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SOCIAL SPECTRUM: UNDERSTANDING THE INCREMENTAL DEVELOPMENT OF SOCIAL SKILLS IN INFANTS AT-RISK FOR AUTISM

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Dedication

To my parents,

for their endless love, support, and encouragement.

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***SOCIAL SPECTRUM*: UNDERSTANDING THE INCREMENTAL DEVELOPMENT OF SOCIAL SKILLS IN INFANTS AT-RISK FOR AUTISM**

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Autism Spectrum Disorder (ASD) is a neurological developmental disorder, characterized by difficulties with social communication and interactions. Social functioning varies within ASD as well as in neurotypical development (known as the *Social Spectrum*). This dissertation investigated the origins and incremental development of four social skills, and in particular, how social development differs across the *Social Spectrum*. This project assesses: 1) how four specific social skills develop independently and in relation to each other over time, and 2) the consequences of early social impairment on the development of these skills. Utilizing a longitudinal prospective study design, 40 infants at high- and low-risk of ASD (i.e., with or without a sibling with ASD) were evaluated at 12, 15, and 18 months, during a period when social skills are emerging and social impairment becomes apparent. First, individual skill development was evaluated over time and across the *Social Spectrum* using linear-mixed effects models. Results indicated that from 12 to 18 months: 1) certain joint attention skills are increasing over time, 2) social orienting skills varied across the *Social Spectrum*, and 3) development of certain response to distress reactions varied over time across the *Social Spectrum*. Secondly, the development of skills in relation to each other at each visit and over time was assessed, as well as how these interrelations differed based on the *Social Spectrum*. Key findings suggested that: 1) greater responding to joint attention is related to faster helping behaviors at and across 12 to 18 months, and 2) interrelations of the *Social Spectrum*, social orienting, and initiating joint attention at 15 months were related to helping at 18 months, such that greater social impairment and reduced initiating joint attention skills at 15 months were related to reduced social orienting at 15 months which was associated with slower latencies to offer help at 18 months. Investigating the incremental progression of social development and the diversion from development helps provides the target areas crucial for the early identification of and interventions for ASD.

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Introduction

IMPORTANCE OF SOCIAL DEVELOPMENT

Humans are innately social from birth. The development of social communication and interaction skills begins in infancy (Legerstee, Haley, & Bornstein, 2013). Social communication and interaction skills can, in turn, impact social relationships (Ogelman & Seven, 2012) and influence the development of morality (Turiel, 1983), cognitive abilities (Parlakian, 2003),and leadership skills (Zaccaro, 2002). Those who struggle with social impairment (i.e., deficits in social communication and interaction skills), such as children with Autism Spectrum Disorder (ASD; American Psychological Association, 2013), experience a much lower quality of life across their lifespan because of this impairment, than those without such social deficits (van Heijst & Geurts, 2015).

AUTISM SPECTRUM DISORDER

Public health significance

One in 68 children are diagnosed with ASD, a neurological developmental disorder associated with social, emotional, communication, and behavioral challenges (Center for Disease Control and Prevention [CDC], 2016a; American Psychological Association, 2013). In the last 10 years, the prevalence of ASD has increased from one in 150 to one in 68 children (CDC, 2016a). Infants who have a sibling with ASD (high-risk, HR) are at increased risk (2-18%) of being diagnosed with ASD themselves (Ozonoff et al., 2011; Hallmayer, Cleveland & Phillips, 2011)[1]. Even in the absence of an ASD diagnosis, an additional 28% of HR infants are likely to develop subclinical characteristics of ASD, known as the broader autism phenotype (BAP; Ozonoff et al., 2014). There is a significant

[1] See Appendix Table 1 for a list of common acronyms related to the ASD literature and their definitions.

economic burden of ASD, as total estimated costs for children with ASD are between $11.5-60.9 billion per year (CDC, 2016a). Despite research suggesting ASD can be diagnosed reliably at age two (Lord et al., 2006; Kleinman, Ventola & Pandey, 2008), children with ASD are often not diagnosed until after age four (CDC, 2016a). Yet parents of children with ASD report, and research has confirmed, that developmental problems are evident by children's first birthdays (Chawarska, Macari, & Shic, 2013; Goodman, Lamping, Ploubidis, 2010; Osterling, Dawson, & Munson, 2002; Ozonoff, Young, & Steinfeld, 2009).

Prodromal social impairment

Social impairment, including deficits in attending to and responding to social partners, is a cardinal feature of ASD. Prodromal symptoms of ASD (i.e., symptoms that are present prior to receiving a diagnosis) include: 1) limited spontaneous attention to people and their activities at six months (Chawarska, Macari, & Shic, 2013), 2) reduced orienting to name (social orienting) at 12 months (Osterling, Dawson, & Munson, 2002), 3) limited responsiveness to social cues meant to coordinate attention to share experiences (responding to joint attention) at 14 months (Goodman, Lamping, & Ploubidis, 2010; Sullivan et al., 2007), and 4) reduced attention and response to the distress of others at 18 months (Hutman et al., 2010). Research on ASD has focused on when specific skills deficits can be identified (i.e., red flags for ASD), yet research has traditionally analyzed these skills separately.

SOCIAL SPECTRUM

There is substantial heterogeneity in social functioning among children diagnosed with ASD. Moreover, heterogeneity in social functioning extends beyond that of the clinically significant social impairment observed in ASD. The broader autism phenotype

(BAP; Piven et al., 1997; Wassink et al., 2004; Ozonoff et al., 2014) specifically refers to those HR infants who are at increased risk of being diagnosed with ASD (Ozonoff et al., 2011; Hallmayer, Cleveland & Phillips, 2011) or of developing subclinical ASD characteristics (Ozonoff et al., 2014). There is also extensive heterogeneity in social functioning within and across typical development (i.e. little to no social impairment, TD) and subclinical social impairment (as observed in BAP). This variability in social functioning in children with ASD has been often overlooked in previous research. Historically, research has broadly compared children with and without ASD (e.g., Dawson et al. [2004] compared children with ASD, developmental-delayed children, and TD children) or HR and LR infants (e.g., Cassel el al. [2007] compared HR and LR infants) or both (e.g., Cornew et al. [2012] compared HR-ASD, HR-nonASD, and LR-TD). It is the appearance of these subclinical characteristics that enables researchers to conduct prospective longitudinal studies and make group comparisons between the HR and LR infants or between groups based on their diagnostic outcome (e.g., ASD vs. HR-nonASD vs. LR-nonASD).

Some researchers have focused on the distribution of children's social outcomes. Constantino et al. (2000) examined the distribution of children's reciprocal social behavior across children from clinical and non-clinical populations, as well as across three pervasive developmental disorders (PDD; American Psychological Association, 2000), which under current diagnostic standards (American Psychological Association, 2015) would likely qualify for a diagnosis of ASD. The authors found that reciprocal social behavior scores were continuously distributed across all of the groups and emphasized the clinical importance of examining these behaviors that were subthreshold with regard to PDD diagnosis, but nonetheless significant. Additionally, Constantino et al. (2006) examined the distributions of social impairment, as measured by the Social Responsiveness Scale

(SRS; Constantino & Gruber, 2012), in children with a diagnosis of ASD and their siblings. Three groups were examined: families with more than one sibling with ASD and/or PDD, families with one sibling with ASD and/or PDD, and families with children with non-ASD related psychopathology. The authors found social responsiveness scores to be continuously distributed across the children with ASD and the sibling groups, suggesting that there is variability across all children regardless of any diagnostic classifications.

Yoder, Stone, Walden, & Malesa (2009) also emphasize the importance of examining social impairment outcomes within the HR population as a continuous variable. The authors examined how early social behaviors were related to later social impairment. Social impairment was examined as an outcome variable in a unique way by comparing HR infants' responses (collected for the study) to TD-referenced mean responses (based on literature review). Social outcomes (responding to joint attention [RJA] and Social Behavior Checklist at 34 months) were grouped into three levels: comparable to the TD-referenced mean and +/- one standard deviation from the TD-referenced mean. Yoder et al. (2009) examined the growth of RJA and weighted triadic communication from 15 to 30 months, as it varied across these social outcomes at 34 months. The authors found that initial RJA and the weighted triadic communication growth rate were predictive of the social outcomes, supporting the need for examining social impairment as a continuous measure. In fact, this study demonstrates that a portion of the HR infants had scores equivalent to or better than the TD-referenced mean. Importantly, this study examined social impairment based on only three levels of social outcome (scoring within one standard deviation of the TD-referenced mean, or scoring one standard deviation above or below the TD-referenced mean). As such, this study did not examine the full continuum of social functioning within the HR infants as well. Furthermore, by utilizing the TD-referenced group's mean response, rather than the full range of scores, this study did not consider the full continuum of social outcomes within the TD-referenced sample.

Paulus and Rosal-Grifoll (2017) also speak to this variability in social outcomes and emphasize the importance of examining prosocial behaviors, not only between diagnostic groups, but by severity of symptoms (i.e., the severity level identified with the ASD diagnosis). The authors found that examining differences in symptom severity can provide important information about the different behavioral responses across these children.

Despite evidence of the distribution of social impairment in the ASD and HR populations, researchers tend to focus on differences in dichotic outcome (e.g. ASD vs. non-ASD). Furthermore, when researchers attempt to examine the broader distribution of social impairment, they often only do so at outcome and/or within a narrow range of the overall distribution of social functioning. *Social Spectrum* was coined by Dowd et al. (2018) and refers to "the full spectrum of social functioning from typical development to subclinical impairment (e.g., BAP) to clinically severe impairment (e.g., ASD)" (p.66).

SOCIAL DEVELOPMENT BY SKILL

Social orienting

Typically-developing (TD) infants will try to orient towards their parent at two months of age; by six months of age, most TD infants respond (i.e., orient towards) a person calling their name (CDC, 2016b). Arguably one of the first-emerging and fundamental social deficits in ASD is failing to respond to social stimuli (Dawson et al., 1998; Dawson et al., 2004; Mundy & Neal, 2001). The term *social orienting impairment* was coined in recognition of children with ASD's failures to spontaneously orient toward social cues (Dawson et al., 1998). Retrospective studies have shown that infants later diagnosed with

ASD are less likely to orient towards people calling their names aloud at 8-10 months of age than their TD peers (Werner, Dawson, Osterling, & Dinno, 2000), and at 12 months, infants later diagnosed with ASD looked less toward people and oriented less to their name than both TD infants and infants with intellectual disability (Osterling, Dawson, & Munson, 2002). Importantly, the deficits in orienting to stimuli in children with ASD are likely not the result of general attentional deficits, as Dawson et al. (1998) found that young children with ASD oriented less to social stimuli (i.e., humming, calling the child's name, snapping, and patting leg) than TD children and children diagnosed with Down's Syndrome children, while no group differences were found for attending toward nonsocial stimuli (i.e., beeping, ringing phone, whistle, car horn).

Additionally, a prospective study of HR and low-risk (i.e., low familial risk of ASD; LR) infants calculated the specificity (0.89) and sensitivity (0.50) of failing to respond to name at 12 months to a clinical best estimate diagnosis of ASD at 24 months (Nagid et al., 2007). Interestingly, Nagid et al. (2007) hypothesized that failing to respond to name during infancy could be indicative of BAP because all LR infants responded to their names at 12 months while some HR infants, who did not receive a diagnosis at 24 months, did not respond. These findings suggest that, while failing to respond to name is highly suggestive of ASD diagnostic outcome, not all children later diagnosed with ASD will fail to respond to their names at 12 months and some children who fail to respond to their name will not receive an ASD diagnosis.

Prosocial behavior

Prosocial behavior broadly refers to all behaviors intended to benefit another (Eisenberg, 1986). Extensive research has attempted to understand the theoretical underpinnings and mechanisms of prosocial behavior (see Dunfield, 2014; Brownell, 2013;

Radke-Yarrow et al., 1992 for review). While some researchers have examined prosocial behavior broadly, others have focused on specific behaviors (e.g., helping, sharing, comforting, and other empathy-related prosocial responses). Variability in such behaviors across individuals and ages warrants focusing on these behaviors separately, and research has demonstrated that these different subtypes are unique and distinct from each other (Dunfield & Kuhlmeier, 2013; Paulus et al. 2013).

Instrumental helping (hereon referred to as helping) refers to providing assistance to people who are unable to achieve their goal due to an instrumental problem (out-of-reach object, physical obstacle, wrong result, or wrong means; Warneken & Tomasello, 2006). Helping others is a complex social skill that requires: recognizing that someone needs help, understanding how to assist that person in achieving his/her goal, and being motivated to help (Dowd, 2011; also see Dunfield, 2014; Warneken & Tomaselo, 2006; Liebal, Colombi, Rogers, Warneken, & Tomasello, 2008).

Extensive research has shown that even very young TD infants understand a great deal about helping situations. Recognizing the goals of others is a prerequisite ability to identifying when others are in need of help in achieving their goals. By six months of age, infants can recognize reaching for an object as a goal-directed action to obtain a specific object (Woodward, 1998). By seven months of age, infants can recognize a variety of gestures, including reaching, pointing, and grasping, as goal-directed actions (Hamlin, Hallinan, & Woodward, 2008). By nine months, infants recognize that goals are associated specifically with the individual who performed the goal-directed actions and that these goals do not necessarily generalize to others (Buresh & Woodward, 2007).

In order to help others, one must recognize another's intended goals before they have been accomplished, and understand the appropriate means necessary to achieve these goals. Hamlin, Hallinan, and Woodward (2008) demonstrated that infants are capable of doing all of the above. In their experiment, 7-month-olds observed an experimenter attempting but failing to obtain an object. Rather than imitating the experimenter's failed attempts, the infants were able to acquire the experimenter's desired object, which suggests that 7-month-olds have the cognitive abilities to recognize someone's intended goal and to understand how to achieve this goal. Furthermore, Koster, Ohmer, Nguyen, & Kartner (2016) found that 9- to 18-month-olds were able to understand when others were in need of help (via eye tracking) and that this understanding was not related to their own prosocial behaviors; this suggests that infants understood others' needs prior to offering help themselves.

By 14 months of age, infants are already capable of helping by offering another the desired object that is out-of-reach (Warneken & Tomasello, 2007). By 18 months of age, infants are capable of providing even more complex forms of helping to others who are physically prevented from achieving their goal or who are failing because they are using the wrong means (Warneken & Tomasello, 2006). These findings suggest that helping behaviors are apparent around 14 months of age and rapidly increase in their complexity over a short time. Dowd (2011) suggests that 14-month-old failures to help may result from different reasons. Lacking the cognitive abilities to understand the situation or misunderstanding how to correctly help another person is one possible explanation. Alternatively, these failures could be the result of a lack of motivation to help "(e.g., lacking initiative or reacting egocentrically rather than altruistically)" (Dowd, 2011, p.66).

Very little research to date has examined helping behaviors in children with ASD, and therefore it is unclear to what extent and at which level (recognition, understanding, or motivation) children with ASD may struggle to help others. In the few studies that have examined helping behaviors in children with ASD, there were mixed findings with children of different ages. Liebal et al. (2008) found that 2- to 5-year-olds with ASD did not differ from their peers with general developmental delay in their rate of helping. Paulus and Rosal-Grifoll (2017) found that 3- to 6-year-old children with ASD, in comparison to their TD peers, were actually more inclined to show spontaneous helping, when the person in need was absent (i.e., helping when person drops pen while leaving the room). Helping in the absence of the person in need may be the result of different motivations, such as preferring to obtain the object for themselves rather than to help another. In contrast, Sigman & Ruskin (1999) found that 10- to 13-year-old children with ASD helped less frequently than their peers with Down's Syndrome. It is unclear at what age infants with social impairment first start to differ from their peers in either their understanding or motivation to help.

Response to distress

Empathy has been defined in many ways, varying based on different theoretical underpinnings (Eisenberg & Strayer, 1987; see Zahn-Waxler & Radke-Yarrow, 1990, for review). Additional variations in construct definitions were apparent when examining the early emergence and development of empathy (see Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992; Davidov, Zahn-Waxler, Roth-Hanania, & Knafo, 2013, for review). For instance, gaze (attending to another distress) is a typical response for 8-month-old infants observing another in distress (Liddle, Bradly, & McGrath, 2015). While this attention is suggestive of some understanding and possibly concern for the victim, this definition (attention to the victim) is not what most people would consider empathy.

One common conceptualization of empathy consists of two dependent components: cognitive empathy and affective empathy (Knafo et al., 2009). *Cognitive empathy* refers to one's ability to comprehend another person's distress, which is achieved through understanding the situation and recognizing the other person's feelings. In young children, cognitive empathy appears as inquisitiveness and is seen in children's active attempts to understand another's problem (Knafo, Zahn-Waxler, Van Hulle, Robinson, & Rhee, 2008, p.737). *Affective empathy* refers to experiencing the other person's emotional state and is evident in young children through their emotional displays and vocalizations of concern for another (Knafo et al., 2008, p.737).

Cognitive and affective empathy are highly correlated and, thus, considered dependent components of a single construct of empathy (see Knafo et al., 2009). In fact, both cognitive and affective empathy are associated with similar activation in overlapping brain regions (Singer, 2006). Interestingly however, cognitive and affective empathy appear to have different developmental trajectories, with cognitive empathy developing later than affective empathy (Singer, 2006). Therefore, it is important to examine the development of both components independently and, perhaps, to designate different age-appropriate developmental milestones for each element.

Previous research suggests that empathic responses emerge within the first year of life (see Davidov, Zahn-Waxler, Roth-Hanania, & Knafo, 2013) and continue to develop in early childhood (Knafo et al., 2008; Roth-Hanania et al., 2011; Zahn-Waxler, Radke-Yarrow, & King, 1979; Zahn-Waxler, Radke-Yarrow, Wagner, & Chapman, 1992). As young as six months of age, infants directed their attention toward their crying peers (Hay, Nash, & Pederson, 1981). Additionally, Roth-Hanania et al. (2011) found modest amounts of both cognitive and affective empathy were already evident by eight to 10 months of age. The strength and variety of these empathic responses increase over time in typical development (Geangu, Benga, Stahl, & Striano, 2011; Zahn-Waxler & Radke-Yarrow, 1990), with most infants demonstrating prosocial behaviors such as helping others in distress by two years of age (Zahn-Waxler & Radke-Yarrow, 1990). However, individual differences in empathic responses are also apparent at each age across these early developmental periods (Young, Fox & Zahn-Waxler, 1999). Given the variability in children's reactions over time, *response to distress* is a term commonly used to refer to infants' early reactions to another's distress because these reactions are evident prior to the more colloquial notions of empathy (i.e., providing comfort, a type of prosocial behavior in response; see Dunfield, 2014).

While deficits in responding empathically are not part of the diagnostic criteria for ASD, research has shown that children with ASD are not as empathically responsive as their TD peers or even as responsive as children with other developmental disorders (Bacon, Fein, Morris, Waterhouse, & Allen, 1998; Charman et al., 1997; Dawson et al., 2004; Sigman, Kasari, Yirmiya, & Kwon, 1992). Sigman et al. (1992) found that children with ASD looked less and also played more in response to another's distress. Similarly, Dawson et al. (2004) found that 3- to 4-year-old children with ASD looked less and took longer to attend to the distress than their same-age developmentally-delayed peers and mental-age matched TD peers. The children with ASD also exhibited less concern than their TD peers. McDonald and Messinger (2012) found that HR toddlers, at 24 and 30 months of age, diagnosed with ASD exhibited less global empathic concern, less bodily arousal, and less concern towards their parent in distress than the HR toddlers who were not diagnosed with ASD (HR-nonASD). The authors also found that those infants who were less responsive to their parent's distress had higher ASD symptom severity at 30 months. This finding suggests that individual differences in the range of social impairment, as observed within the ASD group, may be related to individual differences in empathic responses. It is unclear whether sub-clinical social impairments within the HR-nonASD similarly affected their empathic responses.

In a prospective longitudinal study of HR and LR infants, Hutman et al. (2010) explored infants' empathic responding to an experimenter's distress at 12-, 18-, 24- and

36-months, where response to distress was assessed by coding infants' attention to the experimenter's distress and infant's affective responses. Emerging at 12 months of age and stable through 36 months, infants later diagnosed with ASD were less attentive and displayed fewer affective responses than their HR-nonASD and LR-nonASD peers (i.e., HR and LR infants who are not later diagnosed with ASD; Hutman et al., 2010). These distress-responses were predictive of having an ASD diagnosis at 36 months (Hutman et al., 2010). In contrast to the research on HR infants in social orienting and joint attention, the HR-nonASD and LR-nonASD infants displayed similar attention and affective responses between 12 and 36 months, with only one unexpected exception: the HR-nonASD infants displayed more affective responses than the LR infants at 12 months (Hutman et al., 2010). Because the HR-nonASD and the LR-nonASD had similar affective responses by 18 months, the group difference at 12 months suggests that affective responses are still developing around this time. Additionally, as no group differences were seen between the HR-nonASD and LR-nonASD infants, deficits in affective responses may not be a characteristic of the broader autism phenotype (BAP).

In a follow-up study, Hutman et al. (2011) examined infants' visual attention during the distress display, identifying where and for how long infants attended to the various targets. Infants' attention was coded as attending to social targets (the experimenter's hand and face or the caregiver) or nonsocial targets (toy mallet that hurt the experimenter or elsewhere). While no significant differences were found between the HR and LR infants at 12 months of age, infants later diagnosed with ASD were found to look more towards the nonsocial target during the distress display.

In a prospective longitudinal study of HR and LR infants, Dowd et al. (2018) examined how attention to various social targets (experimenter and mother) and affective responses during a distress task developed from 12 to 15 months across the *Social*

Spectrum. In this study, the Autism Observation Scale for Infants (AOSI; Luyster et al., 2009) was used as a measure of social impairment. Infants attended, similarly across the *Social Spectrum*, to the social targets during approximately 75% of the task at 12 months. From 12 to 15 months, attention increased for infants with minimal social impairment; however, infants with greater social impairment did not show the same developmental gains (i.e., increase in attention) as their peers. Similarly, affective responses were similar at 12 months across the *Social Spectrum*, but by 15 months, infants with minimal social impairment demonstrated greater affective responses.

Joint attention

Extensive research has examined the early emergence and development of social cognition and communication in infancy (Bates, 1977; Bates, Benigni, Bretherton, Camaoini, & Volterra, 1979; Bruner, 1975; Dore, 1974; Golinkoff, 1983; Scaife & Bruner, 1975). Specific types of early nonverbal. social communication behaviors including joint attention, behavioral requests, and social interaction behaviors have been examined in typically-developing children (see Bates, 1979; Bruner & Sherwood, 1983; Mundy et al., 1988; Seibert et al., 1982, 1984). In particular, research focused on the development of these early nonverbal communication behaviors suggests that early joint attention skills provide an index of infants' social understanding.

Joint attention is defined as the ability to coordinate attention with a social partner around an object for the purpose of sharing an awareness of the object (Mundy, Sigman, Ungerer, & Sherman, 1986). There are two types of joint attention: initiating joint attention (IJA) and responding to joint attention (RJA; Bates, 1979; Bruner & Sherwood, 1983; Mundy et al., 1988; Mundy, Sigman, Ungerer, & Sherman, 1986; Seibert et al., 1982, 1984). IJA has been defined as a child's ability to initiate shared attention with a social partner through the use of eye contact, pointing, and showing (Mundy, Delgado, Block, Venezia, Hogan & Seibert, 2003). RJA has been defined as a child's capacity to follow a social partner's gaze and/or pointing gestures (Mundy et al., 2003).

A hallmark social deficit for children with ASD is failing to engage in joint attention with social partners (Loveland & Landry, 1986; Mundy, Sigman, & Kasari, 1990). Dawson et al. (2004) found that, while three-year-old children with ASD show greater impairment in social orienting, attention to other's distress, and joint attention compared to developmentally delayed and TD children, impaired IJA may be a better predictor of ASD diagnosis than deficits in social orienting and attention to distress (Dawson et al., 2004).

However, research examining the prospective development of IJA in infants at varying degrees of risk for ASD (e.g., HR vs. LR), as well as infants later diagnosed with or without ASD, has yet to reveal a coherent story as to when IJA skills, or lack thereof, can distinguish these groups. Cassel et al. (2007) found that compared to LR infants, HR infants initiated joint attention less frequently at 15 months, but not at 8, 10, 12, or 18 months. Comparably, Golderberg et al. (2005) compared IJA skills in children with ASD (~30 months old), HR infants (~17 months old), and TD infants (~15 months old). The children with ASD demonstrated less IJA compared to the TD infants, and the HR infants did not significantly different from the children with ASD, suggesting that the HR infants may have similarly demonstrated less IJA than their TD peers (Golderberg et al., 2005). By 18-months, Cornew et al. (2012) found that HR-ASD infants were slower in their social referencing or information seeking (i.e., IJA) than both their HR-nonASD and LR-TD peers. Similarly, Charman et al. (1997) found that 20-month-old infants with ASD demonstrated less IJA than children with pervasive developmental disorder (PDD) or developmental delays. These findings suggest that HR infants are at increased risk of demonstrating reduced IJA around 15 months, but by 18 months, only the children who are later diagnosed with ASD appear to demonstrate reduced IJA.

Paperella, Goods, Freeman, and Kasari (2011) used both cross-sectional and longitudinal designs to examine the development of nonverbal joint attention skills in children with and without ASD. The researchers found that children with ASD were able to follow another's point, similar to the TD children across ages (12 to 64 months) while only the children with ASD who had higher expressive language age-equivalents (above 47 months) followed another's gaze (RJA). Paperella et al. (2011) found that initiating coordinating looks (IJA) and following another's point (RJA) were present early in development (<20 months expressive language age), similar to TD children. However, children with ASD were slower than TD peers to show, point, and follow another's gaze (Paparella et al., 2011). Additionally, Mundy et al. (2007) examined the development of IJA over time from 9 to 18 months and found a cubic effect of IJA over time, such that IJA rapidly increased from 9 to 12 months and generally remained stable from 12 to 18 months, with slight increases occurring from 12 to 15 months.

Substantive research has focused on the development of specific joint attention skills over time in TD infants (Bakeman & Adamson, 1984; Bates et al., 1975, 1979, 1987; Bruner, 1983; Butterworth, 1991; Crais, Douglas, & Campbell, 2004; Leung & Rheingold, 1981; Moristte at al., 1995; Murphy & Meisser, 1977). Scaife and Bruner (1975) found that infants as young as two to four months old have the capacity for RJA. However, the authors noted that infants did not demonstrate mastery of RJA (e.g., 100% success) until 11-14 months of age. Carpenter et al. (1998) reported that, in the context of TD, RJA skills emerge between 9-13 months of age, with most children following the examiner's point (RJA) by 11 months of age (15 out of 24 infants) or 13 months of age (21 out of 24 infants). Seventeen of 24 infants followed the examiner's gaze (RJA) by 13 months (Carpenter et al., 1998). Mundy et al. (2007) found that linear increase in RJA from 9 to 18 months, as well as a quadratic effect from 9 to 18 months, such that RJA rapidly increases from 9 to 12 months then levels out at 15 months before increasing slightly from 15 to 18 months.

With regard to the development of RJA in ASD, one prospective developmental study found that compared to LR infants, HR infants responded less to an examiner's bid for joint attention at 18 months, yet no differences were seen at 8, 10, 12, or 15 months (Cassel et al., 2007). Similarly, Bedford et al. (2012) found no significant differences in RJA between HR and LR infants at either 7 or 13 months of age. In contrast, Presmanes et al. (2006) found that, at 15 months, HR infants showed significantly lower RJA scores than their LR peers. Additional analyses by Bedford et al. (2012) found that, while HR infants later diagnosed with ASD or atypical development did follow the gaze of their partner at 13 months, these infants did attend to the object of interest less than their peers. Thus, these findings suggest that while 13-month-old HR infants later diagnosed with ASD may successfully follow their social partner's joint attention, the nature of the interaction may be qualitatively different.

Looking specifically within a HR sample, Sullivan et al. (2007) assessed HR infants' RJA at 14 and 24 months and compared the infants later diagnosed with ASD (HR-ASD), BAP (HR-BAP), and non-BAP (HR-TD). In this HR sample, RJA at 14 months was predictive of a later ASD diagnosis. HR-ASD infants showed minimal increases in RJA from 14 to 24 months and showed significantly lower RJA than both HR-BAP and HR-TD infants at 24 months (Sullivan et al., 2007). Perhaps the variability in RJA across all HR infants, as seen in Sullivan et al. (2007), prevented the earlier identification of differences between HR and LR infants in both Bedford et al. (2012) and Cassel et al. (2007).

Interestingly, Goldberg et al. (2005) did not see a significant difference in RJA across three groups: children with ASD (mean age of 29.9 months), HR infants (mean age of 17.1 months), or TD infants (mean age of 15.3 months). Again, perhaps the variability in the HR sample prevented earlier group differences from being identified, or perhaps group differences in the frequency of RJA are not apparent until later in development (at 18 months). While together these findings may appear to be inconclusive or incongruent, it is possible that there is a more complex developmental story that could explain the timing of group differences. Additional research is needed to assess how RJA develops over time in infancy and toddlerhood across the full spectrum of social functioning.

DEVELOPMENTAL MODEL OF SOCIAL ATTENTION AND RESPONSIVENESS

As with most developmental skills, learning is an incremental process. Basic fundamental skills are learned before progressing to more advanced skills. Social skills often develop naturally (i.e., without specific instruction) and rapidly (i.e., increasing within 2- to 3-month developmental windows from birth to 18 months). These skills begin as simple reactions and then progress into more advanced initiations and responses. Consider the order of these developmental milestones: two-month-olds begin to look and smile at parents; by four months, infants smile spontaneously and copy their parents' movements and expressions; by six months of age, infants can recognize familiar faces and respond to others' emotions; by nine months, infants may fear unfamiliar people and cling to familiar adults; by 12 months of age, this fear may exhibit itself as shyness or nervousness with strangers while in contrast they play social games like peek-a-boo and pat-a-cake with familiar people; and 18 months of age, infants may offer objects to others and point to things to share in a social experience (CDC, 2016b). According to these developmental milestones, infant responses to social partners progress from looking, to imitating, to recognizing and responding, to developing preference, to playing social games, to initiating shared interactions. It is easy to see how these skills may importantly build upon each other.

Social development occurs along a time continuum, such that early social development can influence the trajectory of subsequent social development (Mundy & Neal, 2001; Carpenter, Nagell, & Tomasello, 1998). Social attention is a broad domain that can be broken down into specific skills. In early development, these skills vary in complexity from orienting to social stimuli (social orienting) to attending to another's emotional distress (attention to distress) to coordinating attention with social partners who are attempting to share experiences (responding to joint attention, RJA) to initiating shared attention with a social partner to share experiences (initiating joint attention, IJA). Previous research, examining the role of social orienting in the early development of joint attention in infants at 6, 8, and 12 months old, found that fixating on eyes of neutral faces in photos was positively related to later RJA (Schietecatte, Roeyers, & Warreyn, 2012). Another study investigating the developmental interrelations among joint attention engagement, gaze and point following, imitation, gestures, and language in TD infants from 9 to 15 months of age, found that social attention progressed from sharing, to following, to directing others' attention (Carpenter, Nagell, & Tomasello, 1998). Despite this evidence that early social attention skills are associated with later social attention skills, no research to date has examined the interrelations between social orienting, attention to distress, RJA, and IJA as they develop from 12 to 18 months.

The development of social attention might also have broader consequences for the development of social responsiveness. In order to respond appropriately to a social partner, infants must first attend to a social situation and gather important social information. For example, infants must recognize that someone is in distress by attending to the person (attention to distress) before it is possible for them to display concern for that person (response to distress). Additionally, infants must first recognize that another person is in need of help, likely by attending to and coordinating their attention with that person, before offering assistance to that person (helping). No work has examined if social attention plays a fundamental role in the subsequent development of social responsiveness from 12 to 18 months.

Importantly, Mundy and Neal (2001) posit that early impairments in attending to social situations deprive children of social information that subsequently limits the development of other social skills. Such disruptions in early social attention could impede the development of later social behaviors as infants miss important opportunities to acquire and practice social skills (Dawson et al., 2004) and learn about their environment (Yoder, Stone, Walden, & Malesa, 2009). Thus, it makes sense to examine these early social behaviors as important contributors to the social deficits observed in ASD. Infants as young as six months of age who are later diagnosed with ASD were found to look less toward the social scenes in videos, and when they did attend, they looked less at the actress, and in particular to the actress's face (Chawarska et al. 2013). If differences in visual social attention are apparent as early as six months in infants later diagnosed with ASD, consider the repercussions of this reduced attention on the development of social cognition and communication (Chawarska et al., 2013). Research has shown that deficits in social attention and responsiveness predict later diagnostic ASD outcome (see above), yet little is known about the developmental impacts of these early social attention deficits in relation to subsequent deficits in social attention and responsiveness at the heart of ASD diagnostic criteria.

INTERRELATIONS OF SKILLS IN SOCIAL DEVELOPMENT

Two studies with TD children prospectively examined the relationships between empathy and prosocial behaviors. Roth-Hanania et al (2011) found that TD infants' cognitive and affective empathy at eight months predicted their prosocial behavior at 16 months. Findlay, Girardi, & Coplan (2006) similarly found that TD children who demonstrated greater empathy in kindergarten had greater prosocial behaviors in first grade.

Hutman et al. (2010), in their prospective study of HR and LR infants' response to distress from 12 to 36 months, further examined if infants' response to distress was indicative merely of infants' broader social responsiveness. The authors assessed if social responsiveness, measured by infants' response to name at 18 months, attenuated the relationship between response to distress and diagnostic outcome. Response to name was marginally significant in the prediction of diagnostic outcome, above and beyond attention to distress. Response to name was statistically significant in the prediction of diagnostic outcome, above and beyond affective response to distress. However, response to name did not add unique information in the prediction of diagnostic outcome, once verbal mental age was added as a predictor. The authors interpreted these findings as, "the atypical distress response that characterizes the ASD group is not mediated by general social responsiveness" (Hutman et al., 2010, p.1017). However, because research suggests that social orienting deficits emerge prior to the development of empathy, more research is needed to understand if early deficits in social responsiveness prior to 18 months is impeding the development of empathy.

Two prospective studies of joint attention further demonstrate how early social skills can impact later social behaviors. Vaughan Van Hecke et al. (2007) found that IJA and RJA in 12-month-old TD infants was related to their social competency, measured via parent report survey, at 30 months. Secondly, Yirmiya et al. (2006) found that HR infants who displayed more neutral affect in response to their mother expressing a neutral-still face at four months exhibited less IJA at 14 months. Additionally, HR infants who were less responsive to their name at four months made fewer requests at 14 months. This study suggests that early responsiveness can impact later social behaviors.

Paparella et al. (2011) suggest that the emergence of joint attention skills in children with ASD differs from TD children, progressing from coordinating joint attention (IJA) to following another's point (RJA) to showing and pointing (IJA) to following another's gaze (RJA) from 12 to 64 months of age. This developmental progression differs from Carpenter, Pennington, and Rogers' (2002) study that suggested joint attention in children with ASD progresses from coordinating joint attention (IJA) to directing behaviors (i.e., pointing and giving to request) to following another's point or gaze (RJA) to directing attention (i.e., showing, pointing, or giving to share attention; IJA) from approximately 43 to 54 months of age. Importantly, neither of these studies assesses the developmental progression of joint attention skills in relation to each other from 12 to 15 to 18 months, when these skills seemingly undergo rapid progression (see Mundy et al., 2007). Given that these studies are conducted with older children with ASD, it is possible that the results are more suggestive of, or at least influenced by, children's motivation to engage in the social situation, rather than their ability to engage. Additional research examining the presence and development of these skills, from 12 to 15 to 18 months, could be a better indication of the infants' abilities.

Dawson et al. (2004) found that 3- to 4-year-old children with ASD showed deficits in social attention (social orienting, joint attention, and attention to another's distress) in comparison to age-matched developmentally delayed children and to mental age-matched TD children ranging from 12 to 46 months old. Furthermore, the combination of both joint attention and social orienting deficits best distinguished the children with ASD from those without. Importantly, Dawson and colleagues (2004) also found that joint attention played a mediating role between language ability and both social orienting and attention to distress.

Across the ***Social Spectrum***

The author conducted several preliminary studies using extant data from the Child Development in Context Lab at The University of Texas at Austin to begin to examine how these skills develop during infancy and toddlerhood. Specifically, the authors used data collected as part of longitudinal study of HR and LR infants assed in the lab at 9, 12, 15, 18, and 24 months. Specific items were selected from the battery of assessments that were administered as proxies for RJA, IJA, social orienting, and social impairment. For example, the AOSI was originally administered for clinical diagnostic information to assess for red flags of ASD; however, these preliminary studies used this measure as a way to quantify social impairment, which was in turn used as a proxy for the *Social Spectrum*.

Dowd, Davidson, and Neal-Beevers (2016) examined how infants' concurrent RJA, IJA, and social orienting abilities were related to their response to distress from 12 to 15 months. Results suggest that as response to distress develops from 12 to 15 months, infants with deficits in RJA also attend less and display less affect to another's distress. Infants with deficits in social orienting also attend less to another's distress. Attention to another's distress was lower when infants had deficits in both RJA and social orienting. However, infants attended more when they exhibited the more advanced skill (RJA), even when they had failed the developmentally easier skill (social orienting). Affective response to distress did not vary when infants had deficits in IJA, regardless of their RJA skills. Affect was higher when infants had strengths in both RJA and IJA; however, affect was lower in infants with high IJA but low RJA. Perhaps initiating too frequently may inhibit infants' ability to respond appropriately to other's distress and bids for attention. Thus, the period between 12 and 15 months may be a critical developmental period for infant response to distress, which may be influenced by the infant's ability to respond to joint attention and orient to his name.

Additionally, an exploratory study was also conducted to extend these findings from social skill development in infancy and toddler to early childhood. Infants in the aforementioned longitudinal study returned to the lab at 48 months. In this study, social impairment was characterized by reduced social responsiveness, per parent report on the Social Responsiveness Scale (SRS; Constantino & Gruber, 2012). Dowd, Davidson, and Neal-Beevers (2017) found that failing to respond to a social partner's distress by either attending less or displaying fewer affective responses, at 12 or 15 months, predicted greater social impairment at four years of age. Additionally, reduced RJA at 15 months was predictive of greater social impairment at three years. Interestingly, IJA at 12 or 15 months was not related to later social impairment. The researchers suggest that these null-findings, which were contrary to their hypotheses, may have been influenced by their use of the SRS as a measure of social impairment. Forty-two of the 65 items on this parent-report measure assess children's social responsiveness. In accord, follow-up analyses (unpublished) found that reduced IJA in infancy was significantly related to children's lack of social motivation (as measured by another subscale of the SRS). These findings highlight a crucial developmental period, as well as the importance of examining how early social deficits influence the development of early attention and behavioral responsiveness. Additionally, these findings demonstrate the feasibility of finding significant relationships between these social constructs of interest even with a small sample size.

The Proposed Study

Brief overview

The objective of this study is to investigate the developmental progression of social skills during infancy across the full spectrum of social functioning (*Social Spectrum;* Dowd et al., 2018) and, in particular, identify how early social impairment impacts subsequent social development. This study focuses on how four specific social skills develop in relation to one another between 12 and 18 months of age. This project examines how an infant's social attention (eye contact) contributes to the subsequent development of more complex social attention (joint attention) and of behavioral responses (response to distress and helping). This project distinguishes itself from most ASD and prodromal HR infant sibling research by examining differences in skill development across the *Social Spectrum*, whereas most research focuses on comparing those with and without ASD and/or comparing those at HR and LR for ASD. These two more common approaches fail to account for the substantial complexity and diverseness of social skills that can be seen across children both with and without ASD. To better understand the development of social skills and social impairment, it is vital to account for this variability.

This prospective-longitudinal study of infants at 12, 15, and 18 months repeatedly assesses infant attention and response to a social partner: 1) calling their name (social orienting), 2) feigning distress (response to distress), 3) using nonverbal cues to share interest in an object (joint attention), and 4) failing to retrieve out-of-reach objects (helping). Two groups of children (HR and LR) were recruited in order to capture the full range of social functioning (*Social Spectrum*) from TD to likely ASD. Additionally, the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012), the gold standard measure used to diagnose ASD in children as young as 12 months of age, was administered at each age in order to provide an index of social functioning at each visit.

SPECIFIC AIMS AND HYPOTHESES

Aim 1: *Social Spectrum* impacts individual skill development at and across 12, 15, and 18 months

First, this study evaluates if social impairment is related to infants' concurrent social skills, separately, at each age (i.e., 12, 15, & 18 months). Identifying at which ages the skills are significantly impacted by social impairment contributes to understanding the emergence and development of these skills and help identify crucial times for intervention.

Next, this study evaluates if the development of each social skill varies over time, from 12 to 15 to 18 months of age, and by infants' concurrent social impairment. Significant differences in social skills between ASD and non-ASD children, as well as between HR and LR infants, have been observed in previous research for different skills between 12 and 18 months. It is hypothesized that a more continuous measure of social functioning, rather than previous group comparisons, will congruently reflect the impact of early social impairment on skill development evident early in life. Furthermore, utilizing this continuous measure of social functioning, thereby accounting for the complexity of social development, may more precisely identify the extent to which early social impairment can impact social development. Lastly, the individual progression of social impairment from 12 to 18 months was examined to assess for different developmental pathways.

Aim 2a: Evaluate the incremental development of social attention

Research on ASD has focused on when specific social skills deficits can be identified (i.e., red flags for ASD), yet research has traditionally analyzed these skills separately. In contrast, this study focuses on when and how these skills develop in relation to each other over time, and specifically, how they build upon each other. Early social orienting is hypothesized to positively impact the development of IJA and RJA. IJA is also hypothesized to positively impact the development of RJA. IJA is hypothesized to mediate the relationship between social orienting and RJA. Furthermore, social orienting is hypothesized to mediate the relationships between social impairment and IJA and social impairment and RJA.

Aim 2b: Impacts of social attention on subsequent behavioral responses

Next, this study assesses how social attention impacts the subsequent development of behavioral responses and identifies how these developmental relations vary by infants' social functioning over time. Social orienting is expected to mediate the relationships between social impairment and response to distress and social impairment and helping. Lastly, it is hypothesized that both IJA and RJA will positively impact the development of infants' response to distress and helping. Both IJA and RJA are expected to mediate the relationships between: 1) social orienting and response to distress, 2) social orienting and helping, 3) social impairment and response to distress, and 4) social impairment and helping.

Broader implications for scientific knowledge and clinical practice

This project helps to clarify the development of social attention and responsiveness during infancy and toddlerhood across the full spectrum of social functioning. The study advances scientific knowledge by expanding upon the current literature in two essential ways: 1) investigating the progression of social attention and responsiveness as it varies across the full spectrum of social functioning (e.g., from typical development to likely ASD), and 2) identifying how these skills develop in relation to each other, and specifically, how they build upon each other. Enlightened by this knowledge, one can identify the order with which one should target skills for interventions, with the goal of identifying which skills should be targeted separately versus simultaneously. For example, if joint attention (i.e., shared eye contact around an object of interest) leads to helping behaviors, teach the child to follow the girl's gaze to the shattered toy (joint attention) before teaching the child how to respond when a peer breaks their favorite toy (helping).

Lastly, the proposed project further contributes to general developmental knowledge by identifying the nature of the relationships between these attentional and behavioral responses during the second year of life. This knowledge may contribute to a better understanding of the variety of social responses observed within and across these skills at any age, which in turn could be used to shape educational programs to maximize infant social development, as well as to further inform recommendations for the timeline and target areas for intervention programs.

Research Methodology

Participants

Forty infants (21 males, 19 females) participated in a longitudinal study at the Child Development in Context Lab at The University of Texas at Austin. Two groups of infants (HR and LR) were recruited, yielding a sample of 18 HR and 22 LR infants. Infants were classified as HR if they had an older sibling who had been diagnosed with ASD. Infants were classified as LR if they had an older sibling who had not been diagnosed with ASD. Demographic data of the sample generally reflected the racial and ethnic diversity of the area of the University and broader community (Table 1). Infants were recruited via letters, fliers, and online posts distributed to resources associated with The University of Texas at Austin, (e.g., research resources, childcare centers, etc.) and various off-campus sites, such as community childcare centers and local ASD organizations and providers. One infant (LR) discontinued participation prior to the 15 or 18 month visits. Additionally, two LR infants (at 15 months) and one HR infant (at 18 months) completed the online surveys, but did not participate in the lab assessments due to scheduling difficulties.

Inclusion and exclusion criteria

To be eligible for this study, the infants must: 1) have an older biological sibling between one and 25 years of age, 2) be primarily English language learners, and 3) be born at least 37 weeks after gestation. Infants were excluded if they have clear biological causes of biological developmental delay, such as, genetic and metabolic disorders or prior significant brain injury. Infants were included if their older sibling has such biological developmental delays, and such delays in the older sibling were tracked by having mothers complete the Diagnostic Evaluations Outcome Questionnaire for the older sibling. Additionally, mothers of infants must: 1) be older than 18 years of age, 2) be the biological mother of the infant, 3) be available to attend the lab visits with their infant, and 4) be fluent in English.

Demographics	Frequency
Gender (M:F)	21:19
Risk (HR:LR)	18:22
Age in days (mean, *sd*)	
12 months	384.7 (*11.5*)
15 months	472.2 (*16.9*)
18 months	555.5 (*17.4*)
Maternal Race	
African American	1
Asian American	3
European American	30
Mexican American	3
Other/Mixed Race	2
Unknown	1
Maternal Education	
College/Graduate Degree	34
High School/Vocational/Some College	6
Income	
< $50,000	5
$50,000-$74,999	10
$75,000-$99,999	7
$100,000 +	17
Unknown	1

Table 1. Demographics

Lastly, infants' HR and LR status were confirmed via two methods. First, the ASD status of the older siblings of HR infants was confirmed with a laboratory administration of the Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord et al., 2012). All of the older siblings who participated in the assessment met diagnostic criteria on the ADOS-2. One additional HR infant was recruited and participated in the 12-month visit; however, his family discontinued participation in study prior to the older sibling's ADOS-2 evaluation and thereby excluded from the data sample. Secondly, the Social

Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) was completed for the older siblings of LR infants to ensure that the older siblings do not meet criteria for ASD. LR families with scores on the SCQ indicating a possible ASD diagnosis for the older sibling were to be excluded from the remainder of the study and given appropriate referrals for further evaluation. No exclusions were made based on these criteria.

EXPERIMENTAL DESIGN

This prospective-longitudinal study included three visits over the course of six months when infants are approximately 12, 15, and 18 months old (+/- two weeks; i.e., 12-13.5 months for the 12-month visit, 14.5-16.5 months for the 15-month visit, and 17.5-19.5 months for the 18-month visit). At each visit, infants and their mothers participated in various play-based assessments and experimental tasks, and mothers were asked to complete several surveys about their infants' language and behavior. Additionally, prior to the infants' 15-month visit, all mothers were asked to complete surveys online regarding the infants' older sibling (SCQ and Diagnostic Evaluations Outcome Questionnaire), and HR families attended an additional visit with the older siblings, previously diagnosed with ASD, in order to confirm the older siblings' diagnostic status (ADOS-2).

MEASURES

Infant measures

Demographics

The Background Information Questionnaire was used to assess demographic information about mothers, mothers' partners, and children. This measure was created for use in a prior study in the Child Development in Context Lab at The University of Texas at Austin. Mothers were asked to answer questions about family income, age, ethnicity, race, and education history. Information regarding all children will be obtained, including birthdates, genders, diagnoses, and age at diagnoses. Gender, maternal race, and maternal education were used as covariates in the statistical models, as is standard within in the literature on ASD.

Social Spectrum

The ADOS-2, Toddler Module (ADOS-2-T; Lord et al., 2012) is a semi-structured, standardized assessment of communication, social interaction, and play or imaginative use of materials, and it is considered the gold-standard tool for identification of ASD symptoms in 12- to 30-month-olds (Luyster et al., 2009). The ADOS-2-T utilizes an algorithm to sum the number and severity of specific social deficits for two domains: Social Affect (adosSA) and Restricted and Repetitive Behavior (adosRRB), as well for an Overall Total (i.e., adosSA+adosRRB). The ADOS-2-T assesses for a variety of deficits in social communication and interaction and thereby provides an important proxy for assessing the full spectrum of social impairment. The adosSA[2] domain of the algorithm is comprised of specific age- and language-dependent items that are best predictive for identifying the range concern for ASD. *Social Spectrum* was assessed by summing the scores on items identified in the adosSA algorithm domain (10 items, for infants 12-20 months old). Higher scores depict greater social impairment.

Additionally, mothers completed the Communication and Symbolic Behavior Scales Developmental Profile, Infant-Toddler Checklist (CSBS; Wetherby & Prizant, 2002), a 24-item screening tool that assesses for early delays in three domains: social communication, receptive language, and symbolic functioning. The Social Communication composite score (13-items; CSBSs) from the CSBS is comprised of questions in three areas: 1) emotion and eye gaze, 2) communication, and 3) gestures. CSBSs was used as a

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[2] See Table 4 for a list of variable acronyms and their definitions.

parent measure of *Social Spectrum*, with items being reversed scored from the original form so that greater scores reflect greater social concern.

Social orienting

Social orienting has previously been assessed with a number of different developmental measures. For this study, specific items from three standardized assessment measures will be used to evaluate participants' ability to orient to their name in various contexts. From the Autism Observation Scale for Infants (AOSI; Luyster et al., 2009; see Table 1), the "Orients to Name" item were utilized. From the Bayley Scales of Infant Development, Third Edition (Bayley, 2006), three items from the Receptive Subdomain were used: 1) "Responds to a Person's Voice", 2) "Responds to Name", and 3) "Interrupts Activity" (see Table 2). A composite score (expSO) was calculated from these measures to ascertain the consistency of responses across situations with varying complexity. Additionally, the "Response to Name"[3] item from the ADOS-2-T was used as another indicator of social orienting (adosSO; Dawson et al., 2004).

The experimenter also asked the mother two interview questions from the Vineland Adaptive Behaviors Scale, Second Edition, Receptive Subdomain (Vineland; Sparrow, Cicchetti, & Balla, 2005; see Table 2). Lastly, one item from the CSBS parent checklist was used that asks how often "when you call your child's name, does he/she respond by looking or turning toward you?" A composite score (parSO) was calculated from these measures to ascertain the consistency of responses across situations with varying complexity, based on parent report.

[3] This item is not included in the adosSA algorithm domain for children 12-20 months, but it is included in the RSI section. This specific item will be utilized separately as it has previously been used as such in other studies, whereas the other items from the AOSI and Bayley have been specifically utilized independently in research.

Item	Measure	Item Description	Item Scale
expSO			
Orients to Name[5]	AOSI[1]	"infant's ability to move his/her eyes toward the examiner and establish at least brief eye contact when his/her name has been called"	0 – "does not orient with eye contact to name on any trial [within 2 seconds] (fails on all four trials with examiner)" 1 – "inconsistent orienting to name (i.e., docs not meet criteria for '0', but does orient with eye contact on at least one trial" 2 – "orients (with eye contact) to name being called on both presses, at least one of which must be on the first trial"
Responds to a Person's Voice	Bayley[2]	"During testing, observe the child to see if he or she responds to a person's voice."	0 – "Child shows no change in behavior in response to the person's voice." 1 – "Child clearly responds to the person's voice by startling, moving eyes, turning his or her head, changing activity level, changing facial expressions, or vocalizing."
Responds to Name	Bayley[2]	"During testing, observe the child to see if he or she responds when his or her name is called.... Wait briefly and call the child by an unfamiliar name. Again, wait briefly and call the child by his or her name."	0 – "Child responds to unfamiliar name. Child does not respond both times his or her name is called." 1 – "Child turns his or her head both times his or her name is called, but does not respond to the unfamiliar name."
Interrupts Activity	Bayley[2]	"Engage the child's interest in an object. Allow the child to play independently, then call the child's name."	0 – "Child does not look up and continues to play." 1 – "Child looks up and briefly pauses during play when you call his or her name."
parSO			
-	Vineland[3]	"looks, toward parent or caregiver when hearing parent's or caregiver's voice"	0 – Never 1 – Sometimes or Partially 2 – Usually
-	Vineland[3]	"responds to his or her name spoken"	0 – Never 1 – Sometimes or Partially 2 – Usually
-	CSBS[4]	"When you call your child's name, does he/she respond by looking or turning toward you?"	0 – Not Yet 1 – Sometimes 2 – Often

[1]*Autism Observation Scale for Infants;* [2]*Bayley Scales of Early Development, Third Edition;* [3]*Vineland Adaptive Behavior Scales, Second Edition;* [4]*Communication and Symbolic Behavior Scales Developmental Profile, Infant-Toddler Checklist;* [5]*Item is reversed scored from the original AOSI composite format.*

Table 2. Social Orienting Composite Items

Joint attention

IJA and RJA behaviors was assessed utilizing the Early Social Communication Scales (ESCS), a video-recorded, semi-structured experimenter-child interaction paradigm (Mundy, Delgado, Block, Venezia, Hogan & Seibert, 2003). Following the ESCS assessment, trained undergraduate research assistants coded the video recording nonverbal communication skills using Noldus, The Observer XT, Version 11. Undergraduate research assistants were first trained and demonstrate initial coding reliability on a separate sample of ten videos provided by the ECSC authors (Mundy et al., 2003). The initial training reliability was established with interclass correlations meeting the .80 or above threshold. Reliability was then evaluated in comparison to the graduate student (author) separately for each age (12, 15, and 18 months). Between 15-20% of the videos at each age were double coded to achieve reliability. Intraclass correlations met the reliability threshold of .80 or above for RJA and IJA outlined below at each age (see Table 3 for reliability scores at each visit).

Variables by Measure	**12 months**	**15 months**	**18 months**
ESCS			
RJA	.969	.971	.990
IJA	.901	.841	.832
Response to distress			
attendDIST	Kappa = .81	Kappa = .85	Kappa = .85
ecDIST	100%	100%	83%
htDIST	100%	83.3%	100%
Helping			
latHELP	85.7%	100%	100%
latOFFER	100%	100%	100%

Table 3. Measure Reliability Scores by Visit

Low- and high-levels (differ by complexity) of IJA and RJA were calculated following the ESCS guidelines. Low-level IJA (loIJA) is calculated as the number of times the child initiates shared attention by making eye contact with the experimenter and alternating their gaze between the experimenter and toys (loIJA = eye contact + alternating gaze). High-level IJA (hiIJA) is calculated as the number of times the child initiates shared attention by pointing, pointing while making eye contact with the experimenter, and showing (hiIJA = point + point with eye contact + show). Low-level RJA (loRJA) is calculated as the percent of trials that infants correctly follow the experimenter's proximal point or touch (loRJA = # correct follow proximal point or touch / total trials * 100). High-level RJA (hiRJA) is calculated as a percent of trials that infants correctly follow the experimenter's distal point to the line of regard (hiRJA = # correct follow distal point / total trials *100).

Additionally, from the ADOS-2-T, the "Response to Joint Attention"[4] item was used as another indicator of RJA (adosRJA; see Dawson et al., 2004), and the "Spontaneous Initiations of Joint Attention" [5] item was used as another indicator of IJA (adosIJA; see Dawson et al., 2004).

Response to distress

Previous studies have utilized variants of a widely-used behavioral measure to assess for children's response to distress (Knafo, Zahn-Waxler, Van Hulle, Robinson, & Rhee, 2008; Charman et al., 1997; Bacon, Fein, Morris, Waterhouse, & Allen, 1998; Hutman et al., 2010; Sigman, Kasari, Kwon, & Yirmiya, 1992; Dowd et al., 2018). In this paradigm, the experimenter pretended to hurt her finger on a toy mallet, displaying facial and vocal distress, continuously making vocal statements about the pain, and alternating

[4] This item is included in the adosSA algorithm domain for children aged 12-20 months.
[5] This item is included in the adosSA algorithm domain for children aged 12-20 months.

between visually examining or shaking her finger for 15 seconds (Dowd et al., 2018). Off-line video coding of infants' attention and affective responses was conducted by trained undergraduate research assistants using Noldus, The Observer XT, Version 11.

Utilizing the attentional coding outlined in Dowd et al. (2018), infants' attention to the distress display was continuously coded as looking to one of several targets: experimenter, mother, distress toy, unknown (i.e., infant's face isn't on camera), or as not attending (i.e., looking anywhere other than these targets). Attention to the social targets (experimenter + mother) was calculated as the percentage of attention to each target out of the total duration of the distress display, accounting for the unknown duration (attendDIST = [(experimenter + mother) / (total duration – unknown) * 100]).

Infant reactions were also coded for empathic concern and hypothesis testing (Knafo et al., 2008; Zahn-Waxler et al., 1992). Empathic concern refers to infants displaying facial, vocal, or gestural-postural signs of concern for the victim. Empathic concern (ecDIST) were rated on a 4-point scale, from absent expressions of concern (score of 0) to substantial concern, sustained signs of sympathy (score of 3; Knafo et al., 2008). Hypothesis testing refers to infant behaviors as they explore and/or attempt to understand the situation. Hypothesis testing (htDIST) was rated on a 4-point Likert scale from no exploration or attempts to understand (score of 0) to repeated or sophisticated attempts to understand (score of 3).

Reliability was evaluated in comparison to the graduate student (author) separately for each age (12, 15, and 18 months). The Kappa threshold for establishing reliability for attention with scores of .80 or above was met at each visit. Additionally, intraclass correlations of ecDIST and htDIST exceeded the .80 threshold for reliability at each visit (see Table 3 for reliability scores at each visit).

Helping

Infants' prosocial behaviors were assessed in response to the experimenter's need for help, utilizing a standard research paradigm during which, the experimenter "accidently" drops some toys on the floor (Over & Carpenter, 2009). At specific time intervals, the experimenter increases her comments and attempts to retrieve the out-of-reach objects, and if warranted, asks for help directly. Mothers were instructed to not direct their child's attention to the task nor prompt them to help. The task continues until the infant attempts to help by picking up fallen sticks or 60 seconds have passed without responding.

The video-recordings of the paradigm were coded offline for infants' behavioral responses. latHELP is calculated as the latency to retrieve the fallen toys (in seconds) within 60 seconds, with a maximum latency of 60 seconds for those who do not respond. latOFFER is calculated as the latency to offer the sticks to the experimenter (in seconds) within 60 seconds, with a maximum latency of 60 seconds for those who do not respond. Off-line video coding of infants' helping behaviors was conducted by trained undergraduate research assistants using Noldus, The Observer XT, Version 11. Reliability was evaluated in comparison to the graduate student (author) separately for each age (12, 15, and 18 months). Inter-coder agreement for latHELP and latOFFER met the 80% or more threshold for reliability within one second at each visit (see Table 3 for reliability scores at each visit).

Older sibling measures

Diagnostic assessment

The ADOS-2 was administered to verify the presence of ASD for the older siblings in the HR group. The ADOS-2 is a semi-structured, standardized assessment of communication, social interaction, and play or imaginative use of materials, and is considered the gold-standard tool for identification of symptoms of ASD. It is considered a valid and reliable assessment for individuals from two years of age to adulthood. ADOS-2 assessments were videotaped for reliability purposes. One of five modules were administered to the older sibling, depending on age and language level.

The SCQ was administered to rule out the presence of ASD for the older siblings in the LR group. This questionnaire contains 40 yes or no questions regarding social functioning and communication skills. This instrument takes less than 10 minutes to complete. It generates a total score that identifies individuals who may have ASD and should be further evaluated.

PROCEDURE

Determining eligibility

Mothers of infants were first pre-screened over the phone to determine study eligibility. A trained research assistant conducted the standardized intake interview, and eligibility was confirmed by the graduate student. Eligible families were invited to schedule their first study visit once their infant turned 12 months old.

Experimental sessions

Prior to each visit, mothers were asked to complete various surveys online through REDCap (Research Electronic Data Capture; Harris et al., 2009). REDCap is HIPAA compliant and provides secure and web-based survey input data using secure web authentication, data logging, and Secure Sockets Layer encryption.[6] Trained research assistants greeted the families, provided free parking passes to families upon availability

[6] "REDCap at UT is supported by grant, 5 R24 HD042849, Population Research Center, awarded to the Population Research Center at The University of Texas at Austin by the Eunice Kennedy Shriver National Institute of Health and Child Development" (Harris et al., 2009).

to the reserved parking spaces, and escorted the families to the Child Development in Context Lab at The University of Texas at Austin. At the first 12-month visit, the experimenter reviewed the study procedures and obtained informed consent. At each session, infants and their mothers were both escorted to the testing room where the mothers were asked to complete an additional survey on paper while the experimenter begins to administer the measures with the infant. Table 4 outlines the order of measures and their estimated duration to be completed at each session. Upon receiving compensation, families were escorted back to their vehicles.

Measure	**Duration (minutes)**
ADOS-2-T	45
Social orienting items (partial)	2
Helping task	2
Social orienting items (partial)	1
ESCS	15
Social orienting items (partial)	1
Response to distress task	2
Social orienting items (partial)	1

Table 4. Presentation Order and Durations of Visit Measures

Data storage and coding

Data collected at lab visits was stored electronically on secure departmental servers and on REDCap. Trained research assistants transferred information from the paper measures to the online database (i.e., REDCap). Video-recordings of the visits were stored on the secure departmental servers. Videos were coded separately by trained research assistants on secure lab computers for the response to distress task, helping task, and ESCS, on Noldus, The Observer XT, Version 11 software program.

ANALYTIC PLAN

Power analyses

Various problems conducting power and sample size estimations for mixed effects designs have been well documented (Snijders, 2005; Westfall, Kenny, & Judd, 2014). However, similar designs conducted in the lab (see the response to distress and across the *Social Spectrum* sections above) suggest that this proposed study has adequate power with the sample size of 40.

Aim 1

To assess how each social skill develops over time and evaluate the impact of concurrent social impairment on development, linear mixed effects models (LME) were conducted for each social skill (see Table 5) separately with Visit (12-, 15-, and 18-month visits) and *Social Spectrum* (adosSA or CSBSs, assessed separately) as the predictors. Visit was centered around the 15-month visit to better understand the outcomes for the y-intercept. In this study, it was important to initially examine the development of these skills across visits in the LME models, rather than across age in days, in order to be consistent with the SEM models in Aim 2 which was restricted to comparing skills over time by utilizing skill data at different visits in the models, without accounting for differences in age in days. Additional post hoc analyses utilized age in days to address concerns regarding the somewhat broad age range allowed for each visit. Backwards elimination techniques were employed such that main effects, fixed effects, and random effects were removed from the model, when their removal minimizes the Akaike information criterion (AIC; Akaike, 1973). The initial full models were also tested for the main effects of the identified demographic variables (Gender, Race, and Maternal Education) first; backwards elimination techniques informed which non-significant demographic variables could be removed from the models. Non-significant variables were removed from all subsequent analyses. When the optimal LME models suggested that the data did not follow a normal distribution, suggesting the LME model may not be an appropriate fitting model for the data, additional bootstrap analyses with Monte Carlo Simulation for 10,000 random samples (with replacement) were conducted.

Additional post hoc simple regressions were conducted separately for each time point, to assess if skills significantly differ across the *Social Spectrum* (adosSA or CSBSs) present at each visit as well as by Age (in days at the 12-, 15-, and 18-month visits, centered by the median age across visits). Non-significant main effects were removed from these post hoc regression models using backwards elimination techniques, including AIC, AICc, and likelihood ratio tests comparing the two nested models (Agresti & Finlay, 2009).

Based on the previous research outlined in the Introduction, the following hypotheses were made. Social orienting is anticipated to remain stable over time for all infants, with those with mild social impairment demonstrating frequent responses and those with greater social impairment minimally responding. It is hypothesized that latHELP will be present at a moderate degree at 12 months and remain stable over time for those who have greater social impairment, whereas those with mild social impairment will demonstrate an increase in helping behavior and will be quicker to respond over time. Similarly, it is hypothesized that latOFFER will be faster over time for those with mild social impairment, whereas those with greater social impairment will demonstrate minimal offering behaviors that will remain stable over time.

It is hypothesized that social attention to the response to distress task will remain high and stable over time for those with minimal social impairment, whereas those with greater social impairment will demonstrate similar attention at 12 months that will decrease over time. Empathic concern (ecDIST) is expected to increase over time for those with mild social impairment, whereas those with greater social impairment are expected to display mild concern that will not improve over time. Similarly, htDIST is expected to be present at low levels at 12 months for all children, and those with mild social impairment are expected to make slight gains over time.

Regarding initiating joint attention, hiIJA is expected to be present to a large degree across 12 to 18 months for those with mild social impairment, whereas those with increased social impairment are anticipated to appear similar at 12 and 15 months before demonstrating a decline in hiIJA at 18 months. All children are hypothesized to have moderate amounts of loIJA at 12 months; children with greater social impairment are hypothesized to have a decline in loIJA over time. In contrast, those with mild social impairment are hypothesized to have a similar or mild increase in loIJA by 18 months, with a possibility of a slight reduction of loIJA at 15 months.

Regarding responding to joint attention, hiRJA is anticipated to increase between 12 and 15 months for infants with mild social impairment and then remain stable or possibly demonstrate a mild decrease between 15 to 18 months. Infants with greater social impairment are expected to demonstrated similar hiRJA responses at 12 months before there is a decline in hiRJA over time, particularly by 18 months. It is hypothesized that loRJA will be present to a high degree and remain stable over time for children with mild social impairment; those with greater social impairment are expected to display a similar presentation at 12 months, with the possibility of a mild decrease in responsiveness over time. AdosRJA and adosIJA are anticipated to have similar developmental trajectories as hiRJA and loIJA, respectively.

Further LME models will be conducted to assess if the development of each *Social Spectrum* predictor (adosSA and CSBSs) varies by Visit, again centered at the 15-month visit. Fixed and random effects will be removed from the model, when their removal minimizes the AIC. It is hypothesized that *Social Spectrum*, as measured by adosSA and CSBSs, will be stable across 12 to 18 months; thus, Visit will not be a significant predictor in these models.

Variables by Category	Definitions
Social Spectrum	
adosSA*	ADOS-2-T Social Affect algorithm domain (higher scores indicate greater social impairment)
CSBSs	CSBS social communication composite score (higher scores indicate greater social impairment)
Social orienting	
expSO*	Behavioral assessment of response to name; items from the AOSI and Bayley (see Table 2)
parSO	Parent report of response to name on items from the CSBS and Vineland (see Table 2)
adosSO	ADOS-2-T Response to Name Item
Joint attention	
hiRJA*	ESCS higher level RJA skills
loRJA	ESCS lower level RJA skills
adosRJA	ADOS-2-T Response to Joint Attention item
hiIJA*	ESCS higher level IJA skills
loIJA	ESCS lower level IJA skills
adosIJA	ADOS-2-T Spontaneous Initiation of Joint Attention item
Response to distress	
attendDIST	Percent attending to social targets in the response to distress task
ecDIST*	Empathic concern rating from the response to distress task
htDIST	Hypothesis testing rating from the response to distress task
Helping	
latHELP	Latency (seconds) to help pick up sticks during the helping task (lower scores indicate quicker responses to pick up the sticks)
latOFFER*	Latency (seconds) to offer sticks during the helping task (lower scores indicate quicker responses to offer the sticks)

*Selected variables within each category used in the SEM models.

Table 5. Variable Definitions by Category

Aim 2

Structural equations modeling (SEM) was conducted to identify how early social attention impacts subsequent social attention and behavioral responses and to assess if social impairment mediates these developmental relations. Given the small sample size, particular variables within each category (see asterisks in Table 5) were selected rather than conducting SEM with factor analysis to allow for sufficient power to detect mediating relationships. The following variables demonstrated the most consistent patterns of prediction in past research and were included as predictors in the current study: adosSA, expSO, hiRJA, hiIJA, ecDIST, and latOFFER.

SEM models were conducted to assess for relationships between adosSA, expSO, and 1) hiRJA and hiIJA (Figure 1), 2) hiRJA and ecDIST, 3) hiRJA and latOFFER, 4) hiIJA and ecDIST, and 5) hiIJA and latOFFER (see Figure 2 for the SEM design for models 2-5). These five outlined models, each utilizing four variables, were first conducted separately for each visit. For each model at each visit, the six pathways between the variables were set to zero to create a fully reduced model. Using this reduced model, the modIndices function was used to assess which pathways should be added into to the model. The model with the added pathway was compared to the former reduced model by comparing the root mean square error of approximation (RMSEA), AIC, and AICc indices between the models. These steps were repeated until the addition of a recommended pathway reduced the goodness of fit of the model, and the optimal model was identified based on the best fitting model utilizing these forward elimination techniques.

Next, additional SEM models were conducted to examine mediation effects over time by using: 1) 12-month data for adosSA, expSO, and hiIJA, and 15-month data for hiRJA; 2) 12-month data for adosSA, expSO, and either hiRJA or hiIJA, and 15-month data for either ecDIST or latOFFER; 3) 12-month data for adosSA, expSO and either hiRJA or hiIJA, and 18-month data for either ecDIST or latOFFER; 4) 15-month data for adosSA, expSO and either hiRJA or hiIJA, and 18 month data for either ecDIST or latOFFER; 5) 12-month data for adosSA and expSO, 15-month data for either hiRJA or hiIJA, and 18-month data for either ecDIST or latOFFER. As these SEM models are using observed data across different ages, the SEM models were examined for mediation in a different way to evaluate the direct and indirect relationships between the variables. First, a full, saturated model (i.e., all possible pathways included) was conducted. Next, the full, saturated model was compared to two separate models: 1) c' reduced to 0 (indirect relationships assessed); 2) a1 and b1 reduced to 0 (direct relationship assessed). The AIC, AICc, and RMSEA indices were used to determine which models were better fits for the data, and the models were compared to assess how pathways change when the selected direct or indirect pathways were removed. These same steps will be repeated to examine the two remaining possible mediating roles on the behavioral responses for each SEM pathway identified.

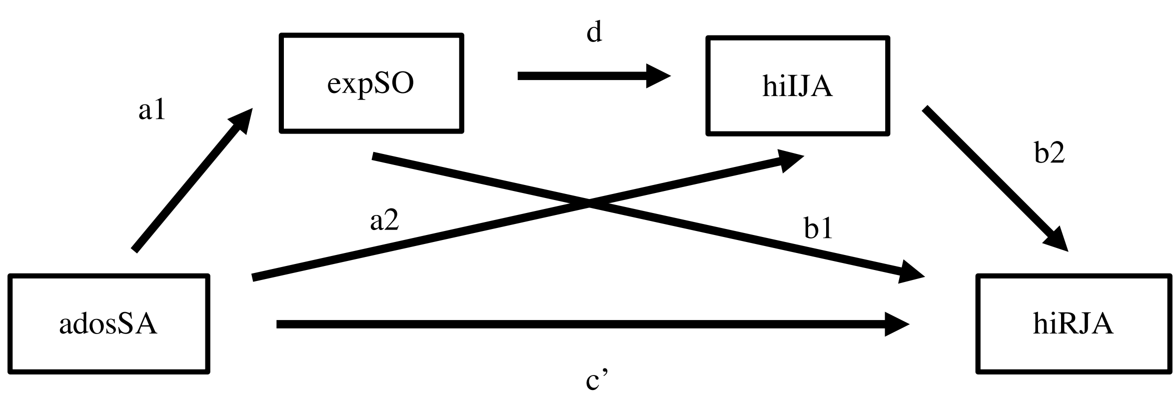


Figure 1. Hypothesized SEM Pathway #1 including variables of social attention.

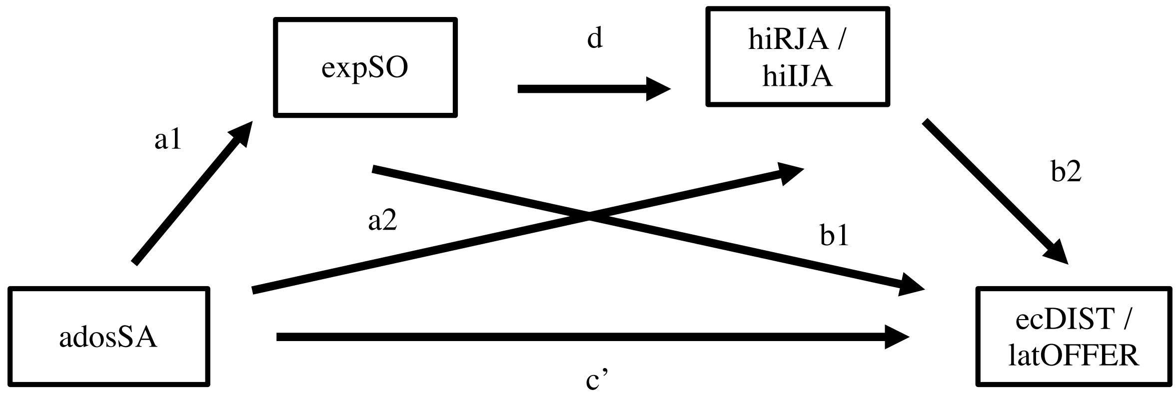


Figure 2. Hypothesized SEM Pathway #2-5 including variables of social attention and behavioral responses.

	Range	Mean *(sd)*		
		12 months	15 months	18 months
Social Spectrum				
adosSA	0-20	6.45 *(4.20)*	4.81 *(3.13)*	3.97 *(2.63)*
CSBSs	0-26	9.35 *(5.11)*	7.08 *(4.43)*	5.51 *(4.18)*
Joint attention				
hiRJA	0-100%	22.10 *(21.09)*	42.81 *(24.48)*	63.11 *(30.22)*
loRJA	0-100%	65.42 *(34.39)*	79.02 *(28.62)*	81.56 *(32.49)*
adosRJA	0-2	1.47 *(.83)*	1.89 *(.46)*	1.95 *(.33)*
hiIJA	0-n/a	.43 *(.87)*	.95 *(1.25)*	1.24 *(1.84)*
loIJA	0-n/a	10.72 *(6.17)*	7.22 *(4.53)*	9.16 *(4.73)*
adosIJA	0-2	1.73 *(.51)*	1.89 *(.34)*	1.84 *(.37)*
Social orienting				
expSO	0-5	3.26 *(1.14)*	3.35 *(1.27)*	3.24 *(.93)*
parSO	0-6	5.18 *(1.17)*	5.06 *(1.17)*	5.51 *(.80)*
adosSO	0-2	1.8 *(.46)*	1.73 *(.56)*	1.71 *(.61)*
Response to distress				
attendDIST	0-100%	73.48 *(27.83)*	70.61 *(20.26)*	73.13 *(20.37)*
ecDIST	0-3	1.64 *(1.04)*	1.65 *(.92)*	2.05 *(.97)*
htDIST	0-3	.49 *(.51)*	.32 *(.47)*	.73 *(.56)*
Helping				
latHELP	0-60s	39.69 *(21.90)*	32.07 *(23.26)*	24.00 *(22.93)*
latOFFER	0-60s	50.71 *(16.00)*	42.82 *(19.30)*	36.03 *(20.64)*

Table 6. Means and standard deviations of variables by category at each visit.

Results

Descriptive statistics

Table 6 provides the means and standard deviations at each visit (12, 15, and 18 months) for each variable by category, as well as the range of potential scores each variable for reference. To evaluate the range of *Social Spectrum* in our sample, the means and standard deviations for adosSA and CSBSs were calculated at 12-, 15-, and 18-month visits for the entire sample. The range of adosSA and CSBSs scores at each visit suggest that a wide variety of social impairment was captured in the sample, thus a wide range of social functioning across the *Social Spectrum* is represented in the sample. Few infants demonstrated severe social deficits, as is consistent with the general population (i.e., 1 in 68 kids are diagnosed with ASD). Of note, several variables demonstrated limited variability within and/or across visits.

Aim 1: LME analyses

Tables 7-10 shows the coefficient values and standard errors included in the final optimal LME models for each social skill predicted by adosSA and CSBSs (assessed separately) over time. Significant main effects and interactions resulting from selected optimal models are depicted in Figures 3-6, which display predicted values for each social skill at specific levels of the independent variables based on the linear equation identified in the optimal models [Figures 3-6]. The optimal LME models for hiRJA, adosRJA, hiIJA, loIJA, attendDIST, adosIJA (adosSA only), and expSO (CSBS only) included random slopes for Visit, suggesting that there is some variance over time that was not accounted for in the current sample by these predictors. Of note, there were no significant main effects of Maternal Education in any of the final optimal models. However, there was a significant main effect of Race in both the adosSA and CSBSs optimal models for parSO. There was also a significant main effect of Gender for loIJA in both the adosSA and CSBSs optimal models and a marginally significant effect of Gender for adosRJA in the optimal CSBSs model. The effects of these significant demographic variable are discussed below.

Social Spectrum

The optimal LME models for adosSA and CSBSs over time both revealed a significant main effect of Visit (p=.002, p <.001, respectively), such that *Social Spectrum* decreased over time (coefficient=-.414, *SE*=.128, coefficient=-.633, *SE*=.103, respectively). Examination of the qqPlot of residuals suggested the assumption that the variables follow a normal distribution failed. Outliers were identified and removed; when the models were re-run without these outliers, the same significant main effects of Visit were found.

Social orienting

Coefficients and standard errors for the predictors identified in the optimal LME models for the social orienting variables with both adosSA and CSBSs as the predictors of the *Social Spectrum* are listed in Table 7. The optimal LME models for expSO did not yield any significant main effects or interactions with adosSA as the predictor; a non-significant main effect of adosSA was included in the optimal model (p=.110). In contrast, with CSBSs as the predictor, the optimal model for expSO included a significant main effect of CSBSs (p=.006) and a non-significant effect of Visit (p=.331). Examination of the qqPlot of residuals confirmed that the normality assumption was not violated, and no outliers were identified. Further examination of the residuals plotted against the independent variables and fitted variables suggested no assumptions were violated. Additional post hoc analyses, conducted separately for each visit for expSO did not yield a significant main effect of Age at any time point (not included in optimal models), nor for *Social Spectrum* at the 12 or 18 month visits (not included in the optimal models). There was a significant main effect of adosSA at 15 months (p=.011) and of CSBSs at both 15 (p=.003) and 18 (p=.021) months, such that greater social impairment was associated with reduced social orienting.

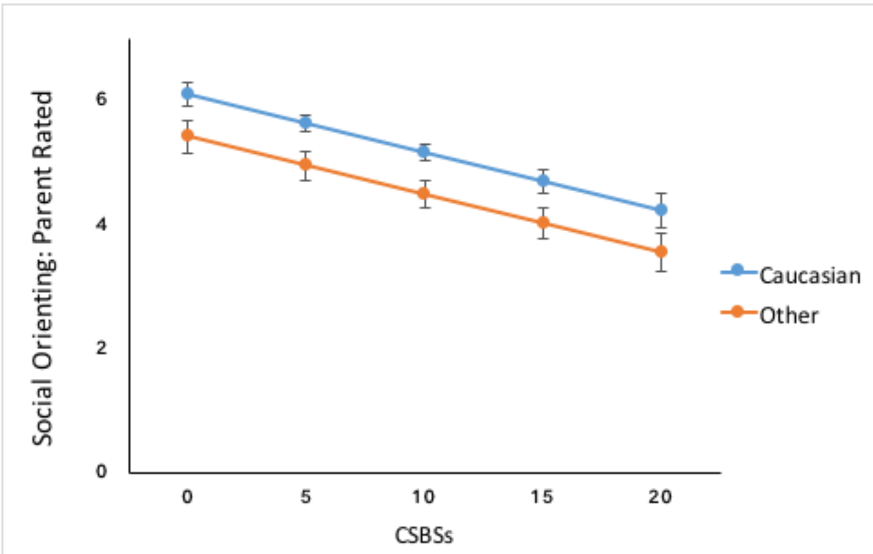


Figure 3. LME predicted values and standard errors of parSO by Race

The optimal models for parSO yielded significant main effects of *Social Spectrum*, with both adosSA (p=.004) and CSBSs (p<.001) as predictors, as well as significant main effects of Race (p=.015, p=.011). As Figure 3 reveals, greater social impairment was associated with reduced infant responding to name, per parent rating, at each visit. Additionally, maternal racial minority status was associated with reduced responsiveness to name, per parent report of social orienting. Examination of the qqPlot of residuals suggested the assumption of the variables were normally distrusted failed marginally in both models. Outliers were identified and removed; when the models were re-run without these outliers, the same significant main effects of adosSA, CSBSs, and Race were found. Additionally, bootstrap multiple regression, with adosSA as the predictor, showed a significant effect of Race (ß=-3.392, 95% CIs [-5.959, -1.019]) and adosSA (ß=-2.925, 95% CIs [-5.129, -.872]). Bootstrap multiple regression, with CSBSs as the predictor, showed a significant effect of Race (ß=-3.111, 95% CIs [-5.439, -.0862]) and CSBSs (ß=-6.553, 95% CIs [-9.061, -4.156]). Post hoc analyses yielded a significant main effect of adosSA at 12 months (*p*=.013) and significant main effects of CSBSs at 12 (*p*<.001), 15 (*p*<.001), and 18 (*p*<.001) months. Additionally, a non-significant effect of Age was included in both adosSA and CSBSs models at 12 months (*p*=.115, *p*=.092, respectively).

The optimal model for adosSO were identical with both adosSA and CSBSs as predictors of *Social Spectrum*. The main effects and interaction of Visit and *Social Spectrum* were not included in the optimal models. The models yielded only significant Intercepts, suggesting there is a significant difference in scores around the 15-month visit that is not accounted for Visit or *Social Spectrum*. However, post hoc analyses revealed a significant main effect of adosSA at 12 months (*p*=.035). No other significant main effects of adosSA, CSBSs, or Age were seen at 12, 15, or 18 months (not included in optimal models).

Model terms		adosSA		CSBSs	
		Coefficients	*SE*	Coefficients	*SE*
expSO					
	Intercepts	3.51***	.19	3.77***	.22
	Visit			-.04	.04
	Social Spectrum	-.05	.03	-.07**	.02
parSO					
	Intercepts	5.76***	.19	6.09***	.18
	Social Spectrum	-.07**	.02	-.09***	.02
	Race	-.80*	.31	-.68*	.25
adosSO					
	Intercepts	1.74***	.05	(same)	

* *p*<.05
** *p*<.01
*** *p*<.001

Table 7. Coefficients, standard errors, and *p*-values for predictors identified in optimal LME models for the social orienting variables.

Joint attention

Tables 8-9 display the coefficients and standard errors for the predictors identified in optimal LME models for each joint attention variable with both adosSA and CSBSs as the predictors of the *Social Spectrum*. With regards to responding to joint attention, the optimal LME models for hiRJA were identical for both *Social Spectrum* predictors. The model yielded significant main effects for Visit (p<.001), such that there is an increase in infants' high-level RJA responses from 12 and 18 months for all infants across the *Social Spectrum* [Figure 4]. There were no significant effects of *Social Spectrum*, and neither *Social Spectrum* terms were included in their respective optimal models. Examination of the qqPlot of residuals confirmed that the normality assumption was not violated, and no outliers were identified. Examination of graphs of the residuals against the predictors as well as the predicted values of the model confirmed that the constancy of variance assumption was not violated. Additional post hoc analyses, conducted separately for each visit for hiRJA, did not yield a significant main effect of Age at any time point, nor for *Social Spectrum* at the 15 or 18 month visits. At 12 months, there was a significant main effect of adosSA (p=.014), but not CSBSs, suggesting that high-level RJA responses decreased as social impairment increased, as measured by the experimenter.

Similarly, the optimal LME models for loRJA similarly yielded significant main effects of Visit (p=.011), such that infants' responses to low-level RJA bids increased over time. There were no significant effects of *Social Spectrum*, and neither *Social Spectrum* terms were included in their respective optimal models. Examination of graphs of the residuals against the predictors as well as the predicted values of the model confirmed that the constancy of variance assumption was not violated. Although no outliers were identified, examination of the qqPlot of residuals suggested that the normality assumption was violated. Therefore, bootstrap linear regression was conducted, and the results also yielded a significant effect of Visit (ß=2.279, 95% CIs [.165, 4.489]). Additional post hoc analyses did not yield significant effects for Age or *Social Spectrum* at any visit for loRJA, and these effects were not included in the optimal models.

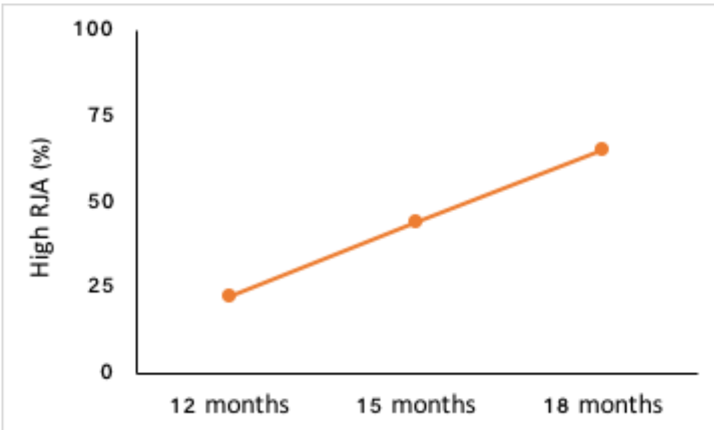


Figure 4. LME predicted values for hiRJA over time.

Model terms	adosSA Coefficients	adosSA *SE*	CSBSs Coefficients	CSBSs *SE*
hiRJA				
Intercepts	43.69***	3.5	(same)	
Visit	7.11***	.71	(same)	
loRJA				
Intercepts	75.44***	3.6	(same)	
Visit	2.77*	1.1	(same)	
adosRJA				
Intercepts	2.03***	.09	1.92***	.11
Visit	-.01	.03	.06*	.02
Social Spectrum	-.05***	.01	-.04**	.01
Visit by *Social Spectrum*	.02**	.01		
Gender (Males)			.19°	.10

° *p*<.075
* *p*<.05
** *p*<.01
*** *p*<.001

Table 8. Coefficients, standard errors, and *p*-values for predictors identified in optimal LME models for the responding to joint attention variables.

The optimal models for adosRJA yielded a significant Visit by *Social Spectrum* interaction with adosSA as the *Social Spectrum* predictor (p=.004). The nature of this interaction is such that greater social impairment (as observed by the examiner) was associated with fewer responses at 12 and 15 months, but not at 18 months. However, examination of the qqPlot of residuals suggested the normality assumption failed, and therefore, bootstrap multiple regression was conducted. Results from the bootstrap simulation showed a significant effect of Visit by *Social Spectrum*, as predicted by adosSA, interaction (ß=-2.411, 95% CIs [.023, 5.065]), a significant effect of adosSA (ß=-3.550, 95% CIs [-5.624, -1.626]), and non-significant effect of Visit (ß=-.553, 95% CIs [-2.32, 1.046]). Post hoc analyses yielded a significant main effect of adosSA at 12 (p=.002) and 15 (p=.019) months, but not at 18 months (not included in optimal model). Importantly, the majority of infants successfully responded to their name by 12 months, and limited variability in scores was observed across visits.

The optimal CSBSs model yielded significant main effects of Visit (p=.013) and *Social Spectrum* (p=.001), such that responses improved over time for all infants across the *Social Spectrum* and greater social impairment was associated with reduced responsiveness across visits. Additionally, there was a marginally significant main effect of Gender (p=.063), suggesting that males responded to their name slightly more than the females. Post hoc analyses yielded significant main effect of CSBSs at 15 (p<.001) and 18 (p=.043) months, but not by 12 months (not included in optimal model). However, examination of the qqPlot of residuals suggested the normality assumption. Bootstrap multiple regression with CSBSs as the *Social Spectrum* predictor showed a significant effect of CSBSs (ß=-3.556, 95% CIs [-6.403, -.744]), a significant effect of Visit (ß=2.447, 95% CIs [.254, 4.509]), and a significant effect of Gender (ß=2.356, 95% CIs [.237, 4.448]).

Model terms	adosSA		CSBSs	
	Coefficients	*SE*	Coefficients	*SE*
hiIJA				
Intercepts	1.13***	.22	1.23***	.24
Visit	.11*	.05	.10°	.06
Social Spectrum	-.05	.03	-.05°	.03
loIJA				
Intercepts	10.12***	.78	11.24***	1.1
Visit			.13	.38
Social Spectrum			-.17	.11
Visit by *Social Spectrum*			-.07	.04
Gender (Male)	-2.32*	1.1	-2.21*	1.0
adosIJA				
Intercepts	2.0***	.07	1.82***	.04
Visit	.05	.03		
Social Spectrum	-.04***	.01		
Visit by *Social Spectrum*	-.01°	.00		

° $p<.075$
* $p<.05$
** $p<.01$
*** $p<.001$

Table 9. Coefficients, standard errors, and *p*-values for predictors identified in optimal LME models for the initiating joint attention variables.

With regards to initiating joint attention, the optimal LME model for hiIJA with adosSA as the predictor yielded a significant main effect for Visit ($p=.040$), such that high-level IJA skills increased over time. A non-significant main effect of adosSA ($p=.104$) was also included in the model. Examination of the plot of residuals suggested the normality assumption had been violated. Four potential high leverage cases were removed, and the models were re-run, resulting in the same main effects with improved graphs of the residuals. Additionally, cases with high residuals were removed from the initial model, and the models were re-run, similarly resulting in the same main effects with improved residual graphs. Furthermore, bootstrap multiple regression with adosSA as the *Social Spectrum* predictor showed a significant effect of adosSA (ß=-2.032, 95% CIs [-3.349, -.693]) and a significant effect of Visit (ß=1.954, 95% CIs [.139, 3.779]). Post hoc analyses did not yield any significant main effects of Age, nor was a significant main effect of adosSA included at 12 or 15 months; by 18 months, there was a significant main effect of adosSA (*p*=.030).

The optimal LME model for hiIJA with CSBSs as the predictor yielded marginally significant main effects of CSBSs (*p*=.058) and Visit (*p*=.073). However, examination of the plot of residuals suggested the normality assumption had been violated. When three identified outliers were removed from the model, the optimal results improved the graphs of residuals and yielded a significant main effect of Visit and a non-significant effect of CSBSs, congruent with the optimal model with adosSA as the predictor. However, bootstrap multiple regression showed a significant effect of CSBSs (ß=-1.760, 95% CIs [-3.358, -.056]) and a significant effect of Visit (ß=1.937, 95% CIs [.001, 3.793]). Post hoc analyses only yielded a marginally significant main effect of CSBSs at 12 months (*p*=.052). No other significant main effects were observed or included in the optimal models at 12, 15, or 18 months.

For the optimal loIJA models, no significant effects of Visit or *Social Spectrum* or their interaction were present. Of note, the optimal model for CSBSs included a non-significant CSBSs by Visit interaction (*p*=.113) in the model. However, there was a significant effect of Gender in the loIJA model, (*p*=.035) such that male infants demonstrated slightly fewer lower-level IJA skills at all ages compared to their female peers. Examination of the qqPlot of residuals confirmed that the normality assumption was not violated, and no outliers were identified. Post hoc analyses yielded a significant effect of CSBSs at 18 months (*p*=.048), and non-significant main effects of adosSA (*p*=.086) and

Age in both the adosSA and CSBSs models (*p*=.072, *p*=.101, respectively) were also included at 18 months.

The optimal LME model for adosIJA yielded a marginally significant Visit by adosSA interaction (*p*=.065). In contrast, with CSBSs as the predictor, no significant interaction or main effects of Visit or *Social Spectrum* were found, nor were they included in the optimal models. However, examination of the qqPlot of residuals suggested the normality assumption failed in both models. Bootstrap multiple regression with adosSA as a predictor yielded a non-significant interaction of Visit and *Social Spectrum* (ß=-1.711, 95% CIs [-4.009, .532]), a non-significant effect of Visit (ß=1.675, 95% CIs [-.182, 3.521]), and a significant effect of adosSA (ß=-3.119, 95% CIs [-5.261, -1.023]). Bootstrap multiple regression with CSBSs as a predictor yielded a non-significant a non-significant effect of Visit (ß=1.264, 95% CIs [-.764, 3.269]), and a non-significant effect of CSBSs (ß=.227, 95% CIs [-2.139, 2.570]). Post hoc analyses yielded a significant main effect of adosSA at 15 (*p*=.005) and 18 (*p*=.008) months, as well as a significant main effect of Age at 15 months in both the adosSA and CSBSs models (*p*=.009, *p*=.011, respectively).

Response to distress

Table 10 shows the coefficients and standard errors found in the optimal LME models for each response to distress variable with both adosSA and CSBSs as the predictors of the *Social Spectrum*. The optimal LME models for attendDIST yielded a significant Visit by adosSA interaction (*p*=.044) and a marginally significant Visit by CSBSs interaction (*p*=.057), suggesting that change in infants' attention to the distress task over time varied by the *Social Spectrum*. Additionally, the optimal models included a marginally significant effect of adosSA (*p*=.055) and a significant effect of CSBSs (*p*=.002). Figure 5 depicts the nature of this interaction such that, at 12 months, attention did not differ across the *Social Spectrum*, but over time, greater social impairment was associated with reduced attention, whereas attention increased or remained stable over time for those with minimal social impairment [Figure 5]. Post hoc analyses did not yield significant effects of adosSA or CSBSs, nor were they included in the optimal models, at 12 months. At 15 months, these effects of *Social Spectrum* were significant (SA: p=.048, CSBSs: p=.025). At 18 months, a significant main effect of CSBSs (p=.003) was observed, whereas a non-significant main effect of adosSA (p=.159) was included in the optimal model at 18 months. Importantly, examination of the qqPlot of residuals suggested the normality assumption was violated for the model with adosSA, but not CSBSs. Results from the bootstrap simulation showed a significant effect of Visit by *Social Spectrum*, as predicted by adosSA, interaction (ß=-2.185, 95% CIs [-4.149, -.220]), as well as a non-significant effect of adosSA (ß=-1.317, 95% CIs [-3.454, .768]) and non-significant effect of Visit (ß=1.661, 95% CIs [-.456, 3.784]).

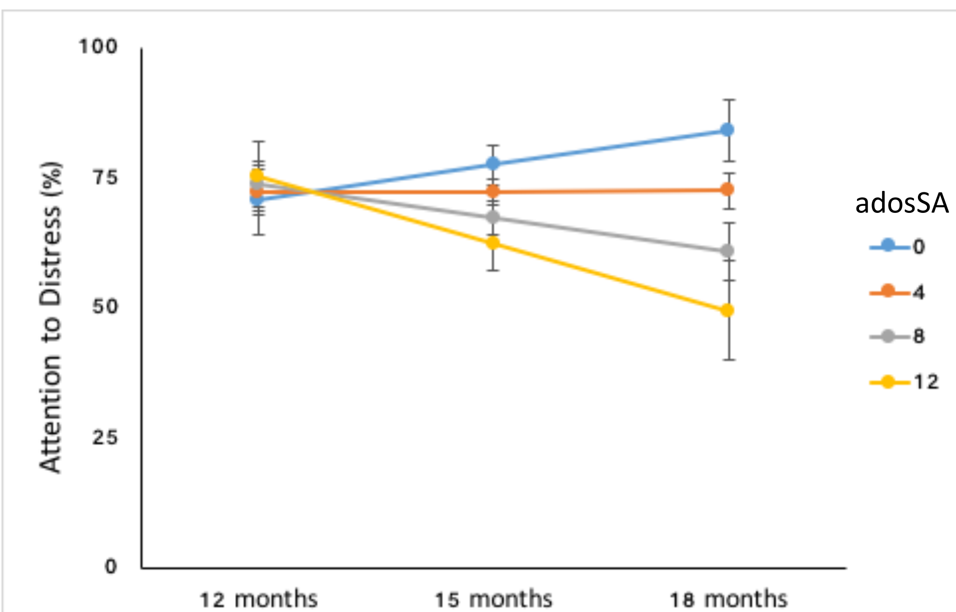


Figure 5. LME predicted values and standard errors for attendDIST by adosSA.

For ecDIST, significant Visit by *Social Spectrum* interactions were found in the optimal models for both adosSA and CSBSs predictors (p=.004, p=.045, respectively), suggesting that the development of empathic concern over time differs across the *Social Spectrum*. Figure 6 depicts the nature of this interaction, such that greater social impairment is associated with reduced empathic concern over time while minimal social impairment is related to increasing empathic responses over time. Examination of the qqPlot of residuals confirmed that the normality assumption was not violated, and no outliers were identified. Further examination of the residuals plotted against the independent variables and fitted variables suggested no assumptions were violated. Additional post hoc analyses yielded a significant main effect of adosSA at 18 months (p=.031) and marginally significant main effects of CSBSs at 15 (p=.054) and 18 (p=.074) months, such that greater social impairment is related to reduced affective responses. Non-significant main effects of Age were also included in the optimal CSBSs models at 15 (p=.120) and 18 (p=.090) months.

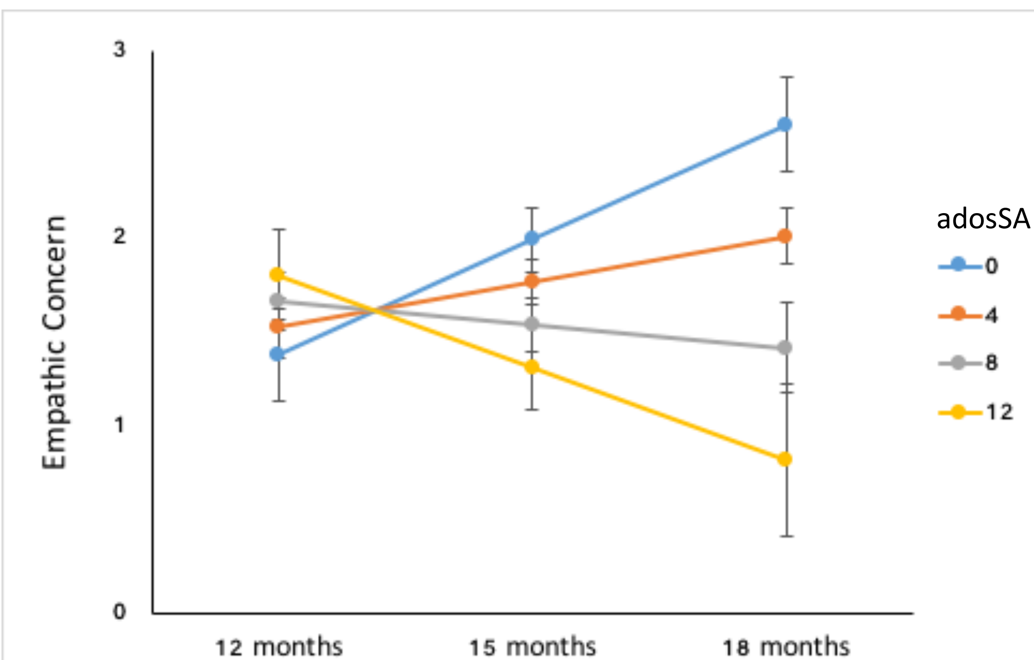


Figure 6. LME predicted values and standard errors for ecDIST by adosSA.

Model terms	adosSA		CSBSs	
	Coefficients	*SE*	Coefficients	*SE*
attendDIST				
Intercepts	77.36***	3.9	81.78***	4.2
Visit	2.19	1.6	1.63	1.7
Social Spectrum	-1.26°	.65	-1.52**	.48
Visit by *Social Spectrum*	-.54*	.26	-.38°	.20
ecDIST				
Intercepts	1.99***	.17	1.99***	.20
Visit	.20***	.06	.15*	.06
Social Spectrum	-.06*	.03	-.04	.02
Visit by *Social Spectrum*	-.03**	.01	-.02*	.01
htDIST				
Intercepts	.52***	.05	.71***	.09
Visit	.04°	.02		
Social Spectrum			-.03*	.01

° $p<.075$
* $p<.05$
** $p<.01$
*** $p<.001$

Table 10. Coefficients, standard errors, and *p*-values for predictors identified in optimal LME models for response to distress variables.

In contrast, the optimal models for htDIST yielded a significant main effect of CSBSs ($p=.012$) and a marginally significant main effect of Visit ($p=.054$) in the adosSA model. However, examination of the qqPlot of residuals suggested the normality assumption failed in both models. The only two infants whose htDIST responses were rated as a 2 were identified as outliers within these models. When these outliers were removed and the models were re-run, the same main effect of CSBSs was found, but there was no longer a marginally significant main effect of Visit in the adosSA model. Similarly, bootstrap linear regression with CSBSs as a predictor yielded a significant effect of CSBSs (ß=-2.621, 95% CIs [-4.687, -.687]), and bootstrap linear regression showed a non-significant effect of Visit (ß=1.959, 95% CIs [-.018, 3.960]). Additional post hoc analyses yielded a significant main effect of CSBSs at 15 months (p=.012), such that greater social impairment was associated with reduced htDIST.

Helping

Coefficients and standard errors for the predictors identified in the optimal LME models for the helping variables with both adosSA and CSBSs as the predictors of the *Social Spectrum* are listed in Table 11. The optimal LME models for latHELP yielded significant main effects for Visit with both adosSA and CSBSs as the predictors (p<.001, p=.012, respectively), such that the latency to help pick up the sticks became faster over time. No significant effects of *Social Spectrum* (as predicted by adosSA or CSBSs) were present, although CSBSs was included as a non-significant term in the optimal model (p=.097). Examination of the qqPlot of residuals confirmed that the normality assumption was not violated, and no outliers were identified. Further examination of the residuals plotted against the independent variables and fitted variables suggested no assumptions were violated. Additional post hoc analyses, conducted separately for each visit for latHELP did not yield a significant main effect of Age at any time point, nor for *Social Spectrum* at the 12 or 15 month visits. At 18 months, there was a significant main effect of CSBSs (p=.018), but not adosSA, suggesting greater social impairment, per parent report, was associated with slower latency times to help pick up the sticks.

The optimal LME model for latOFFER yielded significant main effects for Visit (adosSA model: p=.005, CSBSs model: p=.022) .and *Social Spectrum*, as predicted by both adosSA (p=.036) and CSBSs (p=.002). As Figure 7 reveals, the nature of these main effects is such that the latency to offer the sticks decreases (i.e., infants are quicker to offer) from 12 to 18 months for all infants across the *Social Spectrum* and that greater social impairment suggested slower latency times [Figure 7]. Examination of the qqPlot of residuals confirmed that the normality assumption was not violated, and no outliers were identified. Further examination of the residuals plotted against the independent variables and fitted variables suggested no assumptions were violated. Post hoc analyses of latOFFER at 12 months yielded a significant (*p*=.046) and a marginally significant (*p*=.072) effect of Age, for the adosSA and CSBSs models respectively, suggesting that quicker responses to offer were observed across the ages seen for the 12-month visit period. A non-significant effect of CSBSs (*p*=.112) was also included in the optimal model for latOFFER at 12 months. Of note, the removal of the non-significant main effect of CSBSs yielded the same significant main effect of Age at 12 months as seen in the adosSA model. At 15 months, no significant effects of Age or *Social Spectrum* were identified, and neither were included in the optimal models. At 18 months, there were significant main effects of adosSA (*p*=.042) and CSBSs (*p*=.008), such that the latency to offer the sticks was slower as social impairment increased.

Model terms		adosSA		CSBSs	
		Coefficients	*SE*	Coefficients	*SE*
latHELP					
	Intercepts	32.11***	2.6	25.71***	4.6
	Visit	-2.60***	.73	-2.05*	.79
	Social Spectrum			.88	.52
latOFFER					
	Intercepts	37.73***	3.2	33.99***	3.4
	Visit	-1.98**	.69	-1.63*	.70
	Social Spectrum	1.09*	.51	1.27**	.39

* *p*<.05
** *p*<.01
*** *p*<.001

Table 11. Coefficients, standard errors, and *p*-values for predictors identified in optimal LME models for the helping variables.

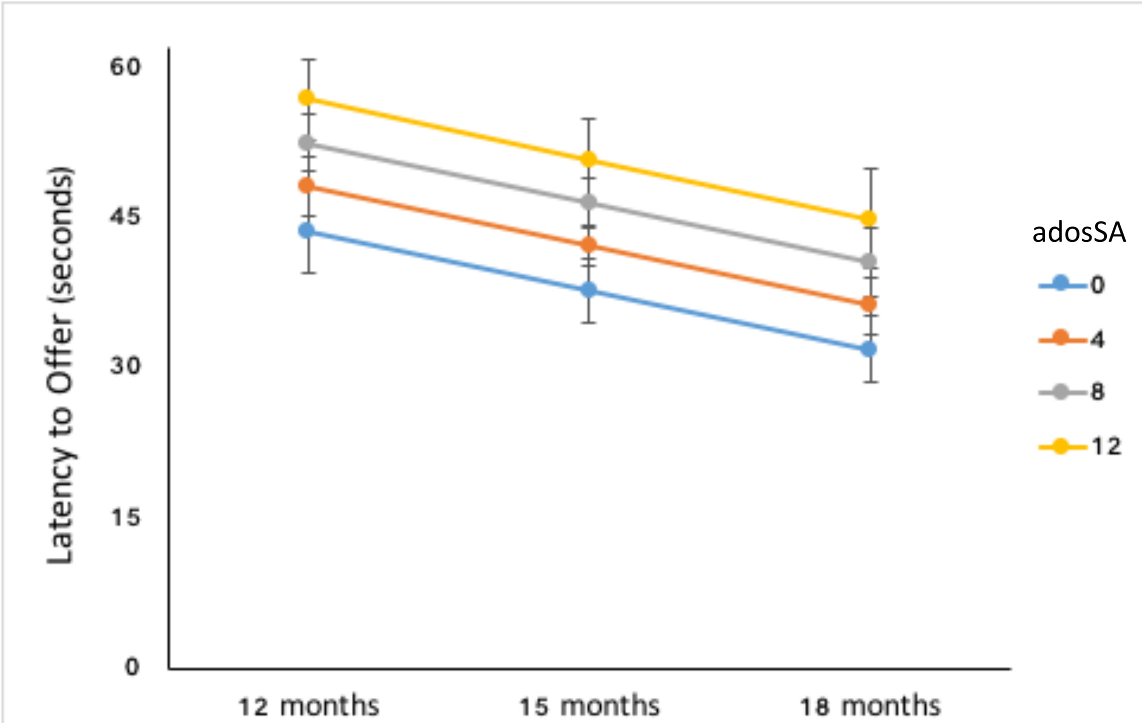


Figure 7. LME predicted values and standard errors for latOFFER by adosSA

Aim 2: SEM analyses

No significant effects of Gender, Race, or Maternal Education were observed in the optimal LME models in the prediction of the variables selected a priori for inclusion in the SEM models (i.e., adosSA, expSO, hiRJA, hiIJA, ecDIST, and latOFFER). Therefore, these demographic variables were not included in the subsequent SEM models. Correlations among all possible indicators used across the various SEM models at each visit are presented in Table 12.

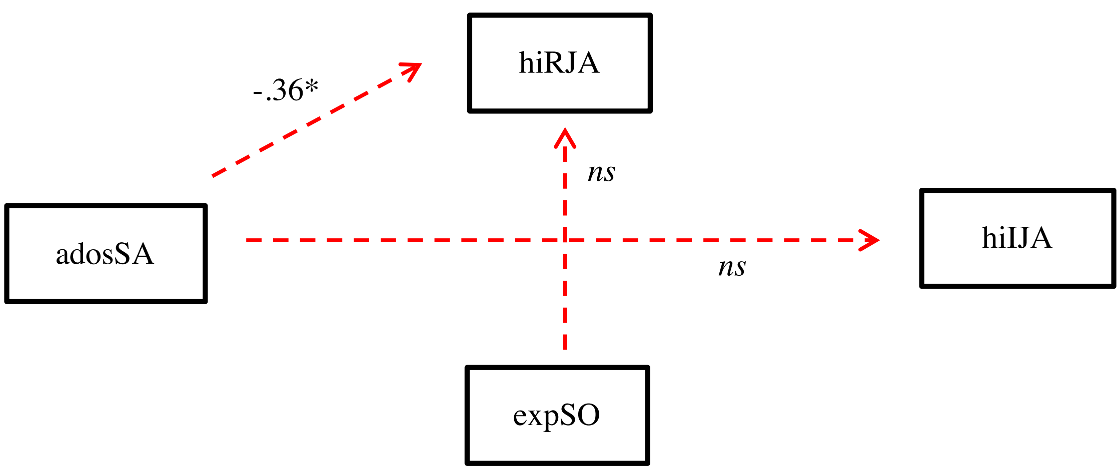
	adosSA	expSO	hiIJA	hiRJA	latOFFER	ecDIST
12 months						
adosSA	1					
expSO	-.037	1				
hiIJA	-.193	-.088	1			
hiRJA	-.385*	-.145	.086	1		
latOFFER	.231	.235	.086	-.392*	1	
ecDIST	.178	.080	-.112	.004	.222	1
15 months						
adosSA	1					
expSO	-.415*	1				
hiIJA	-.052	.310	1			
hiRJA	.068	.195	-.275	1		
latOFFER	.132	-.096	.290	-.262	1	
ecDIST	-.188	.251	.419**	-.065	-.021	1
18 months						
adosSA	1					
expSO	-.115	1				
hiIJA	-.352*	-.056	1			
hiRJA	-.047	.440**	.010	1		
latOFFER	.332*	-.267	-.297	-.555***	1	
ecDIST	-.354*	.117	.255	.004	-.156	1

* p<.05
** p<.01
*** p<.001

Table 12. Correlations amongst variables used in the structural equation models by visit.

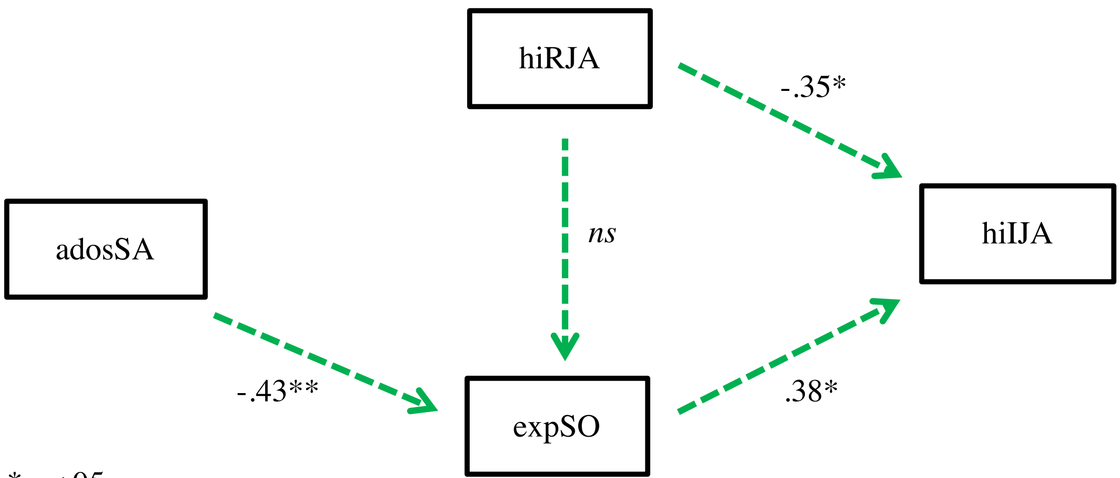
Relations of *Social Spectrum* (adosSA) and social attention (expSO, hiIJA, hiRJA) at each Visit

Initial SEM models examined the relationships between adosSA, expSO, hiIJA, and hiRJA, separately at each visit (Figures 8-10). All optimal models were found to be a good fit for the data (RMSEA = 0, for each visit). At 12 months, there was a significant relationship between adosSA and hiRJA (adosSA → hiRJA: p=.002), such that as adosSA increased, hiRJA decreased (estimate= -.362, se=.149; Figure 8). At 15 months, hiRJA was related to hiIJA (hiRJA → hiIJA: p=.022), such that greater hiRJA was associated with less hiIJA (estimate=-.348, se=.152; Figure 9). Additionally, adosSA was related to expSO (adosSA → expSO: p=.003), such that as adosSA increased, expSO decreased (estimate=-.430, se=.147), and expSO was related to hiIJA (expSO → hiIJA: p=.012), such that greater expSO was related to greater hiIJA (estimate=.378, se=.151), suggesting an indirect relationship between adosSA and hiIJA through expSO at 15 months. While at 18 months (Figure 10), the optimal model suggested a direct relationship between adosSA and hiIJA (adosSA → hiIJA: p=.031), such that adosSA increased, hiIJA decreased (estimate=-.339, se=.157). Additionally, there was a significant relationship between expSO and hiRJA (expSO → hiRJA: p=.003), such that greater expSO was related to greater hiRJA (estimate=.441, se=.150). Additional non-significant pathways were included at 12 months (adosSA → hiIJA, p=.263; expSO → hiRJA, p=.289) and at 15 months (hiRJA → expSO, p=.128).



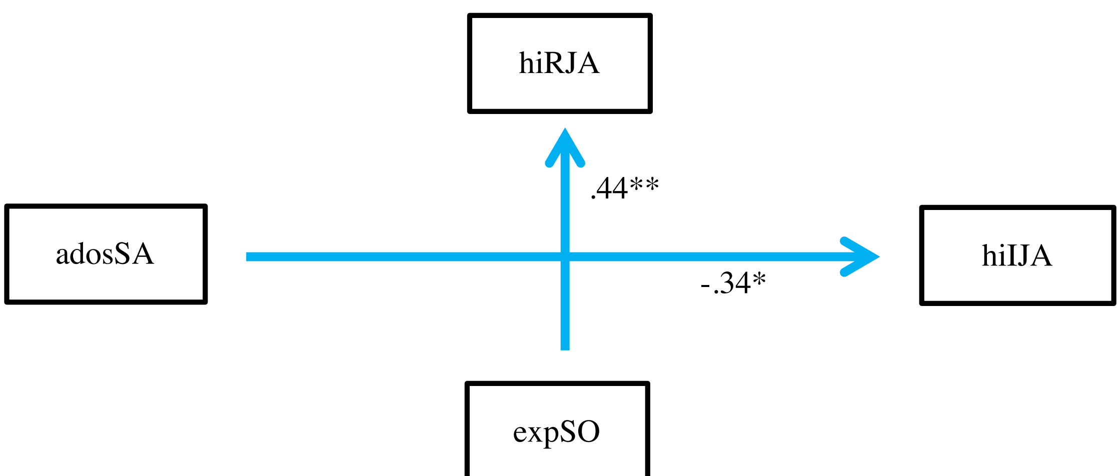
* p<.05
** p<.01
*** p<.001

Figure 8. Structural equation pathways for relationships between social attention variables and the *Social Spectrum* at 12 months.



* p<.05
** p<.01
*** p<.001

Figure 9. Structural equation pathways for relationships between social attention variables and the *Social Spectrum* at 15 months.



* p<.05
** p<.01
*** p<.001

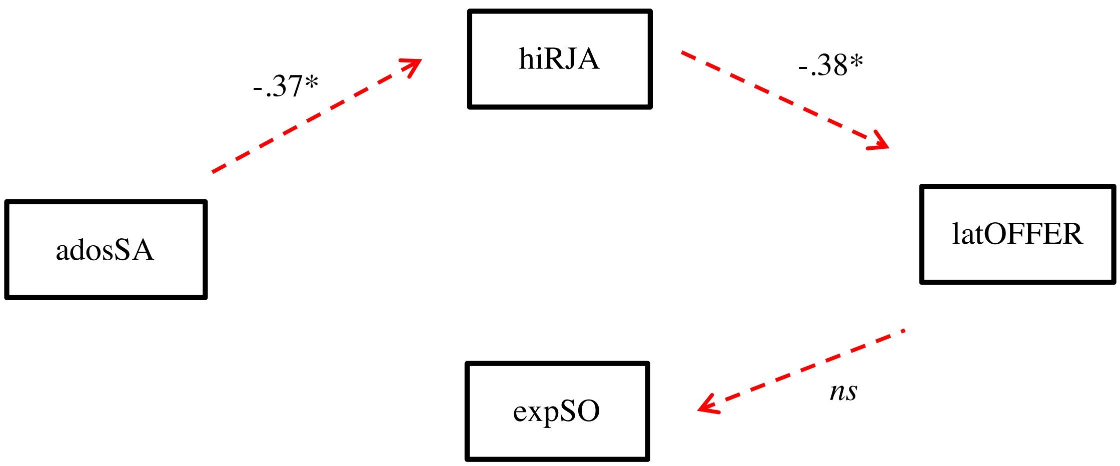
Figure 10. Structural equation pathways for relationships between social attention variables and the *Social Spectrum* at 18 months.

Relations of *Social Spectrum* (adosSA), social attention (expSO, hiIJA *or* hiRJA), and behavioral responses (ecDIST *or* latOFFER) at each Visit

The previous SEM models used data for adosSA, expSO, hiRJA, ***and*** hiIJA at each visit. The models were designed to include four variables to allow for sufficient power for the study's sample size. Therefore, in order to identify how variables of social attention (expSO, hiRJA, hiIJA) are related to behavioral responses (ecDIST, latOFFER) across the *Social Spectrum* (adosSA), the models were first conducted with hiRJA and then with hiIJA as a social attention predictor for ecDIST and latOFFER. Specifically, SEM models were conducted, separately for each visit, with adosSA, expSO, either hiRJA ***or*** hiIJA, and either ecDIST ***or*** latOFFER. Thus, four models were conducted for each visit.

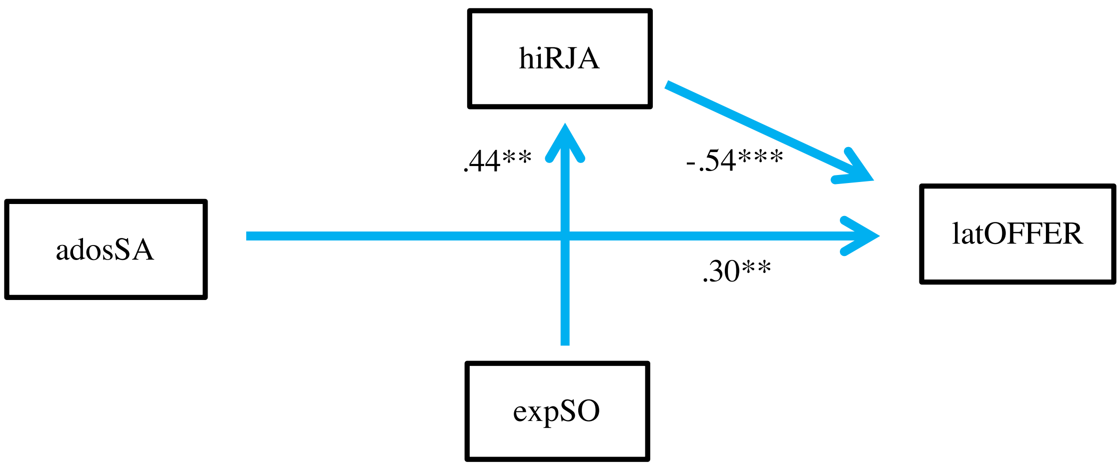
All optimal models were found to be a good fit for the data (RMSEA = 0, for each model at each visit). Importantly, all significant pathways depicted in Figure 11 from the previous optimal models examining the relationships between the *Social Spectrum* (adosSA) and all of the social attention variables (expSO, hiRJA, ***and*** hiIJA) continued to emerge as significant pathways in these subsequent models which utilized only 3 of 4 of the original SEM variables (adosSA, expSO, hiRJA, ***or*** hiIJA). No additional significant pathways between adosSA, hiRJA ***or*** hiIJA, and ecDIST ***or*** latOFFER emerged at any visit.

In addition to these significant pathways between the *Social Spectrum* and social attention variables previously identified, at 12 months, there was a significant relationship between hiRJA and latOFFER (hiRJA → latOFFER, p=.018), such that greater hiRJA was related to faster latOFFER (estimate=-.383, se=.154). A non-significant pathway between latOFFER and expSO was also included at 12 months. At 15 months, no significant relationships to latOFFER were found. A non-significant pathway between hiRJA and latOFFER was included at 15 months. At 18 months, the optimal SEM model yielded a significant relationship between hiRJA and latOFFER (hiRJA → latOFFER, p<.001), such that greater hiRJA was related to faster latOFFER (estimate=-.537, se=.129), consistent with the model for 12 months (Figure 11). Additionally, at 18 months, there was a significant relationship between adosSA and latOFFER (adosSA → latOFFER, *p*=.002), such that greater adosSA was related to larger/slower latOFFER (estimate=.299, se=.129; Figure 12).



* *p*<.05
** *p*<.01
*** *p*<.001

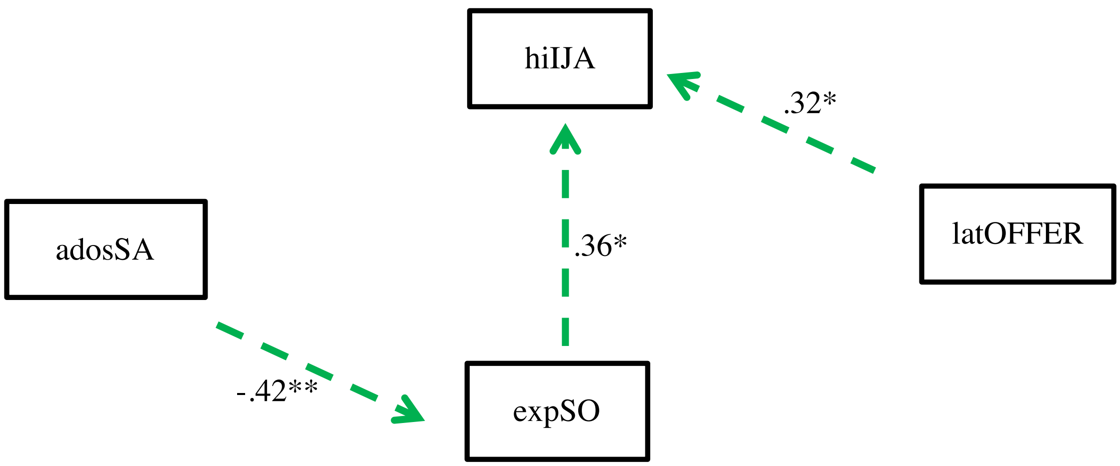
Figure 11. Structural equation pathways from the optimal model for relationships between adosSA, expSO, hiRJA, and latOFFER at 12 months.



* $p<.05$
** $p<.01$
*** $p<.001$

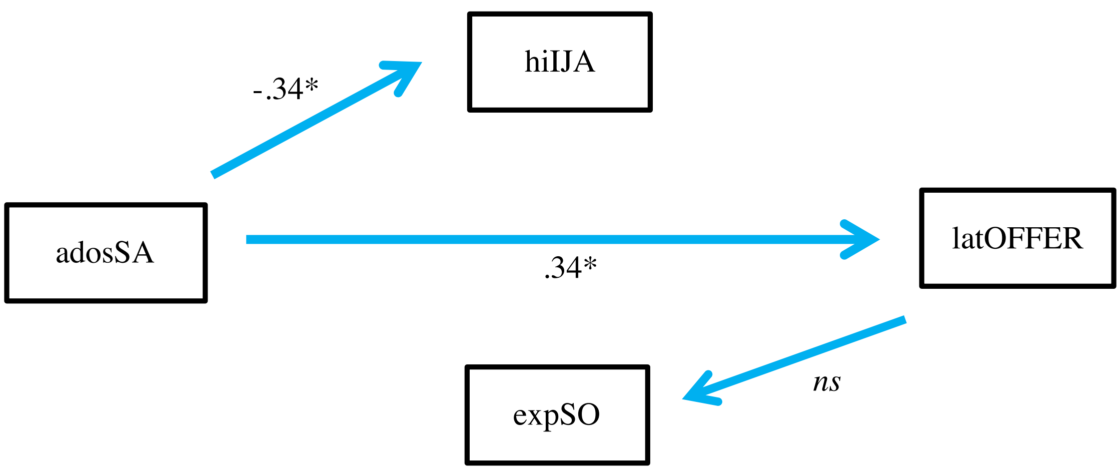
Figure 12. Structural equation pathways from the optimal model for relationships between adosSA, expSO, hiRJA, and latOFFER at 18 months.

For latOFFER, in the models using hiIJA, in addition to the significant pathways between the *Social Spectrum* and social attention variables previously identified, no significant relationships to latOFFER were found at 12 months. At 12 months, the optimal model included non-significant pathways between adosSA and latOFFER and between expSO and latOFFER. At 15 months, hiIJA was related to latOFFER (latOFFER → hiIJA, p=.031), such that greater hiIJA was related to larger/slower latOFFER (estimate=.324, se=.150; Figure 13). At 18 months, there was a significant relationship between adosSA and latOFFER (adosSA → latOFFER, p=.031), such that greater adosSA was related to larger/slower latOFFER (estimate=.339, se=.157; Figure 14). Additionally, at 18 months, there was a non-significant relationship between latOFFER and expSO.



* p<.05
** p<.01
*** p<.001

Figure 13. Structural equation pathways from the optimal model for relationships between adosSA, expSO, hiIJA, and latOFFER at 15 months.



* p<.05
** p<.01
*** p<.001

Figure 14. Structural equation pathways from the optimal model for relationships between adosSA, expSO, hiIJA, and latOFFER at 18 months.

Regarding ecDIST, in the models using hiRJA, in addition to the significant pathways between the *Social Spectrum* and social attention variables previously identified, no significant relationships to ecDIST were found at 12 or 15 months. At 12 months, the optimal model included a non-significant pathway between adosSA and ecDIST; at 15 months, the optimal model included a non-significant pathway between expSO and ecDIST. At 18 months, there was a significant relationship between adosSA and ecDIST, (adosSA → ecDIST, $p<.001$), such that greater adosSA was related to reduced ecDIST (estimate=-.331, se=.160).

Similar findings were found in the optimal models with hiIJA and ecDIST. In the models using hiIJA, in addition to the significant pathways between the *Social Spectrum* and social attention variables previously identified, no significant relationships to ecDIST were found at 12 months; the optimal model included a non-significant pathway between adosSA and ecDIST, consistent with the model utilizing hiRJA. In contrast, at 15 months, hiIJA was related to ecDIST (hiIJA → ecDIST, $p=.006$), such that greater hiIJA was related to greater ecDIST (estimate=.419, se=.151). Additionally, at 15 months, the optimal model included a non-significant pathway between adosSA and ecDIST. At 18 months, there was a significant relationship between adosSA and ecDIST, (adosSA → ecDIST, $p<.001$), such that greater adosSA was related to reduced ecDIST (estimate=-.331, se=.160), consistent with the model utilizing with hiRJA.

Relations of *Social Spectrum* (adosSA) and social attention (expSO, hiIJA, hiRJA) over time

Additional SEM models examined the relationships between adosSA and the social attention variables (i.e., expSO, hiRJA, and hiIJA) over time, rather than at each visit. These models were conducted to examine mediation effects over time by using 12-month data for adosSA, expSO, and hiIJA, and 15-month data for hiRJA. As these SEM models are using observed data across different ages, the SEM models were examined for mediation in a different way to evaluate the direct and indirect relationships between the variables. Full, saturated models were compared to models that removed either direct or indirect pathways previously outlined. In the initial model utilizing 12-month data for adosSA, expSO, and hiIJA and 15-month data for hiRJA, no significant pathways were found between these social attention variables or with the *Social Spectrum*. Specifically, hiRJA at 15 months was not associated (*ns*) with adosSA or expSO or hiIJA at 12 months. Removal of the nonsignificant direct pathways to hiRJA (15 months), separately, from adosSA (12 months), from expSO (12 months), and from hiIJA (12 months) resulted in slightly better fitting models compared to the full, saturated model, according to the AIC, yet all pathways remained non-significant. Similarly, separately removing the three sets of indirect pathways (adosSA→expSO→hiRJA; adosSA→hiIJA→hiRJA; expSO→hiIJA→hiRJA) resulted in better fitting models compared the full, saturated model, yet no significant pathways emerged (*ns*). Additionally, within the context of the models examining the relationships between adosSA (12 months), expSO (12 months), hiIJA (15 months), and behavioral responses (18 months), neither adosSA or expSO at 12 months were related to hiIJA at 15 months (*ns*) in the full, saturated models.

Relations of *Social Spectrum* (adosSA), social attention (expSO, hiIJA *or* hiRJA), and behavioral responses (ecDIST *or* latOFFER) over time

Lastly, additional SEM models examined the relationships between the *Social Spectrum,* the social attention variables (i.e., expSO and either hiRJA ***or*** hiIJA), to behavioral responses (i.e., ecDIST ***or*** latOFFER) over time. Specifically, additional SEM models were conducted to examine mediation effects over time by using: 1) 12-month data for adosSA, expSO, and either hiRJA or hiIJA, and 15-month data for either ecDIST or latOFFER; 2) 12-month data for adosSA, expSO and either hiRJA or hiIJA, and 18-month data for either ecDIST or latOFFER; 3) 15-month data for adosSA, expSO and either hiRJA or hiIJA, and 18 month data for either ecDIST or latOFFER; 4) 12-month data for adosSA and expSO, 15-month data for either hiRJA or hiIJA, and 18-month data for either ecDIST or latOFFER. As these SEM models are using observed data across different ages, the SEM models were examined for mediation in a different way to evaluate the direct and indirect relationships between the variables. Full, saturated models were compared to models that removed either direct or indirect pathways previously outlined.

First, the models examined how the *Social Spectrum* and social attention variables at 12 months were related to behavioral responses at 15 months. Regarding initiating joint attention, SEM models, utilizing 12-month data for adosSA, expSO, and hiIJA, and 15-month data for either ecDIST and latOFFER, did not yield any significant pathways in the full, saturated model nor when any of the direct or indirect relationships to ecDIST or latOFFER at 15 months were removed from the models. Removal of all direct and indirect pathways resulted in better fitting models, according to the AIC, with one exception. Removing the direct pathway from hiIJA to either ecDIST or latOFFER slightly increased the AIC and AICc and resulted in poorer fitting models compared to the full, saturated model (RMSEA=.188, RMSEA=.204, respectively). However, when the indirect pathways from hiIJA to ecDIST or latOFFER through expSO were removed, the direct pathway from hiIJA to ecDIST or latOFFER remained nonsignificant. In summary, social impairment, social orienting, and initiating joint attention at 12 months were not found to related to the behavioral responses at 15 months.

Similarly, SEM models, utilizing the same 12-month data for adosSA, expSO, and hiIJA, but with the 18-month data for either ecDIST and latOFFER, did not yield any significant pathways in the full, saturated model or when any of the direct or indirect relationships to ecDIST or latOFFER at 15 months were removed from the models, with one exception. The initially full, saturated model of adosSA, expSO, and hiIJA at 12 months to latOFFER at 18 months included a marginally significant relationship between adosSA and latOFFER (18 months, *p*=.066), such that greater social impairment at 12 months was related to slower latencies to offer the sticks (Estimate=.300, *se*=.159). Removing this direct pathway resulted in higher AIC and AICc values and was a poorly fitting model (RMSEA=.248). Removal of the indirect pathways from adosSA to latOFFER through expSO or through hiIJA yielded better fitting models based on the AIC and AICc (RMSEA=0, RMSEA=0, respectively), yet the relationship from adosSA to latOFFER remained marginally significant (*p*=.060, *p*=.060, respectively). In summary, greater social impairment at 12 months was marginally associated with slower latencies to offer help at 18 months, yet no other relationships between social impairment, social orienting, or initiating joint attention at 12 months was related to the behavioral responses at 18 months.

Regarding responding to joint attention, the initial full, saturated SEM models, utilizing 12-month data for adosSA, expSO, and hiRJA, and 15-month data for latOFFER, yielded a significant pathway between hiRJA at 12 months to latOFFER at 15 months (*p*=.005), such that greater hiRJA at 12 months was associated with faster latencies to help (Estimate=-.455, se=.161) at 15 months. Additionally, there was a broadly marginally significant pathway between adosSA and hiRJA at 12 months (*p*=.079), such that greater social impairment was marginally related to reduced responding to joint attention at 12 months (Estimate=-.288, se=.164). Removing the indirect pathways from hiRJA to latOFFER through expSO resulted in a better fitting model according to the AIC and AICc and was overall a good fit for the data (RMSEA=0). Results yielded a similar significant relationship between hiRJA at 12 months and latOFFER at 15 months (Estimate=-.440, se=.162, *p*=.007), yet the relationship between adosSA and hiRJA at 12 months was no longer marginally significant (*p*=.088). Removing the pathway from hiRJA at 12 months to latOFFER at 15 months, resulted in a poorer fitting model, according to the AIC and AICc, and was a found to be a poor fit for the data (RMSEA=.426). Removal of this significant pathway did not result in the emergence of any other significant pathways. In summary, the optimal SEM models found a direct relationship between hiRJA at 12 months and latOFFER at 15 months, such that greater responding to joint attention at 12 months was related to faster latencies to help at 15 months.

For the ecDIST behavioral responses at 15 months, the full, saturated model similarly yielded a broadly marginally significant pathway between adosSA and hiRJA at 12 months (*p*=.076), such that greater social impairment was marginally related to reduced responding to joint attention at 12 months (Estimate=-.286, se=.161). The pathway from adosSA to hiRJA at 12 months was no longer broadly marginally significant (*p*=.090) in the models that removed the pathway from hiRJA to ecDIST or pathway from expSO to hiRJA. The removal of the pathways resulted in better fitting model, according to the AIC and AICc, that were good fits for the data (RMSEA=0), and did not yield any new significant pathways.

In contrast, when evaluating the relationships of adosSA, expSO, and hiRJA at 12 months to the 18-month data for latOFFER and ecDIST, the initial full models yielded a significant relationship between adosSA at 12 months and hiRJA at 12 months; *p*=.025[latOFFER], *p*=.025[ecDIST]). Removing the indirect pathways from adosSA to ecDIST through hiRJA resulted in a poorer fitting model, based on the AIC and AICc, and no new significant pathways emerged in this model, which was also a poor fit for the data (RMSEA=.202). No other significant pathways were observed in the full models or after removing direct and indirect pathways to ecDIST (18 months).

Regarding latOFFER at 18 months, the full, saturated moved yielded a non-significant relationship between hiRJA (12 months) → latOFFER (18 months; *p*=.089). However, when the direct pathway from adosSA at 12 months to latOFFER at 18 months was removed from the model, the indirect pathways from adosSA to latOFFER through hiRJA became significant, such that greater social impairment was related to reduced hiRJA (Estimate=-.344, se=.154, *p*=.025), which was related to slower latOFFER (Estimate=-.354, se=.159, .026). However, although this reduced model yielded a smaller AIC and AICc, the overall fit of the data using this model was poor (RMSEA=.118). When these indirect pathways from adosSA to hiRJA and hiRJA to latOFFER were removed, it yielded a poorer fitting model, based on the AIC and AICc, that was a poor fit for the data (RMSEA=2.76). In this reduced model, the direct path from adosSA at 12 months to latOFFER at 18 months was marginally significant (*p*=.060). In summary, these findings, which should be interpreted with caution, may suggest that the marginally significant relationship between adosSA at 12 months and latOFFER at 18 months may be mediated by hiRJA at 12 months.

For the SEM models evaluating the 15-month data for adosSA, expSO, and hiRJA, and 18-month data for either ecDIST and latOFFER, there was a significant relationship between adosSA at 15 months to expSO at 15 months (*p*=.007 [latOFFER], *p*=.016 [ecDIST]). Removing the indirect pathways from adosSA to either ecDIST or latOFFER through expSO did not yield any significant pathways, and resulted in poorer fitting models, according to the AIC and AICc that were also poor fits for the data (RMSEA=.222, RMSEA=.293, respectively). Initial full, saturated models also included a significant relationship between hiRJA at 15 months to latOFFER at 18 months (*p*=.003), such that greater hiRJA at 15 months was associated with faster latOFFER at 18 months (Estimate=-.437, se=.149). Removing this pathway from the model yielded a marginally significant pathway between expSO at 15 months and latOFFER at 18 months (*p*=.073). However, removal of this direct pathway resulted in a poorer fitting model based on the AIC and AICc that was also a poor fit for the data (RMSEA=.438). In summary, these models suggest that greater social impairment is associated with reduced expSO at 15 months and that greater hiRJA at 15 months is associated with faster latOFFER at 18 months.

Regarding initiating joint attention, the initial full, saturated models utilizing 15-month data for adosSA, expSO, and hiIJA, and 18-month data for ecDIST, yielded significant relationships between adosSA and expSO at 15 months (*p*=.016), such that greater social impairment was associated with reduced expSO (Estimate=-.382, se=.159). Additionally, there was a marginally significant relationship between expSO and hiIJA at 15 months (*p*=.065), such that greater expSO was related to greater hiIJA at 15 months (Estimate=.326, se=.177). Removing the indirect pathways from adosSA to expSO and expSO to ecDIST resulted in a poorer fitting model based on the AIC and AICc, which was a poor fit for the data (RMSEA=.230), yet with the absence of the significant adosSA to expSO relationship, the marginally significant pathway from expSO to hiIJA became significant (*p*=.046). Interestingly, removing the pathways from adosSA to hiIJA and from hiRJA to ecDIST resulted in a better fitting model (RMSEA=0) where the pathway from expSO to hiIJA was no longer significant (*p*=.0871).

For latOFFER at 18 months, the full, saturated models utilizing the 15-month data for adosSA, expSO, and hiIJA, and the 18-month data for latOFFER yielded a significant relationship between adosSA and expSO at 15 months (*p*=.007), and significant relationships between expSO and both hiIJA (*p*=.044) and latOFFER (*p*=.030). These findings suggest that greater social impairment is associated with reduced expSO (Estimate=-.413, se=.154) and that greater expSO is associated with both greater hiIJA (Estimate=.354, se=.176) and faster latOFFER (Estimate=-.382, se=.183). Removing the significant indirect pathways from adosSA to latOFFER through expSO did not yield a significant direct relationship between adosSA and latOFFER and resulted in a poorer fitting model that fit the data poorly (RMSEA=.351). Removing the significant pathway from expSO to latOFFER resulted in a poorly fitting model (RMSEA=.297), and did not alter the effects of the other relationships. Interestingly, removing the indirect pathways from adosSA to latOFFER through hiIJA, resulting in a better fitting model that was a good fit for the data (RMSEA= 0), yielded marginally significant pathways between expSO and hiIJA (p=.057) and expSO and latOFFER (p=.073). Lastly, removing the significant indirect pathways from hiIJA to latOFFER through expSO from the initial full model resulted in a poorer fitting model and did not cause the direct relationship from hiIJA at 15 months to latOFFER at 18 months to become significant. In summary, these models suggest that both greater social impairment and reduced hiIJA are associated with reduced expSO which is associated with slower latOFFER at 18 months.

Lastly, SEM models utilizing 12-month data for adosSA and expSO, 15-month data for hiIJA, and 18-month data for either ecDIST and latOFFER, did not yield any significant pathways in the full, saturated model or when any of the direct or indirect relationships to ecDIST or latOFFER at 18 months were removed from the models. However, utilizing hiRJA at 15 months, the initial full, saturated SEM model yielded a significant pathway from hiRJA at 15 months to latOFFER at 18 months (p=.005), such that greater hiRJA was associated with faster latOFFER (Estimate=-.434, se=.156). Removing the indirect pathways from adosSA at 12 months to latOFFER at 18 months through hiRJA at 15 months did not yield any significant pathways and resulted in a poorer fitting model based on the AIC and AICc that was a poor fit for the data (RMSEA=.293). No other significant pathways were observed in the full, saturated models or after removing any of the direct or indirect pathways to either latOFFER (18 months) or ecDIST (18 months). In summary, the SEM models utilizing data from 12, 15, and 18 months resulted in only one significant relationship which was between hiRJA at 15 months and latOFFER at 18 months.

Discussion

OVERVIEW

This study evaluates how four social skills develop independently and in relation to each other from 12 to 18 months. Additionally, this study examines how this social development differs across the *Social Spectrum*.

INDEPENDENT SOCIAL SKILL DEVELOPMENT

Social orienting

Social orienting, reflected by the infant's tendency to respond to their name when called, is a skill that develops early in life and is a hallmark deficit in ASD (Dawson et al, 1998; Dawson et al., 2004; Mundy & Neal, 2001). While most typically developing infants respond to their name by 6 months (CDC, 2016b), research suggests that infants later diagnosed with ASD are less likely to respond to their name at 8-10 months (Werner et al., 2000) and 12 months (Osterling, Dawson, & Munson, 2002; Nagid et al., 2007). Consistent with a priori hypotheses, social orienting did not vary over time from 12 to 18 months. This finding was consistent across both modes of assessment of social orienting (i.e., parent report and experimenter behavioral ratings). While this skill was stable over time, it was also hypothesized to vary across the *Social Spectrum*, such that greater social impairment was thought to be related to reduced social orienting. This hypothesis was confirmed for the parent report of social orienting across both modalities of *Social Spectrum* symptom assessment (parent and experimenter). However, in the experimenter behavioral ratings of social orienting, differences were only observed across the *Social Spectrum* when information regarding *Social Spectrum* symptoms was provided by parent report (CSBSs), but not when rated by the experimenter (adosSA).

Interestingly, parent report of social orienting varied by race, such that mothers of racial minority reporting reduced social orienting in their infants. This finding was unexpected and has not been observed in previous research. However, it may be indicative of cultural differences in eye contact. For example, recent research suggests that studies of differences in eye gaze across cultures are rare and that "in Western cultures, eye contact during social interaction is considered more important than in East Asian cultures" (Akechi et al., 2013, p. 1). While differences in the duration of eye contact and rules have been found, Akechi et al. (2013) found that differences in gaze behaviors in adults across cultures based on "differential display rules and cultural norms, as opposed to culture affecting eye contact behaviour directly at the physiological level" (p. 2). Importantly, only three of the mothers of racial minority identified as Asian in the current study. An additional three mothers identified as Mexican American. The cultural expectations regarding eye contact in the Hispanic population may or may not be different than Western culture and/or East Asian culture. Considering cultural differences may be important for the use and interpretation of different modes of assessments, such as parent report versus experimenter observation, when evaluating social orienting.

Joint attention

Responding to joint attention was measured using two instruments in this study. It was measures using the Early Social Communication Scale (ESCS), a semi-structured child-experimenter interaction paradigm that includes structured opportunities for the child to demonstrate their capacity to follow the line of regard of the tester to proximal (loRJA) and distal (hiRJA) targets. A separate index of the child's capacity to follow the line of regard of the tester to a distal object was provided using a single item from the Autism Diagnostic Observation Schedule-Second Edition, Toddler Module (adosRJA).

Importantly, during the ESCS, the experimenter uses eye contact paired with a gestural point (proximal and distal, respectively) to elicit hiRJA and loRJA responses, and percentages are calculated for the number of times the infant correctly follows the experimenter's line of regard. In contrast, during the ADOS-2-T, adosRJA is administered first by using only eye gaze to direct the infant's attention to follow the experimenter's line of regard. After three failed attempts, the experimenter then provides additional support by using a distal point. Scores for adosRJA may therefore reflect varying complexity (e.g., with or without a distal point) whereas hiRJA and loRJA may better reflect the consistency of the skill.

Previous research found a linear increase in RJA from 9 to 18 months, as well as a quadratic effect from 9 to 18 months, such that RJA rapidly increases from 9 to 12 months then levels out at 15 months before increasing slightly from 15 to 18 months (Mundy et al., 2007). Regarding low-level RJA skills observed in the Early Social Communication Scale, infants were expected to largely demonstrate loRJA skills by 12 months that would remain stable over time in those with minimal social impairment and possibly decrease over time in those with greater social impairment. In contrast to a priori hypotheses, the results of this study revealed that a moderately high amount of low-level RJA was present at 12 months and increased from 12 to 18 months. No differences were observed across the *Social Spectrum*.

Consistent with a priori hypotheses, this study found that high-level RJA increased from 12 to 18 months for infants across the *Social Spectrum* using the ESCS. In contrast to previous literature that led to the hypothesis that differences across the *Social Spectrum* would not be observed until 18 months, rather this study found no differences in hiRJA across the *Social Spectrum* over time, and post-hoc analyses suggested that greater *Social Spectrum*, per experimenter ratings, was only related to fewer hiRJA at 12 months.

Previous research found no differences in RJA between HR and LR infants at either 7 or 13 months of age (Bedford et al., 2012), yet Presmanes et al. (2006) found that HR infants showed significantly lower scores than their LR peers. Variability in the research may similarly reflect the variability observed in this study.

Similarly, utilizing the adosRJA, the findings were consistent with this hypothesis that there was an increase in infant capacity to respond, or follow, the line of regard of a social partner from 12 to 18 months. Furthermore, this development varied across the *Social Spectrum* with different patterns for experimenter ratings versus parent report of social spectrum symptoms. Specifically, it was observed that experimenter ratings of *Social Spectrum* were associated with lower adosRJA at 12 and 15 months whereas parent ratings of the *Social Spectrum* were associated with lower adosRJA at 15 and 18 months. Of note, the majority of infants demonstrated this skill at 12 months and very few failed this skill at 15 (n=2) and 18 months (n=1), suggesting a ceiling effect is emerging at 12 months and present at 15 and 18 months. The additional complexity of adosRJA (with or without a distal point), compared to hiRJA (with distal point) items, may better differentiate skill development across the *Social Spectrum*.

Initiating joint attention (IJA) was also measured using the Early Social Communication Scale (hiIJA, loIJA) and the Autism Diagnostic Observation Schedule-2 (adosIJA). Previous research by Mundy et al. (2007) found a cubic effect of IJA from 9 to 18 months, such that IJA rapidly increased from 9 to 12 months, then remains stable from 12 to 18 months with a slight increase seen from 12 to 15 months in typical development. Yet HR infants were found to be at increased risk of demonstrating reduced IJA around 15 months, and infants later diagnosed with ASD demonstrated reduced IJA at 18 months (Charman et al., 1997). Thus, high-level initiating joint attention skills were hypothesized to be present to a large degree at 12 months and to remain stable over time for those with mild social impairment and to possibly decline from 15 to 18 months in those with greater social impairment. In contrast to the previous literature, this study found that infants demonstrated minimal high-level IJA behaviors at 12 months which increased slightly from 12 to 18 months. There was no main effect of *Social Spectrum* from 12 to 18 months, yet differences in hiIJA were found based on experimenter ratings of the *Social Spectrum* specifically at 18 months, which is in line with the previous research. Low-level IJA was hypothesized to be present at moderate amounts at 12 months and to decline over time in those with greater social impairment. Results of this study revealed moderate amounts of loIJA at 12 months; however, no significant developmental differences were observed over time or across the *Social Spectrum*, with one exception. Greater social impairment, per parent report, was associated with reduced loIJA at 18 months which is consistent with the previous research. Additionally, this variability was also somewhat reflected in the progression of adosIJA, which found a significant difference in initiating joint attention at 15 and 18 months per experimenter rating of the *Social Spectrum*.

Response to distress

Regarding infant attention to the distress task, previous research found that children with ASD attend for shorter periods of time in response to another distress (Sigman et al., 1992). In a prospective study, infants who were later diagnosed with ASD were less attentive to another's distress from 12 to 36 months compared to their HR-nonASD and LR-nonASD (Hutman et al., 2010). Furthermore, in an additional prospective study, attention did not differ across the *Social Spectrum* at 12 months, but by 15 months, greater social impairment was associated with reduced attention to the social targets during the task, suggesting that attention decreased from 12 to 15 months with increased social impairment whereas attention remained stable over time for those with minimal social impairment (Dowd et al., 2018). Therefore, it was hypothesized that these developmental differences across the *Social Spectrum* would continue to be observed 3 months later (i.e., at 18 months). Consistent with the previous research, there was a statistically significant Visit by *Social Spectrum* interaction, based on experimenter ratings of social impairment, whereas based on parent report there was a marginally significant Visit by *Social Spectrum* interaction as well as an additional significant effect of *Social Spectrum*. Post hoc analyses confirmed that attention did not differ across the *Social Spectrum* at 12 months and that reduced attention was associated with greater social impairment at 15 months. As hypothesized, reduced attention was also associated with greater social impairment at 18 months, yet this developmental difference was only apparent when utilizing parent report at 18 months, rather than experimenter ratings, of *Social Spectrum*. Differences in infant attention over time across different raters of the *Social Spectrum* may suggest that parent ratings of greater social impairment are more consistently associated with reduced attention over time, whereas experimenter ratings of social impairment and attention to distress suggest differences in attention to distress across the *Social Spectrum* become apparent over time.

Regarding infant affective responses to another's distress, previous research suggests that modest amounts of affective empathy are already evident by 8 to 10 months of age (Roth-Hanania et al., 2011) and increase over time in typical development (Geangu, Benga, Stahl, & Striano, 2011; Zahn-Waxler & Radke-Yarrow, 1990). HR toddlers with ASD were found to be less responsive to another's distress, showing less concern and less bodily arousal, at 24 and 30 months compared to their HR non-ASD peers, and reduced responses were associated with greater symptom severity at 30 months (McDonald & Messinger, 2012). In a prospective study, infants who were later diagnosed with ASD were displayed fewer affective responses from 12 to 36 months compared to their HR-nonASD and LR-nonASD (Hutman et al., 2010). It was hypothesized that differences in empathic concern (i.e., affective expressions of concern) across the *Social Spectrum* would emerge over time. Consistent with this hypothesis, this study found that empathic concern did not differ by the *Social Spectrum*, per parent and experimenter ratings, at 12 months, yet over time greater social impairment was associated with fewer displays of empathic concerns. The differences in the developmental progression of empathic concern found in this study and in previous research conducted by the author further highlights the necessity of intervening to teach this skill in infants between 12 and 18 months.

In contrast, research suggests that hypothesis testing develops later in life (Singer, 2006), yet modest amounts were found by 8 to 10 months of age in typically developing children (Roth-Hanania et al., 2011). Therefore, it was hypothesized that infants would demonstrate low levels of hypothesis testing at 12 months, and those with minimal social impairment would demonstrate slight increases in their behaviors from 12 to 18 months. Overall, infants in this sample were rated to have low levels of hypothesis testing (primarily scores of 0 or 1 at each visit) consistent with the hypothesis. Hypothesis testing did not differ across the *Social Spectrum* over time; however, at 15 months, greater parent-ratings of the *Social Spectrum* was related to reduced hypothesis testing, suggesting some variability in development may be observed early in development; however, these statistically significant differences may not reflect clinically meaningful differences given that the limited nature of these responses expected during this early developmental period. Importantly, this study is the first to examine hypothesis testing early in development in HR and LR infants.

Helping

Helping is a complex skill that requires recognizing when someone needs help, understanding how to help, and being motivated to help (Dowd, 2011). Previous research suggests that understanding how to help develops prior to the ability to offer help between 9 to 18 months of age (Koster et al., 2016). Warneken and Tomasello suggest that typically developing infants are capable of helping by offering out-of-reach objects at 14 months (2007) and rapidly develop the ability to help in more complex situations by 18 months (2006). This study examined helping in two ways by evaluating the length of time it took for infants to: 1) help by picking up the experimenter's desired, fallen sticks, and 2) offer the experimenter the desired sticks. As expected, the current study found that infants became quicker over time both to help pick up the sticks and to offer the sticks to the experimenter, suggesting the ability to help others is continuing to develop from 12 to 18 months of age.

Previous research examining helping behaviors in children with ASD has yielded mixed results, varying from fewer to greater helping behaviors compared to their peers without ASD (Sigman & Ruskin, 1999; Liebal et al., 2008; Paulus & Rosal-Grifoll, 2017). The variability in helping behaviors in children with ASD seen in the previous research could result from different methodologies that are addressing different components of helping. Recall that Paulu & Rosal-Grifol (2017) found that children with ASD were more inclined to help by retrieving the person's fallen pen when that person had left the room, which may suggest that children with ASD were more inclined to acquire the object for themselves rather than for the purpose of helping another. Therefore, it is important to differentiate the intentionality of the child's behavior, particularly when comparing children with varying degrees of social impairment. This study is the first to examine how social impairment impacts helping skills in early development when these skills are first emerging. Furthermore, this study differentiates between helping in two ways (i.e., assessing for when infants pick up the sticks and when infants offer the sticks).

As hypothesized, greater social impairment was related to slower responses to *offer* the sticks from 12 to 18 months, based on both experimenter observations and parent ratings of the *Social Spectrum*. In contrast, no differences were seen in the latency to help by *picking up* the sticks from 12 to 18 months based on both experimenter observations and parent ratings of the *Social Spectrum*. Helping by picking up the sticks, rather than offering them, could be suggestive of personal motivation to obtain the object rather than for the social purpose of helping. Thus, the lack of differences in the latency to pick up the sticks across the *Social Spectrum* could have resulted from different motivations, such that infants with mild social impairment picked up the sticks for social purposes while infants with greater social impairment picked up the sticks based on personal motivation. Importantly, the additional complexity of helping by *offering* the sticks to the experimenter appears to be a better indicator for differentiating abilities in infants across the *Social Spectrum*.

RELATIONAL SOCIAL SKILL DEVELOPMENT

Progression of social attention

Little research has been conducted to evaluate how social attention develops between a variety of skills, nor examined how this development may differ in those with and without social impairment. Through the use of SEM, this study examined how selected variables of social attention were related to each other as well as across the *Social Spectrum*. These relationships were assessed at each visit as well as over time. When assessing the relationships between the *Social Spectrum* and social attention variables at each visit, forward elimination techniques were used to identify the optimal models for the data at each visit. At 12 months, greater social impairment, as measured by the experimenter, was related to reduced high-level RJA, as observed in the ESCS. However, no other significant relationships were found between the *Social Spectrum*, high-level RJA, high-level IJA, or social orienting at 12 months.

In contrast to the 12-month visit which yielded one significant pathway, at 15 months, three significant relationships were identified, perhaps suggesting that interrelations between skills are more apparent as the development of these skills is progressing. At 15 months, significant relationships were observed between the *Social Spectrum* and social orienting, between social orienting and high-level IJA, and between high-level IJA and high-level RJA. Greater social impairment was associated with reduced social orienting, greater social orienting was associated with greater high-level IJA, and greater high-level IJA was associated with reduced high-level RJA. The latter relationship is consistent with previous research which hypothesized that initiating frequently may inhibit infants' ability to respond (Dowd, Davidson, & Neal-Beevers, 2016).

As skills begin to refine, at 18 months, greater social impairment was related to fewer high-level IJA. Additionally, greater social orienting was related to greater high-level RJA. Importantly, the significant pathways between the *Social Spectrum* and the social attention variables yielded in the optimal SEM models for each visit were consistent with the post hoc linear regressions in aim 1. Specifically, the relationships between adosSA, and 1) hiRJA at 12 months, 2) expSO at 15 months, and 3) hiIJA at 18 months were significant in the post hoc regressions as well as in the optimal SEM models, providing additional support that these relationships were still present in these larger models.

Importantly, while these variables were found to be related at different time points, these differences do not imply causation. For example, even though greater social impairment is related to reduced social orienting at 15 months and reduced social orienting is related to reduced high-level RJA at 18 months, these findings do *not* suggest that greater social impairment at 15 months is related reduced high-level RJA at 18 months. Direct and indirect relationships amongst these variables over time must be examined explicitly. This study selected data at different visits to assess how skills were related over time.

When examining how the *Social Spectrum* and social attention variables were related over time, no significant relationships were observed amongst the variables and ages tested. Specifically, adosSA and social orienting at 12 months were not related to joint attention (hiRJA or hiIJA) at 15 months, nor was 12-month high-level IJA associated with high-level RJA at 15 months. This is the first study to examine how these social attention skills develop in relation to each other over time early in development as these skills are emerging and rapidly developing. While no significant relationships were found, these null findings are informative, perhaps suggesting that these social attention skills are rapidly developing together and that differences in their development progression do not differ with infants with high and low social impairment across the *Social Spectrum*.

Social attention impact behavioral responses

Although limited, previous research examining the interrelations of social skill development over time has focused on the relationships between social attention and behavioral responses. This study not only examines the relationships between social attention and behavioral responses, at and across development from 12 to 18 months, but also how these relationships differ across the *Social Spectrum*.

First, when examining the relationships among skills at each visit, at 12 months, greater high-level RJA was associated with faster latencies to offer the sticks. This relationship was also present at 18 months. This finding is new to the literature and suggests that responding to others by following their point and by identifying, retrieving and offering a desired out-of-reach object may be related. The more consistently infants can follow another's line of regard, the faster they may be to identify another person's need for help by following that person's gaze to the desired object, which in turn, may result in faster responses to help.

Previous research examining the combination of both high- and low-level RJA to affective responses found that differences in affective responses to distress at 12 months did not differ based on RJA, but by 15 months, the differences were present (Dowd, Davidson, & Neal-Beevers, 2016). However, the current study found no significant relationships between high-level RJA and empathic concern at any age. One key difference between these two studies was that the previous study examined the combination of both high- and low-level RJA, whereas the current study only examined the relationships of high-level RJA to affective responses. An additional key difference between these studies was that affective responses were coded differently in both studies, with the current study using a more specific, rather than broader definition of affective responses. Furthermore, in contrast to this previous research, which did not find a significant effect of IJA, again combined for high- and low-level responses, on affective responses to distress, the current study found that greater high-level IJA was associated with greater empathic concern at 15 months. This finding is in line with previous research which found that HR infants who displayed more neutral affect in response to their mother's neutral-still face at four months exhibited less IJA at 14 months (Yirmiya et al., 2006).

Additionally, this study found that greater high-level IJA was also associated with longer latencies to offer the sticks at 15 months. One possible explanation for this finding could be that the infants with greater initiating joint attention skills are responding to the examiner's need for help by first initiating joint attention (i.e., looking from the sticks to the examiner and back to the sticks) which is delaying their response times to offer the sticks. This study is the first to compare high-level IJA and helping behaviors early in development.

Additionally, this study found that at 18 months, greater social impairment was associated with both slower latencies to offer and reduced empathic concern. These findings suggest strong relationships between reduced behavioral responses and greater social impairment are apparent in these optimal models at 18 months. Additionally, whereas differences in helping behaviors have not been consistently found when making group comparisons based on diagnoses (Paulus & Rosal-Grifoll, 2017; Liebal et al., 2008), differences in behaviors may be more apparent when examining skills across the *Social Spectrum*.

This study is the first to evaluate the mediating roles between social impairment, social attention, and behavioral responses from 12 to 18 months of age. Specifically, this study was interested in examining how these social attention variables and the *Social Spectrum* were related to behavioral responses over time. Examining the relationships between the *Social Spectrum* and social attention variables (expSO, hiRJA or hiIJA) at 12 months and behavioral responses (ecDIST or latOFFER) at 15 months only yielded one significant relationship over time, such that greater responding to joint attention at 12 months was associated with faster latencies to offer help at 15 months. This finding also suggests that difficulties in responding to joint attention at 12 months may in turn result in slower responses to offer help at 15 months.

When examining the *Social Spectrum* and social attention variables at 12 months to 18-month behavioral responses, a marginally significant relationship was observed between adosSA at 12 months and latOFFER at 18 months, in both models including either hiRJA or hiIJA. However, in the model with hiRJA, the results suggest that the relationship between adosSA at 12 months and latOFFER at 18 months may have been mediated by hiRJA at 12 months. These results suggest that greater social impairment present at 12 months may lead to slower responses to offer help at 18 months. However, this direct relationship may be indirectly related to hiRJA, such that greater social impairment at 12 months is related to reduced responding to joint attention at 12 months which is related to slower response times to offer help. Interventions targeting deficits in responding to joint attention at 12 months could perhaps improve subsequent response times to offer help later in development. Additionally, this study examined how the Social Spectrum and social attention variables at 15 months were related to the behavioral responses at 18 months. The results found that greater responding to joint attention at 15 months was associated with faster latencies to offer help at 18 months, thereby continuing to show a relationship between responding to joint attention and offering help later in development.

For initiating joint attention, while there was not a direct relationship between hiIJA at 15 months and latOFFER at 18 months, greater amounts of initiating joint attention at 15 months were associated with greater social orienting at 15 months which were associated with faster latencies to offer help at 18 months. Therefore, it may be beneficial to target both deficits in initiating joint attention as well as in responding to name present at 15 months in order to potentially impact subsequent helping behaviors in development.

LIMITATIONS AND FUTURE DIRECTIONS

It is important to acknowledge the limitations of this study. First, this study has a modest sample size (N=40), and some infants were not able to attend all of the lab visits or had missing data at visits. Therefore, it is possible the results of this study may not generalize to the general population. Furthermore, some of the optimal LME models included random slopes suggesting that there was some variance that was not accounted for within this sample, which may also have been the result of the modest sample size.

Additionally, the age range for which infants were allowed to participate at each visit was somewhat broad (i.e., 12-13.5 months for the 12-month visit, 14.5-16.5 months for the 15-month visit, and 17.5-19.5 months for the 18-month visit). It is common in the literature to use a range of ages to assess development, varying from using +/- two weeks from the day the infant turns that age (e.g., "13 months" refers to the ages of 12.5-13.5 months) to examining infants of several months (e.g., "8-10 months"). Given the expected rapid development of these skills during the 6-month developmental window examined, it may be beneficial for future research to replicate these findings by narrowing the developmental windows for each visit, as well as to include additional time points during this 6-month period.

In this study, it was important to initially examine the development of these skills across visits in the LME models, rather than across age in days, as the SEM models compared skills over time by utilizing skill data from different visits. However, to address this limitation, post hoc linear regressions were conducted to examine the effect of age (in days) at each visit on each skill. Few instances found a significant effect of age in days. Specifically, in both the adosSA and CSBSs models, there was a significant effect of age on the prediction of adosIJA at 15 months; however, in the bootstrap multiple regression analyses of adosIJA over time, there were no significant effects of Visit. There was also a significant effect of age in the prediction of latOFFER at 12 months in the adosSA model, however this was congruent with the optimal LME model which found a significant effect of Visit.

Further research should significantly increase the sample size in order to run one-comprehension SEM model on variable interrelations rather than several smaller models, as was necessary for the present study. Additionally, increasing the sample size of HR and LR infants could increase the variability of the *Social Spectrum* observed at each visit as well as increase the sample count within the observed range of social functioning. It may be helpful to narrow the age range to within two weeks of turning the visit age (e.g., 14.5-15.5 for the 15-month visit) for which infants can participate in visits to help further distinguish the developmental differences between visits and therefore between the variables in the SEM models over time. Furthermore, a larger sample size would allow for factor variables of each skill to be included in the SEM models rather than selecting one variable to represent each construct as in the present study.

CONCLUSION

Despite a modest sample size, the current study found significant differences that meaningfully contribute to and expand upon the existing research on early social skill development. Additionally, this study examines social skill development in a unique way by evaluating differences across the *Social Spectrum*. Furthermore, this study identifies not only how individual social skills develop over time, but also how these skills develop in relation to each other. The most important findings of individual skill development suggest that: 1) responding to joint attention (high- and low-levels) and initiating joint attention (high-level) increase over time from 12 to 18 months, 2) the development of attention and empathic concern in response to another's distress from 12 to 18 months varied across the *Social Spectrum*, and 3) social orienting skills remained stable over time, with differences seen across the *Social Spectrum*, particularly at 15 months. In examining how social skills are related over time, the strongest findings suggest that: 1) experimenter ratings of greater *Social Spectrum* were related to various reduced skills various at different months, 2) high-level responding to joint attention is related to faster latencies to offer help to others at and across 12 to 18 months, and 3) significant interrelations between the *Social Spectrum*, social orienting, and high-level initiating joint attention at 15 months were related to the latency to offer help at 18 months, such that at 15 months both greater social impairment and reduced initiating joint attention were associated with reduced social orienting, which was associated with slower latencies to offer help at 18 months.

Appendix

Acronym	Definition
Classifications	
ASD	Autism Spectrum Disorder (DSM-5 diagnosis)
PDD	Pervasive Developmental Disorders (Autistic Disorder, Asperger's, and PDD-Not Otherwise Specified diagnoses from DSM-IV-TR)
BAP	Broader autism phenotype (i.e., HR infants with subclinical characteristics of ASD)
TD	Typically-developing (i.e., lack of clinical diagnoses)
HR	High familial risk for ASD (i.e., have an older sibling with ASD)
HR-ASD	HR with ASD diagnosis at study outcome
HR-BAP	HR with BAP characteristics at study outcome
HR-nonASD	HR without an ASD diagnosis at study outcome
HR-TD	HR classified as TD at study outcome
LR	Low familial risk for ASD (i.e., no older siblings with ASD)
LR-nonASD	LR without an ASD diagnosis at study outcome
LR-TD	LR classified as TD at study outcome
Measures	
SRS	Social Responsiveness Scale
ADOS-2-T	Autism Diagnostic Observation Schedule, Second Edition, Toddler Module
SCQ	Social Communication Questionnaire
CSBS	Communication and Symbolic Behavior Scales Developmental Profile, Infant-Toddler Checklist
ESCS	Early Social Communication Scales
AOSI	Autism Observation Scale for Infants
Bayley	Bayley Scales of Early Development, Third Edition
Vineland	Vineland Adaptive Behavior Scales, Second Edition

Appendix Table 1. Acronym Definitions

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