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Precursors to Theory of Mind in Infants At-Risk and Not-At-Risk for Autism Spectrum Disorders

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Abstract

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This study examined the presence of precursors to theory of mind in 63 infants at-risk and not-at-risk for autism spectrum disorder based on their performance on an early autism screener. The goal was to test the hypothesis that performance on precursors to theory of mind tasks may help indicate whether or not an infant is at-risk for an autism spectrum disorder. All participants were administered standardized tests to determine whether or not the infant was at-risk. They then received the 4 minute Rapid-ABC screener, which includes five activities, three of which incorporate physical occlusion tasks which measure precursors to theory of mind. Results indicated that there were differences in deficits in precursors to theory of mind abilities between the two groups. At-risk infants demonstrated more deficits on physical occlusion tasks than the control group on all tasks except for tickling, where there was no difference in group performance. Further, there was a correlation between performance on physical occlusion tasks and joint attention tasks in the at-risk infants. Trends in the correlations indicated a relationship between scores on the first visit physical occlusion performance and second visit physical occlusion scores. Finally, there were no significant differences in deficits based on age.

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Precursors to Theory of Mind in Infants at At-Risk and Not-At-Risk for Autism Spectrum Disorder

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Precursors to Theory of Mind in Infants at At-Risk and Not- At-Risk for Autism

The ability to accurately infer what another person is thinking is a key component to cognitive development. This capacity, known as "theory of mind," refers to the comprehension of the full range of mental states that cause another's action, as well as understanding that others possess distinct thoughts from oneself (Baron-Cohen, 2001). In typically developing children, this ability usually emerges around the age of 4 years old (Wellman & Lagattuta, 2000, Chapter 2). However, it has been established that individuals with autism are impaired in communication, socialization, and imagination (Happé, 1995). This causes them to fail false-belief tasks (such as 'seeing leads to knowing' tests, the Sally-Anne test, and other similar tests), which measure one's theory of mind capacity (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 2000, Chapter 1). This deficit is a significant feature of autism spectrum disorder (Baron-Cohen, 2001). The present study examined whether there was a difference in performance on tasks which measure the development of precursors to theory of mind between infants at-risk and not-at-risk for autism. Additionally, the study also examined the relationship between performance on precursor to theory of mind tasks and other social tasks to determine if there was consistency in performance across conceptually-related tasks.

Theory of Mind

Origin and purpose. Theory of mind is hypothesized to be one of the key differences between humans and other primates (Frith & Frith, 2005). Whiten (1993) claimed that theory of mind "remains one of the quintessential abilities that makes us human" (as cited in Baron-Cohen, 2000, p. 4, Chapter 1). While chimpanzees may possess some rudimentary theory of mind abilities, they are not fully developed or as advanced as these skills prove to be in humans (Frith

& Frith, 2005). In examining the social interactions of other primates and comparing them to humans, it does appear that visual processing of social signals such as interpreting facial expressions and body language is crucial to the understanding of the intentions and emotions of others (Emery & Perrett, 2000, Chapter 12). Therefore, this visual processing, and especially interpreting social information expressed through the eyes, is essential to human social interactions. The social interactions and processing evident in primates seem to serve as the origins of human social processing. Notably, the importance of visual processing and eye gaze is seen in human infants as their social abilities begin to develop (Baron-Cohen, 2001).

The social advantage of theory of mind is that this ability allows for the recognition that others' knowledge is different than one's own, possible manipulation of others based on understanding their knowledge, and the ability to adopt a common goal and work towards collaboration (Frith and Frith, 2005). This capacity is evidenced in such instances as understanding that when there is a conflict between one's belief and reality, it is the person's belief and not reality that determines the behavior (Frith & Frith, 2005). For example, theory of mind would occur when an observer watches an individual place on object on a desk, leave the room, and subsequently, another person enters the room and moves the item into a drawer. When the individual returns, an observer would understand that they would still believe the item is on the desk and would not yet have the knowledge that the item has been moved to the drawer.

Precursors to theory of mind. In aiming to understand theory of mind development, there has been a large body of research examining the presence of precursors to theory of mind. While the basic theory of mind capacity emerges in the early preschool years, the understanding of others' desires, wants, and intentions tends to be present before an individual is 2 years old (Wellman & Lagattuta, 2000). Baron-Cohen (1995) claimed that the understanding of others is actually present at the end of the first year of development and social referencing is present as early as 10 months of age. Social referencing is the ability to determine another person's emotional expression or behavior, or to clarify emotional uncertainty based on another individual's demonstrated emotions (Klin, Schultz, & Cohen, 2000, Chapter 15). Eventually, this basic understanding will evolve into a more complex comprehension of others' thoughts, beliefs, and feelings. Numerous studies have indicated that the development of social competence, such as the ability to understand goal-directed behavior and self-propelled objects as early as 6 to 12 months of age, may be the mechanism that later develops into theory of mind (Klin, Schultz, & Cohen, 2000, Chapter 15).

Since infants are nonverbal at this young age, methods that measure theory of mind in other capacities were developed. Visual fixation, looking tasks, and eye tracking have been the most utilized methods. It has been found that children as young as 4 years old can identify the emotions of another individual based on eye gaze direction, which signifies the relevance of studying gaze and visual processing in infants to determine the presence of precursor to theory of mind abilities (Baron-Cohen, 2001).

Theory of mind and looking time tasks. Studies have indicated that infants demonstrate precursors to theory of mind as early as 14 months of age (Sodian & Thoermer, 2008). In their study examining precursors to theory of mind, Sodian and Thoermer (2008) employed looking time tasks to measure 14 and 16-month-olds' ability to keep track of what another individual was able to see, thus intimating their understanding of another person's position. The results suggested that there may be precursors to theory of mind in looking time tasks in infants as young as 14-months-old. The first experiment tested infants' understanding of knowledge formation by recording their looking times as they watched a person sitting behind a desk reach for a toy that was hidden, as the adult either saw the toy being hidden or did not see the toy being hidden. Based on looking time tasks, they found that infants distinguished between correct and incorrect test trials when the person was present and had visual access to the event during test trials. Therefore, Sodian and Thoermer concluded that infants do not base expectations on whether or not the person was present during a critical event, but rather on situational, or environmental cues and others' behavioral cues. Infants have a sense of what individuals are able to see and what they are not able to see.

A second experiment by Sodian and Thoermer utilized tests in which they examined visual perspective-taking in 14-month-olds. This idea was based on the importance of infants' gaze at this stage of development. They found that the ability to link what one sees with future actions is present in 18-month-olds, but not in 14-month-olds (Sodian & Thoermer, 2008). Therefore, infants were able to comprehend the knowledge of what another individual does or does not know about a situation, however this ability seems to develop gradually.

Theory of mind and visual occlusion tasks. Other measures of theory of mind in infants have also been applied. One of these is the Woodward paradigm, a visual occlusion test which keeps items out of sight and uses infant looking patterns to measure their understanding of goal directed behavior (Woodward, 1998). In the initial study, researchers habituated infants to observing an individual reach and grasp of one of two toys (Woodward, 1998). They then measured infants' looking times when the actor deviated from the routine and reached for the other toy. For infants to comprehend the deviation in routine, they must have seen the actions as directed and made an association between the person completing the action as well as the object (Wellman &Lagattuta, 2000, Chapter 2). The results demonstrated that, by 6 months of age, infants encode the actions of other people with a goal-directed perspective (Woodward, 1998).

Further, when a rod or automated claw replaced the actual hand, there was no difference in the looking times between the two conditions (Woodward, 1998). Therefore, infants were able to distinguish between humans and objects, which provides the foundation for understanding others' behaviors from a psychological perspective (Woodward, 1998). This study revealed that by 6 months of age, infants view humans as purposive agents and encode action goals when watching a grasping movement (Woodward, 1998). Schöppner, Sodian, and Pauen (2006) obtained similar results in a study that utilized a habituation task to see how infants looked at interactions between two people, known as agent-agent social relationships.

Joint Attention

Joint attention is often identified as both a precursor to and crucial component of an individual's theory of mind capacity. Tomasello (1995) identified joint attention as the coordination of attention between the self, the other, and some external object or event. He also proposed that the emergence of these skills and other similar social-cognitive abilities serves as the basis for a later, more advanced theory of mind (Tomasello, 1995). Joint attention may be the foundation to social knowledge acquisition and the sharing of experiences and knowledge with other individuals (Mundy & Jarrold, 2010). It is also essential to developing social cognition, competence, and symbolic representation in the primary stages of development and beyond (Mundy, Sullivan, & Mastergeorge, 2009).

Researchers have found that between the ages of 6 and 9 months, infants demonstrate the capacity to respond to joint attention signals (Kristen, Sodian, Thoermer, & Perst, 2000). Therefore, they share their experiences of an event or object by following the gaze of another individual (Mundy & Jarrold, 2010). Subsequently, they develop the skills to actually initiate these cues (Kristen, Sodian, Thoermer, & Perst, 2000). Tomasello further explained that in the next stage of development between 9 and 12 months, the recognition of people as "intentional agents" emerges, which then leads to more advanced skills. Previous research suggested that preliminary evidence of this skill was present in infants as young as 2 months, but becomes a refined mechanism between 9 and 18 months (Korkmaz, 2011).

There are a number of different types of joint attention behaviors. For example, declarative joint attention cues convey information about objects or events, while imperative gestures convey requests for another person to act on something (Kristen et al., 2000). The most common joint attention actions include gestures, such as pointing, and eye gaze, which show the infant is attending to the same event as the researcher or other agent (Korkmaz, 2011; Morgan, Maybery, & Durkin, 2003). Gestures, most significantly pointing, play an important role in joint attention (Korkmaz, 2011). The skill of pointing usually develops between 9 and 14 months and is considered a major milestone in theory of mind development (Korkmaz, 2011).

The emergence of joint attention capacities relies on the ability to identify others as agents that can impact another object or individual, or execute an action (Korkmaz, 2011). These joint attention actions can reference something or someone, channel one's attention toward an object, or be a response to another's gesture or cue (Kristen et al., 2000). In linking these joint attention skills to later theory of mind ability, it has been found that joint attention skills performance at 20 months of age is associated with an infant's theory of mind capacity at 44 months (Charman et al., 2000). Since theory of mind does not develop until later in a child's maturation process, measuring joint attention skills at a younger age may serve as an accurate measure of one's later theory of mind capability, and whether or not it is appropriately developing.

A number of measures have been used to assess joint attention capabilities. Tasks such as blocking, teasing, and the active toy task – which includes activating mechanical toys for the child, are used as probe activities (Morgan et al., 2003). The child's responses to these activities are interpreted as an manifestation of joint attention. These responses may include an indication that the child wants to change the researcher's behavior so that they will provide a toy, stop blocking access to the toy, or reactivate a mechanical toy (Morgan et al., 2003). Other studies focus on measuring pointing and gaze switches as the main measures of joint attention skill in response to these tasks (Charman et al., 2000). In one study, gaze switches provided the most robust measure for predicting future theory of mind abilities. That is, Charman et al. found that gaze switches between an adult and an active toy, and looking to an adult during an ambiguous goal detection task (i.e., blocking or teasing) at 20 months, were found to be associated with theory of mind ability at 44 months (Charman et al., 2000).

Pause tasks. Asking to continue an activity after a pause occurs in the action is also considered to be a joint attention skill. If a child asks for a continuation of an activity or game, it is assumed that he or she has detected a particular sequence of events and knows or anticipates what is supposed to happen next (Morgan et al., 2003). This is indicated as their detecting contingency, understanding how another's actions are related to one's own (Rochat, 2001). Eventually, this understanding leads to developing a sense of self, reciprocity with others, and the ability to engage with others (Rochat, 2001). Evidence of these abilities emerge early in development (Rochat. 2001). At about 2 months of age, infants show intersubjectivity, the understanding that they have social experiences with others (Rochat. 2001). However, they do not demonstrate reengagement (i.e,. attempts to continue interaction by actions such as clapping and making noises) until 7 months of age (Rochat, 2001). Studies of social attention, however, suggest that infants expect and anticipate another's action and engage in social referencing prior to 7 months, and possibly, as early as 3 months of age (Klin, Schultz, & Cohen, 2000, Chapter 15).

Joint attention and theory of mind. Charman et al. (2000) suggests that joint attention might be a precursor to later theory of mind ability. There are two possible ways in which joint attention and theory of mind may be related. The first suggested connection is that infant manifestation of these cognitive abilities, joint attention, grows or is transformed into theory of mind. The other is that theory of mind develops due to one's experiences in childhood. This connection between theory of mind and joint attention is further illustrated in that these joint attention skills directly reflect how an individual will later develop theory of mind and more complex mind understanding skills (Kristen et al, 2000). Korkmaz (2011) stated that theory of mind is a composite function, and joint attention is one of the components that creates this ability. Further, he outlines looking, smiling, and smiling back in response to a stimulus as first signs of social behavior, which grow into more complex displays.

Theory of mind and autism. Autism spectrum disorders are characterized by deficits in reciprocal social interactions, communication, and restricted repetitive behaviors, and delays and deficits must be evident prior to 36 months of age (American Psychiatric Association, 2000). In individuals with autism, research has shown that there is impairment in theory of mind abilities (Baron-Cohen, 2001). Individuals with autism have a difficult time understanding other perspectives and instead tend to generalize their own knowledge to other individuals (Baron-Cohen, 2001). While there has been some debate over the universality of this deficit in individuals with autism, in that some are able to pass theory of mind tests, there is a clear delay in the early development of these skills (Baron-Cohen, 2000, Chapter 1). Tests to measure first and second-order theory of mind capacities have been developed. First-order theory of mind tests measure if one can understand that different people have different perspectives than themselves. The most well-known of these is the Sally-Anne test (Baron-Cohen, 2000, Chapter 1). Second-order theory of mind tests measure embedded mental states, such as asking what Tom thinks Susie thinks (Baron-Cohen, 2000, Chapter 1). When administering these tests to children with autism, it has been found that, although some are able to pass the tests, they do so at a much later age than typically developing children (Baron-Cohen, 2000, Chapter 1). A verbal mental age of at least 9 years is needed in individuals with autism, whereas typically developing children pass first-order tests around 4 years of age, and second-order tests around 6 years (Baron-Cohen, 2000, Chapter 1). Further, although they are able to pass the test, individuals with autism struggle to apply these skills to actual social settings (Klin, Schultz, & Cohen, 2000, Chapter 15). Additionally, the way in which they eventually acquire the skills for theory of mind may be divergent from the normal means, which may impact their later theory of mind capacity (Klin, Schultz, & Cohen, 2000, Chapter 15). Further, individuals with autism spectrum disorder also have difficulty understanding deception, jokes, sarcasm, irony, and pragmatics, since these all require an understanding of the speaker's aims, mindset, and intentions (Baron-Cohen, 2001).

Infants with autism demonstrate an atypical pattern of social development, often meeting early social developmental milestones later than typically developing infants (Gopnik, Capps, & Meltzoff, 2000, Chapter 3). Some of the most significant delays in developing these early social capacities involve social referencing and linking thoughts and actions towards objects, which usually occur around 18 and 19 months of age, respectively in typical infants (Gopnik, Capps, & Meltzoff, 2000, Chapter 3). Therefore, as these fundamental social cognitive abilities are already deficient, these individuals may lack the initial step to understanding the relationship between the self and others, which may impact later social development (Gopnik, Capps, & Meltzoff, 2000, Chapter 3). As a result, the entire developing process of theory of mind seems to be different in these individuals with autism spectrum disorder as they do not proceed through typical stages of development and therefore, ultimately do not possess the same comprehension of the social world (Gopnik, Capps, & Meltzoff, 2000, Chapter 3).

Since individuals with autism are already behind on reaching typical developmental milestones at the appropriate ages, this may lead to the manifestation of the syndrome and have potentiated effects later in life in their social skills capacities and understanding (Jones, Carr, & Klin, 2008). In retrospective parental reports of symptoms as well as in video coding for individuals later diagnosed with autism, these infants showed impairments in many aspects of precursors to social communication abilities, such as less pointing, fewer initiating of social interactions, play, and gaze (Ornitz et al as cited in Charman, 2000, Chapter 17). They also showed poor attention, and a lack of a social smile and appropriate facial expression (Ornitz et al as cited in Charman, 2000, Chapter 17). As a result, precursors to theory of mind capacities may serve as an early manifestation of these later deficits in infants at-risk for autism spectrum disorder.

Eye tracking and autism. Eye tracking technology is being utilized to observe patterns on looking tasks of typical infants and those at-risk for autism spectrum disorder (Schultz, Klin, & Jones, 2011). If infants fail looking time tasks, this may be a preview of later deficits in theory of mind and perhaps an early sign of autism. Also, individuals with autism have difficulty decoding information within the eye region, which is a key to understanding another individual's thoughts and emotions (Baron-Cohen, 2000, Chapter 1). They tend to overlook this aspect, as looking at the eyes does not come naturally to them (Baron-Cohen, 2001).

Further, in a study looking at blink inhibition in typically developing infants and those at-risk for autism spectrum disorder, there was a delay in blink inhibition in the at-risk infants, indicating that they may not anticipate the next action or event in a given situation (Schultz, Klin, & Jones, 2011). Blink inhibition occurs when there is important information to be observed, so preventing the blink minimizes the loss of this data (Schultz, Klin, & Jones, 2011). While both groups did inhibit blinking and shifted visual fixation, the typical toddlers inhibited their blinking earlier than the at-risk toddlers (Schultz, Klin, & Jones, 2011). Therefore, children with autism may react to events after they happen, as opposed to anticipating the action. This may also be due to the fact that they do not spend as much time looking at socially relevant cues, such as the face and eyes, and as a result, do not interpret social cues as do typical infants (Schultz, Klin, & Jones, 2011). These results may illustrate a lack of development of precursors to theory of mind at this age in the deficient consideration of others' actions. Further, research has found that less fixation on the eyes in anticipation of an event predicts greater social disability in an individual, signifying the importance of infants' looking at socially salient facial information (Jones, Carr, &Klin, 2008). Therefore, infants that fail early precursor to theory of mind looking tasks may be at-risk for autism.

Joint attention and autism. Similar to previous studies that found individuals with autism to be deficient in their development of theory of mind, children with autism consistently demonstrate impairments on joint attention tasks (Charman, 1997). Scholars argue this is the case because joint attention measures capabilities fundamental to the development of theory of mind (Baron-Cohen, 1995). For example, children with autism rarely initiate joint attention actions, such as pointing or shifting gaze, to look at another agent's facial expression (Baron-Cohen, 1995). Further, in children with autism, deficits in comprehension and productive or declarative gestures, gestures designed to direct another's attention to a subject of common interest, are more pronounced than imperative gestures, gestures designed to get another person to do something (Kristen et al, 2000). If these precursors are found to strongly predict one's later development of theory of mind and are related to one's performance, then these may prove beneficial not only for early detection, but also as areas of emphasis for treatment (Charman et al, 2000). A difference in the performance of joint attention tasks between children at-risk for autism and typically developing children would be expected. In the study conducted by Charman et al. (2000), they found that only joint attention behaviors, as opposed to play and imitation behaviors, were longitudinally associated with theory of mind ability at 44 months. These tasks were measured through the number of gaze switches between the child and adult, and other tasks. They argued that what is distinct about joint attention from play and imitation is that there is a directly social goal, in sharing one's state with another or understanding another's goal.

Early detection and diagnosis - The Rapid-ABC screener. As more children are diagnosed with autism – the current statistic according to the Centers for Disease Control is 1 in 110 children in the United States – early detection and intervention is becoming more and more essential (as cited in Ousley et al., 2010). Research has shown that early intervention when children are as young as possible produces the best verbal and social changes in individuals with autism spectrum disorder, changes which cannot be accomplished if these treatments are started later in life (Ousley et al., 2010). According to Wiggins, Baio, and Rice (2006), individuals with autism are often not diagnosed until they are 4 or 5 years old; however, signs often emerge much earlier in the developmental process. In order to better detect infants who may be at-risk for autism spectrum disorders, The Rapid-ABC, a 4-minute rapid-screener which measures social capacities, is being developed. The Rapid-ABC aims to determine if infants are at-risk for autism based on observed deficits in performance on social-communication activities (Ousley et al., 2010). In examining other measures for detecting autism, it has been found that parent reports are not as accurate in observing deficits in social abilities when compared to coding data on videos (Ozonoff, 2010). Therefore, there is a benefit to in-person, more naturalistic trials, such as this screener, as a compliment to parental or caregiver reports. The Rapid-ABC is a 4-minute interactive screener which consists of common adult-child activities (saying hello, rolling a ball, reading a book, and tickling). This screener is referred to as the Rapid-ABC, with "Rapid" referring to the brief nature of the screener, and "abc" referring to the instrument's assessing social attention, the back-and-forth nature of social interactions, and nonverbal communication (Ousley et al., 2010). Preliminary results indicate it is a reliable measure to distinguish young children at-risk for a diagnosis of autism spectrum disorder from typically developing children (Ousley et al., 2010).

Precursors to theory of mind in the Rapid-ABC. While more research is being conducted to focus on early detection and theory of mind capacity in individuals with autism, there is little literature linking the early development of precursors to theory of mind in at-risk and typical infants. Further, there has been minimal research incorporating looking time tasks, pauses, and blocking or "physical occlusion" tasks with other possible precursors to theory of mind (such as joint attention) in infants.

To facilitate early detection of autism, employing measures of precursors to theory of mind within an autism screening test provides information regarding the development of this ability and allows for the comparison of at-risk infants and typical infants. Physical occlusion tasks, such as limiting a child's access to a desired object or activity, may tap precursors to theory of mind. There are three tasks which measure such precursors to theory of mind within the Rapid-ABC screener. As a variation to other tests that include blocking tasks, the present study includes physical occlusion tasks, or interruption of a social routine, and measures whether or not a child anticipates the actions of the clinician or communicates a desire for the task to continue. The first physical occlusion task involves the clinician pausing before rolling the ball back to the infant in a ball game after three turns have been completed. A second task involves reading a book, where the clinician holds the page momentarily, preventing the infant from turning the page, after at least three pages have been turned by either the clinician or the infant. The third occurs during a tickling activity, during which the researcher pauses before tickling the child after having established the routine. An infant with a typically developing theory of mind would be expected to look up at the researcher in anticipation of their continuing the game, which may also occur in conjunction with a gesture or vocalization to request continuation. This action intimates that the child realizes the sequence of events and the pattern of the game that has been established in responding to the break in the activity. In contrast, an infant with developmental delays or deficits will not demonstrate eye contact or indicate that they are aware of the fact that the physical occlusion task has paused the game. Therefore, it is expected that infants at-risk for autism spectrum disorder would fail to acknowledge and react to behavioral cues that typically developing infants use to predict another person's behavior (Sodian & Thoermer, 2008).

Hypotheses. The current study compared the performance of at-risk infants and a control group of not-at-risk infants on their precursor to theory of mind ability, measured by physical occlusion tasks. Infants were designated to be at-risk by a consensus judgement that involved two clinicians. Based on the previous literature, it was hypothesized that in measuring the response to physical occlusion tasks in the at-risk and control groups, there would be a difference between infants who were determined to be at-risk for an autism spectrum disorder and those who were not-at-risk for this disorder. Specifically, at-risk infants would manifest more deficits on these tasks. It was also predicted that the at-risk infants would also show deficits on other social tasks, such as measures of joint attention. Further, it was predicted that there would also be a correlation in performance for the participants who came in for a second visit with their first performance score on physical occlusion tasks and their subsequent physical occlusion and joint attention performance. Finally, it was predicted that there would be a difference in abilities of these tasks based on age, such that infants showed fewer deficits as they progressed through developmental stages.

Method

Participants

In the overall sample there were significant differences in the age and gender distribution between the control and at-risk groups, with the control group being younger on average and having significantly more females. In order to equate the groups on age and the sex ratio, eight of the youngest females from the control group were excluded. Therefore, the sample used consisted of 63 infants between the ages of 13 and 29 months of age. Within this sample, 32 of the infants were not-at-risk for autism spectrum disorder (20 males, 12 females, M_{age} = 20.97, SD = 4.162), while 31 were at-risk for autism spectrum disorder (22 males, 9 females, M_{age} = 22.23, SD = 3.748). For the subset of participants who returned for a second visit, there were 41 participants, 24 of them were not-at-risk (14 males, 10 females, M_{age} = 20.96, SD = 4.227), while 17 of them were at-risk for autism spectrum disorder (11 males, 6 females M_{age} = 21.41, SD = 4.473).

The racial and ethnic identity of the participants was also noted and the infant's race was determined by the race reported by their mother. In the control group, 26 identified as White or Caucasian (81.3 %), two identified as Black or African American (6.3%), and four identified as other (12.5%). In the at-risk group, 20 identified as White or Caucasian (64.5%), six identified as Black or African American (19.4%), one identified as Asian or Pacific Islander (1.6%), one identified as Hispanic or Latino (1.6%), and seven identified as other (11.1%). The mothers' education was measured on a scale from 1 to 8. A score of 1 represented having completed graduate or professional level education and 8 represented having completed less than ninth grade education.

The sample of infants from the greater Atlanta area was recruited through a number of means. Most of the at-risk infants were recruited through the Emory Autism Center, while most of the control participants were recruited through the larger community. For recruitment, flyers were posted around Emory University, The Emory Autism Center, the Georgia Institute of Technology, as well as on autism research websites. In addition, the Georgia Institute of Technology included the information on a website where individuals could complete a form online if they were interested in participating in the study. Fox 5 news television channel also publicized the research project. Any infant within the given age range was eligible to participate.

Measures

Parent-report checklists. The Communication and Symbolic Behavior Scales Developmental Profile: Infant-Toddler Checklist (CSBS DP: ITC) consists of a number of questions that parents answer to identify their child's behavior and developmental progress (Wetherby & Prizant, 2002). The CSBS DP: ITC is a checklist designed for parents and caregivers of infants and toddlers between 6 to 24 months. In this test, cut-off scores are designated for each month of age. This checklist measures three developmental subdomains, including social, speech, and symbolic behavior, by giving the child a score for each type of behavior. These scores are then added up to a composite score. An infant that scores in the "no concern" range for all subdomains and the overall composite is considered to be not-at-risk for a developmental disorder. The Modified Checklist for Autism in Toddlers (M-CHAT) is another parent questionnaire that determines if certain behaviors are present or absent in their child (Robins, Fein, Barton, & Green, 2001). Results are determined by "failed" items. On this test, if more than three items are failed or if the total number of critical items failed equals two or more, the child is considered at-risk for autism (Robins, Fein, Barton, & Green, 2001).

Rapid-ABC. The Rapid-ABC is an instrument under development with the ultimate goal of determining whether or not infants are at-risk for an autism spectrum disorder or demonstrate social-communication difficulties (Ousley et al., 2010). The test is administered by engaging the infant in five activities and scoring whether specific social behaviors are present or absent. Although the Rapid-ABC is still being developed, preliminary results show that the total score on this test is a useful tool in differentiating between typical and at-risk infants (Ousley et al., 2010). The measures within the test were chosen based on literature that showed that deficits in joint attention, turn taking, and other social skills indicate at-risk status for autism spectrum disorder. The inter-rater reliability between the experimenters who administered the test was adequate, with the average percent agreement between two raters equaling 80.6% (SD=11.4) and the Cohen's Kappa equaling 0.68.

The Rapid-ABC utilizes a series of five different activities in which the child is engaged for 4 minutes. Within this test, deficits on specific tasks are scored. The tasks within the Rapid-ABC are specifically designed to measure certain social and communication deficits. Behaviors rated include looking directly at the examiner, smiling, shifting gaze from an object to the examiner, participating in activities, pointing, and anticipation and continuation of a social routine. Within these, two types of precursors to theory of mind are coded including physical occlusion tasks and joint attention measures, such as gaze switches and pointing.

In this study, the dependent variable is the presence of deficits in the tasks observed. On each specific task, the infant's performance is either scored as the behavior being present or absent. The presence of a target behavior is coded as a 0, while the absence of the ability receives 1 point. The present study measured three physical occlusion behaviors; therefore, possible scores range from a minimum of 0 to a maximum of 3. The same range was possible for total joint attention scores, as there were also three behaviors being measured, so the range in scores included a minimum of 0 and a maximum of 3. Thus higher scores indicate poorer performance, or more autistic-like traits. In addition to scoring specific behaviors within each category, each of the five tasks also includes a score from 0 to 2 based on how easy it is to engage the child (0 being easy to engage, 2 being difficult to engage). A score of 1 is also allowed, but this score is then re-coded as a 2. Total scores are calculated by counting the number of deficits on performance of target behaviors and adding these to the overall ratings that record "ease" of engaging the child at five different points in the screener.

The present study focused specifically on three physical occlusion tasks and three joint attention tasks within the larger screener; therefore, other behavioral scores and the ease-of-engagement scores were not considered. The first activity, smiling and saying hello, measures whether or not the child makes eye contact when greeted by the examiner, smiles at this greeting, and overall ease of engagement. Failing to demonstrate any of these behaviors indicates a deficit and is scored as a 1. This task was not included in the present study. The second activity involves rolling a ball back and forth between the infant and the clinician in a ball game. During this task, joint attention was measured upon the initial presentation of the ball, noting if the infant shifts his or her gaze between the ball and the clinician, and response to physical occlusion was scored when the examiner limits the infant's access to the ball by pausing before rolling the ball back. For this task, rolling the ball back and smiling are also scored but were not analyzed for this study. The third task, a book task, includes observing joint attention when the book is first presented to the infant and noting if the infant shifts his or her gaze. Joint attention is also measured by recording if the infant points to a picture in the book. A physical occlusion task is included in reading the book, where the clinician holds the page momentarily, preventing the infant from turning the page. Examining the infant's responses, whether or not the infant looks at the examiner during these pauses in tasks, serves as a measure of their precursor to theory of mind capacity. Additional behavioral scores, not included in the current analyses, include smiling during the initial presentation of the book, turning a page in the book, and smiling during this interaction. In the next activity, the clinician uses the book as a hat, placing it on his or her head, and observes whether or not the infant looks at the book, smiles, and points at the "hat." Pointing to the hat occurred rarely in the control group, thus was not considered in the joint attention analyses, and there are plans to remove this code from future versions of the Rapid-ABC. Finally, the last task involves smiling and tickling, in which the examiner tickles the infant. During this task, response to physical occlusion is presented when the examiner pauses before tickling the infant, and notes if the infant looks at them in anticipation of the tickle. Smiling and eye contact before the pause is also coded, but is not included in the current analyses.

Procedures

A standard procedure was established for each session. All sessions were conducted at the Emory Autism Center. The participants engaged in a 45-minute assessment with a Masters or PhD level clinician. Parents were first asked to complete an informed consent form, and subsequently filled out paperwork including the CSBS DP: ITC, and other information. Following this, the 4-minute Rapid-ABC was administered. Parents remained in the room with their child, and the placement of the infant (i.e., sitting on the parent's lap, in the chair, or other location in the testing room) was recorded. After this assessment, there was a feedback session in which the clinician referred the parents for further evaluation based on the CSBS DP: ITC scores, the endorsement of critical items on the M-CHAT, or the presence of parent concerns. The risk status research code was not shared with the parent. This was a non-blind study in that the clinicians who conducted the assessments also assigned the risk status evaluation at the end of the session. Therefore, the score on the dependent measure, presence of deficits on tasks performed, was a component of the information that was included in the risk status determination. Infants were referred to the Emory Autism Center and/or other early intervention community service resources (e.g., Babies Can't Wait, which is Georgia's statewide, early intervention service). The same protocol was followed for those that returned for the second visit. Participants returned for the follow up between 3 weeks and 14 months after the first visit.

Determination of Risk Status

Risk status was determined by at least two members of the study team. A masters level researcher determined the risk status based on scores from two parent-report screeners and overall clinical impression. In addition, a PhD level researcher conducted an independent chart review and confirmed risk status. Disagreements in risk status were resolved by a third PhD level researcher who conducted a chart review.

Each participant was given a final score for Autism Spectrum Impressions with possible scores ranging from 0 to 3. This score was based on all information available. A 0 indicated not-at-risk for autism status, while a 1 suggested that the infant appeared not to be at-risk but that the infant displayed some other behavioral delay or temperament problem that precluded a clear not-at-risk status. A score of 2 indicated that the infant demonstrated autism-spectrum-like behaviors based on the parent report and behavioral observations, and a score of 3 indicated that they were highly at-risk as a result of failing three M-CHAT test items, failing two critical M-CHAT items, or having already been diagnosed. For the purposes of future publication, follow up studies are currently being conducted to confirm diagnostic status. In the present study, infants were considered to be in the control group if they received an Autism Spectrum Impression score of 0 or 1 and were at-risk if they received scores of 2 or 3.

Results

It was hypothesized that in a comparison of infants at-risk for autism and a control group of typical infants, there would be a difference in performance on precursors to theory of mind. Specifically in this study, these include physical occlusion tasks, which would reveal more deficits in at-risk infants. Secondly, it was hypothesized that children who show more deficits on physical occlusion tasks would also show more deficits on other possible precursor tasks such as joint attention tasks, including shifts in attention between an object and a person and pointing. Further, it was hypothesized that there would be consistency in performance across time for those infants who were seen for two visits. Finally, age differences would be present in the performance on these tasks, as there would be improved performance as these theory of mind capacities develop.

In comparing the control and at-risk groups for demographic information, the groups were equated on gender and age, and there were no significant differences based on racial or ethnic background. However on maternal education, there was a significant relationship between education level and risk status, $t(61) = -4.583$, $p = .000$. Higher levels of education were associated with not-at-risk infants. Correlations between maternal education level and performance on physical occlusion and joint attention tests were also computed. There were no significant correlations between maternal education and the four total scores for either group, except for the joint attention score during visit 2 for the control group ($r(22) = .457$, $p = .012$). Thus, higher levels of education were associated with higher joint attention deficit scores.

The data were screened to determine if there was a normal distribution, which would determine the type of tests that were used for data analysis. A Shapiro-Wilk test was completed to decide if the data were normally distributed. The results of the Shapiro-Wilk Test indicated that the data were not normally distributed, due to the fact that the Shapiro-Wilk test was only significant for one variable for both the at-risk ($n = 31$) and control groups of infants ($n = 32$) (Table 1). Therefore, since the data proved not to be normally distributed, nonparametric tests were used in the analysis including the Mann-Whitney *U* test or the Kruskall-Wallis test to compare means, and the Spearman's rho test for correlation analysis. Based on the above stated hypotheses which were created a priori, one-tailed tests were used for the analyses.

The following results on physical occlusion tasks were recorded for infants and toddlers during their first visit; the ball pause task, the book pause task, and the tickle pause task (Table 2). Comparison of infants' performance on these tasks yielded differences between the two groups on two out of the three physical occlusion tasks. A Mann-Whitney *U* test was conducted to evaluate the hypothesis that infants at-risk for autism displayed more deficits on these tasks than the control group. There was a difference between the two groups on the ball pause task during visit 1, $U = 350.5$, $z = -2.711$, $p = .0035$, and on the book pause task during visit 1, $U = 238$, $z = -4.216$, $p =.000$ (Table 3). For both tests, the control group performed better than the at-risk infants (Figure 1). However, there was no significant difference for the tickle pause task for visit 1 $U = 458$, $z = -.613$, $p =.27$ (Table 3). The same results were seen for infants that came in for a second visit (Table 4). There was a difference between the two groups on the ball pause task during visit 2, $U = 102.5$, $z = -3.147$, $p = .001$, and on the book pause task during visit 2, $U = 118$, $z = -2.77$, $p = .003$ (Table 4). The control group again performed better than the at-risk infants (Figure 2). However, there was no significant difference for the tickle pause task for visit 2 $U = 201$, $z = -.107$, $p =.458$ (Table 4).

To test the second hypothesis, that performance on physical occlusion tasks will be correlated with performance on joint attention tasks, a one-tailed Spearman's rho test was conducted. Total physical occlusion scores as well as total joint attention scores were compiled to explore this correlation. On this test, a lower score indicated better performance on a task. Results revealed that for the control group, there was not a statistically significant relationship between performance on physical occlusion tasks and joint attention tasks for visit 1 (r_s (30) = .253, $p = .081$) (Table 5) or for visit 2 (r_s (22) = .299, $p =.078$) (Table 6). However, for individuals at-risk, there was a correlation between performance on physical occlusion tasks and joint attention tasks for the first visit (r_s (29) = .454, $p =.005$) (Table 7) as well as for the second visit (r_s (15) = .608, $p =.005$) (Table 8).

For the participants who came in for two visits (24 control, 17 at-risk), a correlation between performance on physical occlusion tasks on visit 1 and joint attention and physical occlusion tasks on visit 2 was conducted to examine how well the initial performance on the physical occlusion task predicted performance over time. Although the outcomes indicated some trends in the data, there were mixed results. The total physical occlusion and total joint attention tasks were again used for this test. For the control group, there was a significant correlation between the total physical occlusion task score for visit 1 and the total physical occlusion task score during visit 2 ($r_s(22) = .348$, $p = .048$), but there was not a significant correlation between the total physical occlusion task score during visit 1 and the total joint attention score during visit 2 ($r_s(22) = .162$, $p = .225$) (Table 9). For the infants at-risk, although the results were not significant between total physical occlusion task scores during visit 1 and visit 2 ($r_s(15) = .398$, $p = .057$), a nearly significant correlation was present (Table 10). However, the correlation was not significant between the total physical occlusion scores during visit 1 and the total joint attention scores on visit 2 ($r_s(15) = .026$, $p = .461$) (Table 10).

In comparing performance on physical occlusion and joint attention tasks during visit 1 across three age groups, there were no significant results. Infants were divided into three groups based on their age at the first visit. Group 1 included infants aged 13-18 months, group 2 included infants aged 19-24 months, and group 3 included infants aged 25-30 months. For the control group, there were 10 infants in the first age group, 14 in the second age group, and eight in the third group. For the at-risk infants, there were 12 infants in the first age group, 10 in second age group, and nine in the third age group. A Kruskall-Wallis revealed that for both the control group and the at-risk group, there were not significant differences based on age for total physical occlusion tasks or total joint attention tasks (Table 11, Table 12).

Discussion

Interpretation of Findings

In this study, the research explored whether there is a difference between performance on tests of precursors to theory of mind capacities in infants at-risk for autism spectrum disorder and typical infants, with a particular focus on response to physical occlusion tasks. The results of the study do demonstrate a difference between the at-risk and control groups in their performance on these tasks. Specifically, at-risk infants showed more deficits than typical infants. In addition, a relation between performance on physical occlusion tasks and other measures of social development - such as joint attention – was found for the at-risk group, but not the control group. This pattern of results was found at both time points in the study. There were mixed results in examining how well performance on physical occlusion tasks predicted performance on both physical occlusion and joint attention tasks across time. A significant correlation existed in the control group between visit 1 and visit 2 total physical occlusion scores, and a strong trend was present for at-risk infants. However, the total physical occlusion visit 1 scores did not correlate with joint attention scores at visit 2. Finally, there were no significant differences in performance based on age in either group. These results confirm the previous literature in that they support the notion that at-risk infants show more deficits in precursors to theory of mind than control infants, yet contradict the previous literature in that some relationships between different performance tasks were not found to be significant for the control group or across time for either group (Charman et al., 2000). These findings add to the understanding of the development of how precursors to theory of mind differ in these populations and specifically about the deficits in infants at-risk for autism spectrum disorder.

In examining maternal education, the correlation between maternal education and risk status – with higher education levels found in mothers of at-risk infants. One study found that infants whose parents had less than 12 years of education had twice the odds of being reported as not having autism spectrum disorder (Kogen et al., 2009). This may be due to the fact that these parents are not as educated about developmental milestones and delays and therefore may not report significant deficits in their child (Kogen et al., 2009). Further, parents with less education were less likely to continue treatment or seek treatment for their child (Kogen et al., 2009). This may lead to the results suggesting a correlation between education level and risk-status. The results in this study, however, suggest the opposite: that mothers of not-at-risk infants have higher education levels. This may be due to the fact that, in this study, the at-risk status was not only determined by parental report, but instead depended on a combination of sources and was ultimately decided by a clinician. Therefore, parental education level – implying greater awareness of appropriate developmental milestones – may not lead to higher incidence of identification of their children as at-risk. There may instead be other factors influencing the results, such as distance to treatment centers, cost, and living in rural versus metropolitan areas which have also been found to impact amount of treatment (Koegel, Symon, & Koegel, 2002). Considering these factors may point to potential additional variables to consider for future studies regarding at-risk status and environmental factors.

Analyses of study results revealed differences between the two samples in their performance on physical occlusion tasks, specifically on the ball pause and book pause tasks, with the at-risk infants showing more deficits. However, there were no differences on the tickle pause task. These results are consistent with the hypothesis that there would be a difference in the performance of the two groups. This supports previous literature which hypothesized that individuals with autism do not develop a fully functioning theory of mind and that these deficits may be evident early in life (Baron-Cohen, 2001). As previously noted, for these tests, a higher score indicated more deficits, therefore at-risk infants received higher scores on average than control infants. The higher scores for the at-risk infants on these physical occlusion tasks may be due to the fact that they do not anticipate the action of the researcher, whereas typical infants actively participate in the social activity and wait for the action of the researcher (Wellman & Lagattuta, 2000). For typical infants, understanding the routine that has been established and anticipating the next action are skills already present at this age (Rochat, 2001). The lack of these skills in the at-risk infants may indicate a delay in social development. Therefore, these delays appear to help distinguish infants who are at-risk for autism, as these developmental differences are already present (Wellman & Lagattuta, 2000, Chapter 2).

In considering the non-significant difference between the two groups in results for the tickle pause task, this may have occurred because individuals with autism tend to respond positively to tactile events that promote laughter (Reddy, Williams, & Vaughn, 2002). Previous research has found that preschool aged children with autism respond similarly to typical children to laughing and tactile events such as tickling (Reddy et al., 2002). On the tickle physical occlusion task, the at-risk infants may have demonstrated typical-like behaviors because they were engaged in the activity and therefore responded appropriately to the event. This may suggest that some precursor to theory of mind capacities are possible in at-risk infants depending on the activity, and possibly the child's level of interest in the activity. This may indicate that observing a response to tickling may not be a valid measure of whether or not an infant is at-risk for autism spectrum disorder.

In comparing the performance on physical occlusion tasks and joint attention tasks, the results were mixed. For the first visit, there was not a significant relation between the performance on these two tasks for typically developing infants. However for individuals at-risk for autism, there was a correlation between the performance on the two types of tasks, as predicted in the hypothesis. The correlation evident between physical occlusion and joint attention tasks in infants at-risk for autism may indicate a trend in their development. This may result from infants at-risk for autism having delayed development that is consistent in all social developmental milestones, including different types of precursors to theory of mind, such as physical occlusion and joint attention tasks (Wellman & Lagattuta, 2000, Chapter 2). As a result, the entire developmental process may be delayed, as both their precursors to theory of mind as well as joint attention seem to be related (Gopnik, Capps, & Meltzoff, 2000, Chapter 3). This also suggests that the infant's performance on the physical occlusion task was not due to the nature of the task, but was truly based on a lack of development in these pre-theory of mind abilities, as similar deficits were evidenced in other social tasks, here, in joint attention skills. For individuals at-risk, this may indicate that if their joint attention skills are improved, so too will their theory of mind capacities improve (Charman et al., 2000). Therefore, it may be beneficial to work on these abilities and enhance their theory of mind skills as they develop.

The lack of a significant relationship for joint attention and physical occlusion tasks in the control group is surprising, as previous studies indicated that theory of mind may grow out of these precursors and joint attention skills (Baron-Cohen, 1996). However, the results from this study may be due to the fact that for typically developing infants that follow a traditional developmental process, certain skills such as joint attention skills and physical occlusion abilities, or more general theory of mind capacities, may emerge at different times throughout development and therefore, these correlations may not be evident until they are older (Gopnik, Capps, & Meltzoff, 2000, Chapter 3). These results may also be due to the fact that there was a small sample size and the overall performance scores may not be indicative of the accurate abilities that is typical of this age group.

Results varied from the predictions of the third hypothesis regarding consistency of performance on physical occlusion tasks during visit 1 and the subsequent scores for both physical occlusion total scores and joint attention total scores for visit 2 in control and at-risk groups. For the control group, the total physical occlusion score for visit 1 and the total physical occlusion score for visit 2 were correlated, however there was no relationship between total physical occlusion total score for visit 1 and total joint attention score for visit 2. Similar results were evident in the at-risk group, as there were strong trends in the physical occlusion scores, but these trends were not present between the total physical occlusion score on visit 1 and total joint attention score for visit 2. The significant relationship and strong trend between physical occlusion scores may suggest that there is a relationship between their performance on physical occlusion tasks over time, as these social skills evolve on a development trajectory (Kristen et al, 2000). Therefore, if an infant shows less deficits when they are younger, they are expected to show less deficits when they are older (Charman et al., 2000). This may suggest that measuring physical occlusion task performance over time may give an accurate idea of an infant's later theory of mind capacity.

However, the non-significant relationships between physical occlusion scores and later joint attention scores contradict previous studies that suggest there is a relationship between these abilities. Specifically, these results do contradict the findings that a longitudinal relationship exists between joint attention skills and theory of mind abilities in a group of typically developing children (Charman et al., 2000). In this longitudinal study that looked at joint attention, imitation, and play as precursors to theory of mind and tested infants at 20 and then 44 months, they found that gaze switches between an adult and an object as well as blocking tasks were associated with theory of mind ability at 44 months (Charman et al., 2000). In the present study, such relationships were not found to be significant. One explanation for these results is that the sample of infants that returned for the second trial may not be representative of the larger population. Further, the physical occlusion and joint attention tasks in the present study may require different social capacities, therefore some infants may possess the abilities to complete one of these tasks, while still having deficits in the other tasks.

Finally, in comparing the difference in performance based on age, there were no differences for either group on their visit 1 performance. This may be due to the fact that the sample sizes were small for each age group, which did not lead to strong differences. Further, the division of ages into the three groups should also be considered. One study found that a significant change is evident between 6 and 12 months, but not in other comparison age groups (Ozonoff et al., 2010). In this study, the infants ranged from 13 to 29 months, therefore perhaps age divisions did not capture differences in developmental stages and were between the phases in which there are significant changes in developmental abilities related to theory of mind. In addition, the ability to perform physical occlusion and joint attention tasks should be consolidated by about 12 months, which is younger than the age of the typical subjects; therefore, age related differences were not necessarily anticipated (Ozonoff et al., 2010).
The lack of significant age effects may be due to the fact that there was a restricted age range (13-29 months) used in this study, so therefore, this may not capture significant changes in their developmental abilities as they mature. Further, the fact that this study is concerned a group that has a restricted range of performance due to their impairments, may also lead to the lack of significance results. Future studies should include a wider range of ages and examine longitudinal rather than cross-sectional data in order to explore when specifically the critical stages in development occur.

Limitations

A number of limitations were present in this study. Most significantly, the small sample size may have led to a lower statistical power in assessing the results. There were only 63 participants in total, with 31 in the at-risk group and 32 infants in the control group. By conducting the study with more participants, the research may lead to stronger results. Another limitation is the fact that only 41 participants returned for a second trial. This may impact the data, as the entire sample was not tested twice so there was not complete data to draw truly significant conclusions regarding performance across numerous trials. Further, since maternal education was found to be related to risk status, future studies should attempt to control for this factor. In order to improve the results, a much longer longitudinal study must occur with the majority of infants returning for more than one trial. This study would also be aided by incorporating more frequent intervals of testing, which would control for variability of factors such as time of day, affect of child and other situational factors.

Another limitation to consider is the fact that each infant that returned for visit 2 did not return after the same length of time after the initial visit. The second visits ranged from 3 weeks to 14 months after the initial visit, a wide time span. The time at which the second visit occurred in relation to the first visit may be crucial for comparing developmental progress from visit 1 to visit 2 (Ozonoff et al., 2010). In this study, the infants came in at a range of different time intervals for their second visit, so there were differences in developmental change between visit 1 and visit 2. Therefore, there was variability on how much they had grown and developed between the two trials and even how familiar they may have been with the test and the clinician. Future studies should ensure that all infants return at the same time intervals for the second visit.

Additionally, the highly structured nature of this test is a limitation. One issue which has been highlighted in experimental theory of mind findings is that these tests and measures do not always model real life situations. Results are most accurate when they are as naturalistic as possible (Klin, Schultz, & Cohen, 2000). In considering this in the present study, the infant might not respond as they typically would, as they are not in a familiar environment and specific probes are being implemented which may or may not relate to the child's interests or prior experiences. Perhaps having the child interact with parents and observing this exchange might enhance the current results.

Future Directions

Despite these limitations, the findings of the present study have significant implications for contributions to the field of understanding the development of theory of mind and early detection of autism spectrum disorder. In considering future directions for this research, measuring precursors to theory of mind ability may be a way to determine whether or not a child is at-risk for autism spectrum disorder. Therefore, such tasks as the physical occlusion activities could be incorporated into more screening tests, as failure on these activities which measure precursors to theory of mind may be a characteristic of a child who is at-risk for autism spectrum disorder. Further, it would be interesting to conduct a longitudinal study to assess how the infant performs on these tasks over time and as they develop. Following the children longitudinally will indicate how these early theory of mind abilities truly impact later capacities. This would also allow researchers to examine verbal acquisition as well as other social measures throughout a child's development and indicate how these later developmental abilities are related to early precursors to theory of mind.

Another factor to consider is the impact of family, specifically the presence and number of siblings in an infant's family. Previous research has suggested that family experiences, family conversations, and the presence of siblings may impact one's theory of mind development (Perner, Ruffman, & Leekam, 1994). Therefore, it would be interesting to explore if the performance on physical occlusion precursors to theory of mind tasks are influenced by the presence of a sibling or communication with family members. Further, research could also consider if the sibling is at-risk or not-at-risk for autism, and how that effects the development of a younger sibling on their theory of mind skills.

Additionally, measuring of infants' looking behavior after the physical occlusion tasks may be further studied by applying eye tracking to this study. Eye tracking technology is able to measure the frequency at which infants focus on certain items, the length at which they focus, and where they focus (Jones, Carr, & Klin, 2008). This research has found that individuals with autism spectrum disorder display atypical patterns of visual attention to social interaction, intact response to physical attentional cues, and intact ability to predict and attend to physical events (Schultz, Klin, & Jones, 2011). Further, their looking at the eye region was decreased and they had less eye contact than typical infants (Jones, Carr, & Klin, 2008). Therefore, measuring where specifically the infants look after these tasks and for how long, may provide significant information on the development of these precursors to theory of mind capacities, and also about the severity of various levels of at-risk infants.

Applying this knowledge to future treatments may be beneficial. Although individuals with autism can learn to pass theory of mind tests, they often do not demonstrate the effective application of these skills to everyday theory of mind situations (Swettenham, 2000). However, use of specific teaching techniques – such as indicating that others have pictures of events in their head that change depending on what they have seen – has proven to be particularly successful (Swettenham, 2000). Therefore, in incorporating the results of this study to developing the most effective treatment, it would seem that a deficit in theory of mind ability at this young of an age would mean that therapies should address these deficits early on. As a result, clinicians should consider the most beneficial methods of strengthening these precursors to theory of mind capacities, so that as an individual matures they are not as deficient in these capacities, and therefore have a smaller delay. Clinicians may adopt similar theory of mind strengthening methods specifically applicable to younger children. This may allow researchers to apply helpful methods for aiding these individuals in their development and diminish the social impairments they have as they mature.

Finally, looking at the neurological correlates related to theory of mind may also provide significant information. Researchers have identified the limbic system (amygdala, orbitofrontal cortex, and anterior cingulate cortex) and the superior temporal cortex as being part of the social brain (Frith & Frith, 2000). Monkeys with lesions in these areas show unusual movement patterns, absence of emotional behavior and vocalizations in response to other monkeys, and social disinterest, characteristics similar to those seen in individuals with autism spectrum disorder (Frith & Frith, 2000). This may indicate that these brain regions are involved in some of the key developmental deficits in autism. In specifically considering areas identified as being involved in mentalizing, another term for theory of mind abilities, these include the medial frontal cortex (posterior cingulate cortex) and right temporoparietal junction (Frith & Frith, 2000). One study measured brain activity in individuals with Asperger's syndrome when engaged in theory of mind activities (Frith & Frith, 2000). The results revealed lower levels of activation in these brain regions for these individuals (Frith & Frith, 2000). Therefore, future studies may first measure the brain activity in these theory of mind areas in typically developing infants while engaging in activities that measure precursors the theory of mind, and then compare the brain activation in at-risk infants. Findings from such a study may help researchers determine if there is in fact an early difference in activation in these regions. If there are brain differences in these regions, researchers will also be able to better determine when these differences emerge in development. Additionally, this may also shed light on the neurobiological correlates of autism and when these changes occur developmentally, and if subjects are followed longitudinally, determine if brain responses can be altered by various therapies and treatments.

Conclusions

In sum, this experiment provides a basis upon which future researchers can build in exploring the role of precursors to theory of mind in early autism detection. The results of this study, which compared 63 at-risk and typical infants on their performance on physical occlusion tasks, indicate that there is a difference in the performance in these two samples on two out of the three physical occlusion tasks (ball task and book task) in which at-risk infants showed more deficits. In addition, some correlations exist for individuals at-risk for autism on joint attention and precursors to theory of mind tasks, tasks which both measure precursors to theory of mind. Therefore, these measures of theory of mind should be included in more early screening tests as the field of autism research continues to expand. While similar tasks are included in well-known diagnostic tests such as the Autism Diagnostic Observation Schedule - Toddler Module (ADOS-T), specifically examining the performance on physical occlusion tasks and including them in infant tests that assess a broad array of developmental skills which can be used in primary care or early intervention settings, may be truly beneficial in better detecting autism early (Luyster et al., 2009). This may help with future detection methods, as well as methods of early treatment and therapy to help these individuals with autism spectrum disorder improve their social abilities as they mature, and lead researchers one step closer to understanding the nature of autism.

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Table 1

Shapiro-Wilk Test of Normality

	ASD	Statistic	df	Sig.
Age	Control	0.956	32	0.211
	At-risk	0.948	31	0.139
Mother Level of Education	Control	0.685	32	0.000
	At-risk	0.831	31	0.000
Gender	Control	0.615	32	0.000
	At-risk	0.571	31	0.000
Ball Pause 1	Control	0.334	32	0.000
	At-risk	0.619	31	0.000
Book Pause 1	Control	0.391	32	0.000
	At-risk	0.607	31	0.000
Tickle Pause 1	Control	0.615	24	0.000
	At-risk	0.635	17	0.000
Ball Pause 2	Control	0.503	24	0.000
	At-risk	0.579	17	0.000
Book Pause 2	Control	0.454	24	0.000
	At-risk	0.632	17	0.000
Tickle Pause 2	Control	0.542	24	0.000
	At-risk	0.533	17	0.000
Ball Attention 1	Control	0.172	32	0.000
	At-risk	0.591	31	0.000
Book Attention 1	Control	0.391	32	0.000
	At-risk	0.638	31	0.000
Book Point 1	Control	0.391	32	0.000
	At-risk	0.591	31	0.000
Ball Attention 2	Control	omitted	24	0.000
	At-risk	0.642	17	0.000
Book Attention 2	Control	0.209	24	0.000
	At-risk	0.632	17	0.000
Book Point 2	Control	0.393	24	0.000
	At-risk	0.642	17	0.000
Total Physical Occlusion Score 1	Control	0.737	32	0.000
	At-risk	0.885	31	0.005
Total Physical Occlusion Score 2	Control	0.703	24	0.000
	At-risk	0.868	17	0.020
Total Joint Attention Score	Control	0.497	32	0.000

1	At-risk	0.88	31	0.003
Total Joint Attention Score	Control	0.454	24	0.000
2	At-risk	0.829	17	0.005

Table 2
Tasks

Physical occlusion tasks	**Joint attention tasks**
Ball Pause	Ball Gaze
Book Pause	Book Gaze
Tickle Pause	Book Point

Table 3

Comparison of physical occlusion task performance in control and at-risk groups

Visit 1

	Ball Pause	Book Pause	Tickle Pause
Mann-Whitney U	350.5	238	458
z	-2.711	-4.216	-0.613
p	0.0035	0.000	0.27

Table 4

Comparison of physical occlusion task performance in not-at-risk and at-risk groups

Visit 2

	Ball Pause	Book Pause	Tickle Pause
Mann-Whitney U	102.5	118	201
z	-3.147	-2.77	-0.107
p	0.001	0.003	0.458

Table 5

Total physical occlusion and total joint attention score correlations

Control group, visit 1

		Total Joint Attention Score 1
Total Physical Occlusion Score 1	Spearman's rho	0.253
	p	0.081
	n	32

Table 6
Total physical occlusion and total joint attention score correlations
Control group, visit 2

		Total Joint Attention Score 2
Total Physical Occlusion Score 2	Spearman's rho	0.299
	p	0.078
	n	24

Table 7

Total physical occlusion and total joint attention score correlations

At-risk group, visit 1

		Total Joint Attention Score 1
Total Physical Occlusion Score 1	Spearman's rho	0.454
	p	0.005
	n	31

Table 8

Total physical occlusion and total joint attention score correlations

At-risk group, visit 2

		Total Joint Attention Score 2
Total Physical Occlusion Score 2	Spearman's rho	0.608
	p	0.005
	n	17

Table 9

Total physical occlusion visit 1 score and total physical occlusion and joint attention visit 2 scores correlations

Control group

		Total Physical Occlusion Score 2	Total Joint Attention Score 2
Total Physical Occlusion Score 1	Spearman's rho	0.348	0.162
	p	0.048	0.225
	n	24	24

Table 10

Total physical occlusion visit 1 score and total physical occlusion and joint attention visit 2 scores correlations

At-risk group

		Total Physical Occlusion Score 2	Total Joint Attention Score 2
Total Physical Occlusion Score 1	Spearman's rho	0.398	0.026
	p	0.057	0.461
	n	17	17

Table 11

Comparison of age on task performance

Control group

	Total Physical Occlusion Score 1	Total Joint Attention Score 1
x^2	0.16	0.915
df	2	2
p	0.923	0.633

Table 12

Comparison of age on task performance

At-risk group

	Total Physical Occlusion Score 1	Total Joint Attention Score 1
x^2	1.055	3.122
df	2	2
p	0.59	0.21

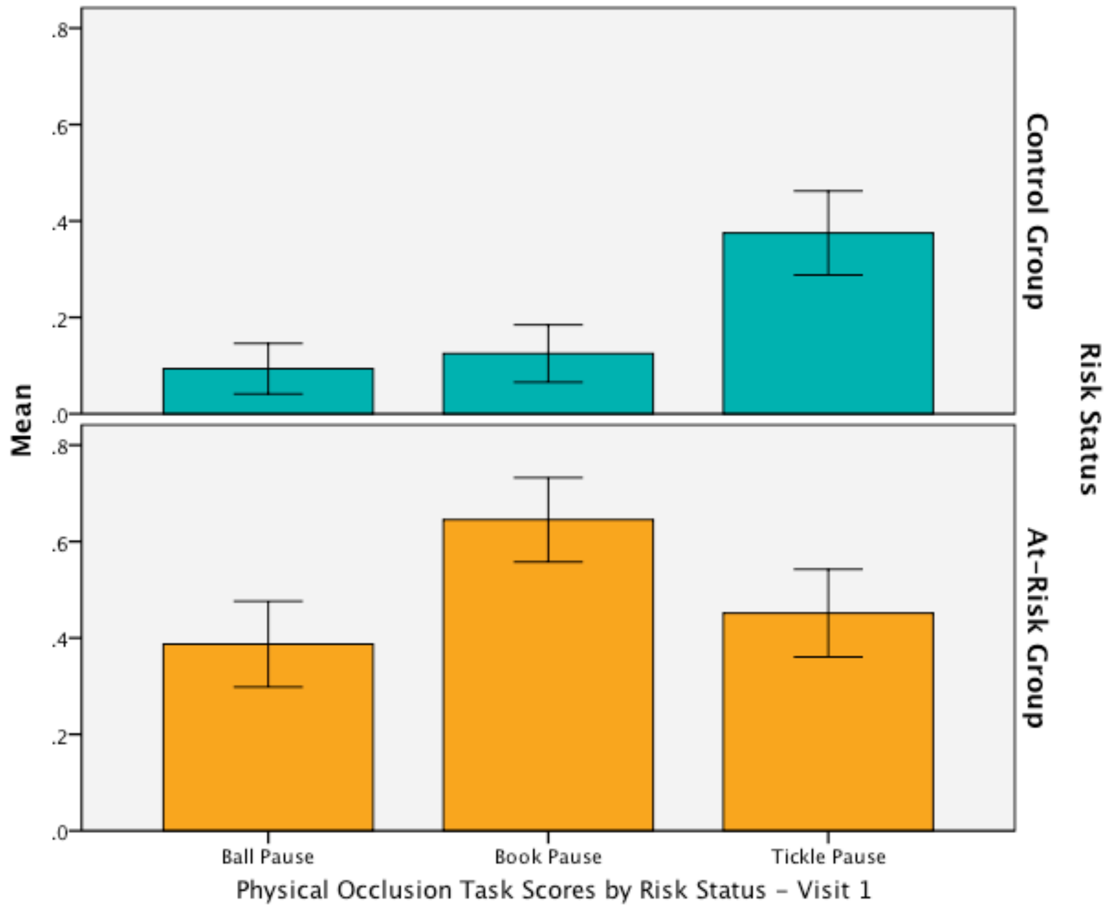

Figure 1: Physical occlusion deficit scores for visit 1 based on risk status. At-risk infants showed more deficits on both the ball pause and book pause task than the control group. The scores were similar in both groups for the tickle pause task.

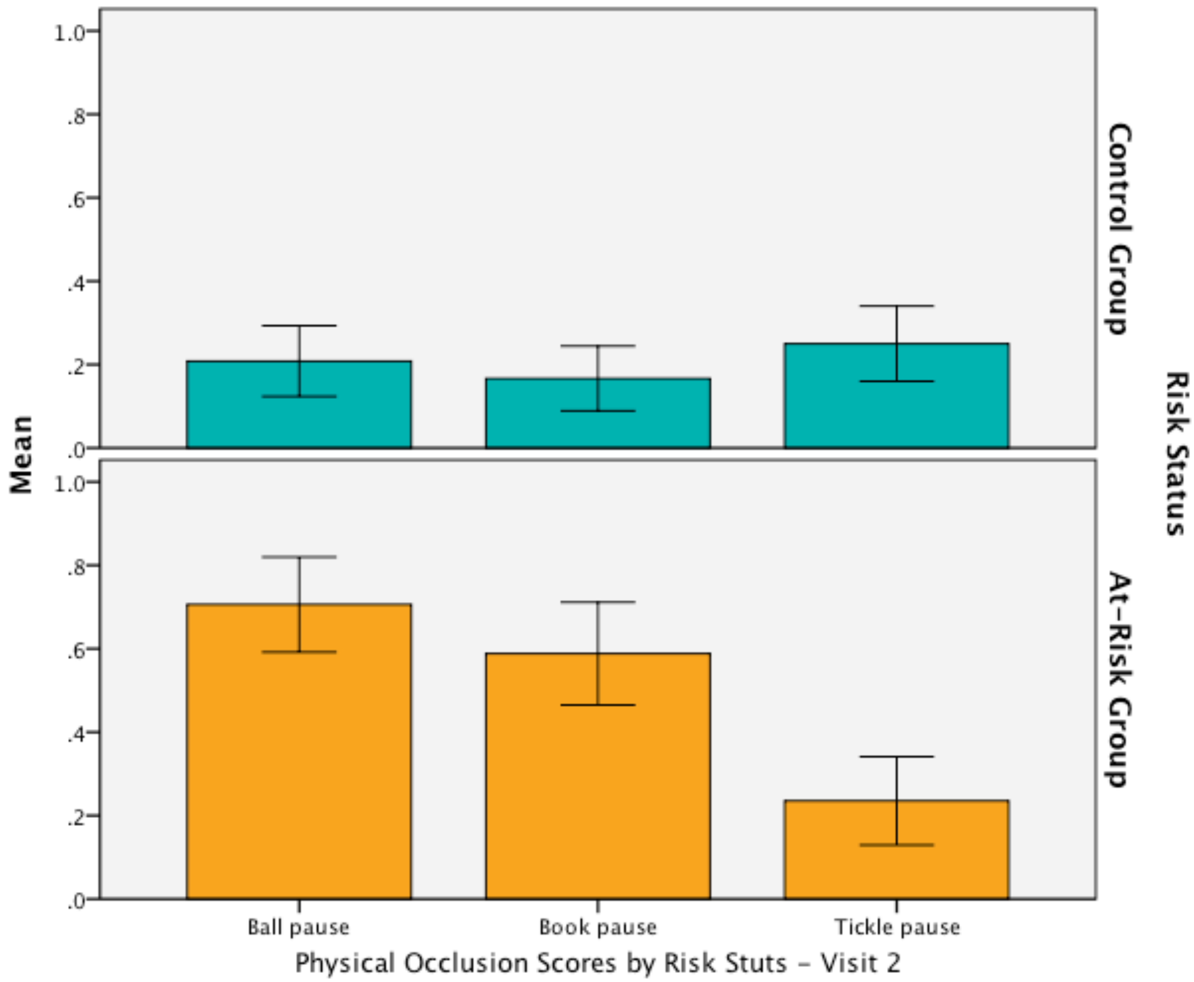

Figure 2: Physical occlusion deficit scores for visit 2 based on risk status. At-risk infants showed more deficits on both the ball pause and book pause task than the control group. The control group displayed more deficits than the at-risk group on the tickle pause task.