use of gaze direction to cue attention: The importance of perceived motion. *Visual Cognition, 7*(6), 705-718.
- Farroni, T., Johnson, M. H., & Csibra, G. (2004). Mechanisms of eye gaze perception during infancy. *Journal of Cognitive Neuroscience, 16*(8), 1320-1326.
- Farroni, T., Mansfield, E.M., Lai, C., & Johnson, M.H. (2003). Infants perceiving and acting on the eyes: Tests of an evolutionary hypothesis. *Journal of Experimental Child Psychology, 85*, 199-212.

- Farroni, T., Massaccesi, S., Menon, E., & Johnson, M.H. (2007). Direct gaze modulates face recognition in young infants. *Cognition*, *102*, 396-404.
- Farroni, T., Massaccesi, S., Pividori, D., & Johnson, M.H. (2004). Gaze following in newborns. *Infancy*, *5(1)*, 39-60.
- Fenson, L., Pethick, S., Renda, C., Cox, J.L., Dale, P.S., & Reznick, J.S. (2000) Short form versions of the MacArthur Communicative Development Inventories. *Applied Psycholinguistics*, *21*, 95-115.
- Fenson, L., Dale, P.S., Reznick, J.S., Thal, D., Bates, E., Hartung, J.P., Pethick, S., & Reilly, J.S. (1993). *Technical manual for the MacArthur Communicative Development Inventory*. San Diego: Singular Press.
- Fenson, L., Dale, P.S., Reznick, J.S., Bates, E., Thal, D.J., & Pethick, S. (1994). Variability in Early Communicative Development. *Monographs of the Society for Research in Child Development*, *59 (5, Serial No. 242)*.
- Field, T. (1981). Infant arousal, attention, and affect during early interactions. *Journal of the American Academy of Child Psychiatry*, *20*, 308-317.
- Flom, R., Deak, G.O., Phill, C.G., & Pick, A.D. (2004). Nine-month-olds' shared visual attention as a function of gesture and object location. *Infant Behavior and Development*, *27*, 181-194.
- Fox, R., & McDaniel, C. (1982). The perception of biological motion by human infants. *Science*, *218(4571)*, 486-487.
- Frieschen, A., Bayliss, A.P., & Tipper, S.P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133(4)*, 694-724.
- Frith, U. (1989). *Autism: Explaining the enigma*. Oxford: Blackwell.
- Glascoe, F.P. (1998). Collaborating with parents: Using parents' evaluation of developmental status to detect and address developmental and behavioral problems. Nashville, TN: Ellsworth & Vandermeer Press.
- Glascoe, F.P. (2000). Early detection of developmental and behavioral problems. *Pediatric Review*, *21(8)*, 272-280.
- Goldstein, M., King, A., & West, M. (2003). Social interaction shapes babbling: Testing parallels between birdsong and speech. *Proceedings of the National Academy of Sciences*, *100*, 8030-8035.
- Hains, S.M.J. & Muir, D.W. (1996). Infant sensitivity to adult eye direction. *Child Development*, *67*, 1940-1951.

- Haith, M.M., Bergman, T., & Moore, M.J. (1977). Eye contact and face scanning in early infancy. *Science*, *198*, 853-855.
- Hernandez-Reif, M. & Bahrck, L.E. (2001). The development of visual-tactual perception of objects: Amodal relations provide the basis for learning arbitrary relations. *Infancy*, *2(1)*, 51-72.
- Hood, B.M., Willen, J.D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*, 131-134.
- Howlin, P. (2005). Outcomes in autism spectrum disorders. In F.R. Volkmar, P. Rhea, A. Klin, D. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders, Vol. 1: Diagnosis, development, neurobiology, and behavior*. Hoboken, NJ: Wiley & Sons.
- Hunnius, S., & Geuze, R.H. (2004a). Developmental changes in visual scanning of dynamic faces and abstract stimuli in infants: A longitudinal study. *Infancy*, *6(2)*, 231-255.
- Hunnius, S., & Geuze, R.H. (2004b). Gaze shifting in infancy: A longitudinal study using dynamic faces and abstract stimuli. *Infant Behavior and Development*, *27*, 397-416.
- Johnson, M. H., & Morton, J. (1991). Biology and cognitive development. Cambridge, MA: Basil Blackwell.
- Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger's Syndrome faster than normal on the Embedded Figures test? *Journal of Child Psychology and Psychiatry*, *38*, 527-534.
- Kannass, K.N., Oakes, L.M., & Shaddy, D.J. (2006). A longitudinal investigation of the development of attention and distractibility. *Journal of Cognition and Development*, *7(3)*, 381-409.
- Karmiloff-Smith, A., Grant, J., Berthond, J., Davies, M., Howlin, P., & Udwin, O. (1997). Language and Williams syndrome: How intact is 'intact'? *Child Development*, *68(2)*, 246-262.
- Kasari, C., Sigman, M., Mundy, P., & Yirmiya. (1990). Affective sharing in the context of joint attention interactions of normal, autistic, and mentally retarded children. *Journal of Autism and Developmental Disorders*, *20(1)*, 87-100.
- Klin, A. (1991). Young autistic children's listening preferences in regard to speech: A possible characterization of the symptom of social withdrawal. *Journal of Autism and Developmental Disorders*, *21(1)*, 29-37.
- Klin, A., & Jones, W. (2006). Attributing social and physical meaning to ambiguous visual displays in individuals with higher-functioning autism spectrum disorders. *Brain and Cognition*, *61*, 40-53.

- Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2005). The enactive mind: From actions to cognition: Lessons from autism. In F.R. Volkmar, P. Rhea, A. Klin, D. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders, Vol. 1: Diagnosis, development, neurobiology, and behavior*. Hoboken, NJ: Wiley & Sons.
- Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002a). Defining and quantifying the social phenotype in autism. *American Journal of Psychiatry*, *159*(6), 909-916.
- Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002b). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, *59*, 809-816.
- Klin, A., Paul, D., Schultz, R., & Volkmar, F. (2005). Three diagnostic approaches to Asperger syndrome: Implications for research. *Journal of Autism and Developmental Disorders*, *35*(2), 221-234.
- Kuhl, P. (2007). Is speech learning 'gated' by the social brain? *Developmental Science*, *10*(1), 110-120.
- Kuhl, P., Coffey-Corina, S., Padden, D., Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: Behavioral and electrophysiological measures. *Developmental Science*, *8*(1), 1-12.
- Kuhl, P.K., & Meltzoff, A.N. (1984). The intermodal representation of speech in infants. *Infant Behavior and Development*, *7*(3), 361-381.
- Kuhl, P.K., Tsao, F.-M., & Liu, H.-M. (2003). Foreign-language experience in infancy: Effects of short-term language exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences*, *100*(15), 9096-9101.
- Kuhl, P.K., Williams, K.A., Lacerda, F., Stevens, K.N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, *255*, 606-608.
- Landau, B., & Gleitman, L.R. (1985). *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.
- Landry, R., & Bryson, S.E. (2004). Impaired disengagement of attention in young children with autism. *Journal of Child Psychology and Psychiatry*, *45*(6), 1115-1122.
- Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry*, *19*, 255-268.
- Leekam, S., Baron-Cohen, S., & Perrett, D. (1997). Eye-direction detection: A dissociation between geometric and joint attention skills in autism. *British Journal of Developmental Psychology*, *15*(Pt 1), 77-95.

- Leekam, S., Hunnisett, E., & Moore, C. (1998). Targets and cues: Gaze-following in children with autism. *Journal of Child Psychology and Psychiatry*, *39*(7), 951-962.
- Leekam, S. & Moore, C. (2001). The development of attention and joint attention in children with autism. In J.A. Burack, T. Charman, N. Yirmiya, & P. Zelazo (Eds.), *The development of autism: Perspectives from theory and research*. Mahwah, NJ: Lawrence Erlbaum.
- Lord, C. (1995). Follow-up of two-year-olds referred for possible autism. *Journal of Child Psychology and Psychiatry*, *36*, 1365-1382.
- Loucas, T., Charman, T., Pickles, A., Simonoff, E., Chandler, S., Meldrum, D., & Baird, G. (2009). Autistic symptomatology and language ability in autism spectrum disorder and specific language impairment. *Journal of Child Psychology and Psychiatry*, *49*(11), 1184-1192.
- Loveland, K.A. & Landry, S. (1986). Joint attention and language in autism and developmental language delay. *Journal of Autism and Developmental Disorders*, *16*, 335-339.
- Maestro, S., Muratori, F., Cavallaro, M.C., Pecini, C., Cesari, A., Paziente, A., et al. (2005a). How young children treat objects and people: An empirical study of the first year of life in autism. *Child Psychiatry and Human Development*, *35*(4), 383-396.
- Maestro, S., Muratori, F., Cavallaro, M.C., Pei, F., Stern, D., Golse, B. et al. (2002). Attentional skills during the first 6 months of age in autism spectrum disorder. *Journal of American Child and Adolescent Psychiatry*, *41*(10), 1239-1245.
- Maestro, S., Muratori, F., Cesari, A., Cavallaro, M.C., Paziente, A., Pecini, C., et al. (2005b). Course of autism signs in the first year of life. *Psychopathology*, *38*, 26-31.
- Maurer, D., & Salapatek, P. (1976). Developmental changes in the scanning of faces by young infants. *Child Development*, *47*(2), 523-527.
- Maye, J., Werker, J.F., & Gerken, L. (2002). Infant sensitivity to distributional information can affect phonetic discrimination. *Cognition*, *82*, 8101-8111.
- McCabe, P.C., & Marshall, D.J. (2006). Measuring the social competence of preschool children with specific language impairment: Correspondence among informant ratings and behavioral observations. *Topics in Early Childhood Special Education*, *26*(4), 234-246.
- McIlreavy, M., Panneton, R., Bhullar, N., & Aslin, R. (2006). Changing patterns of attention to static and dynamic visual events during infancy. Poster presented at the International Conference on Infant Studies, Kyoto, Japan.
- Meltzoff, A.N., & Moore, M.K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, *198*(4312), 75-78.

- Moll, H. & Tomasello, M. (2004). 12- and 18-month-old infants follow gaze to spaces behind barriers. *Developmental Science*, *7*(1), F1-F9.
- Moon, C., Cooper R.P. & Fifer, W.P. (1993). Two-day olds prefer their native language. *Infant Behavior and Development*, *16*, 495-500.
- Moore, C., Angelopoulos, M., & Bennett, M. (1997). The role of movement in the development of joint visual attention. *Infant Behavior and Development*, *20*(1), 83-92.
- Morales, M., Mundy, P., Delgado, C. E. F., Yale, M., Messinger, D., Neal, R., & Schwartz, H. K. (2000a). Responding to joint attention across the 6- to 24-month age period and early language acquisition. *Journal of Applied Developmental Psychology*, *21*, 283–298.
- Morales, M., Mundy, P., Delgado, C.E.F., Yale, M., Neal, R., & Schwartz, H.K. (2000b). Gaze following, temperament, and language development in 6-month-olds: A replication and extension. *Infant Behavior and Development*, *23*(), 231-236.
- Morales, M., Mundy, P., & Rojas, J. (1998). Following direction of gaze and language development in 6-month-olds. *Infant Behavior and Development*, *21*(2), 373-377.
- Mottron, L., Belleville, S., & Menard, E. (1999). Local bias in autistic subjects as evidenced by graphic tasks: Perceptual hierarchization or working memory deficit? *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *40*, 743-755.
- Mundy, P (1995). Joint attention and social-emotional approach behavior in children with autism. *Development & Psychopathology*, *7*(1), 63-82.
- Mundy, P. & Acra (2006). Joint attention, social engagement, and the development of social competency. In P. Marshall & N. Fox (Eds.), *The development of social engagement*. New York: Oxford Press.
- Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). *A manual for the abridged Early Social Communication Scales (ESCS)*. Unpublished manuscript.
- Mundy, P., & Gomes, A. (1998). Individual differences in joint attention skill development in the second year. *Infant Behavior and Development*, *21*, 469-482.
- Mundy, P. & Neal, A.R. (2001). Neural plasticity, joint attention, and a transactional social-orienting model of autism. *International Review of Research in Mental Retardation: Autism*, *23*, 139-168.
- Mundy, P., & Sigman, M. (1989). Specifying the nature of the social impairment in autism. In G. Dawson (Ed.), *Autism: New perspectives on diagnosis, nature and treatment* (pp. 3-21). New York: Guilford.

- Mundy, P. & Sigman, M. (2006). Joint attention, social competence, and developmental psychopathology. In D. Cicchetti & D.J. Cohen, (Eds.). *Developmental Psychopathology, Vol. 1*, (2nd ed.). Hoboken, NJ: John Wiley & Sons, pp. 293-332.
- Mundy, P., Sigman, M., & Kasari, C. (1990). A longitudinal study of joint attention and language development in autistic children. *Journal of Autism and Developmental Disorders*, 20(1), 115-128.
- Mundy, P., Sigman, M., & Kasari, C. (1994). Joint attention, developmental level, and symptom presentation in autism. *Development and Psychopathology*, 6(3), 389-401.
- Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the social deficits of autism: The contributions of non-verbal communication measures. *Journal of Child Psychology & Psychiatry*, 27(5), 657-669.
- Mundy, P., & Willoughby, J. (1996). Nonverbal communication, joint attention, and early socioemotional development. In M. Lewis & M. Sullivan (Eds.), *Emotional development in atypical children* (pp. 65-87). Hillsdale, NJ: Erlbaum.
- Nagai, Y., Hosoda, K., Morita, A., & Asada, M. A constructive model for the development of joint attention. *Connection Science*, 15(4), 211-229.
- Nation, K. & Penny, S. (2008). Sensitivity to eye gaze in autism: Is it normal? Is it automatic? Is it social? *Development and Psychopathology*, 20(1), 79-97.
- Norbury, C.F., Brock, J., Cragg, L., Einav, S., Griffiths, H., & Nation, K. (2009). Eye-movement patterns are associated with communicative competence in autistic spectrum disorders. *Journal of Child Psychology and Psychiatry*, 50(7), 834-842,
- O’Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 719-730.
- Osterling, J., & Dawson, G. (1994). Early recognition of children with autism: A study of first birthday home videotapes. *Journal of Autism & Developmental Disorders*, 24(3), 247-257.
- Osterling, J.G., Dawson, G., & Munson, J.A. (2002). Early recognition of 1-year-old infants with autism spectrum disorder versus mental retardation. *Development and Psychopathology*, 14, 239-251.
- Ozonoff, S. (1997). Components of executive function in autism and other disorders. In J. Russell (Ed.), *Autism as an executive disorder* (pp. 179-211). Oxford: Oxford University Press.
- Ozonoff, S., Iosif, A.M., Baguio, F., Cook, I.C., Hill, M.M., Hutman, T., Rogers, S.J., Rozga, A., Sangha, S., Sigman, M., Steinfeld, M.B., & Young, G.S. (2010). A prospective study of the

- emergence of early behavioral signs of autism. *Journal of the American Academy of Child and Adolescent Psychiatry*, 49(3), 256-266.
- Ozonoff, S., & Jensen, J. (1999). Brief report: Specific executive function profiles in three neurodevelopmental disorders. *Journal of Autism and Developmental Disorders*, 29, 171-177.
- Panneton-Cooper, R., & Richards, J.E. (2003, April). Infants' heart rate responses to multimodal displays of infant-directed speech. Paper presented at the 30th Australasian Conference of the Experimental Psychology Society, Sydney, Australia.
- Pascalis, O., De Schonen, S., Morton, J., Deruelle, C., & Fabregrenet, M. (1995). Mothers face recognition by neonates: A replication and extension. *Infant Behavior and Development*, 18(1), 79-85.
- Pascalis, O., Scott, L.S., Kelly, D.J., Shannon, R.W., Nicholson, E., Coleman, M., & Nelson, C.A. (2005). Plasticity of face processing in infancy. *Proceedings of the National Academy of Sciences*, 102(14), 5297-5300.
- Pelphrey, K. A., Morris, J. P., Michelich, C. R., Allison, T., & McCarthy, G. (2005). Functional anatomy of biological motion perception in posterior temporal cortex: An fMRI study of eye, mouth and hand movements. *Cerebral Cortex*, 15, 1866–1876.
- Pelphrey, K.A., Sasson, N.J., & Reznick, J.S. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders*, 32(4), 249-261.
- Plaisted, K., O’Riordan, M., & Baron-Cohen, S. (1998). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry*, 39, 777-783.
- Richards, J.E. (1989). Development and stability in visual sustained attention in 14, 20, and 26-week-old infants. *Psychophysiology*, 26(4), 422-430.
- Ristic, J., Mottron, L., Friesen, C.K., Iarocci, G., Burack, J.A., & Kingstone, A. (2005). Eyes are special but not for everyone: The case of autism. *Cognitive Brain Research*, 24, 715-718,
- Robins, D.L., Fein, D., Barton, M., & Green, J. (2001). The modified checklist for autism in toddlers: An initial study investigating the early detection of autism and pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, 31, 131-144.
- Robinson, C.W., & Sloutsky, V.M. (2007). Linguistic labels and categorization in infancy: Do labels facilitate or hinder? *Infancy*, 11(3), 233-253.
- Rothbart, M., Ellis, L.K., & Posner, M.I. (2004). Temperament and self-regulation. In R.F. Baumeister & K.D. Vohs (Eds.), *Handbook of self-regulation*. New York, NY: Guilford.

- Ruff, H.A., & Capozzoli, M.C. (2003). Development of attention and distractibility in the first 4 years of life. *Developmental Psychology, 39*(5), 877-890.
- Ruff, H.A., & Lawson, K.R. (1990). Development of sustained, focused attention in young children during free play. *Developmental Psychobiology, 26*, 85-93.
- Ruff, H.A., & Rothbart, M.K. (1996). *Attention in early development: Themes and variations*. New York: Oxford University Press.
- Saffran, J.R., Aslin, R.N., & Newport, E.L. (1996). Statistical learning by 8-month-old infants, *Science, 274*(5294), 1926-1928.
- Salapatek, P. (1968). Visual scanning of geometric figures by the human newborn. *Journal of Comparative and Physiological Psychology, 66*, 247-258.
- Samuels, C.A. (1985). Attention to eye contact opportunity and facial motion by three-month-old infants. *Journal of Experimental Child Psychology, 40*, 105-114.
- Sasson, N. (2006). The development of face processing in autism. *Journal of Autism and Developmental Disorders, 36*(3), 381-394.
- Scaife, M., & Bruner, J. (1975). The capacity for joint attention in the infant. *Nature, 253*, 265-66
- Schultz, R.T. (2005). Developmental deficits in social perception in autism: The role of the amygdala and fusiform face area. *International Journal of Developmental Neuroscience, 23*, 125-141.
- Senju, A., Csibra, G., & Johnson, M.H. (2008). Understanding the referential nature of looking: Infants' preference for object-directed gaze. *Cognition, 108*, 303-319.
- Senju, A., & Hasegawa, T. (2005). Direct gaze captures visuospatial attention. *Visual Cognition, 12*, 127-144.
- Senju, A., Kikuchi, Y., Hasegawa, T., Tojo, Y., & Osanai, H. (2008). Is anyone looking at me? Direct gaze detection in children with and without autism. *Brain and Cognition, 67*, 127-139.
- Senju, A., Yaguchi, K., Tojo, Y., & Hasegawa, T. (2003). Eye contact does not facilitate detection in children with autism. *Cognition, 89*(1), B43-B51.
- Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24*, 613-620.
- Shah, A., & Frith, U. (1993). Why do autistic individuals show superior performance on the Block Design task? *Journal of Child Psychology and Psychiatry, 34*, 1351-1364.

- Sheinkopf, S.J., Mundy, P., Claussen, A.H., & Willoughby, J. (2004). Infant joint attention skill and preschool behavioral outcomes in at-risk children. *Development & Psychopathology, 16*, 273-291.
- Sloutsky, V.M., & Robinson, C.W. (2008). The role of words and sounds in infants' visual processing: From overshadowing to attentional tuning. *Cognitive Science, 32*, 342-365.
- Sigman, M., & Kasari, C. (1995). Joint attention across contexts in normal and autistic children. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.
- Sigman, M., Kasari, C., Kwon, J., & Yirmiya, N. (1992). Responses to the negative emotions of others by autistic, mentally retarded, and normal children. *Child Development, 63*(4), 796-807.
- Sigman, M., Mundy, P., Sherman, T., & Ungerer. (1986). Social interactions of autistic, mentally retarded and normal children and their caregivers. *Journal of Child Psychology and Psychiatry, 27*(5), 647-656.
- Sigman, M., & Ruskin, E. (1999). Continuity and change in the social competence of children with autism, Down syndrome, and developmental delays. *Monographs of the Society for Research in Child Development, 64*(5, Serial No. 256).
- Singer Harris, N.G., Bellugi, U., & Bates, E. (1997). Contrasting profiles of language development in children with Williams and Down syndromes. *Developmental Neuropsychology, 13*(3), 345-370.
- Slater, A., Morison, V., Town, C., & Rose, D. (1985). Movement perception and identity constancy in the newborn baby. *British Journal of Developmental Psychology, 3*, 211-220.
- Squires, J., Bricker, D., Potter, L. (1997). Revision of a parent-completed developmental screening tool: Ages and Stages Questionnaires. *Journal of Pediatric Psychology, 22*, 313-328.
- Squires, J., Bricker, D., & Twombly, L. (2002). *The Ages and Stages Questionnaires: Socio-Emotional. A parent-completed, child-monitoring system for social-emotional behaviors*. Baltimore: Brookes.
- Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Language and communication in autism. In F.R. Volkmar, P. Rhea, A. Klin, D. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders, Vol. 1: Diagnosis, development, neurobiology, and behavior*, 335-364. Hoboken, NJ: Wiley & Sons.
- Tincoff, R., & Jusczyk, P.W. (1999). Some beginnings of word comprehension in 6-month-olds. *Psychological Science, 10*(2), 172-175.

- Tomasello, T. (1995). Joint attention as social cognition. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development*. Hillsdale, NJ: Erlbaum.
- Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
- Tomasello, M., & Farrar, M.J. (1986). Joint attention and early language. *Child Development*, 57, 1454-1463.
- Tomblin, J.B., Records, N.L., Buckwalter, P., Zhang, X., Smith, E., & O'Brien, M. (1997). Prevalence of specific language impairment in kindergarten children. *Journal of Speech and Hearing Research*, 40, 1245-1260.
- Trainor, L.J. (1996). Infant preferences for infant-directed versus noninfant-directed playsongs and lullabies. *Infant Behavior and Development*, 19, 83-92.
- Trevarthen, C. & Aitken, K.J. (2001). Infant intersubjectivity: Research, theory, and clinical applications. *Journal of Child Psychology and Psychiatry*, 42(1), 3-48.
- Triesch, J., Teuscher, C., Deak, G., & Carlson, E. (2006). Gaze following: Why (not) learn it? *Developmental Science* 9(2), 125-157.
- Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T.B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of the American Academy of Child Psychiatry*, 17(1), 1-13.
- Ulvund, S.E., & Smith, L. (1996). The predictive validity of nonverbal communicative skills in infants with perinatal hazards. *Infant Behavior and Development*, 19, 441-449.
- Valenza, E., Simion, F., Macchi Cassia, V., & Umiltà, C. (1996). Face preference at birth. *Journal of Experimental Psychology: Human Perception and Performance*, 22, 892-903.
- Versele, J., Panneton, R., & Polka, L. (2009). Infant-directed voice and face augments infants' attention to speech in noise. Poster presented at the Society for Research in Child Development, Denver, CO.
- von Hofsten, C., Dahlstrom, E., & Fredriksson, Y. (2005). 12-month-old infants' perception of attention direction in static video images. *Infancy*, 8(3), 217-231.
- von Hofsten, C., Uhlig, H., Adell, M., & Kochukhova, O. (2009). How children with autism look at events. *Research in Autism Spectrum Disorders*, 3, 556-569.
- Vouloumanos, A., & Werker, J.F. (2004). Tuned to the signal: The privileged status of speech for young infants. *Developmental Science*, 7(3), 270-276.

- Vouloumanos, A., & Werker, J.F. (2007). Listening to language at birth: Evidence for a bias speech in neonates. *Developmental Science, 10*(2), 159-171.
- Vygotsky, L.S., Hanfmann, E., & Vakar, G. (1962). *Thought and language*. New York: MIT Press and Wiley.
- Werker, J.F., Cohen, L.B., Lloyd, V.L., Casasola, M., & Stager, C.L. (1998). Acquisition of word-object associations by 14-month-old infants. *Developmental Psychology, 34*(6), 1289-1309.
- Yirmiya, N., Gamliel, I., Pilowsky, T., Feldman, R., Baron-Cohen, S., & Sigman, M. (2006). The development of siblings of children with autism at 4 and 14 months: social engagement, communication and cognition. *Journal of Child Psychology and Psychiatry, 47*(5), 511-523.
- Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience, 23*, 143-152.

Table 1. Assessment Timeline

	Task-based Social Attention Assessment	Questionnaire Measures
Time 1 11-12 months	Distracter Task Face Scanning Task Gaze Following Task	Demographic Information Developmental: <i>ASQ</i> , <i>ASQ:SE</i>
Time 2 14 months	Switch Task Early Social Communication Scales	
Time 3 18-20 months		Language (MCDI) Autism Screening: PEDS, MCHAT

Table 2. Descriptive Summary for Social Attention Measures

		Range		Mean (SD)
		Min	Max	
Distracter Task (n=51)				
Latency (Mean)	Voice	3.61	10.0	8.12 (1.95)
	Silent	4.21	10.0	8.15 (1.75)
Duration (Mean)	Voice	5.71	10.0	8.83 (1.18)
	Silent	2.58	10.0	8.49 (1.61)
Gaze Task (n=50)				
Latency (Mean)	Congruent Voice	3.07	3.23	3.13 (.37)
	Congruent Silent	3.03	3.57	3.14 (.07)
	Incongruent Voice	2.61	5.12	3.17 (.31)
	Incongruent Silent	3.05	4.52	3.18 (.22)
Accuracy (Mean)	Congruent Voice	0	1.00	.98 (.14)
	Congruent Silent	0	1.00	.90 (.27)
	Incongruent Voice	0	.50	.03 (.12)
	Incongruent Silent	0	1.00	.04 (.18)
Face Scanning Task (n=26)				
Duration (Sum)	Mother Voice	3.43	24.91	14.00 (5.73)
	Mother Silent	3.14	22.58	10.51 (5.53)
	Other Voice	.55	29.26	14.39 (7.33)
	Other Silent	2.42	19.79	9.64 (4.55)
Joint Attention ESCS (n=51)				
Initiating Joint Attention (IJA)		0	18	6.12 (4.47)
Responding to Joint Attention (RJA)		.07	.94	.53 (.18)

Table 3. Descriptive Summary for Language Skill Measures

	Range		Mean (SD)
	Min	Max	
Switch Task (n=44)			
Same Trial Looking Time	1.70	45.67	12.16 (10.62)
Switch Trial Looking Time	1.71	27.31	9.66 (6.98)
Switch Ratio	.09	.93	.50 (.24)
MacArthur-Bates Communicative Development Inventory (n=47)			
Productive Vocabulary Size	0	69	37.93 (16.92)
Males	0	64	26.94 (19.29)
Females	11	69	34.86 (16.32)
Grammatical Complexity	1	3	2 (.72)
(Combining words: 1=not yet, 2=sometimes, 3=often)			

Table 4. Descriptive Summary for Developmental Screening Measures

	Range		Mean (SD)
	Min	Max	
Ages and Stages Questionnaire (n=46)			
Communication - <i>cutoff</i> <15 (n=6 clinical)	0	95	37.93 (16.92)
Gross Motor - <i>cutoff</i> <18 (n=6 clinical)	0	60	44.57 (19.82)
Fine Motor - <i>cutoff</i> <29 (n=2 clinical)	10	60	47.83 (10.47)
Problem Solving - <i>cutoff</i> <25 (n=2 clinical)	10	60	47.17 (10.83)
Personal Social - <i>cutoff</i> <20 (n=5 clinical)	0	60	40.44 (15.95)
Ages and Stages Questionnaire: Socio-emotional (n=46)			
Socio-emotional - <i>cutoff</i> >48 (n=3 clinical)	0	95	22.61 (16.08)
Modified Checklist for Autism in Toddlers (n=46)			
Critical Items Failed	0	2	.11 (.38)
(Non-critical) Items Failed	0	2	.26 (.49)

Table 5. Cross-correlation Analysis of Social Attention Measures

		Distracter				Face Scanning		Joint Attention	
		Voice Latency	Silent Latency	Voice Duration	Silent Duration	Voice Duration	Silent Duration	IJA	RJA
Distracter	Voice Latency	-							
	Silent Latency		-						
	Voice Duration	.58**		-					
	Silent Duration		.77**	.38**	-				
Face Scanning	Voice Duration					-			
	Silent Duration					.60**	-		
Joint Attention	IJA							-	
	RJA						-.48*		-

*Significant at the 0.05 level; **Significant at the 0.01 level. (Two-tailed)

Note only significant correlations are reported.

Table 6. Switch Outcome Regressed on Social Attention (Distracter & Joint Attention Tasks)

Switch = Distracter Task	Predictor	β	p	Retained [†]
$F(3,36)=.82, p=.49$ $R^2= .06$ $R^2_{adj}= -.01$	Voice Latency	-.33	.16	-
	Silent Latency	-.00	.99	-
	Voice Duration	.33	.16	-

Switch = Joint Attention Task	Predictor	β	p	Retained [†]
$F(2,37)=3.54, p=.04^*$ $R^2= .16$ $R^2_{adj}= .12$	Initiating Joint Attention	.12	.45	-
	Responding to Joint Attention	.37	.02*	Yes

Overall Model: Switch = Joint Attention	Predictor	β	p
$F(1,38)=6.56, p=.02^*$ $R^2= .15$ $R^2_{adj}= .13$	Responding to Joint Attention	.38	.02*

[†]Predictors were retained with coefficients significant at a liberal 0.10 level. (Two-tailed)
 *Significant at the 0.05 level; **Significant at the 0.01 level. (Two-tailed)

Table 7. MCDI Vocabulary Outcome Regressed on Social Attention (Distracter & Joint Attention Tasks)

Vocabulary = Distracter Task	Predictor	β	p	Retained [†]
$F(3,40)=5.46, p=.003^{**}$ $R^2=.29$ $R^2_{adj}=.24$	Voice Latency	.44	.01**	Yes
	Silent Latency	.31	.03*	Yes
	Voice Duration	-.13	.42	-

Vocabulary = Joint Attention Task	Predictor	β	p	Retained [†]
$F(2,37)=3.54, p=.04^*$ $R^2=.16$ $R^2_{adj}=.12$	Initiating Joint Attention	-.05	.72	-
	Responding to Joint Attention	.36	.02*	Yes

Overall Model: Vocabulary = Distracter + Joint Attention		β	p
$F(3,37)=9.09, p=.001^{**}$ $R^2=.42$ $R^2_{adj}=.38$	Distracter Voice Latency	.44	.001**
	Distracter Silent Latency	.25	.07
	Responding to Joint Attention	.30	.03*

[†]Predictors were retained with coefficients significant at a liberal 0.10 level. (Two-tailed)

*Significant at the 0.05 level; **Significant at the 0.01 level. (Two-tailed)

Table 8. Autistic Symptomatology Outcome Regressed on Social Attention (Distracter and Joint Attention Tasks)

MCHAT = Distracter Task	Predictor	β	p	Retained [†]
Chi-square (3)=3.86, p =.28 Cox & Snoll R^2 = .084 Nagelkerke Snoll R^2 = .119	Voice Latency	1.92	.18	-
	Silent Latency	.71	.44	-
	Voice Duration	.56	.26	-
MCHAT = Joint Attention Task	Predictor	β	p	Retained [†]
Chi-square (2)=1.95, p =.38 Cox & Snoll R^2 = .044 Nagelkerke Snoll R^2 = .064	Initiating Joint Attention	.76	.44	-
	Responding to Joint Attention	1.54	.22	-

[†]Predictors were retained with coefficients significant at a liberal 0.10 level. (Two-tailed)

*Significant at the 0.05 level; **Significant at the 0.01 level. (Two-tailed)

Table 9. Switch, Vocabulary and Autistic Symptomatology Outcomes Regressed on Face Scanning Task Measures

Switch = Face Scanning Task	Predictor	β	p	Retained [†]
$F(2,16)=.33, p=.72$ $R^2=.04$ $R^2_{adj}=-.08$	Face Voice Duration	.27	.44	-
	Face Silent Duration	-.15	.66	-

Vocabulary = Face Scanning Task	Predictor	β	p	Retained [†]
$F(2,20)=1.95, p=.17$ $R^2=.16$ $R^2_{adj}=.08$	Face Voice Duration	.12	.64	-
	Face Silent Duration	-.46	.08	Yes

Overall Model: Vocabulary = Face Scanning	Predictor	β	p
$F(1,21)=3.81, p=.07$ $R^2=.15$ $R^2_{adj}=.11$	Face Silent Duration	-.39	.07

MCHAT = Face Scanning Task	Predictor	β	p	Retained [†]
$\text{Chi-square}(2)=4.67, p=.10$ $\text{Cox \& Snell } R^2=.191$ $\text{Nagelkerke Snell } R^2=.277$	Face Voice Duration	.85	.83	-
	Face Silent Duration	.27	.12	-

[†]Predictors were retained with coefficients significant at a liberal 0.10 level. (Two-tailed)
 *Significant at the 0.05 level; **Significant at the 0.01 level. (Two-tailed)

Table 10. Clinical Summary of Sample by ASQ and MCHAT

Infant	Gender	ASQ, ASQ:SE						MCHAT		
		Communication	Gross Motor	Fine Motor	Problem Solving	Personal Social	Socio-emotional	Number of Risk Domains	MCHAT Critical Item Fails	MCHAT Non-critical Fails
1	F									
2	F	20	5	45	35	5	5	2		
3	M	30	35	40	35	40	50	1	0	1
4	F	60	60	50	55	50	20		0	0
5	F									
6	M	15	20	10	40	10	20	2	0	0
7	M								0	0
8	M	55	60	55	60	60	5		0	0
9	F	60	60	50	60	60	0		0	0
10	F	35	45	40	40	25	15		0	1
11	F	50	50	50	50	35	25		0	0
12	F	50	60	60	50	55	30		0	0
13	M	50	60	60	50	55	30		0	0
14	F	50	60	60	50	55	30		0	0
15	M	50	60	50	40	45	50	1	0	0
16	M	50	50	55	50	30	20		1	1
17	M	45	30	60	55	50	20		0	1
18	M	10	5	50	45	45	25	2	0	0
19	M	10	5	50	45	45	25	2	0	0
20	F	40	60	50	50	25	95	1		
21	F	40	60	45	45	40	30		0	0
22	M	35	60	45	45	40	30		1	1
23	F	15	30	45	35	45	20			
24	F	10	15	50	50	25	10	2	0	0
25	M	35	55	25	45	35	20	1	0	0
26	F	60	60	60	60	60	10		0	0
27	F	45	5	40	60	40	20	1	0	0

Table 10. Clinical Summary of Sample by ASQ and MCHAT, *continued*

Infant	Gender	ASQ, ASQ:SE						MCHAT			
		Communication	Gross Motor	Fine Motor	Problem Solving	Personal Social	Socio-emotional	Number of Risk Domains	MCHAT Critical Item Fails	MCHAT Non-critical Fails	MCHAT Any Fails
28	M	50	45	35	30	40	35		0	0	
29	M	25	45	40	35	15	15	1	0	0	
30	F	50	60	60	60	40	35		0	1	1
31	M	10	60	50	45	25	20	1	0	0	
32	F	50	55	50	60	55	10		0	0	
33	F	30	60	60	45	25	0		0	0	
34	M	40	60	60	55	55	10				
35	M	45	60	45	55	45	25				
36	M	35	60	60	50	55	35		0	1	1
37	F								0	0	
38	F	45	45	50	50	50	10		0	0	
39	F	35	60	55	55	45	20		0	1	1
40	F								0	0	
41	F								2	0	1
42	F	60	60	30	45	45	40		0	0	
43	M	60	50	60	60	55	20		0	1	1
44	F	0	20	40	10	10	30	3	1	0	1
45	F	55	60	50	50	50	25		0	0	
46	F								0	1	1
47	F	30	60	50	55	50	15		0	0	
48	F	35	20	40	20	20	0	1	0	0	
49	F	0	0	30	30	0	15	3	0	0	
50	F	40	45	50	50	60	15		0	2	1
51	F	60	20	50	50	60	20		0	0	
52	F	30	35	40	50		35		0	0	
53	F	40	60	50	60	45	5		0	0	

Table 11. Clinical Summary of ASQ

Infant	Gender	ASQ/ASQ:SE Number of Risk Domains	MCDI Vocabulary [†]	Responding to Joint Attention (RJA)	Switch Ratio (Object/Word Association)	Distracter Task Latency
27	F	1	+2	+3	+1	+1
3 ^A	M	1	+1	-2	-1	-1
31	M	1	+1	-1	-2	+1
44 ^B	F	3	+1	-1	-2	+1
15	M	1	-1	+1	-1	+1
24	F	2	-1	-1	-2	-1
25	M	1	-1		-1	+1
29	M	1	-1	-2	-2	-2
48	F	1	-1	+2	+2	-1
49	F	3	-1	+1	+1	-1
6	M	2	-2	-2	-2	+1
18	M	2	-2	-3	-1	-1
19	M	2	-2	+1	-1	-2
2	F	2		-1	+1	-2
20	F	1		+1		+1

[†]Note that the table is organized according to CDI vocabulary size, with infants receiving a 2 falling within the 2nd standard deviation above them mean, and infants with a -1 falling within the first standard deviation below the mean.

^AThe same infant as indicated by ^A in Table 12; ^BThe same infant as indicated by ^B in Table 12; all other infants are unique.

Table 12. Clinical Summary of MCHAT

Infant	Gender	MCHAT Failed Items	MCDI Vocabulary	Responding to Joint Attention (RJA)	Switch Ratio (Object/Word Association)	Distracter Task Latency
10	F	1	+3	+1	+1	+1
17	M	1	+2	+1	-1	-1
41	F	2c*	+2	+1	-1	+1
43	M	1	+2	+2		+1
3 ^A	M	1	+1	-2	-1	-1
16	M	1, 1c	+1	+2	+2	-1
22	M	1, 1c	+1	+1	+1	+1
30	F	1	+1		+1	+1
44 ^B	F	1c	+1	-1	-2	+1
46	F	1	+1	-1	-2	+1
39	F	1	-1	+1	+2	+1
49	F	2	-1	+1	+1	-1
36	M	1	-2	-1		-1

[†]Note that the table is organized according to CDI vocabulary size, with infants receiving a 2 falling within the 2nd standard deviation above them mean, and infants with a -1 falling within the first standard deviation below the mean.

^AThe same infant as indicated by ^A in Table 11; ^BThe same infant as indicated by ^B in Table 11; all other infants are unique.

*A positive screen is indicated on the M-CHAT when 2 or more critical items are failed, or when any 3 items are failed.

Appendix A

GREETINGS FROM THE INFANT PERCEPTION LABORATORY!!!



DEPARTMENT OF PSYCHOLOGY VIRGINIA TECH

Soon after infants are born and over the first postnatal year, infants pay increasing attention to social information, such as faces and voices. Such social attention is thought to play an important role in language learning and social-emotional development. We are particularly interested in studying how infants pay attention to social information (especially eyes, faces, and voices), because this helps us to understand how infants begin to learn, speak, and develop relationships with those around them.

If you have the time and interest, **we would love to have you and your infant participate in this study!** Your participation would involve two visits to the Infant Perception Lab, located on the 3rd floor of Williams Hall on the campus of Virginia Tech (a map is enclosed for your convenience), and completion of brief questionnaires. *We are interested in infants between 10-12 months of age*, who can also participate when they are 14 months of age. We will also have mothers complete some questionnaires when infants are between 18-20 months of age (this can be done at home). We will schedule a 1-hour appointment with you at your convenience (nights and weekends are available if you prefer). If there are older children in the family and you would like to bring them along, we offer free childcare. We also have convenient parking next to our building on campus. If you are interested in scheduling an appointment, or would like to find out more about our work, please feel free to call us at **(540) 231-3972**, or visit our website at **http://www.psyc.vt.edu/infant_speech/pages/Homepage.htm**.

Sincerely,

Robin Panneton, Ph.D.
Associate Professor
Infant Perception Lab Director
panneton@vt.edu

Angela Scarpa, Ph.D.
Associate Professor
Autism Clinic Director
ascarpa@vt.edu

Brenda Salley, M.A.
Graduate Researcher
bsalley@vt.edu



Infant Attention and Language Development Study

Virginia Tech, Department of Psychology
Ages 10-12 months

Dr. Robin Panneton (Infant Perception Laboratory) and Dr. Angela Scarpa (The Autism Clinic), along with their coworkers at Virginia Tech want to learn more about how social attention is related to early language development.

WHAT DOES THE STUDY INVOLVE?

A variety of tasks for your infant that involve attention to faces and voices, and some questionnaires for mom.

WHO CAN PARTICIPATE?

ALL full-term infants are welcome to participate! The first visit to our lab will take place when infants are 10-12 months of age, and we will invite the same infants back between 14 – 15 months of age. We will also have mothers complete some questionnaires when the infants are between 18 – 20 months of age (you can do this at home).

WHO DO I CONTACT?

If you would like to learn more about this study, please contact us at: **(540) 231-3972**, or by email at panneton@vt.edu or ascarpa@vt.edu.



Appendix C

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subject

Title:

Infants' Social Attention and Language Development, Part 1

Principle Investigators:

Dr. Robin Panneton
Dr. Angela Scarpa
Ms. Brenda Salley

I. Purpose of this Research/Project

The purpose of this project is to investigate infants' attention to social information and how this relates to their language and social development.

During the first visit, we will measure infants' attention to a face during distraction, gaze following, and attention to a moving, talking face. We will measure visual attention as an indicator of your infant's attention.

II. Procedures

Your infant will be tested for approximately 30 minutes during the first visit, provided that he/she is quiet and awake. The baby will be held by the mother in her lap, facing a black panel. The baby will view a video screen on which an image or movie will appear. First, an image of an adult female face will be presented, followed by a distracting image. Second, an image of an adult female face and an object will be presented, with the female looking towards or away from the object. Third, a moving, talking video of an unfamiliar adult female and a familiar caregiver will be presented. We will present several trials of each task to measure the

infant's visual attention. Each infant will be videotaped during his/her session for subsequent coding of their visual attention. If for any reason, your infant cries or falls asleep, testing will be discontinued.

III. Risks

There are no apparent risks to your infant or to yourself for participation in this study. Sound levels for all auditory stimuli will be verified prior to the testing of each infant.

IV. Benefits

Although there are no direct benefits to the participants in this study, all parents will receive a summary report (following their participation in the Time 3 data collection) which will present the following information: a) your own infant's measures on each task/questionnaire, b) the aggregate measures (across all infants) on each task/questionnaire, and c) a short paragraph explaining how each measure can be interpreted. Parents will also receive a certificate of appreciation and the results of the study will contribute to a broader body of research on infant attention and language learning.

V. Extent of Anonymity and Confidentiality

All of the information gathered in this study will be kept confidential and the results will not be released without parental consent. However, the results of this project may be used for scientific

and/or educational purposes, presented at scientific meetings, and/or published in a scientific journal. You will be sent a summary of the work when this project is completed.

VI. Compensation

There is no compensation to be earned from participation in this project.

VII. Freedom to Withdraw

You have the right to terminate your infant's involvement at any point in time and for any reason should you chose to do so.

VIII. Participant's Responsibilities

I voluntarily agree to have my infant participate in this study.

IX. Participant's Permission

I have been given an opportunity to ask further questions about this procedure and I understand that I have the right to end this session for any reason if I so choose. This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech. If I have any questions regarding this research and its conduct, I should contact one of the persons named below. Given these procedures and conditions, I give my permission to Dr. Panneton, Dr. Scarpa and their co-workers to test my son/daughter.

Dr. Robin Panneton, Principle Investigator	231-5938
Dr. Angela Scarpa, Principle Investigator	231-2615
Ms. Brenda Salley	231-3972
Dr. David Harrison, Chair, Human Subjects Committee	231-4422
David M. Moore, DVM, Assistant Vice Provost for Research Compliance	231-4991

Signature of Parent: _____

Date: _____

Infant's Name: _____

I would like to be contacted by phone regarding future studies: YES NO

Appendix D



Infant # _____

Study # _____

Infant Perception Laboratory
Family Information Sheet
(All information is strictly confidential)

Infant's Birthdate: _____ Mother's Age: _____ Father's Age: _____

Mother's Occupation: _____ Father's Occupation: _____

Mother's Education: High School Partial College College Master's Ph.D.

Father's Education: High School Partial College College Master's Ph.D.

Annual Family Income: \$10,000-\$20,000 \$20,000-\$35,000 \$35,000-\$50,000 \$50,000-\$65,000
\$65,000-\$80,000 \$80,000-\$95,000 > \$95,000

Marital Status: Married Separated Divorced Unmarried/Single Widowed

Mother's Race: White/Caucasian African American Hispanic Asian Native American

Other _____

Father's Race: White/Caucasian African American Hispanic Asian Native American

Other _____

Was your infant: Full Term (38-42 weeks) Premature (≤ 37 weeks) Postmature (>42 weeks)

Infant's Birthweight: _____ lbs _____ ozs

Has your infant had any medical problems? Yes No Please List: _____

Please list the birth date and gender of any older children:

_____ M F _____ M F

_____ M F _____ M F

Has any child in the family been suspected of a developmental delay/diagnosis? Yes No

If yes, please describe: _____

What is the primary language spoken in your home? _____

Please list any other languages that are spoken in your home: _____

Appendix E

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants in Research Projects Involving Human Subject

Title:

Infants' Social Attention and Language Development, Part 2 and Part 3

Principle Investigators:

Dr. Robin Panneton
Dr. Angela Scarpa
Ms. Brenda Salley

I. Purpose of this Research/Project

The purpose of this project is to investigate infants' attention to social information and how this relates to their language and social development. During this second visit we will measure infants' association of a sound and an object presented together. We will also measure infants' nonverbal social communication skills, and complete a brief developmental measure. Following this visit, when your infant is between 18- and 20-months old, we will mail brief questionnaires (to be completed by a primary caregiver) which will measure infants' language and social development.

II. Procedures

Your infant will be tested for approximately 45 minutes during this visit, provided that he/she is quiet and awake. The baby will be held by the parent in her/his lap, facing a black panel. First, the baby will view a video screen on which object and sound pairs will be presented. After several trials, the sound and object will be switched, and the infant's looking time will be measured. Second, the infant will participate in a series of activities with a female experimenter, designed to

measure the infant's nonverbal social communication behaviors. The infant will be presented with several toys (e.g., a wind-up toy, a picture book, etc.) and will be engaged in play with the experimenter. Third, the caregiver and infant will participate in naturalistic play for approximately 5 minutes, in order to measure the infant's nonverbal social interaction behaviors with a caregiver. Last, an experimenter will administer a brief task designed to measure the infant's cognitive development. The infant will be presented with a series of toys during this interaction. Throughout the session, each baby will be videotaped during his/her session for subsequent coding of their visual attention and behavior. If for any reason, your infant cries or falls asleep, testing will be discontinued.

Approximately 4 months after your visit, you will receive a packet of three short questionnaires about your infant's language and social development. This should be completed by a primary caregiver, and returned by mail (self-address, stamped envelope provided).

III. Risks

There are no apparent risks to your infant or to yourself for participation in this study. Sound levels for all auditory stimuli will be verified prior to the testing of each infant.

IV. Benefits

Although there are no direct benefits to the participants in this study, all parents will receive a summary report (following

their participation in the Time 3 data following information: a) your own infant's measures on each task/questionnaire, b) the aggregate measures (across all infants) on each task/questionnaire, and c) a short paragraph explaining how each measure can be interpreted. Parents will also receive a certificate of appreciation and the results of the study will contribute to a broader body of research on infant attention and language learning.

V. Extent of Anonymity and Confidentiality

All of the information gathered in this study will be kept confidential and the results will not be released without parental consent. However, the results of this project may be used for scientific

collection) which will present the and/or educational purposes, presented at scientific meetings, and/or published in a scientific journal. You will be sent a summary of the work when this project is completed.

VI. Compensation

There is no compensation to be earned from participation in this project.

VII. Freedom to Withdraw

You have the right to terminate your infant's involvement at any point in time and for any reason should you chose to do so.

VIII. Participant's Responsibilities

I voluntarily agree to have my infant participate in this study.

IX. Participant's Permission

I have been given an opportunity to ask further questions about this procedure and I understand that I have the right to end this session for any reason if I so choose. This project has been approved by the Human Subjects Committee of the Department of Psychology and the Institutional Review Board of Virginia Tech. If I have any questions regarding this research and its conduct, I should contact one of the persons named below. Given these procedures and conditions, I give my permission to Dr. Panneton, Dr. Scarpa and their co-workers to test my son/daughter.

Dr. Robin Panneton, Principle Investigator	231-5938
Dr. Angela Scarpa, Principle Investigator	231-2615
Ms. Brenda Salley	231-3972
Dr. David Harrison, Chair, Human Subjects Committee	231-4422
David M. Moore, DVM, Assistant Vice Provost for Research Compliance	231-4991

Signature of Parent: _____

Date: _____

Infant's Name: _____

Appendix F

INFANT PERCEPTION LABORATORY



Department of Psychology
Virginia Tech

Dear (name of mother),

Thank you for taking time to participate in our study! Enclosed you will find the three brief questionnaires that you consented to fill out during your visit to the Infant Perception Lab a few months ago. These questionnaires will help us understand your infant's language and social development. **Please complete each form and return by mail in the enclosed self-addressed, stamped envelope.** All of the information gathered in these forms will be kept confidential and the results will not be released without your consent. However, anonymous summaries of the results may be used for scientific and/or educational purposes, presented at scientific meetings, and/or published in a scientific journal.

If you any questions about completing the questionnaires, please feel free to contact us:

Dr. Robin Panneton at 231-5938 (panneton@vt.edu)

Dr. Angela Scarpa at 231-2615 (ascarpa@vt.edu)

Ms. Brenda Salley at 231-3972 (bsalley@vt.edu)

After you complete this final portion of the study, you will receive a summary report which will present the following information: a) your own infant's measures on each task/questionnaire, b) the aggregate measures (across all infants) on each task/questionnaire, and c) a short paragraph explaining how each measure can be interpreted.

Thank you again for your time! The results of this study will contribute to a broader body of research on infant attention and language learning!

Sincerely,

Robin Panneton, Ph.D.
Associate Professor
panneton@vt.edu

Angela Scarpa, Ph.D.
Associate Professor
ascarpa@vt.edu

Brenda Salley, M.A.
Graduate Researcher
bsalley@vt.edu

Appendix G

ANOVA Analyses on Distracter Task

There were no differences as a function of gender in latency [$F(2, 48)=1.12, p=.33$] or for duration [$F(2, 48)=.07, p=.94$] during silent or voiced trials.

To determine whether infants were significantly slower to disengage from the female speaker as a function of silent versus voice conditions, mean latencies for both trial types were calculated by dividing the sum of latencies during each presentation by the number of trials presented. A mixed 2 x 2 analysis of variance (ANOVA) was performed on infants' mean latencies, with speech condition (silent, voice) as the within-subjects factor and the between-subjects factor as order (silent first, voice first). There was no significant main effect of speech condition [$F(1, 49) = .06, p=.81$] or order [$F(1,49) = 2.05, p=.16$], and no significant condition x order interaction [$F(1,49)=.42, p=.52$].

To determine whether infants differed in their duration of looking to the face as a function of silent versus voice conditions, mean duration was calculated by dividing the total duration for each trial type by the number of trials presented. A mixed 2 x 2 ANOVA was computed on duration of looking, with condition (silent, voice) as the within-subjects factor and the between-subjects factor as order (silent first, voice first). There was no significant main effect of condition [$F(1, 49) = 2.17, p=.15$]. Nor was there a main effects of order [$F(1,49) = 4.52, p=.04$] and the condition x order interaction was not statistically significant [$F(1,49) = .42, p=.52$].

Appendix H

ANOVA Analyses on Face Scanning Task

There were no differences as a function of gender in look duration as a function of speaker (familiar, unfamiliar), or voice condition (silent, speech; all p 's > .05).

To determine whether there were order effects, given the reduced sample size, two ANOVA's were performed. A 2 x 2 mixed ANOVA was performed with speaker condition (mother, other) as the within-subjects factor and speaker order (mother first, other first) as the between-subjects factor. There were no main effects of speaker condition [$F(1,22)=.06$, $p=.80$] or speaker order [$F(1,22)=1.41$, $p=.25$] and no significant interactions. A second 2 x 2 mixed ANOVA was performed with voice condition (silent, speech) as the within-subjects factor and voice order (silent first, speech first) as the between-subjects factor. There was a significant main effect of voice condition [$F(1,22)=20.14$, $p<.001$, partial $\eta^2=.48$] with infants looking longer during speech ($M=28.31$, $SD=10.49$) than silent trials ($M=20.21$, $SD=9.13$). There was no main effect of voice order [$F(1,22)=.01$, $p=.92$].

To determine whether infants looked significantly longer as a function of both conditions (mother versus other; silent versus voiced), durations of looking to the face for each of the four trial types were calculated by summing across the two trials for each combination (mother silent, mother speech, other silent, other speech). A 2 x 2 repeated measures ANOVA was performed with speaker condition (mother, other) and voice condition (silent, speech) as the within-subjects factors. There was a significant main effect of speech condition [$F(1,23)=21.01$, $p<.001$, partial $\eta^2=.48$], with infants looking longer during the speech trials ($M=28.31$, $SD=10.49$) than during the silent trials ($M=20.21$, $SD=9.13$). There was no main effect of speaker [$F(1,23)=.08$, $p=.78$] and no interaction of the two conditions.

Appendix I

ANOVA Analyses on Joint Attention Task

There were no differences as a function of gender in responding to joint attention (RJA) or initiating joint attention (IJA) [$F(2,46)=.048, p=.95$].

Appendix J

ANOVA Analyses on Switch Task

There were no differences in looking times to same and switch trials as a function of gender [$F(2,40)=2.41$, $p=.10$].

To analyze whether infants' as a group were able to learn the sound-object associations (and discriminate between same and switch trials), looking times to same and switch test trials were analyzed. A 2 x 2 mixed ANOVA with trial (same, switch) as the within subjects factor and test order as the between subjects factor (switch first, same first) revealed no significant main effect of trial [$F(1,40)=.87$, $p=.36$], with looking mean looking time to the same trial ($M=12.11$, $SD=10.74$) not differing significantly from mean looking time to the switch trial ($M=9.83$, $SD=6.97$). This indicates that as a group, infants did not have longer looking times to the novel (switch) pairing, and thus did not learn the word-object associations. There was no main effect of trial order [$F(1,40)=.16$, $p=.70$] and no significant interaction.

Analysis of novelty scores [(looking time for switch trials) / (switch trials + same trials)] revealed that infants did not display a lack of preference, that is, novelty scores were not equal to .5 (only two infants had a novelty score of .5) which would be expected if infants looked equally at same and switch trials. Instead, one-sample t-tests revealed that the group of infants with a novelty score $<.5$ displayed a significant looking preference for the familiar ("same" word-object pairing) trial [$t(20)=-7.55$, $p<.001$]. Similarly, infants with a novelty score $>.5$ displayed a preference for the novel ("switch" pairing) trial [$t(21)=6.87$, $p<.001$]. For all regression analyses, infants' switch ratio scores were entered.

Appendix K

ANOVA Analyses on MCDI

There were no differences as a function of gender in vocabulary size [$F(2,44)=1.17, p=.32$], with productive vocabulary size for females ($M=34.86, SD=16.32$) not differing from that of males ($M=26.94, SD=19.29$), and grammatical complexity for females ($M=2.1, SD=0.72$) not differing from males ($M=1.83, SD=0.70$).