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Dyadic Interactions in Children Exhibiting the Broader Autism Phenotype

Ashleigh M. Kellerman
Purdue University

DYADIC INTERACTIONS IN CHILDREN EXHIBITING THE BROADER AUTISM PHENOTYPE

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Ashleigh M. Kellerman

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STATEMENT OF COMMITTEE APPROVAL

Dr. A.J. Schwichtenberg, Chair

Department of Human Development and Family Studies

Dr. Germán Posada

Department of Human Development and Family Studies

Dr. Bridgette Tonnsen

Department of Psychological Sciences

Approved by:

Dr. Doran French

Head of the Graduate Program

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ABSTRACT

Author: Kellerman, Ashleigh, M. MS
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Major Professor: A.J. Schwichtenberg

In families raising a child with an autism spectrum disorder (ASD), infant siblings are at elevated risk for ASD and other developmental concerns including subclinical ASD features, often called the Broader Autism Phenotype (BAP). Recognizing the importance of parent-child social interactions in early development and the known social difficulties associated with BAP, the present study aimed to expand our developmental understanding of the BAP by (1) examining performance on standardized measures, and (2) describing dyadic characteristics to determine if the BAP group is distinguishable from the TYP group on select dyadic constructs. As part of a prospective study, dyads were recruited from families with at least one older child with ASD and families with no history of ASD. Mother-child play interactions were coded when children were 12, 15, 18, and 24 months of age for dyadic synchrony, responsiveness, and joint engagement, respectively. By 36 months, children received outcome classifications for BAP (n = 22) and TYP (n = 52). A series of ANCOVAS were conducted, with terms for infant sex and maternal education, and primarily revealed significant group differences on joint engagement measures by 15 months of age. However, these results were not consistent across visits. Overall, this study provides preliminary support for the importance of dyadic exchanges in the BAP, which may inform later developmental outcomes and early intervention efforts. Recognizing the increasing demand for elevated-risk interventions, these findings highlight several social

constructs through which interventions may promote optimal development in children developing at risk.

INTRODUCTION

With the current prevalence of autism spectrum disorder (ASD) being 1 in 68 (CDC, 2014), early detection researchers are committed to examining genetic and environmental factors that contribute meaningfully to the early ASD identification, stability of risk markers, and early intervention practices. Current research demonstrates that reliable diagnoses are established by 3 years of age, with some samples showing reliable diagnoses by 18 months of age (Ozonoff et al., 2015; Sacrey et al., 2015). As early detection researchers continue to screen young children for ASD risk markers, more children are being identified for a range of developmental concerns, including children exhibiting subclinical features of ASD.

Children with an older sibling diagnosed with ASD (henceforth referred to as high-risk infant siblings) are at an increased risk with roughly 20% receiving an ASD diagnosis in early childhood, compared to approximately 1% of the general population (Ozonoff et al., 2011). Additionally, high-risk infant siblings also exhibit elevated rates of subclinical ASD features, sometimes referred to as the Broader Autism Phenotype (BAP; Constantino, Zhang, Frazier, Abbacchi, & Law, 2010; Messinger et al., 2013). Features of the BAP include social and cognitive impairments (on standardized assessments) that emerge as early as 12 months of age (Georgiades et al., 2013). Thus high-risk infant siblings provide researchers with an accessible sample to study early behavioral markers of the full expression of ASD and subclinical BAP features. Additionally, as speculated in Dawson and Bernier (2013), systematic behavioral observations of infants exhibiting BAP characteristics may identify behavioral differences among high-risk infants that could inform phenotypic ASD risk markers and early interventions. However, to date few studies have explicitly examined early dyadic exchanges in infants later identified with elements of the BAP. The present study aims to contribute to this growing literature by examining infant-mother dyadic exchanges longitudinally, as indexed by synchrony, responsiveness, and joint engagement, in high-risk infant siblings later characterized with elements of the BAP.

Studying infants with phenotypic expressions of ASD in the present study is two-fold. First, from a developmental psychopathology perspective, in order to fully understand ASD, it is necessary to understand similarities and differences in developmental trajectories and/or pathways of subclinical phenotypes. Systematic longitudinal examination of development allows researchers to track possible underpinnings that may lead to adaptive or maladaptive outcomes (Cicchetti, 2014; Sameroff & Fiese, 2000). This also allows developmental trajectories to be observed within equifinality or multifinality contexts, such as family affectedness (Ozonoff et al., 2014; Schwichtenberg et al., 2010). Additionally, since we do not yet fully understand what may contribute to the full manifestation of ASD, as opposed to exhibiting phenotypic features (Rutter, 2013), it is important to document subclinical features that may inform the full expression. It's possible the degree of genetic vulnerability is a deciding factor, or possibly a two-hit mechanism for genetics and another currently unidentified environmental factor (Rutter, 2013). As geneticists continue to examine candidate genes for autism (e.g., Li, Zou, & Brown, 2012), as well as endo-phenotypical properties of genes that may influence the expression of certain traits in BAP (Yirmiya & Ozonoff, 2007), a recent review of environmental risks for ASD highlighted the need to examine gene by environment correlations between genetic risk and parent-child interactions (Mandy & Lai, 2016). Specifically, Mandy and Lai (2016) recently proposed a model illustrating that genetic risk of ASD (e.g., high-risk infant siblings) and experiences in early social environment may contribute to distressed dyadic interactions, which in turn may lead to an increased risk of later ASD outcomes. Though current research has yet to explore this link extensively, Mandy and Lai (2016) suggest that infant sibling designs afford opportunities to begin examining if early social communication difficulties observed during parent-child interactions (e.g., Wan et al., 2013) causally inform ASD risk.

Second, although children exhibiting BAP do not meet diagnostic criteria for ASD-specific intervention services, they do struggle more than typically developing peers on standardized developmental assessments (e.g., Mullen Scales of Early Learning-MSEL, Mullen 1995; Vineland Adaptive Behavior Scales-VABS, Sparrow, Balla, & Cicchetti, 1984), or may engage in restricted or repetitive behaviors that are maladaptive in nature (e.g., Autism Diagnostic Observation Schedule-ADOS, Lord et al., 2000; see section on BAP characteristics for specifics). And thus could benefit from targeted interventions. However, less is known about the developmental trajectories of children who exhibit subclinical features in early childhood. One preliminary study documented language deficits in school-age high-risk infant siblings but little is known about their social skills/competence (Gamliel, Yirmiya, Jaffe, Manor, & Sigman, 2009). Additional studies tracking children's development through early childhood may inform the effects of phenotypic features in later development. In addition, follow-up designs may identify the proportion of children who develop ASD after 36 months of age, which may be misrepresented in early childhood studies (Charman et al., 2017).

As discussed in a review of prospective infant sibling studies, researchers are beginning to conduct interventions targeting early social communication development in high-risk infant siblings, prior to measuring diagnostic outcomes (Szatmari et al., 2016). For example, recent randomized control trial (RCT) intervention designs for high-risk infant siblings target social communication behaviors prior to young children displaying diagnostic features of ASD (Green et al., 2013; 2015; 2017). Results from Green and colleagues' (2017) RCT demonstrated an increase in the experimental group's infant-led initiations and attentiveness to their mothers, as indexed by two behavioral coding techniques (i.e., event coding- Dyadic Communication Measure for Autism-DCMA, Aldred, Green, Emsley, & McConachie, 2012; global rating scale-Manchester Assessment of Caregiver-Infant Child Interaction, Wan, Brooks, Green, Abel, & Elmadih, 2016). These early interventions are primarily parent-mediated, cost-effective, and have simple guidelines. However, until more studies are conducted, it is currently unknown if implementing parent-mediated interventions early in development to high-risk infant siblings will significantly improve developmental outcomes. Furthermore, future studies examining BAP features beyond early childhood may assist clinicians in "best practice" considerations to avoid inflicting unnecessary distress on families by overpathologizing symptoms, while also not denying children services that may benefit their development (Yirmiya & Ozonoff, 2007).

To inform the proposed study, this introduction will: (1) distinguish between the diagnostic criteria for ASD and characteristics of BAP - highlighting current measurement techniques for classifying BAP in early childhood, (2) document infants' social communication development within the first two years of life, relative to ASD-risk and outcome status (i.e., ASD, BAP, TYP), (3) incorporate theoretical frameworks that guide our understanding of early social development during a parent-child free-play interaction between infants with BAP and typically developing peers, respectively, and (4) discuss the role parent-child interactions play on infants' early social development, and how to meaningfully capture/quantify their interactions (i.e., dyadic synchrony, responsiveness, joint engagement). In examining the literature on BAP and social communication development within parent-child interactions, the current study aims to (1) replicate previous research distinguishing infants with BAP from their typically developing peers in the domains of communication, visual reception, and socialization as indexed on standardized developmental measures, and (2) describe dyadic characteristics of the BAP by examining how and when differences emerge, relative to their typically developing peers.

Autism Spectrum Disorder

ASD diagnostic criteria. The Diagnostic and Statistical Manual of Mental Disorders (DSM-5), characterizes ASD by social and communicative deficiencies and restricted, repetitive behaviors that must be present within the early developmental period. The extent of these communicative and behavioral differences may not be fully manifested at the time of diagnosis; however, these differences are not better explained by intellectual disability or a more global developmental delay. Social and communicative deficiencies may include, but are not limited to poorly modulated eye contact and/or the integration of gestures, lack of spontaneously initiated social bids or responding to others, and difficulties engaging in pretend play. Common restricted and repetitive behaviors may include unusual sensory interests in objects, highly restricted intense and repetitive fixations, and repetitive motor movements (American Psychiatric Association, 2013).

ASD early detection. Early work by Peter Mundy and colleagues (1986) noted that children at risk for ASD exhibit notable decreases or absence of social communicative behaviors such as coordinated eye gaze shifts, gestures (e.g., pointing to objects; requesting), positive affect, and spontaneously directed vocalizations. Difficulties in combining these communicative behaviors into multimodal bids is also evident in observing group differences in higher-order constructs, such as joint attention and later theory of mind (e.g., Bennett et al., 2012; Siller & Sigman, 2002). These behaviors, as well as unusual prosody in one's voice, echolalia, rigidity in routines, sensory sensitivities, unusual motor movements, and tendency to prefer playing with parts of toys in a socially inappropriate manner encompass the majority of early ASD risk factors that researchers have documented at various stages throughout early childhood in prospective infant sibling designs, as well as retrospective designs (CDC, 2016). In identifying risk factors for ASD, it is also necessary to consider the developmental progression of infants' social communication.

ASD within the first year. Within the first year, researchers begin documenting the progression of infants' social development by classifying their early communicative behaviors. In high-risk infant siblings, researchers are able to begin tracking differences amongst infants, such as gross motor delays, lack of positive affect, and early signs of regression in skill sets (e.g., eye gaze and gestures) by 6 months of age; however, these differences are modest on current standardized measures (Messinger et al., 2013; Ozonoff et al., 2010).

For prospective infant sibling studies examining dyadic interactions between infants and their mothers, findings within the first year are inconsistent. This likely reflects difficulties detecting subtle behavioral differences, as well as the possibility that basic social communication skills (e.g., gaze and affect) do not appear atypical within the first year (see reviews, Zwaigenbaum, Bryson, & Garon, 2013; Jones, Gliga, Bedford, Charman, & Johnson, 2014; Szatmari et al., 2016). For example, by 4 months of age, Yirmiya and colleagues (2006) detected more neutral affect directed at their mothers during the Still Face Paradigm (SFP; Tronick, Als, Adamson, Wise, & Brazelton, 1978) in high-risk siblings later diagnosed with ASD. Whereas in a similar design, Rozga et al. (2011) did not find significant differences in high-risk infants' frequency of gaze, positive affect, or vocalizations directed to their mothers during the SFP at 6 months of age; however, the high-risk infants diagnosed with ASD by outcome began showing significantly less communicative bids by 12 months on an examiner-administered measure (i.e., Early Social Communication Scales-ESCS; Mundy et al., 2003). Similarly, Wan et al. (2013)

found within a dyadic interaction that infant siblings' positive affect and attention to mothers prior to 12 months did not inform later ASD. Most recently, two studies observing mother and infant play behaviors and dyadic synchrony and responsiveness in high-risk siblings within the first year also did not find consistent group differences until 12 months of age (Schwichtenberg, Kellerman, Young, Miller, & Ozonoff, in review; Schwichtenberg et al., in preparation). Overall these findings highlight that distinct behavioral differences linked to later ASD and Non-TYP outcomes begin to emerge at 12 months (Ozonoff et al., 2014). However, to date no known studies have further evaluated the Non-TYP group to examine early dyadic play behaviors in infants exhibiting features of BAP prior to their first birthday.

ASD within the second year. By 12 months of age, ASD and TYP group behavioral differences become clearly evident and consistent across studies. As typically developing children's social communication skills begin to predominately involve multimodal bids (e.g., social smiling, combined eye contact with vocalizations), distinct differences between those at elevated ASD risk emerge. For example, Chawarska et al. (2014) identified three behavioral combinations at 18 months that distinguished between children later diagnosed with ASD and Non-TYP infants: (1) poorly modulated eye contact with minimal gesture use, (2) poorly modulated eye contact with minimal pretend play, and (3) appropriate eye contact with repetitive behaviors and no giving gestures.

Specific to characterizing Non-TYP high-risk infant siblings, Toth and colleagues (2007) examined a variety of measures (i.e., developmental assessments; parent-report measures; direct observation) and found variable group differences across these measures; the most consistent findings highlighting significant differences in Non-TYP receptive language, adaptive behaviors, and lower frequencies of communication. Additionally, prospective studies examining social communication differences between Non-TYP and TYP have found differences in responding to joint attention bids by 14 months (Sullivan et al., 2007). Overall these findings highlight the variety in behaviors and distinct differences observed in infants within the second year, with special consideration for identifying Non-TYP group differences.

Broader Autism Phenotype

BAP characteristics. As researchers continue to identify distinctions between psychopathological risk and neurotypical development, patterns of subclinical features of ASD in individuals have been identified, particularly within families with at least one first-degree relative diagnosed with ASD. In defining the BAP, multiple levels of analyses have been explored with some consensus on what the BAP encompasses, such as difficulties in social communication skills, language delays, cognitive deficits, and/or some restricted and repetitive behaviors. However, due to the range of functioning levels within these observed differences and countless possible combinations of risk factors, there is no current standardized criteria for BAP in the field (e.g., see recent reviews Pisula & Ziegart-Sadowska, 2015; Gerdts & Bernier, 2011; Sucksmith, Roth, & Hoekstra, 2011; Dawson et al., 2002). To quantify BAP features Messinger and colleagues (2013), focused on high-risk infant siblings with non-ASD outcomes and compared them to their low-risk peers on the MSEL (i.e., verbal and nonverbal developmental quotients) and the ADOS severity score at 36 months of age. Specifically, Messinger et al. (2013) identified five patterns based on MSEL developmental quotients and ADOS severity scores that characterized non-ASD infants. Two of these patterns were distinctly different than those of their low-risk peers: (1) children that demonstrated higher severity scores on the ADOS, with low to moderate developmental quotients as indexed by the MSEL, and (2) children that demonstrated low severity scores on the ADOS, with lower developmental quotients on the

MSEL. The remaining three patterns were not significantly different from low-risk infants (e.g., lower ADOS severity score with average verbal and nonverbal developmental quotients). To ground the current study within this framework, ADOS severity scores and verbal and nonverbal developmental quotients from the MSEL, respectively, were calculated (see Outcome Characteristics in Table 4) and BAP groupings were explored.

BAP early detection. Initial measurement techniques for capturing BAP involved clinical interviews (e.g., Dawson et al., 2007); however, now a variety of questionnaires exist for quickly measuring BAP characteristics in adults and/or children aged 3 and older (e.g., Broader Autism Phenotype Questionnaire, Hurley, Losh, Parlier, Reznick, & Piven, 2007; Social Responsiveness Scale, Constantino, 2002; Autism Spectrum Quotient, Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). The self- or parent-reported questionnaires listed above have been used in numerous studies to either characterize BAP or distinguish between BAP and ASD in individuals beyond early childhood (e.g., Ruzich et al., 2015; Sasson et al., 2014; Maxwell, Parish-Morris, Hsin, Bush, & Schultz, 2013; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010). However, for children under 3 years, clinical judgments and standardized developmental assessments typically inform impressions of the BAP (e.g., ADOS, MSEL, and VABS).

In measuring BAP outcomes across developmental assessments in early childhood, recent studies have established criteria for capturing BAP in high-risk infant siblings. In Landa and colleagues (2012), BAP group membership required a clinical judgment from a trained clinician for social or language delay, a social or communication score at least 1.25 standard deviations below the mean on a developmental measure (e.g., VABS), elevated ADOS scores on key items from the Social Affect section (without a clinical impression of ASD), and either qualified for speech-language services or met criteria on a subscale of the Test of Early Grammatical Impairment (Rice & Wexler, 2001). Most recently, Ozonoff and colleagues (2014) defined outcome criteria for non-typical development associated with BAP, as being a high-risk infant sibling not meeting clinical best estimate criteria for an ASD, and at least one of the following: a minimum of two subscale scores on the MSEL that are 1.5 standard deviations below the mean, a minimum of one subscale score on the MSEL 2 standard deviations below the mean, or an elevated ADOS total score that falls at least 3 points below cutoff for ASD. The current study will replicate Ozonoff and colleagues' (2014) criteria for characterizing BAP given the similarities in study design and data collection measures (i.e., MSEL, ADOS; see Table 1).

BAP within the first year. To date few studies have examined the emergence of BAP prior to 36 months of age. Most recently, Ozonoff and colleagues (2014) tracked high-risk infant siblings from 6 to 36 months and noted that by 12 months, Non-TYP infants - consistent with BAP, displayed significantly slower growth in language and visual reception skills when compared to typically developing infants, as indexed by the MSEL. In terms of behavioral differences, one high-risk infant sibling design including a parent-child interaction at 4 months, and found that five high-risk non-ASD infants with language delays were slightly less synchronous with their mothers than high-risk non-language delay and typically developing peers, respectively (Yirmiya et al., 2006). However, it is important to note that this study did not clearly define the BAP as a subgroup. Similarly, other behavioral differences in Non-TYP infants have been reported within the second year.

BAP within the second year. Few studies have examined BAP beyond developmental assessments, or parent-report questionnaires, recent prospective infant sibling studies interested in behavioral differences in high-risk to ASD outcomes, have included results on infants falling into a high-risk non-ASD and non-typical classification, compared to ASD and typically developing peers. Though it is often unclear if these high-risk infants with non-ASD and non-TYP outcomes meet current considerations to be classified as BAP, these studies do provide some preliminary evidence of emerging differences in social communication. Specific to social referencing, Cornew and colleagues (2012) found that high-risk infants with non-ASD and non-TYP outcomes only showed slightly lower frequencies of information seeking when playing with novel toys, than their typically developing peers, at 18 months of age. Additionally, one study examining response to joint attention bids in high-risk infants with clearly defined outcomes of ASD, BAP, and non-BAP, descriptively noted that infants with BAP at 14 months did not look towards target cues during the task, compared to ASD, and non-BAP. However, further analyses examining responding performance dichotomized the groups into impaired (ASD and BAP combined) and Non-BAP (Sullivan et al., 2007).

Overall, these recent studies have moved the field forward from primarily conducting cross-sectional studies to longitudinally examining developmental trajectories (e.g., Ibanez, Grantz, & Messinger, 2013; Ozonoff et al., 2014). However, studies examining the BAP in early childhood primarily focus on data collected from parent-report questionnaires, standardized developmental assessments (as mentioned above; also see review Szatmari et al., 2016), or possibly include behavioral differences between ASD and subgroups of atypical development (e.g., ASD, BAP and Non-BAP; Sullivan, et al., 2007; Clifford et al., 2013). To build on previous work, the present study will expand our understanding of BAP within a dyadic context over the first two years of life. This longitudinal data may inform when BAP social differences emerge.

Theoretical Framework

Building on a developmental psychopathology perspective, the current study is guided by two theoretical frameworks widely recognized in understanding dynamics within parent-child interactions. In interpreting nuances specific to observable behaviors within a dyadic interaction, Sameroff's transactional model of human interaction is well suited to aid in our interpretation of temporal relations, at the micro-analytic level, in dyadic synchrony and responsiveness between infants and their mothers. Additionally, Vygotsky's sociocultural theory will be useful in describing children's motivation, or active role in jointly engaging with their mothers, within a larger dyadic context.

Transactional model of human development. The transactional model of human development suggests that parents and their children are both significant contributors to the direction and flow of the interaction (Sameroff, 2009; Sameroff & Fiese, 2000). Similarly, the *intricate dance* of dyadic synchrony involves an interactive exchange between play partners, from matching behaviors to sequentially responding to one another (Feldman, 2007). To capture these brief and intense social exchanges, process-oriented micro-level coding techniques are often used to examine who primarily leads the interaction, how responsive play partners are to one another, and the quality of their dyadic states (Feldman, 2003). This allows researchers to examine how each play partner contributes to the interaction, as well as provides an opportunity to identify asynchronous interactions, which may be related to developmental risk (i.e., BAP).

Sociocultural theory. Aside from capturing moment-to-moment transactional processes of dyadic interactions to inform developmental outcomes, examining global representations of dyads social engagement captures higher-order social constructs, such as coordinated joint engagement (Adamson, Deckner, & Bakeman, 2012). These constructs are difficult to assess at a base behavior level without context. Thus Vygotsky's sociocultural theory is particularly relevant in describing development formed by dynamic interactions between two individuals (e.g., parent-child), surrounding social contexts, and cultures (Vygotsky, 1978). Interactions are also fostered in guided participation, which supports the idea that a skilled parent could encourage a child by being actively involved in the child's learning process (Tudge & Winterhoff, 1993). By applying sociocultural theory, 'gestalt' ratings of dyadic engagement states are informed by the overall context of the interaction, which may highlight dyadic differences not observed in a micro-analytic approach.

Dyadic Interactions

Parent-child relationships play a pivotal role in children's early development and promote opportunities for observing early social communication development. To examine early social communication development in high-risk infants within a dyadic setting, several play paradigms and coding techniques exist. The current study will examine dyadic synchrony, responsiveness, and joint engagement within a semi-structured free play, using existing coding schemes.

Types of dyadic exchanges.

Dyadic synchrony. Dyadic interactions promote opportunities for observing temporal relation of early social behaviors between the infant and mother over time (Feldman, 2007). Specifically, dyadic synchrony encompasses a temporal relationship between dyads' social behaviors that are often classified as being brief and intense moment-to-moment exchanges (Feldman, 2007). By 3 months, typically developing infants begin to match other's behavior as well as sequentially regulate one's behavior with the other's behavioral response (Feldman, 2007; Fogel 1993; Tronick & Cohn, 1989). Research investigating the influence of developmental psychopathology on synchrony highlights that biological risks associated with infants may negatively impact their interactions (Feldman, 2007; Feldman, 2015). Previous research examining ASD demonstrates that infants' synchrony may be related to later deficiencies in theory of mind and joint attention skills (e.g., Siller & Sigman, 2002; Yirmiya et al., 2006).

Responsiveness. In addition to matching and sequentially regulating behaviors, by 9 months, typically developing infants' interactions shift to focusing more heavily on partners' responsiveness to their social bids (Stern, 1985). Specifically, responsiveness as a temporal process involves capturing the lag in time from the end of one play partner's behavior (e.g., vocalizations) to the start of the other partner's behavior (e.g., look face). The lag in response may be especially salient in dyads with known psychopathological risk markers, such as maternal depression or infants with ASD (Feldman, 2015). Understanding the development of synchronous interactions and responsiveness in infant siblings of ASD may provide meaningful insight into the development and/or divergence of early social behaviors.

Joint engagement. Joint engagement involves coordinating behaviors in conjunction with a communicative partner; this process typically begins to emerge at 6 months and continues to develop through at least 36 months of age (Bakeman & Adamson, 1984; Adamson, Bakeman, Deckner, & Nelson, 2014). Joint engagement is often examined in the context of being supportive or coordinated. Supported joint engagement involves object/event-oriented dyadic play, such that from the child's perspective he/she is engaging in more mutually directed object/event play with mother. This typically includes behaviors such as manipulating an object, and vocalizing about the object or experience. Though the dyad is engaged together, this requires less effort and sustainment for observation (Adamson et al., 2014). Alternatively, coordinated joint engagement requires more social motivation from the child, such that in addition to engaging in an object/event with the mother, there are clear instances of direct references to mother, in relation to the object/event, identified by looking towards mother's face or vocally acknowledging her (e.g., "Mommy, look"; Bakeman & Adamson, 1984).

Within a joint engagement state, there are also several observable types of communicative bids. The joint attention skills of initiating joint attention (IJA) and responding to joint attention (RJA) typically emerge by 24 months, but they may be markedly delayed by developmental disorders. For example, typical social communication behaviors in small children consist of coordinated eye gaze shifts, gestures (e.g., pointing to objects; requesting), positive affect, and vocalizations; whereas, children at risk of ASD express notable decreases or absence of these communicative acts (Mundy et al., 1986). Typically developing children also begin to combine social communicative behaviors, such as coordinated eye contact, into initiating communicative bids (e.g., initiates joint attention by shifting gaze from toy to partner to share the experience), and responding to communicative bids (e.g., responds to joint attention by following a partner's point towards a picture; Mundy & Newell, 2007); however, children at risk of ASD express difficulties initiating these bids with clear communicative intent.

Measurement. Social communication skills of children at risk of ASD have been previously observed in parent-child interactions; however, the measurements applied to document/quantify dyadic interactions vary (Halle, Anderson, Blasberg, Chrisier, & Simkin, 2010). Currently, researchers tend to apply their own unique coding systems when observing dyadic interactions, whether it is micro-level coding for duration and frequency of directed child and/or parent behaviors, or global rating systems (Halle et al., 2010). Varied measurement techniques likely reflect the types of research questions, as well as the age of the participants. For example constructs requiring more context to the behavior, such as joint engagement, maternal sensitivity or directedness, often use rating scales (e.g., see Adamson et al., 2012; Freeman & Kasari, 2013). Alternatively, when answering questions related to temporal order or process (e.g., synchrony), micro-level codes allow researchers to document subtle differences (Bakeman & Quera, 2011) that may not be captured at a broader level. These diverse coding techniques, may be contributing to the reported mixed representations of observed behavioral differences across outcome groups (particularly within the first year), as well as an inability to directly compare results with similar samples across multiple studies. Given the BAP within a dyadic setting is not yet clearly defined and characterized in the field, it is unknown if a micro-analytic or gestalt approach will better capture meaningful dyadic characteristics between children and their mothers.

The present study builds on existing paradigms to examine dyadic constructs at the micro-level for temporal processes and more global dyadic representations, respectively, in order to provide a more complete representation of dyads' interactions over time. From a systems theory perspective, micro-level coding may be more appropriate to capture subtle differences and/or deficits in the current targeted sample. However, research quantifying the overall quality of social communication development, highlights that children with BAP may exhibit intact early social behaviors (e.g., eye contact, positive affect, vocalizations) similar to typically developing peers but struggle with higher-order social communication skills, such as multimodal bids (Ozonoff et al., 2014). Given the uncertainty of which coding techniques may best capture dyadic differences in children with BAP, the current study will incorporate predefined micro-analytic duration and frequency codes for eye contact, positive affect, and vocalizations, based on Ozonoff et al. (2010), in order to create the dyadic composites (see Tables 2- 3 for code descriptions and composites; see Appendix A for excerpts from coding manual). In addition, the parent-child interactions will be rated on an established 7-point Likert rating scale for joint engagement and responsiveness (see Table 2 for definitions; see Appendix B for excerpts from coding manual). Both coding systems have known reliability and validity in the field.

Current Study

The goals of the current study are two-fold. First, to replicate previous research that distinguishes between BAP and TYP groups using standardized developmental assessments (i.e., MSEL: visual reception, receptive language, and expressive language subscales; VABS: socialization and communication domains). And second, to explore how dyadic interactions in early childhood may capture social difficulties associated with BAP, when compared to their typically developing peers. The current study's unique contribution includes longitudinally examine BAP social/communication characteristics within a naturalistic social task (designed to capture dyadic synchrony, responsiveness, and joint engagement).

Aim 1) to replicate previous studies describing the BAP, across standardized developmental assessments (i.e., MSEL, VABS)

Question 1: How do children with BAP perform on standardized assessments, compared to their typically developing peers?

Hypothesis 1: Based on previous research (Ozonoff et al., 2014; Landa et al., 2012), we expect infants within the BAP group (compared to TYP group) to perform lower on visual reception, language, communication, and socialization measures.

Aim 2) to describe dyadic characteristics of the BAP within a social context-specifically, dyadic synchrony, responsiveness, and joint engagement from 12 to 24 months of age

Question 2: Are children within the BAP group distinguishable from their typically developing peers during naturalistic social interactions?

Hypothesis 2: We expect infants within the BAP group (compared to TYP group) to exhibit less dyadic synchrony, responsiveness, and lower levels of joint engagement.

Question 3: Within a dyadic context, when do differences in BAP emerge?

Hypothesis 3: Based on previous research (Ozonoff et al., 2014; Landa et al., 2012), we expect dyadic differences in the BAP group to be evident within the second year of life.

METHODS

Participants

Ninety-nine mother-child dyads were recruited from the greater Lafayette area of Indiana to participate in a prospective infant-siblings study at Purdue University. The low-risk (LR) group consisted of 55 infants with at least one older biological sibling, as well as no familial history of ASD in 1st, 2nd, or 3rd degree relatives. The high-risk (HR) group consisted of 44 infants with at least one older biological sibling with a confirmed ASD diagnosis.

Outcome groups for infant siblings were assessed at their final visit (i.e., 24, 30 or 36 months of age). Based on outcome criteria developed by the Baby Siblings Research Consortium (BSRC; see Ozonoff et al., 2014), infants from the larger infant-sibling study were classified into 1 of 3 defined groups: Typical Development (TYP; *n* = 52), Non-Typical Development (Non-TYP; *n* = 35), and Autism Spectrum Disorder (ASD; *n* = 6). In addition, seven infants did not complete an outcome visit and were not included in the current study. Infants diagnosed with an ASD met *DSM-5* criteria, as well as received an ADOS score above the threshold for an ASD. Non-TYP outcomes included children with language delays, clinically relevant behavioral challenges, global developmental delay, and children exhibiting subthreshold phenotype characteristics of ASD (i.e., BAP).

For the purpose of the current study, Non-TYP, associated with BAP were derived following Ozonoff et al.'s (2014) criteria, based on infant-risk status, MSEL scores, and ADOS severity (Table 1). Thus the final outcome groups for the current study included BAP (*n* = 22) and TYP (*n* = 52).

Data Collection

Data were collected beginning in the fall of 2013 through fall of 2016, as part of a longitudinal prospective study of infant siblings of autism from 6 to 36 months of age, at Purdue University's Developmental Studies Laboratory. At each of the laboratory visits, mothers were asked to complete a parent-child structured play task. These observations took place in a controlled semi-naturalistic playroom, with two cameras that recorded their interaction. For the current study, 4 of the visits were analyzed: 12, 15, 18, and 24 months of age. Separate models were conducted at each visit to maximize the inclusion of participation at each visit age (Figure 1), after recognizing the variability in visit attendance (Table 2). Each visit to the Developmental Studies Laboratory lasted approximately 2 hours and consisted of developmental assessments, self-regulation tasks, as well as a parent-child play task.

Measures

Mother-child interaction. As part of the prospective study, mothers and their children participated in a standardized play task at the 12-, 15-, 18-, and 24-month laboratory visits. A standardized set of age-appropriate toys were provided and included a baby-doll, blanket, ball, shape sorter, car, rattle, and pair of toy phones. Mothers were asked to play with their children as they typically would at home for approximately 5 minutes. Previous studies highlight that coded interactions for 3 to 6 minutes are sufficient to observe behavioral differences in families raising children with an ASD (e.g., Adamson et al., 2012, Green et al., 2017, Rozga et al., 2011).

Video recordings of the dyadic interactions were viewed in Mangold INTERACT's behavioral coding program for the behavioral sciences, Version 15. Mangold INTERACT's user interface is oriented towards a viewer observing behavior from a digital record and annotating what is occurring during the playback. This setup allows for a user to create start and stop times for coding periods, specific to the participant. A graduate research assistant (GRA) served as the coding lead for the project and trained the undergraduate research assistants. The undergraduate research assistants were unaware of risk and outcome status and were assigned to only one coding scheme to avoid any bias from coding dyads in one context to another. With the incorporation of two behavioral coding schemes in the current study, the following subsections provide coding descriptions and reliability checks for the micro-analytic and global rating scale, respectively.

Micro-analytic coding**.** Child and mother gaze, positive affect, and vocalizations were independently coded using a micro-analytic approach for the first three minutes of the interaction (see Table 3; see Appendix A for coding manual). The predefined behaviors encompassing dyadic synchrony, infant responsiveness, and maternal responsiveness were coded for the frequency and duration of occurrence (i.e., look face, look object, positive affect, and vocalizations, for mother and infant, respectively). Research assistants were trained to watch the digital records in order to capture within-second changes in behaviors. They were also trained to code each assignment one behavior at a time using the slow-motion feature in INTERACT. Coding these base competencies generated a frequency count and total duration for each observed behavior during the interaction, which were exported from Mangold INTERACT and post-processed using a Python script Version 2.7. Consistent with Ozonoff et al. (2010), behaviors lasting 0.5 seconds or more were counted towards respective frequency and duration totals (e.g., durations > 0.5 seconds equal one frequency count). In addition for behaviors, such as brief eye shifts (e.g., look face to look object), the shift must have occurred for at least 0.5 seconds to be counted as a separate behavior (e.g., gaze shift from face to object >.05, equals one look face and one look object, respectively).

Using these base codes (See Appendix A for coding manual), composites were created during post-processing to assess dyads' temporal relationships for dyadic synchrony and responsiveness, respectively (see Table 4). Post-processing involved compiling each coder's completed assignments into one folder with varying copies of a file and then running a Python script to (1) compile the files by ID and visit age (2) organize the codes in order of occurrence (3) convert start and end times from Mangold INTERACT's default time format of nanoseconds to seconds (4) calculate the duration of each observed behavior and (5) output the data in long format.

To capture dyadic synchrony, infant responsiveness, and maternal responsiveness from the processed base codes shown in Table 4, the current study pulled heavily from Feldman (2007) in assessing exchanges between infant and mother to capture who is leading sequences in the interaction (referred to as lead-lag), when the dyad is mutually engaged in a given behavior, and the time it takes for one to respond to the other (referred to as time-lag). In the current study, dyadic synchrony was specified as a continuous variable that included instances of mutual (e.g., mother and infant shared eye gaze) and sequentially led behaviors (i.e., infant-led mother-follow; mother-led infant-follow). Infant and maternal responsiveness were also captured as continuous variables for the lag in time from one play partner's behavior ending to the start of the other partner's behavior, within a three second window (e.g., infant gaze ends, followed by the start of mother's vocalization). Responsiveness was derived for infant and mother, respectively.

Reliabilities. Twelve research assistants were assigned to the micro-analytic coding team and received up to two distinct training sets of five videos to establish reliability (i.e., alpha set; beta set). Convergence across the GRA and two other coders for each of the 10 training videos were used to create the reliability set. The GRA reviewed each coder's training assignments and ran intraclass correlation coefficients (ICCs) for each predetermined code (e.g., infant gaze, mother vocalizations), per reliability sets. Reliability was assessed for both the frequency and duration of occurrence, respectively, and required ICCs of at least .70 on each code to initiate independent coding. Results from the alpha set (ICC Range: -.16 to .99, $M = .82$) revealed that for some coders certain behaviors were easier to code than others (e.g., vocalizations versus eye gaze), and that while some coders may have consistently identified the frequency of a given behavior above .70, they may not have accurately captured the duration, or vice versa. For coders that did not meet the cutoff of .70 for frequency and duration, the GRA provided a beta set of five different videos with instructions to only code for behaviors that they received an ICC of .65 or greater for both the frequency and duration of a given behavior from the alpha set. Thus from the 12 coders assigned to this scheme, several coding sub-teams formed (e.g., mother-only coders, infant-only coders, vocalization-only coders, positive affect and vocalization-only coders, etc.). Though tedious to assign and to manage in post-processing, reliabilities from the beta set based on assigned sub-teams resulted in consistent ICCs above .70 (Range: .77 to .99, $M = .93$). After coders completed both training sets and secured ICCs above .70, periodic unannounced reliability checks were conducted to ensure reliability above .70 throughout coding assignments (Range: .73 to .99, $M = .94$). These checks included running ICCs for a set of 5 videos, for frequency and duration of a given variable, based on coding sub-team (e.g., mother-only coders received a reliability check for mother gaze, positive affect, and vocalizations, respectively).

Global ratings. Separate coders rated joint engagement and child responsiveness rating items for parent-child play interactions on a 7-point Likert scale according to a subset of Adamson, Bakeman, and Suma's Joint Engagement Rating Inventory (JERI, 2016; see Appendix

B). The joint engagement ratings (i.e., total joint, supported joint, and coordinated joint) are categorical variables with values ranging from 1 to 7. Child responsiveness is also captured from the rating scheme as a categorical variable (see Table 3 for definitions).

Reliabilities. Two research assistants that were not a part of the micro-analytic coding team were assigned to the global rating scheme. The coders received the same initial alpha set of five videos from the micro-analytic training set and were unaware of risk and outcome status. The GRA served as the master coder for the rating scheme. Reliability was assessed with ICCs and required at least an ICC of .70 on each code. The initial alpha set was viewed and rated within consensus meetings with the GRA. After completing the initial training set, coders completed an alpha set of nine videos for initial reliability (Range: .80 to .90, *M* = .87). Coders also received periodic unannounced reliability checks which resulted in consistent ICCs above .70 (Range: .83 to 1.00, *M* = .94).

Autism Diagnostic Observation Scales (ADOS). The ADOS-2 is a semi-structured standardized diagnostic tool to measure symptoms of autism in the social communication and restricted and repetitive behavior domains (Lord et al., 2002). The ADOS-2 allows numerous opportunities for social interaction, intentional communication, and pretend play between the child and the examiner. All participants included in analyses received this assessment at their outcome visit, which occurred between 24 and 36 months of age. Depending on age at outcome visit and expressive language level, children received either the Toddler Module, Module 1, or Module 2. To compare symptom severity across modules, total scores on the administered ADOS modules will be converted into severity scores following guidelines established in Gotham et al. (2010) and Esler et al. (2015). For the current study, outcome for BAP will follow criteria established in Ozonoff et al. (2014). See Table 1 for outcome parameters. See Table 5 for outcome descriptive statistics relevant to ADOS module and average severity scores by outcome group.

Mullen Scales of Early Learning (MSEL). The Mullen measures cognitive ability in children aged birth to 68 months across five scales: gross motor, fine motor, visual reception, receptive language, and expressive language (Mullen, 1995). This measure was included at each laboratory visit. This measure was also included in determining outcome group membership for ASD, BAP, and TYP. MSEL raw scores were used to classify infants at outcome as described above.

Vineland Adaptive Behavior Scales (VABS). The VABS is a parent report measure that assesses children's skills on three main domains: communication (receptive; expressive; written), daily living skills (personal; domestic; community), and socialization (interpersonal relationships; play and leisure; coping skills; Sparrow et al., 1984). Questions are tailored to individuals with intellectual and/or developmental disabilities, such as ASD. Mothers completed this measure at each laboratory visit. This measure was also included in determining outcome group membership for TYP following criteria established by BSRC (see Ozonoff et al., 2011). This measure was not used for determining BAP criteria in the current study.

Control Variables.

Infant sex. Sex differences exist amongst children diagnosed with ASD, with males being four times more likely to receive an ASD diagnosis than females (Autism and Developmental Disabilities Monitoring Network, 2007). Additional studies have reported sex differences in ASD associated with intellectual functioning (e.g., Scott, Baron-Cohen, Bolton, & Brayne, 2002). More recently studies have examined sex differences in high-risk infant sibling designs noting a nearly three times increase in ASD risk for males in families with only one older child diagnosed with ASD (simplex families) and a five-time increase risk for males in multiplex families (Ozonoff et al., 2011). Additionally, Zwaigenbaum et al. (2012) explored sex differences across several developmental assessments (e.g., ADOS, MSEL, VABS) and found sex differences between cognitive skills, adaptive skills, and symptom severity in both ASD and non-ASD outcome groups. The present study controlled for infant sex in order to account for any potential sex differences with the current sample.

Maternal education. Sociodemographic factors such as maternal education, maternal age, and social economic status (SES) have been shown to influence parent-child interactions. The influence of socio-demographic factors may be especially salient in families raising children with developmental disabilities, due to associations with elevated levels of parenting stress (e.g., Estes et al., 2013) and financial strains (e.g., Horlin, Falkmer, Parsons, Albrecht, & Falkmer, 2014), that may influence their interactions with their children (e.g., parenting styles- Blacher, Baker, & Kaladjian, 2013). Models in the present study included terms for continuous maternal education.

RESULTS

Coding data were exported from Mangold INTERACT Version 15 and cleaned using IBM Statistical Package for the Social Sciences (SPSS) Version 24. Questionnaire-based data were double data-entered, cross-checked, and cleaned within SPSS. Prior to analyses, data were checked for univariate normality by visual inspection (i.e., histograms and QQ plots) and observed skewness and kurtosis (e.g., DeCarlo, 1997; Small, 1980). For variables with notable outliers resulting in skewness and/or kurtosis above 1.50, a series of natural log transformations were conducted prior to running the analyses (i.e., child responsiveness at 15 months). Infant sex and maternal education served as covariates. Separate models were conducted at each applicable visit age (i.e., 12, 15, 18, and 24 months) for each of the continuous (i.e., receptive language; expressive language; visual reception; socialization; communication; dyadic synchrony; infant responsiveness; maternal responsiveness) and categorical variables (i.e., total joint engagement; supported joint engagement; coordinated joint engagement; child responsiveness), to maximize the number of observations included in each model. Additionally, to limit the possibility of making a Type I error, the Benjamini-Hochberg Procedure (1995) was applied to control for false discovery rates without invalidating the overall results for each aim, respectively (Austin, Dialsingh, & Altman, 2014; Howell, 2010).

Aim 1

To assess the first research question (how children with BAP perform on standardized assessments compared to their typically developing peers), descriptive statistics and a series of ANCOVAS were conducted, while controlling for infant sex and maternal education, are presented in Table 6 and Figures 2-3, respectively. Group comparisons revealed significant differences between children in the BAP and TYP outcome groups by 24 months of age as indexed by MSEL raw scores in receptive, $F(1, 65) = 14.70$, $p < .001$, partial η2 = .18, and expressive language domains, $F(1, 68) = 6.77$, $p = .01$, partial η2 = .09, respectively. Significant differences at 24 months on the VABS were also observed for the socialization, $F(1, 68) = 4.22$, $p = .04$, partial η2 = .06, and communication domains, $F(1, 68) = 5.71$, $p = .02$, partial η2 = .08, respectively. However, prior to 24 months of age, MSEL and VABS scores were not significantly different across the BAP and TYP outcome groups (Table 6; Figures 2-3).

Further inspection revealed significant covariates on select measures (superscripts in Table 6). At 18 months, mothers reported significantly higher communication skills for their sons, as indexed by VABS standard scores, $F(1, 68) = 6.91$, $p = .01$, partial η2 = .10. In addition, as indexed by MSEL raw scores at 24 months, boys scored significantly higher on the visual reception, $F(1, 69) = 7.11$, $p = .01$, partial η2 = .10, and expressive language subscales, $F(1, 72) = 5.94$, $p = .02$, partial η2 = 08. Alternatively, girls scored significantly higher on receptive language, $F(1, 69) = 5.21$, $p = .03$, partial η2 = .08, at 24 months. Maternal education was positively associated with communication skills at 18 months, as indexed by VABS standard scores, $F(1, 68) = 7.79$, $p = .001$, partial η2 = .11. A full summary of these results are provided in Table 6.

Aim 2

Specific to Research Questions 2 and 3, a series of ANCOVAS were conducted with infant sex and maternal education as covariates to examine 1) if the BAP group are distinguishable from the TYP group within a social context and 2) if differences exist, when do they emerge (Table 7; Figures 4-5). Our first hypothesis was partially supported in that children within the BAP outcome group did exhibit more social difficulty with their mothers on select responsiveness measures (i.e., infant responsiveness micro-analytic composite, Figure 4b; child responsiveness rating, Figure 5d) and joint engagement ratings (Figure 5a-c), when compared to their typically developing peers.

As predicted, dyadic differences in children within the BAP group were evident within the second year of life. Specific to the micro-analytic composites, at 15 months of age children within the BAP group exhibited fewer responses to their mothers (*M* = 5.64, *SD* = 6.95) than their typically developing peers (*M* = 14.1, *SD* = 7.98), $F(1, 27) = 5.27$, $p = .03$, partial η2 = .16 (Table 7; Figure 4). Specific to the rating items at 15 months, children within the BAP group spent less overall time engaged with their mothers, $F(1, 27) = 12.02$, $p = .002$, partial η2 = .31, engaged in less supported joint engagement, $F(1, 27) = 17.00$, $p < .001$, partial η2 = .39, and engaged in less coordinated joint engagement, $F(1, 27) = 9.30$, $p = .005$, partial η2 = .26 (Table 7; Figure 5). However, at 18 months, children in the BAP group predominately exhibited similar rates of dyadic exchanges across the measured constructs compared to their typically developing peers. The notable exception being a significant difference in the child responsiveness rating such that children in the BAP group were less responsive to their mothers (*M* = 3.69, *SD* = .21) than their typically developing peers (*M* = 4.44, *SD* = .18), $F(1, 49) = 5.26$, $p = .03$, partial η2 = .12 (Figure 5d). At 24 months of age children in the BAP group continued to engage in less total joint engagement with their mothers, $F(1, 47) = 4.07$, $p = .05$, partial η2 = .08 and supported joint engagement, $F(1, 47) = 4.36$, $p = .04$, partial η2 = .09 (Figure 5).

However, these findings were not consistent across the 12-, 15-, 18-, and 24-month visits (Table 7; Figures 4-5). Specifically, our micro-analytic composite for dyadic synchrony did not identify significant group differences across any of the visits (Figure 5a). However as illustrated in Figures 4 and 5, by 15 months of age children in the BAP group are descriptively less socially engaged across all measured dyadic constructs, when compared to their typically developing peers. It is also important to note a lack of statistical difference in maternal responsiveness from the micro-analytic composite between BAP and TYP groups across all time points (Figure 5c).

With respect to infant sex and maternal education as covariates (indexed by superscripts in Table 7), significant covariates were observed at the 15 and 18 month visits. Specifically, at 15 months, boys exhibited higher ratings of supported joint engagement, $F(1, 31) = 6.41$, $p = .02$, partial $\eta 2 = .19$. At 18 months, maternal education was positively associated with higher ratings of total joint engagement, $F(1, 50) = 6.03$, $p = .02$, partial $\eta 2 = .12$, and supported joint engagement, $F(1, 50) = 10.83$, $p = .002$, partial $\eta 2 = .19$. In addition, at 18 months, boys also exhibited higher rates of supported joint engagement, $F(1, 50) = 4.88$, $p = .03$, partial $\eta 2 = .10$. A full summary of these results are listed in Table 7 and Figures 4 and 5, respectively.

Post-hoc Analyses

Recognizing the variability in the observed results, a series of post-hoc analyses were conducted to ground the current study in previous studies. First, to inform how the observed micro-analytic totals may relate to the joint engagement ratings, a series of correlations were conducted at each visit age. At 12 months, maternal responsiveness was negatively correlated with total joint engagement, $r(22) = .42$, $p < .05$. By 18 months coordinated joint engagement was positively associated with infant responsiveness, $r(48) = .33$, $p < .05$, maternal responsiveness, $r(48) = .29$, $p < .05$, and dyadic synchrony, $r(48) = .33$, $p < .05$. These significant associations were also evident at 24 months between coordinated joint engagement and infant responsiveness, $r(49) = .33$, $p < .05$, maternal responsiveness, $r(49) = .39$, $p < .05$, and dyadic synchrony, $r(48) = .37$, $p < .05$. However with the inclusion of infant sex and maternal education as covariates, no significant partial correlations were observed at each age.

Second, to examine the results beyond null hypothesis significance testing, statistical inferences from the present study and previous studies were explored for MSEL scores. Specific to Ozonoff et al. (2014) 95% confidence intervals were reported between their Non-TYP (n = 83) and low-risk TYP (n = 116) groups highlighting a narrow range of estimates within the first two years that were statistically different (e.g., MSEL expressive language estimate at 12 months: Non-TYP = 11.3, TYP = 11.9, p <.05). In comparing the current study to Ozonoff et al. (2014), effect sizes between the two studies revealed that the majority of Ozonoff et al.'s (2014) effects were large for the receptive, expressive, and visual reception domains from 12 to 24 months. Similarly in the current study, large effects for receptive language at 12 and 24 months, respectively, were observe, and a medium effect of expressive language at 24 months. In addition, post-hoc power analyses conducted in G Power, including two covariates and setting an alpha of 0.05, demonstrated that our current sample (n = 74) had a power of 0.76 to detect a medium effect (f^2 = .31) and 0.99 for a large effect (f^2 = .58).

Third, recognizing that Messinger et al. (2013) identified five developmental patterns within children exhibiting BAP features, two of which being statistically distinguishable from typically developing peers, the present study calculated MSEL nonverbal and verbal developmental quotients and ADOS severity scores as outlined in Messinger et al. (2013; means reported in Table 5). All of the children within the current study were captured by the five described patterns; however, only 77% of our BAP group members fell within the two groups that had significantly different patterns when compared to peers (based on Messinger et al., 2013). Hence, approximately 23% of the children in the current sample did not follow developmental patterns that are distinct from their peers.

DISCUSSION

The present study identified significant group-level differences as early as 15 months of age between children later characterized with BAP and their typically developing peers, as indexed by select social constructs. Though differences between the BAP and TYP groups were not significant at each age, Figures 4 and 5 illustrate a consistent trend for the BAP group to perform lower than the TYP group across each of the standardized and social construct variables from 15 to 24 months of age, respectively. To examine the BAP within a play-based context, the novel data provided by this study highlight that social difficulties within the BAP may be captured by context-based measures. These data, coupled with that of standardized developmental assessments, provide preliminary support for including the BAP as a separate developmental outcome category in elevated-risk developmental research. Recognizing the contributions of the current study, the following sections will discuss how the results may inform current characterizations of the BAP, implications for elevated-risk interventions, as well as identify several key limitations to address in future research.

BAP Characteristics

Although the BAP group preformed descriptively/numerically lower than the TYP group across all standardized measures as early as 15 months of age, the current study did not find robust differences (i.e., statistically significant differences), which is somewhat inconsistent with previous research. Specifically, Ozonoff et al. (2014) first identified significant group differences at 12 months of age on MSEL raw scores for the visual reception, receptive language, and expressive language subscales, respectively, in high-risk infants exhibiting features of the BAP (n = 83) compared to their typically developing peers (high-risk TYP n = 160; low-risk TYP n =

116). The lack of replication in the current study is especially surprising given that the BAP outcome classifications were determined by replicating Ozonoff et al.'s (2014) criteria. Ultimately, our discrepant findings may reflect (1) low power, recognizing the limited sample size at each respective visit (*n* range of BAP group: 12 – 22), and (2) variability in the characterization patterns as described in Messinger et al. (2013). First, recognizing that the current study had sufficient power to detect large effect sizes (similar to those reported in Ozonoff et al., 2014), yet less power to detect medium to small effect sizes, it's possible we were unable to detect significant differences given our study's constraints. In addition, recognizing that the majority of the current sample exhibited patterns similar to those presented in Messinger et al. (2013), future research may consider the heterogeneity evident within the BAP and how varying patterns may inform observed behavioral differences.

To date, current definitions of the BAP in early childhood focus exclusively on observed performance on standardized assessments (e.g., Landa et al., 2012; Ozonoff et al., 2014; Messinger et al., 2013). However, theories of human development readily highlight the importance of social input and dyadic exchanges on children's developmental outcomes (e.g., Sameroff, 2009; Vygotsky, 1978), recognizing that children's social competencies may impact their performance on standardized assessments. For example, many standardized assessments require an innate reciprocal interaction, such as question and answer, in order to progress through the administration. Children exhibiting social communication difficulties may miss administered bids, which may impact their scores on a given assessment. To address this, the current study moves the field forward by introducing observed social constructs that may inform current BAP definitions. Specifically, we found that at 15 months, the BAP group performed significantly lower than the TYP group on measures of total, supported, and coordinated joint engagement, respectively, and infant responsiveness. These results add to a small literature base that has observed social behaviors specifically in the BAP (e.g., Sullivan et al., 2007; Yimiya et al., 2006). For example, Yirmiya et al. (2006) examined social constructs from observed parent-child interactions in high-risk infant siblings loosely characterized with the BAP (i.e., exhibiting language difficulties at 14 months) and found differences on select measures (e.g., more neutral affect; fewer higher-order behavioral requests; less infant-led synchrony); however, the majority of their measures did not identify significant differences (e.g., gaze patterns; initiating joint attention; responding to joint attention; initiating social interactions; responding to social interactions). Whereas, Sullivan et al. (2007) found significant differences for BAP on select responding to joint attention trials (i.e., "look-only") at 14 months. The inconsistency in group differences between observed social behaviors in these two studies (e.g., responding to joint attention) further highlights the complexity of capturing BAP in early childhood. The present study builds upon these findings recognizing that more complex social constructs, such as joint engagement, which by definition includes elements of communicative bids embedded within interactions (e.g., joint attention skills), may be better positioned to capture the BAP.

In addition, understanding social difficulties associated with BAP in early childhood may identify mechanisms that inform later developmental outcomes. For example in typical development, early joint attention skills predict later language and cognitive development (Mundy et al., 2007; Kristen, Sodian, & Thoermer, 2011). And in families raising children with an ASD, copious research highlights difficulties in core social competencies (e.g., eye contact) that inform difficulties in more complex social interactions (e.g., joint engagement, theory of mind), which further inform developmental functioning in later childhood (e.g., Granat, Gadassi, Gilboa-Schechtman, & Feldman 2016; Poon, Watson, Baranek, & Poe, 2011; Siller & Sigman, 2002). However, few studies to date have examined the BAP beyond early childhood, and to our knowledge have only reported on observed difficulties on standardized measures. For example, in high-risk infant siblings with non-ASD developmental concerns in early childhood (e.g., language delays, BAP, global developmental delays), school age concerns have been document (e.g., language development, clinical concerns, social cognition, executive functioning; Gamliel et al., 2007; Miller et al., 2016; Shephard et al., 2016; Warren et al., 2011). Specific to BAP outcomes, Gamliel et al. (2007) followed children from 4 months to 7 years and identified significant group differences in language trajectories between BAP and TYP groups, such that on average the BAP group's receptive, expressive, and total language scores were lower than the TYP group from 14 to 54 months, respectively. In addition, Shephard et al. (2016) conducted a follow-up visit of infant siblings at 7 years of age and found significant group differences between their loosely defined BAP group (i.e., HR-Non-ASD) and TYP group, with lower adaptive functioning and evidence of restricted and repetitive behaviors as indexed by the ADOS in the BAP group. The school-age difficulties faced by children with BAP parallels those highlighted by early joint attention deficits/difficulties.

Although the direct relation between early joint attention and later developmental concerns were not directly assessed in this study, our findings do support a potential transactional pathway (Cicchetti, 2014; Sameroff & Fiese, 2000). Specifically, joint attention difficulty encompasses difficulties in using eye contact or gestures as a communicative tool. As social bids gain complexity with age (e.g., multimodal bids), these missed opportunities for clear communicative initiations and responses impact the ability to sustain high-quality engagement with a social partner (e.g., coordinated joint engagement with mother; Figure 5c), which in turn provides less opportunities for enriched language learning. Recognizing this possibility, recent intervention efforts have begun to include children at elevated risks for developmental concerns (e.g., BAP) in order to optimize their early developmental trajectories, prior to known developmental outcomes.

Implications for Intervention

Acknowledging the recent increase in researchers providing social communication interventions to families with infants at-elevated risks for an ASD within the first two years (e.g., Green et al., 2017; Jones et al., 2017; Rogers et al., 2014), the current study provides preliminary support for the need to continue targeting social communication development in high-risk infants. Particularly in the social domains of joint engagement and child/infant responsiveness. It is important to note that the majority of elevated-risk interventions to date include developmental functioning assessments and/or autism symptom severity assessments as part of their outcome measures to identify treatment effects (e.g., Rogers et al., 2012; Rogers et al., 2014; Watson et al., 2017); however, most of these studies have not been successful in identifying main effects for these measures. Alternatively, elevated-risk designs including behaviorally coded paradigms, such as a parent-child play interaction, have identified subtle, yet significant shifts in progress in either parent or child social behaviors after receiving treatment (e.g., Green et al., 2017; Jones et al., 2017; Kasari et al., 2014). For example, Green et al.'s (2017) intervention found reduced parental nondirectiveness towards their infants, as well as an increase in child attentiveness towards parents. Jones et al. (2017) reduced high-risk infants' habituation time towards pictures of faces. Additionally, in early childhood interventions for children with ASD, previous research highlights the importance of including parent-child constructs, such as responsiveness and joint engagement, to examine treatment effects (e.g., Shire, Gulsrud, & Kasari, 2016; Siller, Hutman, & Sigman, 2012). Within the present study, difficulties in joint engagement and child responsiveness were observed in the BAP group, which are highlighted as specific targets for early interventions and may provide concrete intervention trial outcome measures in at-risk intervention designs. Recognizing preliminary positive treatment effects with elevated-risk infants and their parents prior to known developmental outcomes, retrospective analyses such as in the current study, may continue to inform social constructs to target within an intervention setting (e.g., joint engagement).

Limitations

Overall the current study moves the field forward by exploring the importance of dyadic exchanges in the BAP. However, this study is not without limitations. In recognizing implications for future research, a brief discussion of several limitations in the current study is warranted. First, as with most prospective infant sibling designs, robust sample sizes across outcome classifications are difficult to achieve. Particularly within an infant sibling design, the majority of children are characterized as typically developing, followed by non-typical developmental concerns, and ASD, respectively. In the current study, 22 children were identified as exhibiting the BAP; however, at any given time point data were only included for a subset of these children due to various reasons (i.e., no visit at a particular age, mother not present at visit, child too distressed to complete the play task, and occasional camera malfunctions). Second, we recognize that by including the MSEL as part of the classification criteria and as a dependent variable in Aim 1, we have introduced circular logic. In addition, a more rigorous test of the clinically meaningful differences in dyadic exchanges observed for children with BAP would have been to include the subset of children diagnosed with ASD; however, within the current study's larger project, only six children received an ASD diagnosis, with a maximum of four children's behavioral data available at any given visit age.

Future Research

Behavioral coding methods developed to capture differences within a social context vary. As highlighted in the introduction, research teams often incorporate their own unique coding schemes, which make it difficult to directly compare results across studies (Halle et al., 2010). In addition, deciding whether to code social behaviors from a global or micro-analytic perspective may impact observable group differences. Though time-consuming, the inclusion of two distinct coding techniques in the current study (i.e., micro-analytic and global ratings), provides a deeper understanding of the observed behaviors. Specifically, as speculated in Yirmiya and Ozonoff (2007), in the current study children within the BAP group appeared to demonstrate relatively similar core social competencies as indexed by results obtained from the micro-analytic approach. However, disentangling the *intricate dance* at a minute level, may be especially salient when determining treatment effects, as it best represents the *process* for dyadic exchanges. This further highlights the importance of theoretical frameworks, such as the transactional model of human development, that recognize the need for detailed attention to bidirectional processes between parent and child, respectively (Sameroff, 2009, Sameroff & Fiese, 2000). In addition, attention to the social context surrounding a dyadic interaction may be especially important when measuring the quality of engagement between parent and child (e.g., supported versus coordinated joint engagement; Vygotsky, 1978). For example, Green et al. (2017) included two established behavioral coding schemes (global ratings and event-coding) to examine longitudinal treatment effects for their elevated-risk intervention and found that the global ratings more meaningfully captured select caregiver and child behaviors (i.e., caregiver nondirectiveness; child attentiveness) from the start of therapy; however, after 20 months of receiving the intervention, the event-coding approach more meaningfully captured the caregiver and child social behaviors. Thus the present study aimed to detect social difficulties in the BAP by the inclusion of multiple coding techniques. Overall the global ratings better captured dyadic differences between BAP and TYP in the current study. This may reflect that a micro-analytic approach is not as informative as global ratings; however, it is also important to note that the micro-analytic composites included in the current study were relatively rudimentary. More defined composites, built from the base micro-analytic codes (e.g., multimodal constructs, such as social smiling), may better 1) capture dyadic differences in BAP and 2) correlate with the joint engagement ratings in order to evaluate scheme similarities.

Coding schemes equipped to quantify qualitative differences in social behaviors may also be informative. With respect to instances of joint attention bids during structured assessments, previous research has identified group differences between lower and higher order bids in children with ASD. For example, Pickard and Ingersoll (2015) assessed lower-level (e.g., gaze shift) and higher-level (e.g., gaze + gesture) initiations of joint attention during the ESCS between children with ASD and their typically developing peers and found that higher level initiations were a better predictor of core social communicative deficiencies than lower-level, or combined overall total of initiations, respectively. The researchers noted that higher-level initiations seemed to be more indicative of spontaneously sharing experiences and required more social motivation. Similarly, as noted earlier, Yirmiya et al. (2006) identified significant differences in higher-order behavioral requests in children with the BAP but not in lower-level requests. Within the current study, the engagement ratings better captured social difficulties compared to the micro-analytic approach (i.e., dyadic synchrony; responsiveness). This likely reflects the embedded attention to the quality of dyadic interactions within the global rating scheme, as opposed to the micro-analytic approach, which involved creating composites based on frequencies of core social competencies (e.g., instances of eye gaze; See Tables 2-3; Appendices A and B). Overall, these examples highlight the importance quantifying qualitative differences may have on capturing social difficulties.

Close inspection of the videos used within this study revealed several qualitative elements that were not captured by the micro-analytic or global ratings. For example, deviations in social behaviors commonly observed in ASD, such as focusing on parts of a toy (e.g., baby-doll's eyes); however, for the joint engagement ratings, if these children still included mom in their play, the dyad received credit. Specific to the micro-analytic coding, playing with parts of a toy was captured by the *look object* code, and for children that continued to include mom during their fascination with parts of a toy (e.g., vocalizing to mom; gaze shifts), infant responsiveness and dyadic synchrony may have also been credited. There were also questionable brief episodes of 'sticky attention,' or staring with difficulties shifting attention, which have been associated with later ASD concerns (e.g., Sacrey, Bryson, & Zwaigenbaum, 2013). However, though at times attention appeared "sticky," these children were also able to connect this social difficulty with other elements of social behavior that again resulted in credit for a given social construct (e.g., coordinated joint engagement; responsiveness). Specific to language, neither the rating or micro-analytic coding schemes distinguished between instances of echoed or odd phrased speech, mixed with appropriate spontaneous language. These brief examples highlight some of the difficulties in meaningfully capturing subclinical features of ASD and provide us with considerations for future research.

In addition, infant sibling prospective designs are well suited for exploring dyadic contexts in the BAP. As highlighted in the introduction, recent studies have demonstrated that beyond the approximately 20% familial risk of a subsequent ASD diagnosis (Ozonoff et al., 2010), at least a fifth of the remaining 80% exhibit some features or characteristics of an ASD by 12 months of age (Messenger et al., 2013; Georgiades et al., 2013). Observations like these have likely contributed to the growing research base on elevated-risk interventions (prior to known diagnostic outcomes). To continue providing families support, while also minimizing unnecessary distress, developmental monitoring studies should examine difficulties in the BAP within a social context to provide a foundational understanding of observable similarities and differences between BAP, ASD, and TYP groups respectively, that may directly benefit elevated-risk intervention designs.

In sum, the present study moves the field forward by introducing the importance of longitudinally examining dyadic social constructs in the BAP within the first two years. By examining BAP and TYP group differences across four time points, the current study demonstrates that distinct patterns exist between BAP and TYP groups, such that the BAP group continues to perform lower than the TYP group across standardized measures and select dyadic constructs, as early as 15 months. The present study also highlights the potential importance of characterizing the BAP in early childhood to inform later development outcomes, recognizing traditional associations between social difficulties and later developmental concerns within the larger ASD literature. However, it is also important to consider the practical implications of characterizing subclinical populations, such as the BAP. At its core, ASD encompasses social difficulties with known cascading developmental effects if left untreated. Alternatively, though elements of social difficulties may be observed in the BAP, it is important for us to limit creating unnecessary distress on families by overpathologizing symptoms, while also advocating for opportunities that may promote optimal development (e.g., elevated-risk interventions).

Table 1. *Broader autism phenotype group criteria includes A, B, and at least one of C or D.*

Criteria List	
(A) Familial Risk	High-risk infant sibling
(B) Clinical Best Estimate [a]	Infant does not meet criteria for ASD classification
(C) MSEL [b]	At least 1 subscale 2 standard deviations below the mean, or at least 2 subscales 1.5 standard deviations below the mean
(D) ADOS [c]	Severity score at least 3 points below cut-off for ASD

Note. [a] See Ozonoff et al. (2014) for full description of BAP outcome criteria and clinical best estimate.
[b] MSEL has 5 subscales: Gross Motor, Fine Motor, Visual Reception, Receptive Language, and Expressive Language.
[c] Severity score cut-off varies across module and language level.

Table 2. *Frequency and proportion of visit attendance stratified by outcome status.*

		BAP	TYP
N		22	52
Laboratory Visit Attendance, *n*(%)			
	1 Visit	*1*(5%)	*5*(9%)
	2 Visits	*6*(27%)	*18*(35%)
	3 Visits	*6*(27%)	*14*(27%)
	4 Visits	*9*(41%)	*15*(29%)

Table 3. *Definitions of coding behaviors.*

Scheme	Code	Description
Micro-level Codes [a]		
	Look Face	Gaze directed towards the face of the play partner
	Look Object	Gaze directed towards an object between play partner
	Positive Affect	Displays smiles or laughter at play partner
	Vocalizations	Vocalizes using non-word sounds, words, or phrases directed at play partner
Ratings of Joint Engagement [b]		
	Total Joint	Time spent jointly engaged with play partner
	Supported Joint	Time and quality of object oriented engagement with play partner
	Coordinated Joint	Time and quality of object and directed play with play partner
	Child Responsiveness	How often child is responsive to play partner's bids

Note. [a] Each of these codes will have a total frequency and duration code. [b] Each of these codes is rated 1-7. See Appendices for excerpts from coding manuals.

Table 4. *Dyadic synchrony and responsiveness composite items.*

	Frequency		
Coded Behaviors	Dyadic Synchrony	Infant Responsiveness	Maternal Responsiveness
Shared Look Face Gaze	x		
Shared Positive Affect	x		
Mother-Led Look Face Gaze	x	x	
Mother-Led Look Object Gaze	x	x	
Mother-Led Positive Affect	x	x	
Mother-Led Vocalizations	x	x	
Infant-Led Look Face Gaze	x		x
Infant-Led Look Object Gaze	x		x
Infant-Led Positive Affect	x		x
Infant-Led Vocalizations	x		x

Note. Synchrony and responsiveness composites will be computed based on base micro-analytic codes.

Table 5. *Sample demographic information stratified by outcome status.*

	BAP	TYP
N	22	52
Infant sex, *n*(%)		
Male	*15*(68%)	*29*(56%)
Infant race, *n*(%)		
African American	*1*(~5%)	*1*(~1%)
Caucasian	*20*(91%)	*68*(92%)
Multiracial	*1*(~5%)	*3*(4%)
Other	*0*(0%)	*1*(~1%)
Unreported	*0*(0%)	*1*(~1%)
Outcome Characteristics		
Age in months, *M*(SD)	*31.83*(4.3)	*31.56*(4.4)
ADOS module, *n*(%)		
Toddler	*13*(59%)	*21*(40%)
Module 1	*2*(9%)	*0*(0%)
Module 2	*7*(32%)	*31*(60%)
ADOS symptom severity, *M*(SD)	*2.41*(1.5)	*1.24*(0.7)
MSEL verbal DQ, *M*(SD)	*85.26*(18.4)	*106.80*(16.0)
MSEL nonverbal DQ, *M*(SD)	*89.28*(11.3)	*108.06*(15.6)
Family Characteristics		
Household income, *n*(%)		
$20,000 or less	*2*(9%)	*1*(~2%)
$20,001 - $40,000	*9*(41%)	*5*(10%)
$40,001 - $60,000	*5*(23%)	*7*(13%)
$60,001 - $80,000	*2*(9%)	*17*(33%)
$80,001 - $100,000	*1*(~5%)	*10*(19%)
$100,001 - $125,000	*1*(~5%)	*6*(11%)
$125,001 - $150,000	*1*(~5%)	*1*(~2%)
$150,001 or higher	*1*(~5%)	*2*(4%)

Table 5 continued

Unreported	*0*(0%)	*3*(6%)
Maternal Characteristics		
Maternal age in years, *M*(SD)	*30.17*(4.2)	*31.67*(4.1)
Maternal education, *n*(%)		
High school or GED	*1*(~5%)	*2*(4%)
Trade or vocational	*2*(9%)	*0*(0%)
Associates or 2 year degree	*7*(32%)	*2*(4%)
Some college	*2*(9%)	*4*(8%)
College degree	*8*(36%)	*32*(62%)
Master's degree	*1*(~5%)	*9*(17%)
Professional degree	*1*(~5%)	*3*(6%)

Note: ADOS = Autism Diagnostic Observation Schedule. MSEL = Mullen Scales of Early Learning. DQ = Developmental Quotient.

Table 6. *Descriptive statistics and outcome group analyses (ANCOVAs) for MSEL and VABS at 12, 15, 18, and 24 months of age.*

	12 Months		**15 Months**		**18 Months**		**24 Months**	
	BAP	**TYP**	**BAP**	**TYP**	**BAP**	**TYP**	**BAP**	**TYP**
n	12	19	11	27	21	47	22	50
MSEL Mean (SE)								
Visual Reception	*14.6*(0.8)	*15.6*(0.3)	*17.6*(0.7)	*18.6*(0.3)	*19.5*(0.5)	*20.1*(0.3)	*24.2*(0.8)[i]	*26.1*(0.6)
Receptive Language	*11.6*(0.6)*	*13.4*(0.3)	*13.6*(0.3)	*14.7*(0.3)	*16.2*(1.0)	*18.1*(0.5)	*21.3*(1.0)[i]*	*25.7*(0.4)
Expressive Language	*11.7*(0.8)	*12.1*(0.6)	*13.5*(0.5)	*14.7*(0.5)	*15.4*(0.7)	*16.7*(0.3)	*18.9*(0.8)[i]*	*22.2*(0.5)
n	12	19	12	28	21	47	22	50
VABS Mean (SE)								
Socialization	*100.8* (2.9)	*99.0* (1.6)	*98.9* (3.0)	*99.8* (1.5)	*99.0* (1.8)	*100.7* (1.4)	*98.3* (2.2)*	*103.1* (1.1)
Communication	*94.8* (4.6)	*99.4* (2.4)	*95.3* (3.1)	*100.3* (1.5)	*92.1* (2.4)[im]	*97.7* (1.0)	*93.8* (2.8)*	*102.0* (1.1)

Notes: MSEL: Mullen Scales of Early Learning. VABS: Vineland Adaptive Behavior Scales. * p values < .05 are significant after adjusting for the 20 univariate analyses using the Benjamini-Hochberg false discovery rate procedure at $\alpha = 0.20$ level. [i] infant sex is a significant covariate. [m] maternal education is significant covariate.

Table 7. *Descriptive statistics and outcome group analyses (ANCOVAs) for dyadic play behaviors stratified by outcome status.*

	12 Months		**15 Months**		**18 Months**		**24 Months**	
	BAP	**TYP**	**BAP**	**TYP**	**BAP**	**TYP**	**BAP**	**TYP**
n	10	14	11	20	13	37	17	34
Microanalytic								
Mean (SE)								
DS[a]	*20.60*(3.30)	*26.07*(3.3)	*23.64*(3.31)	*26.90*(2.89)	*24.46*(2.77)	*26.35*(1.96)	*25.76*(3.12)	*27.94*(2.25)
IR[b]	*12.3*(1.77)	*15.36*(1.77)	*5.64*(2.10)*	*14.10*(1.78)	*13.23*(1.44)	*14.73*(1.03)	*14.18*(1.58)	*15.00*(1.19)
MR[c]	*8.30*(1.63)	*10.71*(1.65)	*11.23*(1.46)	*11.62*(1.00)	*20.60*(3.33)	*26.07*(3.30)	*11.59*(1.63)	*12.94*(1.12)
Global Ratings								
Mean (SE)								
TJE[d]	*4.50*(.22)	*4.07*(.29)	*3.64*(.28)*	*5.2*(.30)	*4.46*(.35)[m]	*4.89*(.20)	*4.12*(.33)*	*5.06*(.22)
SJE[e]	*4.80*(.20)	*4.29*(.35)	*3.91*(.29)[i]*	*5.1*(.20)	*4.69*(.29)[im]	*5.11*(.17)	*4.41*(.30)*	*5.15*(.19)
CJE[f]	*2.10*(.23)	*1.79*(.21)	*1.73*(.14)*	*2.8*(.19)	*1.69*(.18)	*2.00*(.13)	*2.12*(.17)	*2.38*(.18)
CR[g]	*3.80*(.29)	*3.93*(.27)	*4.27*(.24)	*4.55*(.21)	*3.69*(.21)*	*4.44*(.18)	*3.88*(.32)	*4.35*(.21)

Note: *p* values < .05 are significant after adjusting for the 28 univariate analyses using the Benjamini-Hochberg false discovery rate procedure at α = 0.20 level. [a] DS = Dyadic synchrony. [b] IR = Infant responsiveness from micro-analytic coding. [c] MR = Maternal responsiveness. [d] TJE = Total joint engagement. [e] SJE = Supported joint engagement. [f] CJE = Coordinated joint engagement. [g] CR = Child responsiveness from rating scale. [i] Infant sex is a significant covariate. [m] Maternal education is significant covariate.

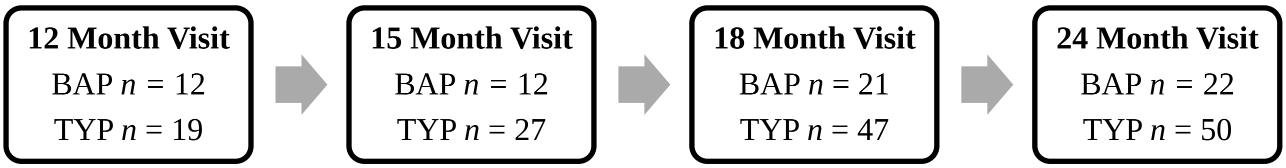

Figure 1. Participant visit attendance stratified by outcome group.

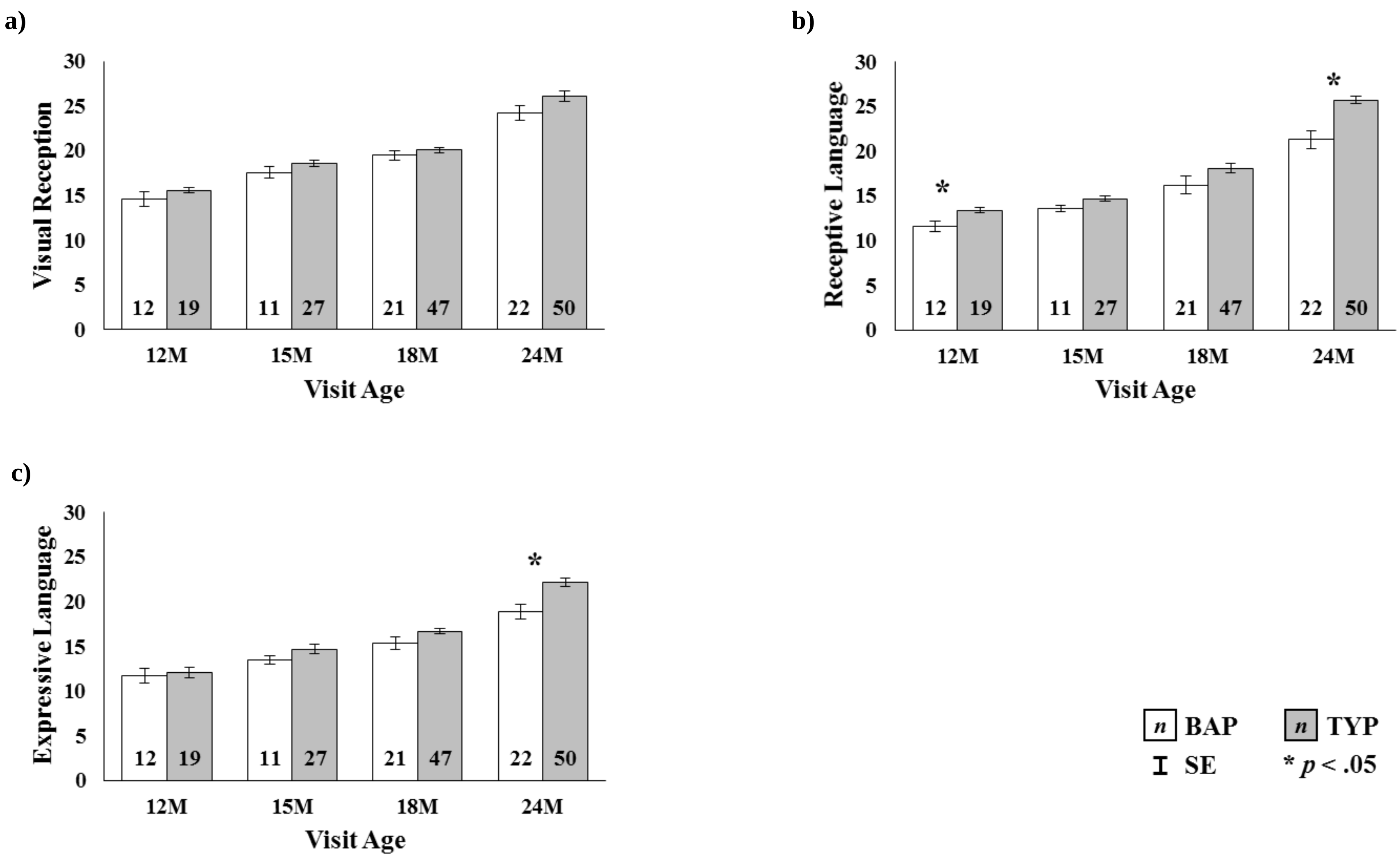

Figure 2. BAP and TYP group MSEL raw scores for (a) visual reception, (b) receptive language, and (c) expressive language.

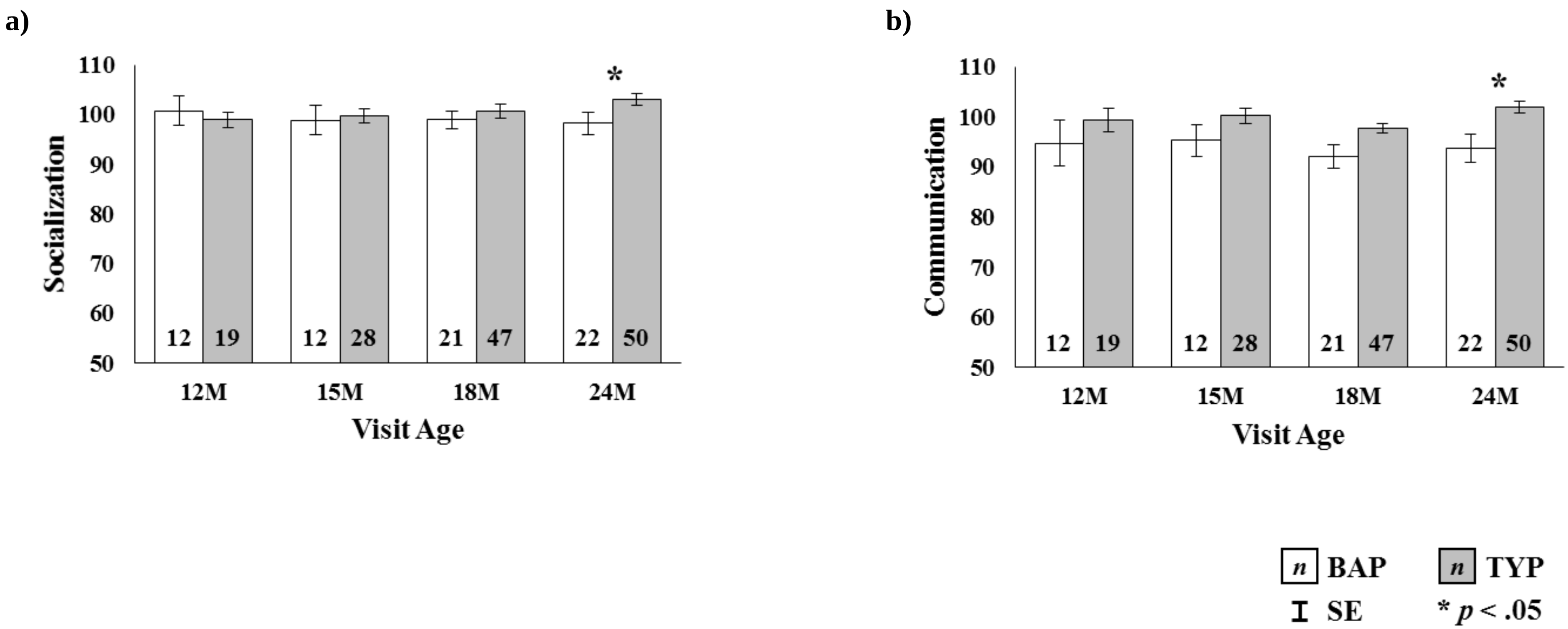

Figure 3. BAP and TYP group VABS standard scores for (a) socialization, (b) communication.

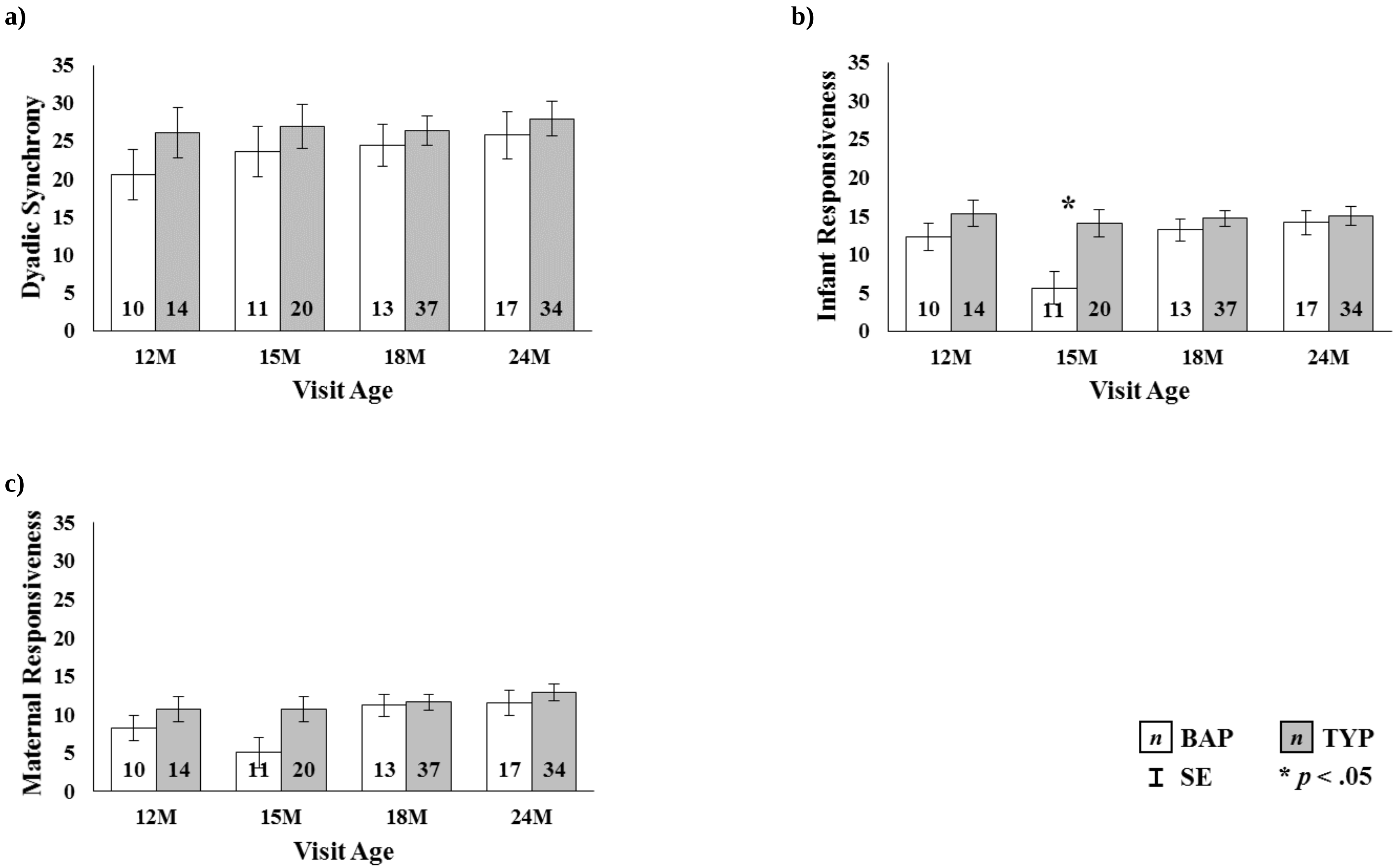

Figure 4. BAP and TYP group means and standard errors for micro-analytic codes (a) dyadic synchrony, (b) infant responsiveness, and (c) maternal responsiveness

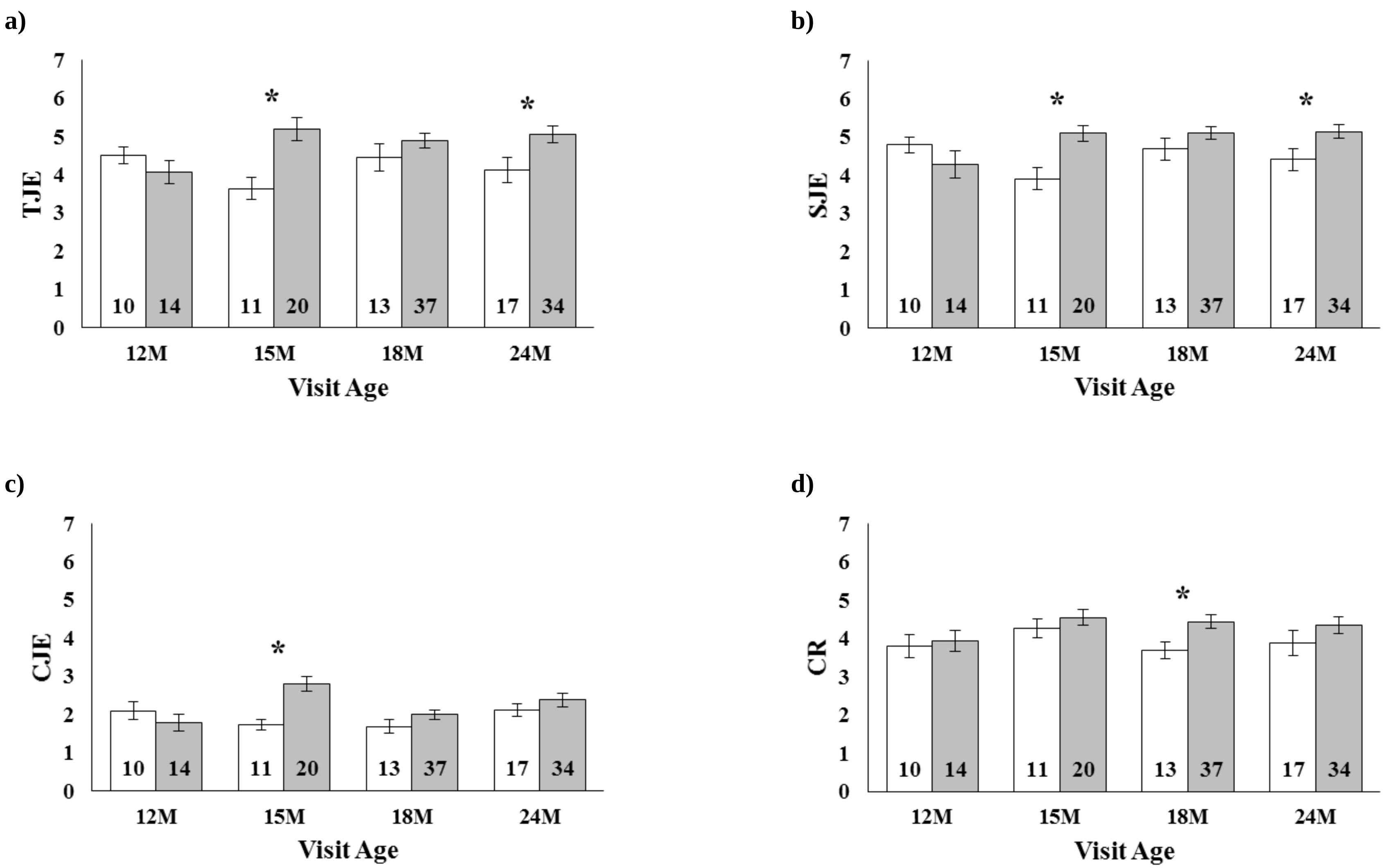

Figure 5. BAP and TYP group ratings for (a) total joint engagement, (b) supported joint engagement, (c) coordinated joint engagement, (d) child responsiveness.

n BAP *n* TYP
I SE * $p < .05$

REFERENCES

Adamson, L. B., Bakeman, R., Deckner, D. F., & Nelson, B. P. (2014). From interactions to conversations: The development of joint engagement during early childhood. *Child Development*, *85*, 941-955. doi:10.1111/cdev.12189

Adamson, L. B., Bakeman, R., Deckner, D. F., & Nelson, P. B. (2012). Rating parent-child interactions: Joint engagement, communication dynamics, and shared topics in autism, Down syndrome, and typical development. *Journal of Autism and Developmental Disorders*, *42*, 2622-2635. doi:10.1007/s10803-012-1520-1

Adamson, L. B., Bakeman, R., & Suma, K. (2016). *The Joint Engagement Rating Inventory* (Tech Report 25). Atlanta, GA: Georgia State University, Department of Psychology.

Autism and Developmental Disabilities Monitoring Network. (2007). Prevalence of autism spectrum disorders–autism and developmental disabilities monitoring network, 14 sites, United States, 2002. *MMWR Surveillance Summaries*, *56*, 12-28.

Austin, S., Dialsingh, I., & Altman, N. (2014). Multiple hypothesis testing: A review. *Journal of the Indian Society of Agricultural Statistics*, *68*, 1-23.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed., text rev.). Arlington, VA: American Psychiatric Publishing.

Bakeman, R., & Adamson, L. B. (1984). Coordinating attention to people and objects in mother – infant and peer –infant interaction. *Child Development*, *55*, 1278-1289. doi: 10.2307/1129997

Bakeman, R., & Quera, V. (2011). *Sequential analysis and observational methods for the behavioral sciences*. Cambridge, UK: Cambridge University Press.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5-17. doi:10.1023/A:1005653411471

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*. *Series B Methodological, 57*, 289-300. doi:10.2307/2346101

Bennett, T. A., Szatmari, P., Bryson, S., Duku, E., Vaccarella, L., & Tuff, L. (2012). Theory of mind, language and adaptive functioning in ASD: A neuroconstructivist perspective. *Journal of the Canadian Academy of Child and Adolescent Psychiatry*, *22*, 13-19.

Blacher, J., Baker, B. L. & Kaladjian, A. (2013). Syndrome specificity and mother-child interactions: Examining positive and negative parenting across contexts and time. *Journal of Autism and Developmental Disorders*, *43*, 761-774. doi:10.1007/s10803-012-1605-x

CDC. (2014). Prevalence of autism spectrum disorders—ADDM Network. *MMWR Surveill Summ*, *63*, 1-22.

CDC (2016). Act Early Campaign. Retrieved from http://www.cdc.gov/ncbddd/actearly/-index.html

Charman, T., Young, G. S., Brian, J., Carter, A., Carver, L. J., Chawarska, K., … Zwaig-enbaum, L. (2017). Non-ASD outcomes at 36 months in siblings at familial risk for autism spectrum disorder (ASD): A baby siblings research consortium (BSRC) study. *Autism Research, 10*, 169-178. doi:10.1002/aur.1669

Charwaska, K., Shic, F., Macari, S., Campbell, D. J., Brian, J., Landa, R., Hutman, T., … Bryson, S. (2014). 18-month predictors of later outcomes in younger siblings of children with autism spectrum disorder: A baby siblings research consortium study. *Journal of the American Academy of Child & Adolescent Psychiatry*, *53,* 1317-1327. doi:10.1016/j.jaac.2014.09.015

Cicchetti, D. (2014). Illustrative developmental psychopathology perspectives on precursors and pathways to personality disorder: Commentary on the special issue. *Journal of Personality Disorders, 28*, 172-179. doi:10.1521/pedi.2014.28.1.172

Clifford, S. M., Hudry, K., Elsabbagh, M., Charman, T., Johnson, M. H., & the BASIS Team. (2012). Temperament in the first 2 years of life in infants at high-risk for autism spectrum disorders**.** *Journal of Autism and Developmental Disorders, 43*, 673-686. doi:10.1007/s10803-012-1612-y

Constantino, J. N. (2002). *The Social Responsiveness Scale*. Los Angeles: Western Psychological Services.

Constantino, J. N., Zhang, Y., Frazier, T., Abbacchi, A. M., & Law, P. (2010). Sibling recurrence and the genetic epidemiology of autism. *American Journal of Psychiatry*, *167*, 1349-1356. doi:10.1176/appi.ajp.2010.09101470

Cornew, L., Dobkins, K. R., Akshoomoff, N., McCleery, J. P., Carver, L. J. (2012). Atypical social referencing in infant siblings of children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *42*, 2611-2621. doi:10.1007/s10803-012-1518-8

Dawson, G. (2008). Early behavioral intervention, brain plasticity, and the prevention of autism spectrum disorder. *Development and Psychopathology*, *20*, 775-803. doi:10.1017/S0954579408000370

Dawson, G., & Bernier, R. (2013). A quarter century of progress on the early detection and treatment of autism spectrum disorder. *Developmental Psychopathology*, *4*, 1455-1472. doi:10.1017/S0954579413000710.

Dawson, G., Estes, A., Munson, J., Schellenberg, G., Bernier, R., & Abbott, R. (2007). Quantitative assessment of autism symptom-related traits in probands and parents: Broader phenotype autism symptom scale. *Journal of Autism and Developmental Disorders*, *37,* 523-536. doi:10.1007/s10803-006-0182-2

Dawson, G., Webb, S., Schellenberg, G. D., Dager, S., Friedman, S., Aylward, E., & Richards, T. (2002). Defining the broader phenotype of autism: Genetic, brain, and behavioral perspectives. *Development and Psychopathology, 14,* 581-611. doi: 10.1017/S0954579402003103

DeCarlo, L. T. (1997). On the meaning and use of kurtosis. *Psychological Methods*, *2*, 292-307. doi:10.1037//1082-989X.2.3.292

Esler, A. N., Bal, V. H., Guthrie, W., Wetherby, A., Weismer, S. E., & Lord, C. (2015). The autism diagnostic observation schedule, toddler module: Standardized severity scores. *Journal of Autism and Developmental Disorders*, *45*, 2704-2720. doi:10.1007/s10803-015-2432-7

Estes, A., Sullivan, K., Greenson, J., Winter, J., Dawson, G., & Munson, J. (2013). Parenting-related stress and psychological distress in mothers of toddlers with autism spectrum disorders. *Brain & Development*, *35*, 133-138. doi:10.1177/1362361309105658

Feldman, R. (2003). Infant-mother and infant-father synchrony: The coregulation of positive arousal. *Infant Mental Health Journal*, *24*, 1-23. doi:10.1002/imhj.10041

Feldman, R. (2007). Parent-infant synchrony and the construction of shared timing: Physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry*, *48*, 329-354. doi:10.1111/j.1469-7610.2006.01701.x

Feldman, R. (2015). The adaptive human parental brain: Implications for children's social development. *Trends in Neurosciences*, *38*, 387-399. doi:10.1016/j.tins.2015.04.004

Freeman, S. & Kasari, C. (2013). Parent-child interactions in autism: Characteristics of play. *Autism*, *17*, 147-161. doi:10.1177/1362361312469269

Fogel, A. (1993). Two principles of communication: Co-regulation and framing. In J. Nadel & L. Camaioni (Eds.), *New perspective in early communicative development* (pp. 9–22). London: Routledge.

Gamliel, I., Yirmiya, N., Jaffe, D. H., Manor, O., & Sigman, M. (2009). Developmental trajectories in siblings of children with autism: cognition and language from 4 months to 7 years. *Journal of Autism and Developmental Disorders*, *39*, 1131-1144. doi:10.1007/s10803-009-0727-2

Georgiades, S., Szatmari, P., Zwaigenbaum, L., Bryson, S., Brian, J., Roberts, W. … Garon, N. (2013). A prospective study of autistic-like traits in unaffected siblings of probands with autism spectrum disorder. *Journal of the American Medical Association Psychiatry*, *70*, 42-48. doi:10.1001/2013.jamapsychiatry.1

Gerdts, J., & Bernier, R. (2011). The broader autism phenotype and its implications on the etiology and treatment of autism spectrum disorders. *Autism Research and Treatment*, *2011*, 1-19. doi:10.1155/2011/545901

Gotham, K., Pickles, A., & Lord, C. (2009). Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *39*, 693-705. doi:10.1007/s10803-008-0674-3

Granat, A., Gadassi, R., Gilboa-Schechtman, E., & Feldman, R. (2017). Maternal depression and anxiety, social synchrony, and infant regulation of negative and positive emotions. *Emotion, 17,* 11-27. doi:10.1037/emo0000204

Green, J., Charman, T., Pickles, A., Wan, M. W., Elsabbagh, M., Slonims, V., … Johnson, M. H. (2015). Parent-mediated intervention versus no intervention for infants at high risk of autism: A parallel, single-blind, randomised trial. *Psychiatry, 2*, 133-140. doi:10.1016/S2215-0366(14)00091-1

Green, J., Pickles, A., Pasco, G., Bedford, R., Wan, M. W., Elsabbagh, M., … Johnson, M. H. (2017). Randomised trial of a parent-mediated intervention for infants at high risk for autism: Longitudinal outcomes to age 3 years. *Journal of Child Psychology and Psychiatry*. doi:10.1111/jcpp.12728

Green, J., Wan, M. W., Guiraud, J., Holsgrove, S., McNally, J., Slonims, V., … Johnson, M. H. (2013). Intervention for infants at risk of developing autism: A case series. *Journal of Autism and Developmental Disorders, 43,* 2502-2514. doi:10.1007/s10803-013-1797-8

Halle, T., Anderson, R., Blasberg, A., Chrisier, A., & Simkin, S. (2011). Quality of caregiver-child interactions for infants and toddlers (Q-CCIT). A review of the literature. OPRE 2011-25. Washington, DC: Office of Planning, Research and Evaluation, Administration of Children and Families, US Department of Health and Human Services.

Horlin, C., Falkmer, M., Parsons, R., Albrecht, M. A., & Falkmer, T. (2014). The cost of autism spectrum disorders. *PLoS ONE*, *9,* e106552. doi:10.1371/journal.pone.0106552

Howell, D. C. (2010). *Statistical methods for psychology*. Belmont, CA: Thomson Wadsworth.

Hurley, R. S. E., Losh, M., Parlier, M., Reznick, J. S., & Piven, J. (2007). The broad autism phenotype questionnaire. *Journal of Autism and Developmental Disorders, 37,* 1679-1690. doi:10.1007/s10803-006-0299-3

Ibanez, L. V., Grantz, C. J., & Messinger, D. S. (2013). The development of referential communication and autism symptomology in high-risk infants. *Infancy*, *18*, 687-707. doi:10.1111/j.1532-7078.2012.00142.x

Jones, E., Gliga, T., Bedford, R., Charman, T., & Johnson, M. H. (2014). Developmental pathways to autism: A review of prospective studies of infants at risk. *Neuroscience and Biobehavioral Reviews*, *39,* 1-33. doi:10.1016/j.neubiorev.2013.12.001

Kristen, S., Sodian, B., Thoermer, C., & Perst, H. (2011). Infants' joint attention skills predict toddlers' emerging mental state language. *Developmental Psychology*, *47,* 1207-1219. doi:10.1037/a0024808

Landa, R., Gross, A. L., Stuart, E. A., & Bauman, M. (2012). Latent class analysis of early developmental trajectory in baby siblings of children with autism. *Journal of Child Psychology and Psychiatry*, *53*, 986-996. doi:10.1111/j.1469-7610.2012.02558.x

Liu, X., Zou, H., & Brown, W. T. (2012). Genes associated with autism spectrum disorder. *Brain Research Bulletin*, *88,* 543-552. doi:10.1016/j.brainresbull.2012.05.017

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., & DiLavore, P. C. (2000). The Autism Diagnostic Observation Schedule—Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*, 205-223. doi:10.1023/A:1005592401947

Mandy, W., & Lai, M. C. (2016). Annual research review: The role of the environment in the developmental psychopathology of autism spectrum condition. *Journal of Child Psychology and Psychiatry*, *57*, 271-292. doi:10.1111/jcpp.12501

Maxwell, C. R., Parish-Morris, J., Hsin, O., Bush, J. C., & Schultz, R. T. (2013). The broad autism phenotype predicts child functioning in autism spectrum disorders. *Journal of Neurodevelopmental Disorder*, *5*, 25-32. doi:10.1186/1866-1955-5-25.

Messinger, D., Young, G. S., Ozonoff, S., Dobkins, K., Carter, A., Zwaigenbaum, L., …Sigman, M. (2013). Beyond autism: A baby siblings research consortium study of high-risk children at three years of age. *Journal of the American Academy of Child & Adolescent Psychiatry*, *52*, 300-308. doi:10.1016/j.jaac.2012.12.011

Miller, M., Iosif, A. M., Young, G. S., Hill, M., Hanzel, E. P., Hutman, T., … Ozonoff, S. (2016). School-age outcomes of infants at risk for autism spectrum disorder. *Autism Research*, *9*, 632-642. doi:10.1002/aur.1572

Mullen, E. M. (1995). *Mullen scales of early learning* (AGS ed.), Circle Pines, MN: American Guidance Service.

Mundy, P., Block, J., Delgado, C. Pomares, Y., Van Hecke, A. V, & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Development*, *78*, 938-954. doi:10.1111/j.1467-8624.2007.01042.x

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). *Early Social Communication Scales (ESCS)*. Coral Gables, FL: University of Miami.

Mundy, P., & Newell, L. (2007). Attention, joint attention, and social cognition. *Current Directions in Psychological Science*, *16*, 269-274. doi:10.1111/j.1467-8721.2007.00518.x

Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the social deficits of autism: The contribution of non-verbal communication measures. *Journal of Child Psychology*, *27*, 657-669. doi:10.1111/j.1469-7610.1986.tb00190.x

Ozonoff, S., Iosif, A. M., Baguio, F., Cook, I. C., Hill, M. M., Hutman, T., … Young, G. S. (2010). A prospective study of the emergence of early behavioral signs of autism. *Journal of the American Academy of Child Adolescent Psychiatry*, *49*, 256-266. doi: 10.1016/j.jaac.2009.11.009

Ozonoff, S., Young, G. S., Belding, A., Hill, M., Hill, A., Hutman, T., … Iosif, A. M. (2014). The broader autism phenotype in infancy: When does it emerge? *Journal of the American Academy of Child & Adolescent Psychiatry*, *53*, 398-407. doi: 10.1016/j.jaac.2013.12.020

Ozonoff, S., Young, G. S., Carter, A., Messinger, D., Yirmiya, N., Zwaigenbaum, L., … Stone, W. L. (2011). Recurrence risk for autism spectrum disorders: A baby siblings research consortium study. *Pediatrics, 128*, e488-e495. doi:10.1542/peds.2010-2825

Ozonoff, S., Young, G. S., Landa, R. J., Brian, J., Bryson, S., Charman, T., … Iosif, A. M. (2015). Diagnostic stability in young children at risk for autism spectrum disorder: a baby siblings research consortium study. *Journal of Child Psychology and Psychiatry, 56*, 988-998. doi:10.1111/jcpp.12421

Pickard, K., & Ingersoll, B. (2015). Brief report: High and low level initiations of joint attention, and response to joint attention--Differential relationships with language and imitation. *Journal of Autism and Developmental Disorders*, *45*, 262-268. doi: 10.1007/s10803-014-2193-8

Pisula, E., & Ziegart-Sadowska, K. (2015). Broader autism phenotype in siblings of children with ASD: A review. *International Journal of Molecular Science*, *16*, 13217-13258. doi:10.3390/ijms160613217

Poon, K. K., Watson, L. R., Baranek, G. T., & Poe, M. D. (2012). To what extent do joint attention, imitation, and object play behaviors in infancy predict later communication and intellectual functioning in ASD? *Journal of Autism and Developmental Disorders*, *42*, 1064-1074. doi:10.1007/s10803-011-1349-z

Rice, M. L., & Wexler, K. (2001). *Rice/Wexler test of early grammatical impairment*. San Antonio, TX: The Psychological Corporation.

Rozga, A., Hutman, T., Young, G. S., Rogers, S. J., Ozonoff, S., Dapretto, M., & Sigman, M. (2011). Behavioral profiles of affected and unaffected siblings of children with autism: Contribution of measures of mother-infant interaction and nonverbal communication. *Journal of Autism and Developmental Disorders*, *41*, 287-301. doi:10.1007/s10803-010-1051-6

Rutter, M. (2013). Developmental psychopathology: A paradigm shift or just a relabeling? *Development and Psychopathology Development and Psychopathology*, *25*, 1201-1213. doi:10.1017/S0954579413000564

Ruzich, E., Allison, C., Smith, P., Watson, P., Auyeung, B., Ring, H., & Baron-Cohen, S. (2015). Subgrouping siblings of people with autism: Identifying the broader autism phenotype. *Autism Research*, *9*, 658-665. doi:10.1002/aur.1544

Sacrey, L. A. R., Bryson, S., & Zwaigenbaum, L.(2013). Prospective examination of visual attention during play in infants at high-risk for autism spectrum disorder: A longitudinal study from 6 to 36 months of age. *Behavioral Brain Research*, *256*, 441-450. doi:10.1016/j.bbr.2013.08.028

Sacrey, L. A. R., Zwaigenbaum, L., Bryson, S., Brian, J., Smith, I. M., Roberts, W., … Armstrong, V. (2015). Can parents' concerns predict autism spectrum disorder? A prospective study of high-risk siblings from 6 to 36 months of age. *Journal of the American Academy of Child & Adolescent Psychiatry*, *54*, 470-478. doi:10.1016/j.jaac.2015.03.014

Sameroff, A. (Ed.). (2009). *The transactional model of development: How children and contexts shape each other*. Washington, DC, US: American Psychological Association.

Sameroff, A. J., & Fiese, B. H. (2000). Models of development and developmental risk. In C. H. Zeanah (Ed.), *Handbook of infant mental health* (2nd ed., pp. 3–19). New York: Guilford Press.

Sasson, N. J., Lam, K. S. L., Childress, D., Parlier, M., Daniels, J. L., & Piven, J. (2014). The broad autism phenotype questionnaire: Prevalence and diagnostic classification. *Autism Research*, *6*, 134-143. doi:10.1002/aur.1272

Schwichtenberg, A. J., Kellerman, A. M., Abu-Zhaya, R., Young, G. S., Miller, M., & Ozonoff, S. (in preparation). Dyadic synchrony and responsiveness in the first year.

Schwichtenberg, A. J., Kellerman, A. M., Young, G. S., Miller, M., & Ozonoff, S. (in review). Mothers of children with autism spectrum disorders: Play behaviors with infant siblings and social responsiveness.

Schwichtenberg, A. J., Young, G. S., Sigman, M., Hutman, T., & Ozonoff, S. (2010). Can family affectedness inform infant sibling outcomes of autism spectrum disorders? *Journal of Child Psychology and Psychiatry*, *51*, 1021-1030. doi:10.1111/j.1469-7610.2010.02267.x

Scott, F. J., Baron-Cohen, S., Bolton, P., & Brayne, C. (2002). Brief report: Prevalence of autism spectrum conditions in children aged 5–11 years in Cambridgeshire, UK. *Autism, 6*, 231-237. doi:10.1177/1362361302006003002

Shephard, E., Milosavljevic, B., Pasco, G., Jones, E. J. H., Gliga, T., Happe, F., Johnson, M. H., Charman, T., & BASIS Team. (2016). Mid-childhood outcomes of infant siblings at familial high-risk of autism spectrum disorder. *Autism Research*, *10*, 546-557. doi: 10.1002/aur.1733

Shire, S. Y., Gulsrud, A., & Kasari, C. (2016). Increasing responsive parent-child interactions and joint engagement: Comparing the influence of parent-mediated intervention and parent psychoeducation. *Journal of Autism and Developmental Disorders*, *46*, 1737-1747. doi:10.1007/s10803-016-2702-z

Siller, M., Hutman, T., & Sigman, M. (2012). A parent-mediated intervention to increase responsive parental behaviors and child communication in children with ASD: A randomized clinical trial. *Journal of Autism and Developmental Disorders, 43*, 540-555. doi:10.1007/s10803-011-1349-z

Siller, M. & Sigman, M. (2002). The behaviors of parents of children with autism predict the subsequent development of their children's communication. *Journal of Autism and Developmental Disorders, 32*, 77-89. doi:10.1023/A:1014884404276

Small, N. J. H. (1980). Marginal skewness and kurtosis testing multivariate normality. *Journal of the Royal Statistical Society Series C Applied Statistics*, *29*, 85-87. doi: 10.2307/2346414

Sparrow, S. S., Balla, D. A., & Cicchetti, D. V. (1984). *Vineland Adaptive Behavior Scales*. Minneapolis, MN: American Guidance.

Stern, D. N. (1985). *The interpersonal world of the infant: A view from psycho-analysis and developmental psychology*. New York, NY: Basic Books.

Sucksmith, E., Roth, I., & Hoekstra, A. (2011). Autistic traits below the clinical threshold: Re-examing the broader autism phenotype in the 21st century. *Neuropsychological Review*, *21*, 360-389. doi:10.1007/s11065-011-9183-9

Sullivan, M., Finelli, J., Marvin, A., Garrett-Mayer, E., Bauman, M., & Landa, R. (2007). Response to joint attention in toddlers at risk for autism spectrum disorder: A prospective study. *Journal of Autism and Developmental Disorders*, *37*, 37-48. doi:10.1007/s10803-006-0335-3

Szatmari, P., Chawarska, K., Dawson, G., Georgiades, S., Landa, R., Lord, C., … Halladay, A. (2016). Prospective longitudinal studies of infant siblings of children with autism: Lessons learned and future directions. *Journal of the American Academy of Child & Adolescent Psychiatry*, *55*, 179-187. doi:10.1016/j.jaac.2015.12.014

Toth, K., Dawson, G., Meltzoff, A. N., Greenson, J., & Fein, D. (2007). Early social, imitation, play, and language abilities of young non-autistic siblings of children with autism. *Journal of Autism and Developmental Disorders*, *37*, 145-157. doi:10.1007/s10803-006-0336-2

Tronick, E., Als, H., Adamson, L. B., Wise, S., & Brazelton, T. B. (1978). The infant's response to entrapment between contradictory messages in face-to-face interaction. *Journal of Child Psychiatry*, *17*, 1-13. doi:10.1016/S0002-7138(09)62273-1

Tronick, E., & Cohn, J. F. (1989). Infant-mother face-to-face interaction: Age and gender differences in coordination and the occurrence of miscoordination. *Child Development*, *60*, 85-92. doi: 10.1111/j.1467-8624.1989.tb02698.x

Tudge, J. R. H., & Winterhoff, P. A. (1993). Vygotsky, Piaget, and Bandura: Perspectives on the relations between the social world and cognitive development. *Human Development*, *36*, 61-81. doi:10.1159/000277297

Vygotksy, L. S. (1978). *Mind in Society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wan, M. W., Brooks, A., Green, J., Abel, K., & Elmadih, A. (2016). Psychometrics and validation of a brief rating measure of parent-infant interaction: Manchester assessment of caregiver–infant interaction. *International Journal of Behavioral Development*, *41*, 542-549. doi:10.1177/0165025416631835.

Wan, M. W., Green, J., Elsabbagh, M., Johnson, M., Charman, T., Plummer, F. (2013). Quality of interaction between at-risk infants and caregiver at 12-15 months is associated with 3-year autism outcome. *Journal of Child Psychology and Psychiatry, 54*, 763-771. doi:10.1111/jcpp.12032

Warren, Z. E., Foss-Feig, J. H., Malesa, E. E., Lee, E. B., Taylor, J. L., Newsom, C. R., Crittendon, J., & Stone, W. L. (2011). Neurocognitive and behavioral outcomes of younger siblings of children with autism spectrum disorder at age five. *Journal of Autism and Developmental Disorders*, *42*, 409-418. doi:10.1007/s10803-011-1263-4

Wheelwright, S., Auyeung, B., Allison, C., & Baron-Cohen, S. (2010). Defining the broader, medium, and narrow phenotype among parents using the Autism Spectrum Quotient (AQ). *Molecular Autism*, 1:10. doi:10.1186/2040-2392-1-10.

Yirmiya, N., Gamliel, I., Pilowsky, T., Feldman, R., Baron-Cohen, S., & Sigman, M. (2006). The development of siblings of children with autism at 4 and 14 months: Social engagement, communication, and cognition. *Journal of Child Psychology and Psychiatry*, *47*, 511-523. doi:10.1111/j.1469-7610.2005.01528.x

Yirmiya, N., & Ozonoff, S. (2007). The very early autism phenotype. *Journal of Autism and Developmental Disorders*, *37*, 1-11. doi:10.1007/s10803-006-0329-1

Zwaigenbaum, L., Bryson, S. E., & Garon, N. (2013). Early identification of autism spectrum disorders. *Behavioural Brain Research*, *251*, 133-146. doi:10.1016/j.bbr.2013.04.004

Zwaigenbaum, L., Bryson, S. E., Szatmari, P., Brian, J., Smith, I. M., Roberts, W., … Roncadin, C. (2012). Sex differences in children with autism spectrum disorder identified within a high-risk infant cohort. *Journal of Autism and Developmental Disorders*, *42*, 2285-2596. doi:10.1007/s10803-012-1515-y

APPENDIX A.

Parent Child Play Behavior Coding Project: Gaze, Affect, and Vocalizations

Excerpt from Ozonoff et al., 2010:

Code	*When to code*
look face	Target's face is on-screen and oriented towards an on-screen partner's face Target's face is on-screen and a portion of the partner's body is visible to visualize location of face from child's perspective Gaze shift to off-screen partner 's face is linked to the on-set of an off-screen voice Partner says something indicating that the target is looking at face: "Oh, now you're looking at me." If target looks off-screen and then partner comes into view at location the target is fixating, back up and code "look face" from fixation point If gaze fixates to point off-screen where you recently saw the partner's face and you are mostly sure that her location is maintained, code "look face".
look object	Target's face is on-screen and looking at an object that: ○ is part of current task (e.g. all toys in box) ○ was previously used in a task ○ was used as a reinforcer (i.e. toy cars or child's blanket or pacifier) If gaze fixates to point off-screen where you recently saw the object and you are mostly sure that the location is maintained, code "look object".
Positive Affect	Code when target is displaying positive affect (ALL INTENSITIES). Examples: • you can see (at least) one corner of the mouth up-turn • you can hear the child laughing A smile can be seen in the corners of the mouth (one or both sides upturned) or in the eyes (flexed orbicularis oculi muscle which raises the cheeks and forms crow's feet around the eyes). A laugh shows emotion (i.e., joy) with a chuckle or explosive vocal sound.
Vocal start	Code at the start of any vocalization, which may include but is not limited to: • Non-verbal sounds (open vowels like aaah or ooh, consonant vowel combinations like gagaga, laughter , cry, coo, lip smacks, breaths, lip raspberries) • Single words or word approximations (ball or bah) • Multi word phrases (bye-bye ball)

APPENDIX B.

Joint Engagement Rating Inventory: Technical Report 25.

Excerpt from Adamson, Bakeman, & Suma, 2016.

	Anchors		
Item	**1 =**	**4 =**	**7 =**
1. Total joint engagement	No episodes of the joint engagement state	In joint engagement for approximately half of the scene (displays several brief or a few relatively sustained episodes)	Almost always in the joint engagement state
2. Supported joint engagement	No episodes of the supported joint engagement state	Spends about a third of the scene in supported joint engagement that is of moderate quality, or briefly in supported joint engagement in a highly striking manner	Frequently in rich and varied episodes of supported joint engagement
3. Coordinated joint engagement	No episodes of the coordinated joint engagement state	Spends about a third of the scene in coordinated joint engagement that is of moderate quality, or briefly in coordinated joint engagement in a strikingly high quality manner	Frequently in rich and varied episodes of coordinated joint engagement
4. Child's responsiveness to partner's communication	Almost always resists or ignores bids	Responds to bids regularly but not continually	Complies with and anticipates almost every bid