UNDERSTANDING DEVELOPMENTAL AND RISK-STATUS EFFECTS ON VISUAL ENGAGEMENT: EVALUATION OF INFANT PLAY BEHAVIOR

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Sidni A. Vaughn

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UNDERSTANDING DEVELOPMENTAL AND RISK-STATUS EFFECTS ON VISUAL ENGAGEMENT: EVALUATION OF INFANT PLAY BEHAVIOR

Approved by:

Dr. Jenny L. Singleton, Advisor
School of Psychology
Georgia Institute of Technology

Dr. Eric Schumacher
School of Psychology
Georgia Institute of Technology

Dr. Agata Rozga
School of Interactive Computing
Georgia Institute of Technology

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SUMMARY

Visual engagement, defined as “preferential attention to biological motion and preferential attention to others eyes or face” (Klin, Shultz, & Jones, 2015) is said to emerge early in infancy and serve as a foundation for social cognition as well as language development. Deficits in visual measures such as gaze shifting are seen as hallmark signs of Autism Spectrum Disorder (ASD). This thesis utilized a microanalysis of audio/video data to evaluate developmental and risk group differences in how infants engage socially across two adult-infant play contexts. Age was expected to have no significant impact on basic visual engagement measures (frequency, fixation) as most of these behaviors are thought to be stable by 12 months of age. Risk status effects were predicted such that infants at risk (AR) for ASD were expected to be lower (in frequency to look) and slower (to shift gaze) compared to typical developing (TD) infants. Age and risk status were predicted to impact latency to shift gaze in response to a violation of expectation (unexpected pause in play). Hypotheses were tested on a sample of 162 infants, ages 15-34 months, of which 37 were considered at-risk (125 considered TD) for autism based on parent report screeners. Results revealed that AR infants looked less compared to TD infants and tended to fixate on non-face (ball) locations compared to face. Additional analyses showed that risk group differences remained significant when controlling for age. No significant age or risk group effects were found for post-pause latency to shift. Limitations of the present study, as well as future directions for both theory and clinical practice are discussed.

CHAPTER 1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a social communication disorder characterized by impaired ability to use verbal and nonverbal communication effectively, participate socially, and form relationships (American Psychiatric Association, DSM-5, 2013). A recent push in pediatrics and ASD research has been to 1) try and diagnose autism earlier and 2) come up with pediatrician friendly screeners that can pinpoint early red-flags without requiring extensive training or administration time like the gold-standard measures (e.g., Autism Diagnostic Observation Schedule; ADOS; Lord et al., 2000) or reliance upon the subjectivity of parent report screeners (e.g., Modified Checklist for Autism in Toddlers; M-CHAT). With this push comes the responsibility of ensuring that such screeners can objectively tease apart early ASD risk from the variability one might observe within the parameters of normal development.

Developmental psychology theories suggest that many communication and social interaction behaviors are innate or come online within the first few years of life in Typical Development (TD). For example, by two months of age infants have already started to develop cognitively (paying attention to faces), socially (smiling at people), and often begin to exhibit language precursors (turning head towards sounds; cooing) (Centers for Disease Control and Prevention, 2016). One particular behavior of interest that is thought to emerge early in infancy and predict long-term social and developmental outcomes is visual engagement. Visual engagement involves directing attention to another person (usually the face), and is often operationalized along the dimension of general (e.g., shifting) to more specific (e.g., joint attention) measures of gaze behavior.

Many behaviors that may constitute visual engagement are thought to be atypical in infants and toddlers with ASD (e.g., gaze shifting, eye-contact, social-referencing). Research has suggested that this atypicality may emerge in early infancy, and diminished occurrence or absence of appropriate gaze behavior is considered one of multiple social interaction red flags for ASD.

However, phrases such as “lack of appropriate eye gaze” yield questions such as, “what is appropriate?” and more specifically, “how drastically does appropriate change over the first few years of infancy and toddlerhood?” As many gaze behavior based questions now appear on widely accepted parent-report autism screeners (e.g., M-CHAT) as well in the behavioral observation assessments that are considered diagnostic, clarifying what is typical and stable across early infancy is essential. The present study begins to address this question by utilizing a microanalysis approach to investigate infant visual engagement behavior when engaged in social play interaction with an adult. By exploring more closely the characteristics of visual engagement in typically developing children and among children considered at-risk for autism, we may be able to more precisely identify early markers of this disorder.

CHAPTER 2. BACKGROUND

To function within society as a whole, or simply to have effective relationships within families, we must learn to relate to one another socially from an early age. This includes not only developing language, but also gaining an understanding of social cognition and social communicative behaviors. For Typical Developing (TD) infants, the foundations for social understanding and development are laid by parent/caregiver interaction (Deák, Triesch, Krasno, de Barbaro, & Robledo, 2013) and appear very shortly after birth. One predictor of what we might later call "social success" involves early gaze behavior. Learning to shift our gaze and to follow the gaze of others lays the foundation for learning by imitation, understanding facial expression and emotion, and is key predictor of later developmental outcomes such as language acquisition (Adamson, Bakeman, Deckner, & Romski, 2009; Brooks & Meltzoff, 2005; Dawson et al., 2004; Mundy et al., 2007). As we align our attention with that of our caregivers in infancy, we are able to learn about the surrounding environment (e.g., "Where are we?") As we develop and become more social and communicative, sharing attention becomes critical in order to share experiences and interests (i.e., "Who are we? How do we differ?; Adamson & Bakeman, 1985).

In children with Autism Spectrum Disorder (ASD), we often see delayed or impaired ability to use both verbal and nonverbal communication effectively. This can prove detrimental to fostering social relationships. Oftentimes, this diminished relationship quality becomes clear as the child enters the school setting and begins to form peer relationships. Unfortunately, the average age of diagnosis lies around 4-5 years of age and many children go undiagnosed until they enter the school system (Wiggins, Baio, & Rice, 2006). This age range constitutes the tail end of what we have typically viewed as the critical period for language and social development (Siegler et al., 2017). Parents report earlier concerns, usually language and social delays, but social development is difficult to evaluate in a uniform, brief way in clinical pediatric settings (i.e., regular baby checkups; Pinto-Martin et al., 2008). By the time diagnosis is made, children may already be impacting their ability to pursue formal education, build relationships with peers and family, and overall quality of life. In 2006, The Centers for Disease Control and Prevention (CDC) estimated that 1 in every 110 children in the US had ASD (CDC, 2009). In 2010, they reported an increased ASD prevalence rate of 1 in 68 (CDC, 2014). This increased prevalence, in conjunction with the apparent social and emotional costs of the disorder, makes earlier diagnosis a national imperative. In recent years, the amount of research surrounding autism and early intervention has vastly expanded. One particular line of research has been towards developing rapid, behavior-based screening tools that can flag early markers for ASD. Efforts towards earlier diagnosis could prove fruitful to providing early social or behavioral intervention and potentially increase the quality of life for individuals with autism. However, in order to develop an effective screening tool, we must first know how gaze behavior develops among typically developing children (TD) and the normal variability observed.

2.1 Visual Engagement: Typical Development

Visual engagement is a mechanism that appears early in social interaction and builds on builds on underlying basic mechanisms of attention. Klin, Shultz, and Jones (2015) define visual engagement as "preferential attention to biological motion (movements of vertebrate animals) and preferential attention to others eyes or face" (p. 3). Attention is a multidimensional concept that enables us to adapt and respond to our social and physical worlds. Attention relies on multiple neural systems and brain areas and may be modulated based on experience or situation. Attention to objects, events, and problems in our external world often involves visually attending to them by directing our eyes towards a source of information as well as being able to maintain this focus long enough to actually attain the needed information. While infants come into the world able to hear, feel, taste, and smell pretty well, vision takes a little longer to fully develop. Sight develops gradually over the first year in Typically Developing (TD) infants and by 12 months the visual system of a baby is more on par with that of an adult's. Beyond the physical development of the eyes and structures of the visual system, there also lies much development in the first year of life regarding how infants view and make sense of their world.

Extensive developmental literature on infant visual perception and attention details what infants can perceive and will naturally attend to (e.g., patterns, forms, objects, faces) throughout early infancy and toddlerhood. Ruff and Rothbart (2001) propose that attention is governed by an 'orienting investigative system' in early infancy and throughout the first year of life. Newborns are selective in what they attend to from the first day of life, spending their early days orienting primarily to novel or otherwise salient objects or events (Bronson, 1990; Leahy, 1976). Very young infants are more 'sticky' in how they focus their attention because they have difficulty disengaging their attention (Hood, 1995). However, by four months of age, infants are able to shift their attention more flexibly from one focus to another (Ruff & Rothbart, 2001).

Some of the earliest evidence for visual engagement in human infants as well as other species (i.e., domestic chicks) includes preferentially attending to another person from birth. Infants' preference for biological motion (BM) (Fox & McDaniel, 1982) examined via studies of preferential looking to point-light animations (Johansson, 1973) is thought to emerge even as early as two days after birth (Simion, Regolin, & Bulf, 2008). Typically developing infants will orient to and fixate on faces from a young age (Haith, Bergman, & Moore, 1977). Studies have shown that four-day-old infants can already distinguish between faces looking towards or away from them (Farroni, Johnson, & Csibra, 2004; Farroni, Massaccesi, Menon, & Johnson, 2007). By three months of age, TD infants can readily recognize their mother (Mash, Bornstein, & Arterberry, 2013). By three months of age, TD infants will look more to the eyes compared to other parts of the face and more to the face compared to other parts of the body (Haith et al., 1977). Attending to the face and eyes is key in learning what another person is looking at, what they may want to tell you, or how they are feeling.

In toddlerhood, selective and sustained attention becomes more socially governed: attention is less influenced by novelty and more so by what others are attending to (Ruff & Rothbart, 2001). The term Joint Attention (JA) is used to describe the ability to coordinate attention between social partners and objects. JA is thought to emerge between 2-18 months (Butterworth & Jarrett, 1991) but usually stabilizes in TD around the first birthday (Scaife & Bruner, 1975). JA and mutual gaze are important for ongoing social development and adaptation as one matures (Brooks & Meltzoff, 2002; Klin et al., 2003; 2009; 2015;). This transition may reflect precursors of social understanding as well as early development of a higher-level control system known as self-regulation (i.e., the ability to modulate behavior according to cognitive, social, and emotional demands of a situation).

2.2 Visual Engagement: Autism Spectrum Disorder

Compromised early social visual engagement appears to be associated with delayed or disrupted social and communicative development that is later seen in individuals with ASD. As previously mentioned, work such as that of Simion et al. (2008) showed that TD newborns as young as two-days-old looked longer at upright point-light animations depicting biological motion (BM) compared to inverted displays. In a study comparing children diagnosed with autism to TD and Developmentally Delayed (DD) controls, children with ASD showed lack of preferential attention for BM (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009); TD and DD children both fixated significantly longer on displays depicting well-known infant BM games (e.g., Peek-A-Boo) compared to inverted BM displays played in reverse. ASD children, however, had nearly equal time spent fixated on both locations, revealing no preferential fixation for recognizable BM. A hallmark sign of ASD is lack of eye contact (Volkmar, Lord, Baily, Schultz, & Klin, 2004) and studies using eye-trackers have indicated that children with ASD do not preferentially attend to the eyes (Jones, Carr, & Klin, 2008) and instead focus more on other facial regions such as the mouth (Klin, Jones, Schultz, & Volkmar, 2003; Neumann, Spezio, Piven, & Adolphs, 2006).

Other more complex visual engagement behaviors, such as gaze shifting and joint attention also appear to be disrupted in children with ASD. Children with ASD have difficulty with or fail to shift gaze (Volkmar et al., 2004; Gliga, Jones, Bedford, Charman, & Johnson, 2014). This often appears socially in a lack of joint attention (Charman, 2003; Landry & Bryson, 2004; Mundy 1995; Mundy, Sigman, & Kasari, 1990). While TD infants beginning shifting their gaze and moving away from ‘sticky’ fixation by four months of age (Hood & Atkinson, 1993), children with ASD are thought to remain ‘sticky’ (Ibanez, Messinger, Newell, Lambert, & Sheskin, 2008). Some (e.g., Landry & Bryson, 2004) suggest this could be due to the breakdown of more specific components of JA (e.g., problems disengaging their attention from objects which prevents gaze-shifting). Others have debated more broadly whether or not autistic individuals are interested in or motivated to reference to social stimuli at all (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Johnson, 2014). Dawson et al. (1998) suggest that perhaps stimuli present in social interaction (e.g., facial expressions, gestures) are less predictable and more complex than other non-social stimuli (e.g., inanimate objects), which is overwhelming to an individual with ASD and results in disinterest.

2.3 Opportunity for Microanalysis

Research has illustrated that visual attention includes both exogenous (reflexive) and endogenous (intentional) orienting. Klin et al. (2015) and others suggest that investigation of this narrow developmental window (in which the transition from reflexive, subcortically controlled visual behavior to the interactional, cortically controlled more social visual behavior occurs) should be prioritized in the future, especially when considering opportunities to detect differences in TD and infants at-risk for developing ASD.

However, oftentimes we discuss milestones as the measuring stick for typical development. The premise for the present study is the idea that a milestone or omnibus approach may not be telling the full story. Assessments such as the Early Social Communication Scales (ESCS), the Rapid-ABC (R-ABC), and the “gold standard” Autism Diagnostic Observation Schedule (ADOS) all involve examiners who observe and document the occurrence or non-occurrence of behaviors considered important to ASD diagnosis. Eye gaze deficits are considered a defining characteristic in ASD (APA, DSM-5, 2013) and often appear as a focal item on these standardized screeners and diagnostic tests (Lord et al., 2000). The assessments usually involve real-time play interaction featuring objects and social presses designed to elicit behaviors such as eye contact, social smiling, and joint attention. These assessments often use checklists or ratings and establish “omnibus” scores that relate to cutoffs thought to indicate risk for ASD. With the development of new screeners and tools, the opportunity arises to do a deeper dive into fine-grained behaviors such as visual engagement that can inform both research and clinical practice. That is, a more detailed “micro-analysis” of the child’s gaze behavior enables us to go beyond “whether the child demonstrated the target behavior” (as checklists do) to questions such as “how often is this behavior demonstrated” and “what is the duration of the behaviors”? This opportunity yielded the inspiration for the current study.

This is not to say that others are not doing microanalysis type work already. Researchers have recently begun exploring the use of eye tracking methods to micro-measure and analyze eye contact and gaze behavior of ASD and at-risk children (e.g., Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Navab et al., 2011; Gliga et al., 2014).

For example, Chawarska, Macari, & Shic (2013) conducted a study in which 6-month-old infants considered high or low risk for ASD viewed social scenes and found that compared to controls, infants who went on to later be diagnosed with autism looked less to the social scene overall and spent less time fixating on the actress's face. Ye, Rehg, and colleagues are also investigating alternate technologies for improving measurement of visual behavior (e.g., using wearable point-of-view cameras to detect the child's looks to face) as well as computational methods for automatizing the micro-coding of social interactions (Rehg et al., 2013; Rehg, Rozga, Abowd, & Goodwin, 2014; Ye, Li, Liu, Bridges, Rozga, & Rehg, 2015). While many researchers are developing these technologies with the aim of better quantifying and expediting the coding of these micro-behaviors, there is still much room for research employing human coding of infant behaviors and analyses that permit a deeper dive into what the infants are doing during these experimental tasks designed to elicit particular gaze behavior.

2.3.1 Response Latency Approach: Violation of Expectation

While a microanalysis of eye gaze can involve looking at how much behavior (frequency counts – e.g., how much shifting), or how long behaviors last on average (average duration – e.g., how much fixation), a third approach can include looking at response latencies to a manipulated or disrupted event. Response or saccade latencies have been studied in adult populations for a wide variety of tasks. In studies of visual engagement, authors sometimes measure 'latency to reference' (i.e., the amount of time between when an infant first notices something novel and the onset of his/her first referential look to either a caregiver or experimenter). For example, Cornew, Dobkins, Akshoomoff, McCleery, and Carver (2012) evaluated latency to reference as a way to index ‘readiness to seek information’ and found that ASD infants at 36 months of age had longer latencies than both low- and high-risk for ASD controls.

When discussing Joint Attention (JA), one can further differentiate between Responsive Joint Attention (RJA: following another person’s gaze to an object or event) and Initiated Joint Attention (IJA: purposefully directing another person’s gaze to an object or event) (Mundy et al., 2007). RJA is the more rudimentary of the two (following another person) versus IJA involves actively trying to engage another person. For visual engagement and social interaction, IJA can be driven by an underlying goal of seeking of information from another person (Cornew et al., 2012) One way researchers try and actively manipulate behavior to tap social referencing and IJA is to disrupt infant’s expectancy of what comes next (Violation of Expectation; VOE). This disruption can include when a person or object does not do what the infant might expect them to do based on previous interaction or experience.

Much research has used Violation of Expectation (VOE) tasks to investigate the age at which children understand false-beliefs. When directly questioned about false beliefs, children are thought to not have this understanding until around four years of age (Baillargeon, Scott, & He, 2010; He, Bolz, & Baillargeon, 2011). However, when inferring false belief understanding from behaviors spontaneously produced by a child who watches a scene (i.e., spontaneous-response tasks), infants have been suggested to understand false beliefs about location, perceptions, and identity as early as the second year of life (Baillargeon et al., 2010; He et al., 2011). VOE tasks feature manipulations such as change-of-location or misleading perceptual cues about what object is present in a scene. Results from VOE studies suggest that TD children respond by shifting and fixating longer when agents act inconsistently with their held false beliefs (Baillargeon et al., 2010; He et al., 2011).

Other research has investigated infant behavior in a different type of task that I also consider to involve VOE. These tasks feature common social games such as tickle or peek-a-boo and violate the infants expectation by ‘perturbing game play’ (Hsu, Iyer, & Fogel, 2014). These types of games have setup and climax components. For example, in tickle play the setup is when the social partner is saying, “I’m going to get you” and may be wiggling fingers or moving hands towards the infant. The climax component is when the social partner actually tickles the infant. Upon repeating this game, the infant grows to ‘expect’ that the setup will be followed by the climax of tickling. Perturbation of this play can involve things such pretending to tickle but not actually contacting the child’s body (Fogel, Hsu, Shapiro, Nelson-Goens, & Secrist, 2006; Hsu et al., 2014). However, much of the research on infant behavior during these back-and-forth and perturbed social games has looked primarily at infant emotional expression and regulation.

The present study uses VOE opportunities (i.e., pauses in play) within the adult-infant interaction to investigate response latency as another microanalytic measure of visual engagement behavior. The R-ABC protocol (detailed in Method section) features perturbed play type tasks as it uses unexpected pauses within a pattern of engagement to disrupt the infant’s expectation. Two R-ABC tasks include the tickle game as used in previous studies, as well as an object-oriented back-and-forth ball rolling game that has a similar set-up and climax procedure. Within both play types, the experimenter pauses to try and elicit an eye gaze shift to her face from the infant (scored as JA on the R-ABC). While there is no concrete way to ‘confirm’ that an infant’s expectation is being met, the protocol assumes that repeated trials of the back-and-forth exchanges in both games will set up the infant to expect certain outcomes and therefore the social presses (pauses) will be novel or surprising and should elicit certain behaviors (Ousley, Arriaga, Abowd, & Morrier 2013; Rehg et al., 2013; 2014). Measuring latency to reference or shift gaze in response to a VOE (pause) provides perhaps the most fine-grained analytic measure of visual engagement behavior in this study. Knowing the frequency of visual engagement behaviors (e.g., looks to social versus nonsocial stimuli) can provide insight into what infants are attending to and how much shifting is occurring. Further investigating how long they fixate on social versus nonsocial locations (i.e., average duration of looks to a certain location), we can dive deeper and investigate hypotheses related to 'sticky' fixation in ASD and whether or not that appears in young infants who are or are not at risk for ASD. However, using latency to shift gaze to a target location (i.e., experimenter's face) as a measure of referential engagement may also shed light on the competing hypotheses in the field related to impaired disengagement versus disinterest in social stimuli that is thought to appear in children with ASD and perhaps those at risk for developing autism as well.

2.4 Present Study

The preceding literature review summarizes research suggesting that visual engagement is something that naturally occurs in infancy during typical development and may appear disrupted or delayed in individuals who receive an ASD diagnosis. However, recent efforts have suggested that maybe we can investigate such behavior earlier in infancy to determine if delay or disruptions are markers of autism risk. Determining red flags could lead to earlier detection and intervention, which could greatly improve the lives of individuals with ASD.

The present study addresses some of these questions by utilizing a microanalysis of TD infant visual engagement behaviors documented during their participation in the "Rapid-ABC" assessment (Ousley et al., 2013). This experimental task engages infants and toddlers in multiple social play contexts with an adult experimenter (see Method section for more detail). The behaviors of TD children are compared to that of a group previously identified as at-risk for autism through other screeners. Investigating visual engagement patterns through a developmental lens during two different social activities expands our understanding not only of typical development but will also provide a more fine-grained baseline to which we can better compare atypical development. That is, given what we know about the social communicative deficits that appear in older children with autism (many of which can be seen in their visual engagement behaviors), can we see some of these differences earlier in children who are identified as at-risk through behavioral measures of visual engagement such as frequency and duration of looks to social partner and objects?

> **Focal Research Question:** Compared to typically developing infants (15-34 months of age), will behavioral differences in visual engagement be observed in a population of children considered at-risk for Autism Spectrum Disorder during a structured social engagement task (R-ABC)?

2.4.1 Predicted Typical Development Behavior

As previously mentioned, research has suggested that gaze shifting and ability to establish joint attention becomes stable around the first birthday. This research would predict that on basic social orienting and gaze shifting tasks, TD infants ages 15-31 months would perform at ceiling because these behaviors have been stable since ~12 months of age. This assumption is also reflected in the omnibus R-ABC scoring method which evaluates whether infants exhibit certain behaviors (e.g., make eye-contact, joint attention) at least once in the respective play activity as would be expected in TD. Based on the literature, TD infants ages 15-31 months should all shift their gaze amongst a social partner and an object. That is, infants in this age range should be interested by both the social partner and object (revealed through looks to both targets) and shouldn't be particularly fixated on one location dependent on age. Therefore, I did not predict significant developmental trends (i.e., age differences) across TD infants for amount of looking or duration of looking. That is, for all TD infants in the study, I expected to observe multiple looks to the experimenter and multiple looks to the interesting toy during a play episode (indicative of gaze shifting back and forth between the two).

However, given the literature suggesting that self-regulation mechanisms of attention continue to develop throughout pre-school years (see Ruff & Rothbart, 2001), it is possible that older infants may be quicker to shift their attention. To examine this, I conducted an analysis of "latency-to-look" occurring during a specific gaze event (a snapshot of the timing of the infant's response following the experimenter's unexpected pause in their play behavior). In this type of context, I do predict a developmental trend for post-pause latency among typically developing infants.

In summary, with typically developing (TD) infants, the following hypotheses (hyp.) are advanced:

Hyp. 1a: No significant age trends for how much (frequency) an infant looks to experimenter's face vs. object.

Hyp. 1b: No significant age trends for how long (average duration) an infant looks to experimenter's face vs. object.

Hyp. 1c: Age will significantly impact post-pause latency to look to experimenter's face. Older infants will have shorter latencies compared to younger infants.

2.4.2 Predicted At-Risk Behavior

In alignment with research that suggests that both children with ASD and those considered at-risk for ASD may be disinterested in social stimuli (e.g., Chawarksa et al., 2013; Dawson et al., 1998, 2004) and be slower to shift disengage and shift gaze (Landry & Bryson, 2004; Ibanez et al., 2008), I hypothesize that for all visual engagement dependent variables in this study, the at-risk infants will be significantly lower or slower compared to the TD infants.

Hyp. 2a: At risk infants will look less often to experimenter and object (i.e., lower values overall) compared to TD infants, which indicates less gaze shifting.

Hyp. 2b: At risk infants will show atypical duration of looks compared to TD infants: either longer durations to all targets ('more sticky' overall) or longer durations on objects compared to faces ('sticky' only with objects).

Hyp. 2c: At risk infants will have atypical response patterns to experimenter pauses compared to TD: either longer post-pause latencies reflecting slowness to shift or being so focused on the ball or hands that they do not notice the experimenter's pause, resulting in a failure to shift.

CHAPTER 3. METHOD

This study utilizes a subsample from an existing dataset originally collected in Dr. Agata Rozga's Child Study Lab (CSL) at the Georgia Institute of Technology. This dataset, known as the Multimodal Dyadic Behavior (MMDB), features audio, video, and physiological recordings of a semi-structured play protocol in which children interact with an adult experimenter. The data was collected under a university-approved IRB protocol. To date, the MMDB dataset features 237 recorded sessions. These sessions include 181 children, ages 15-34 months old, who interact in a toy play assessment known as Rapid-ABC or R-ABC. For 56 children additional, follow-up sessions were completed 2-3 months after the initial visit, yielding a total number of infant sessions of 237. For each session, an infant is classified as Typically Developing (TD) or At-Risk (AR) based on well-known, parent-report autism screeners (e.g., M-CHAT, CSBS:ITC, CBCL). The research goals behind collecting the MMDB dataset are to work towards creating new computational methods of both measuring and analyzing behavioral data of children and adults during face-to-face social interaction (Rehg et al., 2013). These methods will help automatize the processes of analysis such as parsing video-recorded behavioral data into stages and sub-stages, detecting discrete behaviors (e.g., gaze shifts, gestures), and predicting child social engagement ratings at both the stage and session levels.

3.1 Participants

A convenience subsample of 163[1] infant R-ABC sessions, between 15 and 34 months of age (*M* = 22.72, *SD* = 4.69, 55% female) was selected from the larger MMDB dataset (N=237). Selection procedures were as follows: 1) include all AR sessions for which clean data existed (i.e., no technology malfunctions, cross-checked coding (n=37), 2) include nearest age-gender matched controls for those AR sessions (n=37), and 3) randomly select additional TD sessions for which clean data existed (n=89). Once the data was extracted and cleaned for all infants, one additional TD infant was excluded from final analysis for unscorable behavior (i.e., away from the table or out of view for most of the extracted play segments)) leaving the final sample size at 162 sessions (TD: n=125; AR: n=37).

3.2 Apparatus and Materials

Laboratory set-up can be seen in Figure 1. Synchronized cameras recorded separate frontal views of the child and experimenter. Three omnidirectional microphones, one located above the table and two worn on clothing (one by child, one by experimenter) were used to capture audio data. Physiological data was captured via four Affectiva Q-sensors (worn on each wrist; two worn by child; two worn by experimenter) that sense electrodermal activity and accelerometry (sampled at 32Hz). Scores from parent-report ASD screeners (detailed below) determined risk group (TD, AR) classification. The Rapid-ABC (Ousley et al., 2013) assessment (detailed below) was used as the primary task from which behavioral data was compiled for this study.

[1] 129 intake (96 TD, 33 AR) and 33 follow-up (29 TD, 4 AR) sessions constitute full sample. Full sample (162 sessions) includes 133 unique infants (i.e., 29 infants have both intake and follow-up sessions included in the sample). I did not establish exclusion criteria based on session type (intake, follow-up). Of

Figure 1 - Laboratory set-up for data collection.

3.2.1 Parent Report Screeners

Well-established and widely used parent report screeners for autism were utilized in this study to determine risk status for ASD. Parents filled out the appropriate screener(s) based on the infant's age. The M-CHAT was given to all families, while the CSBS was given only to parents of infants 24 months or younger and the CBCL was given to parents of infants 25 months or older. The three individual screeners are described below.

3.2.1.1 Modified Checklist for Autism in Toddlers (M-CHAT; Robins, Fein, Barton, & Green, 2001)

The M-CHAT is a two stage, parent report screener that is used to assess risk status for ASD in children ranging from 16 to 30 months of age. This tool is considered a level 1-category screener. Level 1 means the screeners are designed to differentiate children at risk for ASDs from the typically developing general population, while level 2 screeners are designed to differentiate children at risk for ASDs from those at risk for specific language impairment or other developmental disorders (Johnson, Myers, and the Council on Children with Disabilities, 2007). Parents respond “Yes” or “No” to a series of 23 questions about their child’s development. An example item is “Does your child look at your face to check your reaction when faced with something unfamiliar?” Scoring involves calculating the number of responses that indicate ASD risk. Low risk (score 0-2), Medium risk (3-7), or High Risk (8-20) categories are then used to make recommendations about future follow-ups or surveillance of behavior.

3.2.1.2 Communication and Symbolic Behavior Scales Developmental Profile Infant-Toddler Checklist (CSBS:ITC; Wetherby & Prizant, 2002)

The CSBS-DP:ITC focuses on communication and social skills and is thought to be appropriate for identifying ASD risk in children ranging from 6- to 24-months of age. The screener is split into subsections (e.g., emotion and eye gaze, sounds, object use) and parents respond on a 3-point type scale for most questions (i.e., Not Yet, Sometimes, or Often). An example item is “When you look at and point to a toy across the room, does your child look at it?” Social, Speech, and Symbolic Composite scores are used to evaluate an infant in comparison to standard and percentile scores of other infants his/her age. Recommendations for follow-up checklist completion or developmental evaluation are then made based on how the child’s score compares to the criterion scores.

3.2.1.3 Child Behavior Checklist/1.5-5 (CBCL; Achenbach & Rescorla, 2000; 2001)

The CBCL is a screener designed to assess social, emotional, and behavioral problem behaviors. The tool is a part of the Achenbach System of Empirically Based Assessments (ASEBA) and multiple versions exist for children of different ages. For this study, the preschool (CBCL/1.5-5) version was used. Respondents are instructed to rate the child's behavior on a 3-point scale (0 = Not True (as far as you know), 1 = Somewhat or Sometimes True, or 2 = Very True or Often True) as it presently occurs or has occurred within the previous two months for 100 items. Certain items offer additional room for elaboration (e.g., "Fears certain animals, situations, or places (describe):"). The CBCL also features a Language Development Survey for children 18-35 months of age featuring questions about the child's development and a list of 310 words in which respondents are instructed to circle each word that the child says spontaneously (rather than imitating or understanding).

3.2.2 Rapid-ABC Assessment

The Rapid-ABC or R-ABC task created by Dr. Opal Ousley & colleagues was originally designed as an autism-specific behavioral assessment (Ousley et al., 2013) for young infants and toddlers. The assessment arose from a push by the CDC and others for quick, interactive assessments that could be easily utilized in pediatrician offices. In the name, **R**apid refers to the brief nature of the assessment (~4 min) and ABC refers to the protocols focus on eliciting social **A**ttention, **B**ack-and-forth interaction, and nonverbal **C**ommunication. The protocol features an adult examiner engaging in a semi-structured play interaction with the child that was designed to elicit a broad range of social behaviors which, if atypical, could be noted as potential 'red-flags' pointing towards possible ASD (Ousley et al., 2013).

Dr. Ousley and colleagues (2013) conducted a study with 46 infants and toddlers (18 at-risk, 28 non at-risk for ASD), ages 15-24 months to evaluate the reliability and validity of the R-ABC screener. They found the R-ABC to correlate with other parent report screening measures for ASD and that it could distinguish between the children in the sample who were at-risk for ASD diagnosis and those who were not. Results suggested strong internal consistency, high test-retest validity (stability across time), and highly sensitive and specific cutoff scores (Ousley et al., 2013). Overall, the R-ABC protocol has been evaluated as promising screener for infants and toddlers judged to be at-risk for ASD. As it was originally intended, it provides information about observable socio-communicative behaviors above and beyond what parental report might convey and in less than 5 minutes (most widely used behavior-based ASD assessments (e.g., ADOS) take 60+ minutes to administer). However, more research is needed to evaluate whether the R-ABC can be extended as a diagnostic tool that can differentiate among different developmental disabilities.

3.2.2.1 Five Main Stages of R-ABC

The R-ABC protocol consists of five distinct stages, in the following order:

1. Greeting – The experimenter greets the child by smiling and saying hello using the child's name. The experimenter asks the child if he/she is ready to play then moves to retrieve a ball from below the table.
2. Ball play – Once the ball is visible over the table edge, the experimenter initiates a turn-taking type game of rolling the ball back-and-forth to the child. The experimenter rolls the ball to the child and requests the child to roll it back (if they do not do this on their own). The experimenter then puts the ball away (below the table) and retrieves a picture book.

3. **Book reading** – Once the book is visible over the table edge, the experimenter initiates a social reading activity in which she invites the child to look at the book with her. She reads the book to the child and asks the child "what do you see?" She also offers moments for the child to engage with the book or help turn the pages by asking, "what's next?" Once finished with the book, the experimenter closes it and begins the hat activity.
4. Hat – The experimenter places the book on her head and pretends that it is a hat. She engages the child and asks, "Where is the book?" Once pointing out that the book is on her head like a hat (if the child does not do so him/herself) the experimenter closes the book and puts it away (below the table).
5. Tickle play – Lastly, the experimenter engages the child in a gentle tickling game. This game is social and similar to the back-and-forth ball activity in that the experimenter says, "I'm going to get/tickle you" and tickles the child (saying "tickle tickle tickle") then retreats before repeating the activity.

The R-ABC activities always occur in the 1-5 sequential order as described above. The experimenter's behavior (i.e., how materials are presented) and language used to introduce each activity or object (e.g., "Look at the book") were consistent across all infants.

3.2.2.2 Social Presses Built into the R-ABC

Within the protocol, there are additional presses built in to try and elicit specific behavior from the child. The experimenter silently holds up the toys (ball, book) before introducing them to press for joint attention behavior (i.e., the child shifting attention from the object to experimenter's face). Also, during the activity the experimenter will interrupt the back and forth pattern with a 'pause' that should violate the child's expectation of turn taking. For example, the experimenter regularly says "1, 2, 3… Go!" before releasing the ball. However, during the 'pause' she will say "1, 2, 3…" and then pause and hold the ball (violating the expectation that "Go!" and ball release is coming).

3.2.2.3 Scoring the R-ABC

Immediately following the completion of each task in the R-ABC screener, the experimenter scores the interaction. First, a scoring sheet allows the experimenter to quickly note whether the child engaged in certain socio-communicative and participatory behaviors throughout the stages/sub-stages of the protocol. For example, the experimenter scores whether the child initiated joint attention (looked at ball/book followed by looking to experimenter), smiled, turned book pages, pointed, took turns, established eye contact after 'pauses', etc. Seventeen such behaviors are scored by the experimenter as present or absent (based on a single occurrence of the target behavior). The experimenter then also scores the overall engagement of the child (i.e., how much effort was required to engage the child) during each stage of the protocol on a 3-point Likert type scale (0 = easily engaged, 3= significant effort required to engage the child). Together, these behavior notations and social engagement scores are thought not only to provide 'checks' for key socio-communicative milestones expected to appear in the first years of life, but also to shed light on red flags (i.e., qualitative differences in behavior or diminished occurrence) for an ASD.

3.3 Procedure

Experimental sessions for the MMDB dataset were all conducted in the Child Study Lab at Georgia Tech. All tasks were administered in a single, private session lasting 30 to 45 minutes. A session began with the child playing with the experimenter on the floor in the room with various toys while parents filled out demographic questionnaires, consent forms, and autism screeners (M-CHAT, CSBS, CCBL). This free play was used to warm up the child and get them familiar with the experimenter and the setting. For the Rapid-ABC portion of the protocol, the child was seated in the parent's lap throughout the task and the parent/child are seated across a table from the experimenter. Infants participated in one round of the R-ABC per session. The Rapid-ABC was scored in real-time, while the parent-report screeners were evaluated post-session (i.e., the experimenter was blind to an infants risk status for ASD while administering the R-ABC).

Audio/video recordings of each session were later frame-by-frame annotated using ELAN software by trained research assistants and crosschecked by a second coder for reliability. ELAN is free, opensource software tool created by the Max Planck Institute for Psycholinguistics (http://tla.mpi.nl/tools/tla-tools/elan/). ELAN is used to import audio and/or video data and create annotations or coding of behavior, language, etc. within the multimedia files (Brugman & Russel, 2004). Structural annotations within each video designated the onset and offset of each stage of the R-ABC protocol, pauses during each activity, as well as documented moments when objects (i.e., ball, book) are present and absent throughout the session. Additional annotations were used to code social and communicative behaviors from both the experimenter and child's perspective. Experimenter annotations indicated the precise onset and offset of each instance of experimenter speech and/or gestures throughout each session. Child annotations indicated child's gaze behavior (i.e., to examiner's face or hands, to parent's face, to toys), vocalizations (non-word sounds) and verbalizations (words and phrases), instances of vocal affect (laughing and crying), and communicative gestures (e.g., pointing, clapping, reaching). For this study, annotations of stage (onset to offset), pause (onset to offset) and child directed gaze (onset to offset of each look to a respective location) were considered.

3.3.1 Focal Context Selection

I chose to investigate differences in infant visual engagement behaviors across two contexts or experimental settings: object present and object absent. As mentioned previously, the R-ABC features 5 phases: 1) greeting, 2) ball play, 3) book reading, 4) book as hat, and 5) gentle tickling. Each segment can be categorized as either object present or absent. During the greeting and tickling segments, no objects are used (i.e., the experimenter and infant are interacting socially without a toy). In the other three phases of R-ABC (ball play, book reading, and book as hat) a toy is present. When evaluating object presence versus absence I could have considered all five segments and code them based on whether they involve an object or not. However, in attempts to have object present and absent conditions that were as similar as possible, I decided to choose only one segment of each type from the R-ABC protocol to compare for the scope of this study.

After evaluating the procedure of the R-ABC, I determined the ball play (Figure 2) and gentle tickling (Figure 3) were the most comparable. Both of these segments involve a back-and-forth interaction in which the experimenter sets-up the behavior to come. For example, in ball play, she says "1, 2, 3…" as a set-up and then will says "Go!" as she releases the ball and it rolls towards the child. Once the child rolls the ball back (or the experimenter retrieves it if the child does not roll it back), she repeats this procedure of set-up ("1, 2, 3…") and climax ("Go!" and ball release) two or three more times. In the tickle play, we see this same sort of set-up and climax but there is no object present. Here, the experimenter says "I'm gonna get you…I'm gonna get you… I'm gonna get you" as a set-up while wiggling her fingers and slowly moving closer (leaning in) towards the child. Then as a climax, she says "Tickle tickle tickle!" as she tickles the child on the stomach or arms. She then retreats and then will repeat this set-up and climax procedure in the tickle play two or three more times. Also, in both ball and tickle play, the experimenter pauses in the interaction, which allowed for the investigation of post-Violation-of-Expectation (VOE) latency across both tasks.

Figure 2 - Example of ball play interaction.

Figure 3 - Example of tickle play interaction.

3.3.2 ELAN Extraction

I utilized the synchronized audio/video data in the form of participants' ELAN files to evaluate all hypotheses. One key feature of ELAN is the ability to 'extract' data from the files into formats that can then be analyzed using software such as Microsoft Excel or SPSS. To perform an 'extraction', the user first creates a query in which he/she selects the variables of interest (known as 'tiers' and 'sub-tiers' in ELAN). The user can designate how annotations should be depicted (e.g., separate columns, certain timestamp formats) and the type of output file desired (e.g., tab delimited). ELAN will then auto-generate the quantitative data from the file that corresponds to the user's query and export the data to the saved location set by the user. The queries for my thesis are described below.

3.3.2.1 Visual Engagement Variables

For hypotheses related to overall visual engagement, variables of stage (ball or tickle), and child gaze (to experimenters face, experimenters hands, ball, parent face other/unscorable) were extracted. Stage is defined as the onset-offset of a particular play segment (ball, tickle) of the R-ABC in sec.ms for each child. Infant gaze behavior was extracted to create two dependent measures: frequency of looks to a certain location (which would indicate shifting), and average duration of the looks to a certain location (which would indicate fixation). For frequency, each instance of the onset-offset of a look to a particular location (tagged as face, hands, ball, etc.) was counted as one look. For each infant, the total amount of looks creates the frequency score for each location. For average duration, the duration (onset-offset) of each look type (e.g., each look to the face) was summed and then divided by the amount of looks to that location to create the average duration (sec.ms) variable. Frequencies and average durations (2 DVs) were calculated for each child for the two opposing look locations (ball: face, ball; tickle: face, hands) for the respective task.

3.3.2.2 Violation of Expectation Variables

For hypotheses related to violation of expectation looking, variables of stage (ball, tickle), pause length, and child gaze (to experimenters face) were extracted. Stage involved extracting the ball and tickle portions of the data as stated previously. Pause length was the duration (onset-offset) of the experimenter's pause in play (e.g., onset = start of "ready, set…" to offset = "go" and rolling the ball). This time, child gaze was considered for only his or her first look to experimenter's face either during or post-pause. The VOE data was first divided into categories based on whether or not each child had the opportunity to shift his/her gaze; for some infants, they shifted their gaze to the experimenter's face right before the onset of the pause which eliminated the opportunity to then shift their gaze to her face during or post-pause. For these infants, they were coded as "Already Looking" and excluded from the VOE analyses. An infant was only excluded for the play type(s) in which he/she was considered already looking. For ball play, 14% of the full sample (14 TD infants, 3 AR) was excluded as Already Looking. For tickle, play, 16% of the sample (18 TD, 2 AR) was excluded. The remaining infants (Ball: n=108, Tickle: n=105) were then split into two categories: 1) those who never looked to the experimenter's face during or post-pause (i.e., "Did Not Shift") and 2) those who had a during- or post-pause latency. For the latter, latency was defined as the difference (in sec.ms) between the onset of the first look to experimenters face and the onset of the pause. This latency value was then compared to the length of the pause for that infant (because pause length differed across infants - the experimenter would often go ahead and roll the ball or tickle once the infant had shifted gaze to her face). Infants who had a latency that was shorter than the length of the full pause duration were coded as “During Pause Shift” and those whose latency exceeded the full pause duration were coded as “Post-Pause Shift”. Infants in the “During Pause Shift” and “Post-Pause Shift” categories were then combined for the analysis of Shift versus Did Not Shift.

A criterion was then established to determine what would be accepted as a true “post-pause shift” versus what would be considered a “did not look” as a result of the pause (i.e., at what point is the look not considered a response to the pause). I determined this criterion by taking the average latency of all infants who had a “During Pause Shift” code and calculating a cutoff value of M+(1.96*SD). This cutoff was determined separately for the two play contexts (ball versus tickle) because the infants who shifted in one setting did not necessarily do so in the other. Using the cutoff, the infants who were tagged as “Post-Pause Shift” were included and those who had latencies that exceeded criterions were recoded as “Did Not Shift”.

3.4 Analysis

3.4.1 A-Priori Comparisons: Visual Engagement and Violation of Expectation Latency

This study features a 2 x 2 x 2 mixed design with two dependent variables of interest corresponding with hypotheses. Risk group (TD, AR) was evaluated as a between subjects variable. Within subjects variables include Task (ball play, tickle play) and

Location of looking (Face, Non-face (Ball/Hands)[2]). Analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 22. Significance level was set at $\alpha = 0.05$ (two tailed). Correlations were used to determine relationships between age and dependent variables. Repeated measures mixed Analysis of Variance (rmANOVA) was used to examine group differences on a) task and b) location of looking. Two ANOVAs correspond with the two hypotheses of interest: frequency of looking and average duration of looking. Effect sizes are reported as partial eta squared (η_p^2) and interpreted as small: 0.01-0.05, moderate: 0.06-0.13, and large: ≥ 0.14 (Cohen, 1988). Follow-up t-tests were used where the ANOVA was significant to tease apart effects. Analysis of Covariance (ANCOVA) was conducted to control for age and evaluate if effects found in ANOVA remain. Hypotheses related to VOE latencies were analyzed using chi-square, correlations, and t-tests where appropriate.

3.4.2 Exploratory: Rapid-ABC Discriminative Validity

An exploratory evaluation of the discriminative ability of the R-ABC scores for classifying risk group status for this sample of infants was also conducted using cutoff score (13) suggested by Ousley et al. (2013) validation study. That is, infants in this sample were separately classified into AR/TD groups as based on R-ABC scores relative to the cutoff. This was done to explore whether or not a similar number of infants would be classified in the same categories as the parent-report screeners. Also, the ability of the R-ABC scores to decide the dichotomous Risk Group outcome variable (as decided by the parent-report screeners) in this sample was evaluated using area under the curve

[2] For analysis, location is considered as face versus non-face. Ball is the non-face location in ball play. Experimenter's hands were the non-face location in tickle play. Ball/Hands is used to designate this non-face comparison.

(AUC) scores from nonparametric Receiver Operating Characteristics (ROC) curve analyses. Results were interpreted based on AUC benchmarks suggested by Swets (1988): low (0.5-0.7), moderate (0.7-9), and high (>0.9) accuracy.

CHAPTER 4. RESULTS

4.1 Overall Visual Engagement

Descriptive statistics are provided in Table 1 (for frequency) and Table 2 (for average duration). Violations of sphericity were not a concern as there were only two levels of each Independent Variable. Relationship of age with each of the DVs of interest was evaluated (Pearson's correlation) and Analysis of Covariance (rmANCOVA) was run controlling for age to evaluate developmental trends in relation to risk group differences.

Table 1 - Descriptive statistics for frequency of looking.

	TD (n=125)			AR (n=37)		
Task	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Ball						
to Face	0	21	7.27 (3.5)	0	17	5.81 (3.33)
to Ball	4	20	9.63 (2.37)	6	17	9.76 (2.43)
Tickle						
to Face	0	12	5.78 (2.46)	0	8	4.05 (2.12)
to Hands	0	12	5.14 (2.29)	1	9	4.41 (2.15)

Note: TD = Typically Developing, AR = At Risk, SD = Standard Deviation.

Table 2 - Descriptive statistics for average duration of looking.

	TD (n=125)			AR (n=37)		
Task	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Ball						
to Face	0	4.22	1.1 (0.55)	0	2.64	0.93 (0.52)
to Ball	0.8	5.09	1.78 (0.69)	0.78	4.5	2.17 (0.94)
Tickle						
to Face	0	19.26	1.6 (1.86)	0	3.6	1.25 (0.8)
to Hands	0	6.13	1.71 (1.12)	0.46	6.35	1.89 (1.32)

Note: TD = Typically Developing, AR = At Risk, SD = Standard Deviation.

4.1.1 Frequency of Looking

For frequency of looking, there was a significant main effect of Risk Group $F(1,160) = 8.15$, $p < .001$, effect size = small (.05). Across all tasks and locations, TD ($M = 6.96$, $SE = .16$) looked more on average than AR ($M = 6.00$, $SE = .29$), which was taken as support for Hyp. 2a. Follow-up t-tests (split by task to investigate robustness), show that during ball play, TD infants looked more to the face (M = 7.27, $SD = 3.5$) than AR infants ($M = 5.81$, $SD = 3.33$), $t(160) = 2.26$, $p < .05$, but no significant risk group differences were found for frequency of looks to ball. This same pattern persists in tickle play: TD infants looked more to the face ($M = 5.78$, $SD = 2.46$) than AR infants ($M = 4.05$, $SD = 2.12$), $t(160) = 3.86$, $p < .01$, and again, no significant risk group differences were found for frequency of looks to hands. There was a significant main effect of Task, $F(1,160) = 153.47$, $p < .001$, effect size = large (.49). Across both risk groups and locations, Ball play ($M = 9.11$, $SE = .23$) elicited more looks on average compared to Tickle play ($M = 4.85$, $SE = .19$). There was also a significant main effect of Location, $F(1,160) = 51.53$, $p < .001$, effect size = large (.24). Across all infants and tasks, there were more looks to Non-face ($M = 7.24$, $SE = .17$) on average compared to Face (M =

5.73, *SE* = .22). There was a significant interaction between Task and Location, $F(1,160) = 108.77$, $p < .001$, effect size = large (.41). Across all infants, frequency of looks to face significantly differed from frequency of looks to non-face, but only for the ball task (Figure 4).

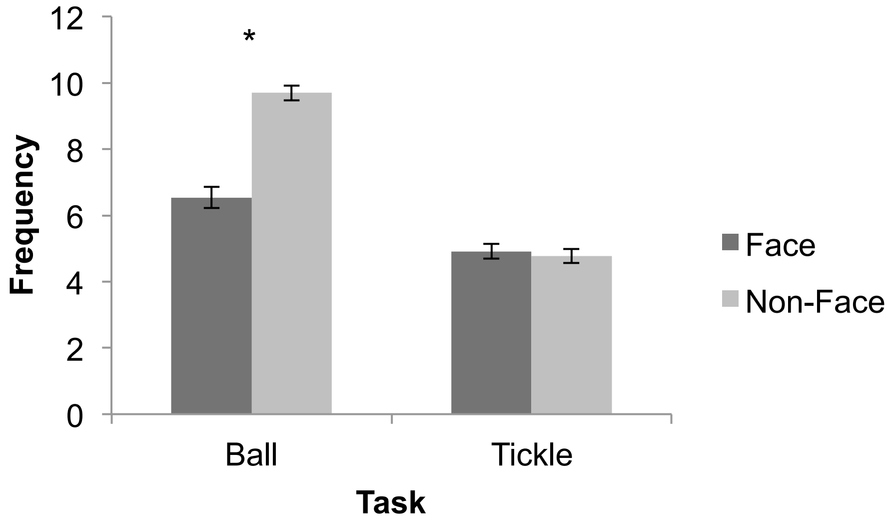

Figure 4 - Depiction of Task x Location interaction for frequency behavior. X-axis shows task. Y-axis shows mean frequency counts. Individual bars illustrate the two locations (face, non-face).

Lastly, there was a significant interaction between Location and Risk Group, $F(1,160) = 9.37$, $p < .001$, effect size = moderate (.06). Across all tasks, frequency of looks to face significantly differed from frequency of looks to non-face, but only for AR infants (Figure 5). The Task x Risk Group and Task x Location x Risk Group interactions were not significant.

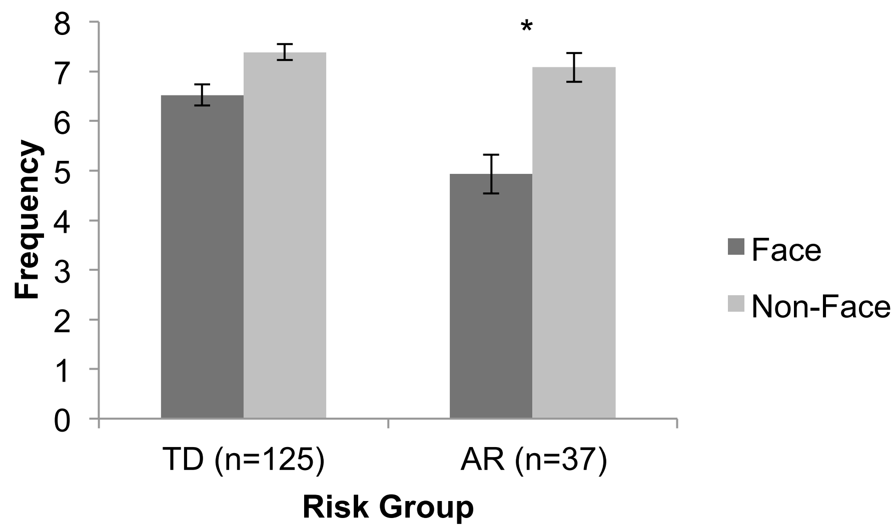

Figure 5 - Depiction of Risk Group x Location interaction for frequency behavior. X-Axis shows risk group. Y-axis shows mean frequency counts. Individual bars illustrate the two locations (face, non-face).

Age (months) was found to correlate with frequency of looks to ball during ball play, $r(162) = -.17$, $p < .05$, but not with frequency of looks to any other location in either task (Hyp. 1a not supported). Splitting this result by risk group, we see that the correlation persists for TD ($r(125) = -.20$, $p < .05$) but not AR ($r(37) = -.09$, $p = .59$) infants. When controlling for age (mixed ANCOVA), the main effects of task ($p < .001$) and risk group ($p < .01$) persisted. The main effect of Location was no longer significant when controlling for age ($p = .46$). The Task x Location ($p < .01$) and Location x Risk Group ($p < .01$) interactions also remained significant (Hyp. 2a supported). To summarize, there were risk group differences across frequency of looking behavior that were not mitigated by age. Typically developing infants had higher frequencies to all locations. At-risk infants looked to non-face locations more than face, while typically developing infants had no significant difference in looks to either location type. Also, at-risk infants look significantly less to face when directly compared to TD infants.

4.1.2 Average Duration of Looking

For average duration of looking, there was a significant main effect of Location, $F(1,160) = 29.84$, $p < .001$, effect size = large (.16). Across both risk groups and tasks, there were longer looks to Non-face ($M = 1.88$, $SE = .07$) on average compared to Face ($M = 1.22$, $SE = .09$). There were no significant main effects of Risk Group or Task. There was a significant interaction between Task and Location, $F(1,160) = 8.10$, $p < .05$, effect size = small (.05). Lastly, there was a significant interaction between Location and Risk Group, $F(1,160) = 5.01$, $p < .05$, effect size = small (.03). Across all tasks, average duration of looks to face significantly differed from average duration of looks to non-face, but only for AR infants (Figure 6). Follow-up t-tests (splitting by task to evaluate robustness) suggest that this result should be interpreted with caution. Levene's test indicated unequal variances across the two risk groups ($F = 6.65$, $p = .011$) for average duration of looks to ball. Adjusting degrees of freedom from 160 to 48, AR infants looked longer on average to the ball ($M = 2.17$, $SD = 0.94$) compared to TD infants ($M = 1.78$, $SD = 0.69$), $t(48) = -2.38$, $p < .05$. Risk group differences in average time spent looking to hands were not significant for the tickle task. No significant differences were found for average time spent looking at the face for either task. The Task x Risk Group and Task x Location x Risk Group interactions were not significant.

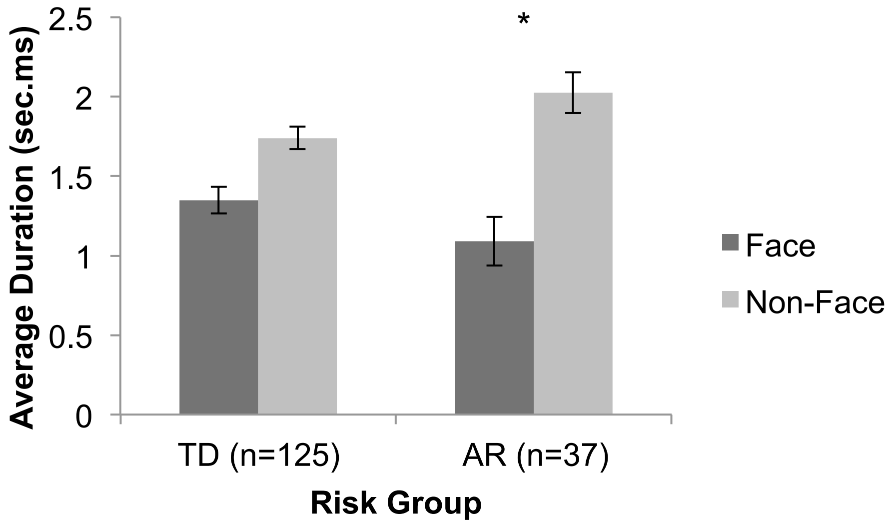

Figure 6 - Depiction of Risk Group x Location interaction for average duration behavior. Average duration units are sec.ms. X-axis shows risk group. Y-axis shows mean average durations. Individual bars illustrate the two locations (face, non-face).

Age (months) was not found to significantly correlate with average duration of looking for any locations across either task (Hyp. 1b supported). However, when controlling for age (mixed ANCOVA), the main effect of location did not persist (p = .228). The interaction between Task and Location also did not persist (p = .275). The interaction between Location and Risk Group remained significant ($p < .05$) Hyp. 2b supported). In sum, age was a better predictor of average duration of looking behavior over location and task. There were significant findings suggesting that at-risk infants looked longer on average to non-face stimuli compared to face, while TD looked similar lengths of time to both. When directly comparing risk group behavior, AR looked longer on average to the ball compared to TD.

4.2 Violation of Expectation Latency

For VOE, overall ANOVA/ANCOVA analyses were not run across the two Tasks (Ball, Tickle) because infants who looked in one task during- or post-pause were not always the same infants who looked in the other task. Specifically, 48% of all infants fell into different outcome categories (i.e., Already Looking, Did Not Shift, Shifted (During or Post-pause)) for each the two tasks. Frequencies for shift categories across the two tasks can be found in Table 3.

Table 3 - Frequency table for Violation of Expectation look categories during both play tasks.

	Ball		Tickle	
Category	TD	AR	TD	AR
AL	14	3	18	2
DNS	27	10	25	17
Shift				
During	83	24	76	15
Post	1	0	6	3

Note: TD = Typically Developing (n = 125), AR = At Risk (n = 37), AL = Already Looking, DNS = Did Not Shift gaze to experimenter's face, During = shifted gaze to experimenter's face during length of pause, Post = shifted gaze to experimenter's face after pause had ended.

Chi-Square Tests were conducted separately for each task to determine whether Risk Group (TD, AR) predicted whether infants shifted or not during- or post-pause (Did Not Shift, Shift). For infants who did shift, correlation analyses determined if there was a relationship with age (months) and latency to shift (sec.ms) (testing Hyp. 1c). Additionally, t-tests were conducted to evaluate risk-group differences in latency to shift (testing Hyp. 2c).

4.2.1 Ball Play VOE Latency

Of the 145 infants (111 TD, 34 AR) who had the opportunity (i.e., those who weren't already looking), 84 TD (76%) and 24 AR (71%) infants shifted their gaze. Of these, only one TD infant was classified as having a post-pause (late) shift. The percentage of infants that shifted did not significantly differ by risk group, $c^2(1, N = 145) = .35$, $p = .55$. There was no significant relationship between age (mos.) and latency to shift (sec.ms), $r(108) = -.09$, $p = .38$ (Hyp. 1c not supported). There was no significant difference in average shift latency across TD ($M = 1.66$, $SD = 1.13$) and AR ($M = 1.63$, $SD = .76$) infants, $t(106) = .121$, $p = .90$ (Hyp. 2c not supported).

4.2.2 Tickle Play VOE Latency

Of the 142 infants (107 TD, 35 AR) who had the opportunity, 82 TD (77%) and 18 AR (51%) infants shifted their gaze. Of these, 9 infants (6 TD, 3 AR) were classified as having a post-pause shift. The percentage of infants that shifted did significantly differ by risk group, $c^2(1, N = 142) = 8.05$, $p < .01$ (partially supporting Hyp. 2c). There was no significant relationship between age (mos.) and latency to shift (sec.ms), $r(100) = -.05$, $p = .59$ (Hyp. 1c supported). There was no significant difference in average shift latency across TD ($M = 1.92$, $SD = 1.30$) and AR ($M = 1.96$, $SD = 1.67$) infants, $t(98) = -.124$, $p = .90$ (Hyp. 2c not fully supported).

4.3 Rapid-ABC Discriminative Validity

For this sample, the area under the R-ABC curve was .71 (Figure 7). This suggests that the Rapid-ABC would be moderately valid in separating TD from AR infants in a similar manner as the parent-report screeners. A cutoff score of 13 (as suggested by Ousley et al., 2013) was compared against the R-ABC scores for infants in this sample to perform an exploratory classification. This cutoff value classified 144 infants as TD and 18 as AR, compared to 125 TD and 37 AR based on parent report screeners. Further analysis would need to be done to confirm whether the same infants who were AR based on parent-report were also AR based on R-ABC.

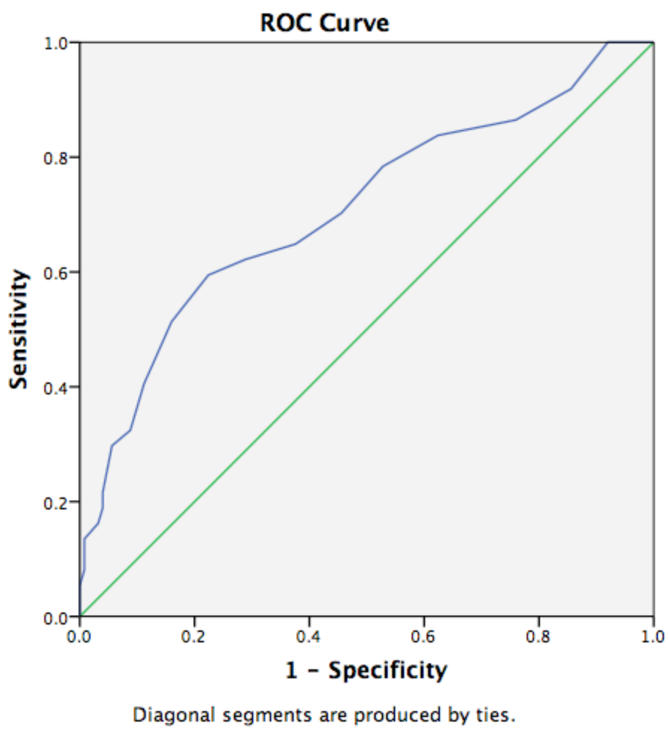

Figure 7 - Depiction of R-ABC Receiver Operating Characteristics (ROC) curve. R-ABC scores predicting dichotomous risk-group outcome (TD versus AR) as classified by parent report screeners in the present sample (N=125). Axes on the scale of 0 (no) to 1 (perfect).

CHAPTER 5. DISCUSSION

The primary aim of this study was to determine whether behavioral differences in visual engagement that are not age related would exist in a population of infants ranging from 15-34 months of age and flagged as at-risk or not at-risk for autism. Previous studies have suggested that differences in visual engagement behaviors (e.g., gaze shifting, length of fixation, social orienting) exist in children diagnosed with autism compared to those who are typically developing. Differences in fine-grained preferential looking patterns or gaze behavior (e.g., preferential looking to eyes of an adult) have also been shown to correlate with level of social disability as measured by gold standard autism diagnostic tools (ADOS; Jones et al., 2008). Research has also suggested that in typical development, many of these behaviors should be well established and stable around one year of age. Thus, it was hypothesized that age (months) would not significantly impact any measures of visual engagement and that differences would exist only across risk groups (TD versus AR). The results of this study largely supported this hypothesis, as differences in risk group behavior existed in both amount of looking and average duration of looking. Moreover, these risk group differences persisted when controlling for age. These results will be discussed in turn.

5.1 Age Effects

Social cognition is exhibited through early behaviors such as social orienting or referencing, disengaging and shifting attention, gaze following, joint attention, and imitation. In typical development, many of these behaviors are thought to emerge or become stable around one year of age, which led me to hypothesize that age would not have significant effects on measures of infant visual engagement. Results revealed that age (months) only correlated with one dependent measure (frequency of looks) to one location (to ball) in one of the two tasks (ball play). Further, when splitting by risk group this relationship only persisted for TD not AR infants. This very specific correlation and the lack thereof for other locations, tasks, and the other dependent measure (average duration of looking) suggests that age does not have a significant consistent impact on measures of visual engagement evaluated in this study. For the significant correlation, it is possible that older TD quickly infants gain an understanding of the task (back-and-forth play with the experimenter) and do not need to gaze check with the ball as much (i.e., "I understand what you want me to do with the ball") to participate. For infants who shifted their gaze in response to the pause in play, age did not significantly correlate with VOE latency. This was true for both ball and tickle play tasks. Taken together, these findings suggest that measures of visual engagement during social play, such as shifting between a face and other location, do not systematically vary within the age range of 15-34 months. This aligns with research suggesting that visual engagement behavior such as gaze shifting (Brooks & Meltzoff, 2005) social orienting and referencing (Dawson et al., 2004; Ibanez et al., 2008) occur and are fairly stable by 12 months. Depending on the type of task (e.g., object included), gaze checking may decrease slightly with age in TD, but these trends do not appear to parallel in AR children.

5.2 Risk Group Differences

Given the extensive literature suggesting that children with ASD experience delay or deficit in social visual engagement behaviors that predict later language and social outcomes, I hypothesized that children who were flagged as being at-risk for ASD would show lower and/or slower visual engagement. Results revealed a small main effect of risk group that persisted when controlling for age: TD infants had higher amounts of looking compared to AR infants. More specifically, TD looked more to face compared to AR in both ball and tickle play, but no significant group differences existed for amount of looking to ball or hands. However, there was no main effect for risk group for average duration of looks, suggesting that TD or AR are not consistently different in how long they fixate across all locations and tasks. These findings suggest more gaze shifting overall for TD infants as well as perhaps a stronger interest in social (i.e., face) interaction during play interaction with an adult. Some research has suggested that children with ASD do not socially orient by shifting their gaze to faces or making eye contact (Volkmar et al, 2004). Lower frequencies for AR infants could be a result of being slower to shift which aligns with research suggesting that infants with ASD have problems disengaging their attention (Landry & Bryson, 2004; Ibanez et al., 2008) which would make them slower to shift and would result in less shifting overall.

Additionally, the medium size interaction effect of location with risk group suggests that across all tasks, frequency of looks to face differs from frequency of looks to ball/hands but only for AR infants. This effect persists when controlling for age. This location by risk group interaction also has a small effect size for average duration of looking. The average time spent fixating on face compared to ball/hands significantly differed, but only for AR infants. More specifically, between-groups analysis indicated that AR infants fixate longer on the ball compared to TD infants during ball play. This fixation did not parallel to a longer fixation on hands compared to TD in tickle play. There were also no significant group differences in average duration of looks to face in either task. AR infants appear to fixate longer but only on objects. This result is interesting as there were no significant differences in how much TD or AR infants looked to the ball, only for how long they looked (AR longer than TD on average). It is clear that AR infants can shift their gaze, though they may be slower to do so as indicated by lower overall frequency values. However, they may choose to do so more toward the object (and fixate longer there) rather than back-and-forth in fairly equal amounts to both locations as was observed with the TD infants. Two different potential explanations stem from the literature, the first being that it is something about the stimulus type (social versus nonsocial) that might lead to disinterest and lack of shifting – it is possible that AR infants have greater interest in less complex, predictable objects (such as a ball) compared to faces (Dawson et al., 1998). Conversely, it is also possible that fixation to objects is only occurring because of slowness to disengage from the object and shift to the face ('sticky attention') which has been hypothesized in the literature on joint attention deficits in children with ASD (Gliga et al., 2014; Landry & Bryson, 2004). Further investigation into whether fixation stems from cognitive processes malfunction or lack of motivation would prove useful to disentangling these types of results.

Whether or not infants would differ in how they responded (shifting or not shifting) or how long it took them to respond (latency to shift) to a Violation of Expectation (VOE) in play was also evaluated. The VOE was the pause in the play interaction (i.e., waiting for ball to be rolled, waiting to be tickled). The infants who shifted gaze in one task (ball or tickle) were not always the same infants who shifted in the other task. Specifically, only 55 TD (44%) and 11 AR (30%) infants shifted gaze in both tasks. In ball play, similar proportions of TD (76%) and AR (71%) infants who had the opportunity to shift did. TD infants were slower to shift their gaze (longer latencies) compared to AR but this difference was not large enough to be considered significant. However, in tickle play, the proportion of TD (77%) infants that had the opportunity and shifted their gaze was significantly different than the proportion of AR (51%) who shifted. AR infants were close to chance whether they shifted their gaze or not during- or post-pause. For all infants who did shift, AR were slower to shift (longer latencies) compared to TD (opposite from the direction found in ball play) but again this difference was not significant. For the measures of overall visual engagement, ball play elicited higher frequency of looking across all tasks and locations (more shifting), so it is possible that an object-based play interaction is more conducive to gaze shifting. This could explain why similar proportions of TD and AR shifted during or after the ball pause but not in the tickle episode. As mentioned earlier, it is also possible that the face-to-hands differentiation in gaze is subtler and harder for a human coder to decipher. Or, perhaps an infant perceives the hands as an extension of the adult's body and thus, shifting gaze from face to hands is not warranted within these interactions. These proposed explanations do not rationalize why similar proportions of TD infants (76% in ball; 77% in tickle) shifted regardless of task type. However, it is also possible that AR infants are less interested in continuing the primarily social game of tickling and are therefore not motivated to shift their gaze in response to the VOE during tickle play. They may be more motivated in the ball play (i.e., "I want the ball back") and therefore do shift their gaze during- or post-VOE during the social interaction where an object is involved. Further exploration into both TD and AR post-VOE shifting would be needed to disentangle these findings. From the present study, it appears that while AR may not shift gaze as much during tickle play, there are no easily seen risk group differences in how fast an infant will shift his/her gaze in response to a pause-style VOE during play interactions.

5.3 Context (Task) Effects

It is also important to note that task type had a large main effect on frequency of looking, indicating that across all infants and locations, the ball play episode elicited more looks on average compared to tickle play. This effect was lessened (became a medium effect size) but persisted when controlling for age. However, task had no significant effect on average duration of looks, suggesting that there was no difference in how long infants fixated on any location across tasks. There was also a large interaction effect (Task x Location) that suggested that where infants look more differs by task. This effect lessened (became a small effect size) but persisted when controlling for age. The two tasks were explored in this thesis to evaluate robustness of visual engagement behavior across a primarily social task (tickling) compared to a social task with an object included (ball). The findings that ball play elicited more gaze shifting and that significantly less AR infants shifted their gaze in response to the VOE in tickle play compared to TD suggest that the two tasks are different from one another and behavior is not uniform across both for either TD or AR infants. Context perhaps is modulating the interaction to some degree. Specifically, TD and AR infants may have different motivations for shifting gaze and socially engaging within the two play types. TD infants may find both the social with object (ball) and only social (tickle) fun and entertaining. AR infants may be less motivated by the social only (tickle) compared to the social with object (ball). To further evaluate context effects, it would be interesting to explore how other tasks in the Rapid-ABC (e.g., book sharing) compare to these findings. One might hypothesize that book reading would elicit similar patterns of behavior as ball play because it is again social and includes an object. An alternate hypothesis might be that book sharing would elicit a unique pattern of behavior because while an object is present, the act of reading a book together is different and more complex (i.e., requires more language, as well as attention and interest for both the physical book and storyline) than physically sharing and turn taking with a ball.

5.4 Rapid-ABC Discriminative Validity

In this study, I conducted an exploratory analysis to see how an R-ABC score of 13 would classify the sample used here. Using 13 as the cut-off (from Ousley et al., 2013), only 18 infants in this sample were classified as AR (144 as TD). This suggests an under-classification of AR and over-classification of TD (as compared to the 37 AR/125 TD classification based on parent-report screeners). In Ousley et al.'s (2013) validation study for the Rapid-ABC, risk status was determined based on an "all-information-available" procedure, which included a behavioral observation as well as parent-report screeners. Their results suggested that the R-ABC cut-off score of 13 had high specificity (.96) and sensitivity (.83) for classifying TD and AR infants. It is possible that the 18 infants classified here by the Ousley et al. (2013) R-ABC cut-off score (13) might indicate "true risk" for autism and the parent-report screeners that are flagging additional infants in the present sample are yielding false positives. To evaluate this, future analysis would need to be conducted to see if the same infants are being classified as TD/AR by the R-ABC and parent-report screeners in this sample.

CHAPTER 6. CONCLUSION

The present study was conducted to investigate the developmental profile for visual engagement behaviors of a sample of infants identified as at-risk or not at-risk for autism. This included an investigation of how age and risk status impacted behavior as well as how robust the target behaviors were across two play tasks. The results indicate that by microanalyzing visual engagement behavior (i.e., using measures of frequency of looking behavior as well as average duration of looking behavior to face versus non-face locations), differences are revealed between at-risk and typically developing infants ages 15-34 months. Importantly, these effects do not appear to be largely impacted by infant age (developmental trends were not significantly different) and differ occasionally by task (ball elicited some differences that tickle did not). These findings suggest that micro-measures of visual engagement may prove useful in efforts to tease apart risk status in young infants who do not yet have a confirmed diagnosis.

6.1 Implications for Theory

The supported hypotheses in this study suggesting that infants at-risk for autism look less to faces, and fixate on objects align with the existing theory that similar behaviors exist in ASD. Also, the finding that AR infants did not shift their gaze in response to a violation of expectation during a purely social task (tickle) suggests that perhaps different contexts yield different levels of motivation to engage socially with another person. This aligns with the views (e.g., Dawson et al. (1998)) that social stimuli are less interesting or too complex to be motivating for individuals with ASD. In sum, existing theories would have predicted the direction of the findings presented in this study. However, this study advocates that one may be able to see these differences at younger ages (pre-diagnosis) using a microanalysis approach. The R-ABC screener and similar measures are built to include screening for visual engagement behaviors (e.g., eye contact), but feature an omnibus scoring method (i.e., does it occur at least once? Yes/No). This study reveals that most infants are perhaps performing at ceiling for omnibus measures (i.e., almost all infants look to the face at least once, regardless of risk status). By evaluating how often and for how long, this study illustrates that fine-grained differences exist and that different contexts (i.e., when an object is present or absent) and/or features of an interaction (e.g., when an expectation is violated) may modulate these different looking patterns seen amongst children at-risk for ASD.

One of this study's largest contributions to theory on development and visual engagement in autism lies is that it evaluates the behavioral differences suggested by existing theory in a live social interaction. As mentioned previously, microanalysis style studies are not widely seen in the existing literature on ASD and developmental theory. Those that do exist often include eye-tracking work as the tool for data collection and analysis. However, most of these studies involve having infants (with and without ASD) watch a social scene or interaction while measuring visual fixation patterns via eye-trackers. For example, Klin et al. (2002) had adolescent males (15 with autism, 15 age- and IQ-matched controls) view clips from the film "Who's Afraid of Virginia Woolf?" which was thought to portray a multitude of socially complex scenes (e.g., high-school cafeteria). The film was also "…depleted of nonessential objects and events that might distract a viewers attention from the social scene" (p. 811). These researchers found reduced time spent fixating on eyes and increased fixation towards mouth and objects. However, viewing a social scene may not directly mimic what it is like to experience one. Also, choosing films that do not have "nonessential objects and events" present may make these types of studies a little less "life-like" as well. The present study's microanalysis approach is one of the first of its type to include looking at behavioral data during a dyadic social interaction. The types of play interactions seen in the R-ABC include everyday activities that infants may experience outside of the study as well. Further work of this type will help elucidate how one visually engages during live social interaction (i.e., what you do in real life, active participation) diverges and/or converges with what one visually engages with when viewing social scenes (i.e., outside party, passive viewing).

6.2 Implications for Practice

While it is recognized that this type of microanalysis may not be appropriate or practical in a large-scale clinical setting, the findings may still have applications in a clinical setting. The results discussed here show how microanalysis (above and beyond the omnibus scoring procedures found in screeners such as the Rapid-ABC) enable us to explore whether "how often?" or "how long?" matters when evaluating an infant's visual engagement behaviors. While it is faster to simply document a single occurrence of a set of target behaviors during an assessment interaction, microanalyses may tell us that it is more strategic to spend those five minutes focusing in on the characteristics of one type of behavior or one type of task. From this study, it would appear that the frequency of gaze shifting between the social partner and the toy during a back-and-forth type task was the measure/context that had the greatest potential for differentiating between TD children and those identified as at-risk. While this approach may still result in false positives (as compared to the R-ABC), this type of detailed investigation within play protocols allows for examination of a variety of contextual factors that may affect visual engagement (such as the presence of objects, social presses, or violations of expectation). Results can then be incorporated in the development of robust, sensitive screeners that optimize time by prioritizing contexts and manipulations that elicit the most notable differences in young infants. Also, the continued efforts towards automated reliable coding of dyadic social interaction could prove useful in making microanalysis a more feasible approach in the future. Lastly, if naturalistic play protocols are found to elicit enough distinctive behavior patterns, parents could be provided with a more objective lens through which to 'screen' for red flags at home, rather than relying on retrospective, self-report screeners.

6.3 Limitations and Future Directions

This study is not without limitations. One limitation of this study is that there are much fewer AR children than TD in the sample. A larger AR sample would help solidify how robust the exhibited behaviors are across infants in this age range. Also, parent-report screeners were used to determine risk status for this study. Self-report screeners are not considered the most reliable or valid measure and additional behavioral observations by a trained clinician (as seen in Ousley et al., 2013) to help classify risk status would be ideal. Lastly, we do not know if the infants in this study go on to receive a diagnosis of autism, so the long term diagnostic validity of these measures cannot fully be evaluated at this point. A longitudinal analysis of infants that carries through the average diagnostic age (4-5 years) would be necessary. Longitudinal work could also evaluate the predictive power of microanalytic measures as compared to omnibus scoring found in behavioral screeners. Future analysis of how the R-ABC scores map onto the visual engagement behaviors measured here, as well as how both measures correspond to parent-report measures could prove to be a very fruitful and exciting line of research. Overall, this study contributes to research on both typical and atypical visual social development and highlights the need for continued efforts toward understanding differences in hopes of establishing clear markers that could reliably indicate risk status for disorders such as autism.

APPENDIX A. JUSTIFICATION FOR INCLUSION OF FOLLOW-UP SESSIONS IN SAMPLE

To increase the sample size and to include infants who were considered At-Risk or Typically Developing for one session (intake, follow-up) but not the other (i.e., status changes), I made the decision to include infants in the sample regardless of which type of session they had. To justify this inclusion, I investigated how the intake-only data compared to that of the full sample (that includes follow-ups). This comparison was done to investigate potential practice effects (i.e., if behavior differences were due to having participated in the task previously and not the other independent variables of interest: risk status, age, location, or task). Follow-up sessions were usually conducted 2-3 months after the intake visit, which led me to believe that practice effects should not exist (i.e., a sufficient amount of time has passed since the intake visit).

Table 4 and Table 5 show the original descriptive tables (TD n=125, AR n=37) combined with the descriptives for the intake-only sample (TD n=96, AR n=33). Table 4 includes data for frequency of looking. Table 5 includes data for average duration of looking. No notable changes were seen in the data (e.g., different means or standard deviations) when comparing intake-only to the full sample (including follow-ups). Therefore, I made the decision to include sessions of both type in this data under the assumption that practice effects, if any existed, were minimal and not impacting the data in a significant way over and above the other variables of interest. I should also note that I did re-run the analyses (ANOVA, ANCOVA) for both dependent variables in the intake-only sample and found the exact same pattern of results. That is, the same main effects and interactions were present for this intake-only sample that are discussed in this paper. Also, the exact same pattern of effects did and did not persist as seen in the reported findings from the full sample, which included follow-ups.

Table 4 - Frequency of looking descriptives for intake only and full sample.

	TD (n=125)			AR (n=37)		
Task	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Ball						
to Face	0	21	7.27 (3.5)	0	17	5.81 (3.33)
to Ball	4	20	9.63 (2.37)	6	17	9.76 (2.43)
Tickle						
to Face	0	12	5.78 (2.46)	0	8	4.05 (2.12)
to Hands	0	12	5.14 (2.29)	1	9	4.41 (2.15)
	TD (n=96)			AR (n=33)		
Task	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Ball						
to Face	0	21	7.49 (3.63)	0	17	5.85 (3.41)
to Ball	4	20	9.65 (2.5)	6	17	9.97 (2.48)
Tickle						
to Face	0	12	5.9 (2.47)	0	8	4.09 (2.18)
to Hands	0	12	5.1 (2.33)	1	9	4.3 (2.17)

Note: TD = Typically Developing, AR = At Risk, SD = Standard Deviation.

Table 5 - Average duration of looking descriptives for intake only and full sample.

	TD (n=125)			AR (n=37)		
Task	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Ball						
to Face	0	4.22	1.1 (0.55)	0	2.64	0.93 (0.52)
to Ball	0.8	5.09	1.78 (0.69)	0.78	4.5	2.17 (0.94)
Tickle						
to Face	0	19.26	1.6 (1.86)	0	3.6	1.25 (0.8)
to Hands	0	6.13	1.71 (1.12)	0.46	6.35	1.89 (1.32)
	TD (n=96)			AR (n=33)		
Task	Min	Max	Mean (SD)	Min	Max	Mean (SD)
Ball						
to Face	0	4.22	1.11 (0.56)	0	2.64	.89 (.53)
to Ball	0.8	5.09	1.8 (.73)	0.78	4.5	2.22 (.97)
Tickle						
to Face	0	19.26	1.73 (2.08)	0	3.0	1.16 (.69)
to Hands	0	6.13	1.72 (1.22)	0.51	6.35	1.95 (1.36)

Note: TD = Typically Developing, AR = At Risk, SD = Standard Deviation.

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