EXPLORING THE ROLE OF EYE CONTACT IN EVERYDAY INTERACTIONS: JOINT ENGAGEMENT, CAREGIVER INPUT, AND LANGUAGE DEVELOPMENT IN INFANT SIBLINGS OF CHILDREN WITH AUTISM SPECTRUM DISORDER

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The present study examined early interactions between infants at heightened risk (HR) for autism spectrum disorder (ASD) and their caregivers in order to better understand the social-communicative environment and its relation to language outcomes in this population. Joint engagement (JE) in HR infants (i.e., younger siblings of children with ASD) has primarily been studied in structured experimenter-infant interactions with a focus on eye contact (i.e., coordinated JE). However, recent work suggests JE without eye contact (i.e., supported JE) in naturalistic interactions is particularly important for language development. Videotaped toy play interactions in the home between 12- and 18-month old infants (at high and low risk for ASD) and their caregivers were coded into mutually exclusive engagement states, and contingent caregiver utterances and labels were coded and examined in relation to language in toddlerhood. HR infants were evaluated for diagnostic outcome at 36 months and classified into three groups: ASD, language delay but no ASD (HR-LD), and no diagnosis (HR-ND). Supported JE was prevalent in the interactions across outcome groups, while both HR-LD and HR-ASD infants spent less time in coordinated JE than their typically developing peers by 18 months. HR infants as a group spent more time solely engaged with objects and less time unengaged than their low risk peers. While caregivers provided similar rates of contingent input and labels across outcome groups, an increase in labels during coordinated JE from 12 to 18 months was apparent for HR-

LD and HR-ASD infants. Furthermore, higher rates of labels during coordinated JE were associated with lower toddlerhood language scores for these groups. Findings suggest that parents may pick up on subtle differences in the second year of life and increase the number of labels they provide, but that this simply may not be enough to bolster language development for infants already on a path to communicative delays. This research highlights supported JE as a potential context for early interventions with HR infants, and a critical goal for future research will be to determine what aspects of caregiver input, at what points in development, are most effective for language learning in this population.

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PREFACE

I would like to thank my advisor, Dr. Jana Iverson for her guidance and support through this process. I would also like to thank my fellow graduate students and the staff of the Infant Communication Lab for their encouragement and support, as well as my undergraduate coders, Alyssa Cooper, Alyson Menzies, Amanda Shields, and Sydney Tan. Finally, I would like to thank the infants and families who participated in this study.

1.0 INTRODUCTION

Infants develop in a complex social environment, full of opportunities for emerging social communication abilities. As infants play together with a caregiver and jointly engage with an object, caregivers provide a scaffold for their learning and demonstrate how people interact socially with others in their culture. Additionally, caregivers may label the object of focus; this provides an opportunity for the infant to associate a word with the object, potentially facilitating language development (e.g., Bruner, 1985; Tomasello, 1988). Thus, joint engagement (i.e., the ability to actively engage with the same object as a social partner) is a crucial process in the development of social communication. Given that social communication deficits are a core feature of Autism Spectrum Disorder, joint engagement in infancy likely plays a key role in understanding the emergence of these differences.

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized in part by deficits in social communication, including deficits in nonverbal communicative behaviors used in social interactions (e.g., eye contact, gesture) and difficulties with social-emotional reciprocity and with developing and maintaining typical social relationships (American Psychiatric Association, 2013). The etiology of ASD is thought to stem from a complex interaction of genetic vulnerabilities and environmental risk factors, which may then influence how children interact with their environment (e.g., Jones, Gliga, Bedford, Charman, & Johnson, 2014). While diagnosis of ASD is not reliable until 2 or 3 years of age, over a decade of research has advanced our understanding of ASD in the first years of life by conducting prospective studies with the younger infant siblings of children with ASD (see Jones et al., 2014, for a review). This population is at a heightened genetic risk for developing the disorder, with 18.7% receiving a diagnosis (HR infants; Ozonoff et al., 2011), as compared to current estimates of 1-2% in the general population (Baio et al., 2018). These prospective studies have allowed researchers to identify emerging signs of ASD and have informed the development of early interventions in the first two years of life (Green et al., 2017; Zwaigenbaum et al., 2016).

Examination of joint engagement in the complex social environment HR infants experience in their everyday lives is a critical area for research. Adamson and colleagues (Bakeman & Adamson, 1984; Adamson, Bakeman, & Deckner, 2004) distinguish two types of joint engagement (JE). One of these, *coordinated JE*, requires the infant to visually acknowledge (i.e., make eye contact with) the social partner. The other, *supported JE*, is a state in which the infant is actively involved with the same object as the social partner *without* making eye contact. The present study contributes to our understanding of the development of social communication by examining these two forms of joint engagement, with and without eye contact, in infant siblings of children with ASD with varying developmental outcomes, by characterizing verbal input during these moments, and by exploring whether this input relates to children's language development.

1.1 LITERATURE REVIEW

1.1.1 Coordinated and Supported Joint Engagement

A majority of the literature describing JE focuses on *coordinated* JE (often referred to as "joint attention"[1]). Coordinated JE is typically defined as the ability to coordinate social attention between an object and another person and is presumed to reflect an infant's developing awareness of the social partner's role in an object-focused interaction (Mundy, Sigman, Ungerer, & Sherman, 1986; Tomasello, 1995). Coordinated JE is often assessed using the Early Social Communication Scales (ESCS; Mundy, Hogan, & Doehring, 1996), a semi-structured interaction during which an experimenter presents interesting toys and objects to the infant and calls the infant's attention to stimuli by pointing while calling the infant's name. The ESCS measures infant behaviors such as alternating eye gaze, following the gaze and/or point of a social partner, and directing attention using gaze or combined gaze and gesture (Carpenter, Nagell, Tomasello, Butterworth, & Moore 1998). These behaviors typically begin to emerge by 9-12 months of age and increase in frequency through the second year of life (Bakeman & Adamson, 1984; Carpenter et al., 1998).

Differences in coordinated JE distinguish ASD from other developmental delays by 3 years of age (Dawson et al., 2004; Adamson, Bakeman, Deckner, & Romski, 2009), and coordinated JE predicts language ability in ASD and in typical development (Dawson et al.,

[1] Coordinated joint engagement and joint attention are similar phenomena, though the terms differ slightly in meaning. Joint engagement requires *active* participation, while joint attention is reflected by *attending* to the same object as a social partner. Furthermore, joint attention is not always defined consistently depending on the methodology used (i.e., eye tracking studies use a precise definition of attention as looking towards an object, while other methods measure discrete observable behaviors by the infant assumed to reflect the underlying process). Here, we use the term joint engagement as an encompassing term and describe its various forms in detail below.

2004; Mundy et al., 2007; Sigman & Ruskin, 1999). A few HR infant studies show that lower rates of these behaviors in infancy predict ASD symptomology in toddlerhood (Ibañez, Grantz, & Messinger, 2013; Rozga et al., 2011; Sullivan et al., 2007). Several research groups have also found differences in coordinated JE between HR and low risk (LR) infants, but because they did not follow HR infants to diagnosis, these studies are not informative with respect to diagnostic outcomes (Cassel et al., 2007; Goldberg et al., 2005; Yirmiya et al., 2006; Presmanes, Walden, Stone, & Yoder, 2007).

Although this line of research has provided valuable data on HR infants' social communication abilities, it utilizes a relatively narrow definition of JE that may limit our understanding in two significant ways. First, it is not clear whether these measures accurately reflect how infants behave in real world interactions. Research comparing the ESCS with unstructured interactions in the home finds minimal agreement between social communication measures (Parladé, 2012). Furthermore, a growing literature using head-mounted eye tracking (i.e., where both the caregiver and infant wear an eye-tracking device as a precise measure of attention) shows that even typically developing infants rarely look at the caregiver's face prior to attending to the same object (Yu & Smith, 2013; 2016). These researchers suggest that in real world interactions, infants are more likely to use caregiver hand location as a proxy for visual attention, rather than needing to follow the caregiver's gaze to engage with the same object.

Second, by requiring eye contact or gaze-following in our measures, we are limited to only understanding *coordinated* JE. This is particularly important given that limited eye contact is a core diagnostic feature of ASD (APA, 2013; Senju & Johnson, 2009; Zwaigenbaum et al., 2005), but some researchers have suggested that individuals with ASD jointly engage with others in ways that are not captured by standard measures (Akhtar & Gernsbacher, 2008; Gernsbacher, Stevenson, Khandakar, & Goldsmith, 2008). These authors suggest that individuals with ASD may covertly attend to social stimuli (i.e., direction of gaze), but respond atypically, not relying on pointing and eye contact. Thus, new approaches to studying JE in infants later diagnosed with ASD are needed in order to provide a more complete picture of its development, its role in infants' social interactions, and its relation to later language abilities.

One such approach involves investigating *supported* JE, a state in which the parent and infant are actively involved with the same object *without* eye contact, in HR infants. While *coordinated* JE is certainly a critical process in the development of social communication, the limitations discussed above point to the additional importance of understanding the role of engagement states that do not involve explicit visual acknowledgement of the social partner. Supported JE reflects the infant's ability to sustain a shared focus on an object in a way that incorporates the parent's contribution (Adamson et al., 2009). This form of JE inherently relies on parental support but does not simply reflect the parent looking on while the infant plays with a toy – both must be actively engaged with the object. In typical development, supported JE accounts for a substantial portion of time in toy-play interactions in the first two years of life (Bakeman & Adamson, 1984; Adamson et al., 2004).

1.1.2 Caregiver Input during Joint Engagement in relation to Language Development

In typical development, verbal input during supported JE is predictive of language in toddlerhood (Adamson et al., 2004; Trautman & Rollins, 2006). Adamson and colleagues (2004) followed children from 18 months of age in a study investigating both supported and coordinated JE. They found that instances of *supported* JE, but not *coordinated* JE, when the child was responding to verbal input, predicted 30-month receptive and expressive vocabulary after controlling for initial 18-month language ability. Trautman & Rollins (2006) also examined the influence of caregiver input during supported JE on language development. They found that the rate of contingent caregiver verbal input (i.e., how often the caregiver commented on the child's object of focus) during *supported* JE at 12 months predicted 30-month language ability. These authors suggest that contingent caregiver input during supported JE may be particularly facilitative of language learning for infants who are not yet skilled at coordinating attention between an object and the social partner (Trautman & Rollins, 2006).

Since limited eye contact is a core diagnostic feature in ASD (e.g., Senju & Johnson, 2009) and children with ASD may jointly engage with others in atypical ways (Akhtar & Gernsbacher, 2008; Gernsbacher et al., 2008), examination of supported JE in children with ASD may be especially informative for understanding communicative development in this population. One research group has investigated supported JE in toddlers with ASD, comparing 24- to 30-month-olds with ASD to typically developing toddlers and toddlers with other developmental delays (Adamson et al., 2009; Adamson, Bakeman, Suma, & Robins, 2017). Consistent with much of the ASD literature, these researchers found a deficit in coordinated JE in toddlers with ASD. However, in one study, they found that the percentage of time spent in supported JE did not differ between 30-month-olds with ASD and typically developing 18-month-olds with similar language abilities. Although it was not a main aim of the study, they also found that toddlers with ASD spent significantly more time engaged solely with objects and more time unengaged than their typically developing peers (Adamson et al., 2009). Instances of supported JE when the child was responding to verbal input predicted receptive and expressive vocabulary the following year across groups, suggesting that supported JE may be a key context for understanding communicative development in ASD (Adamson et al., 2009; 2017).

1.2 THE PRESENT STUDY

Given these findings, exploration of supported JE *earlier* in life is an essential next step for increasing our understanding of communicative development in children with ASD. While many researchers have examined coordinated JE in infants at high risk for ASD and found differences early in life, the literature on supported JE in this population is limited. Furthermore, infants develop in a complex social environment; it is therefore critical to examine communicative development in ASD in the rich social contexts these infants experience in their everyday lives. Accordingly, the present study addresses a significant gap in the literature by examining the early development of both coordinated and supported JE, as well as object engagement and time spent unengaged, in infants at low and heightened risk for ASD. Caregiver-infant toy play interactions were coded at 12 and 18 months of age, and caregiver verbal input during these episodes was examined in relation to language abilities in toddlerhood. At 36 months of age, diagnostic outcomes were assessed. While ASD is of primary interest in this study, prevalence of other developmental concerns (e.g., language delay) is also increased among HR infants (Messinger et al., 2013; Charman et al., 2017; Iverson et al., 2018). Thus, a threefold classification system was used to distinguish between children with ASD (HR-ASD), children with non-ASD language delay (HR-LD), and children with neither ASD nor language delay (No Diagnosis; HR-ND). This allowed us to tease apart some of the considerable variability in communicative development in the HR sibling population. The present study had three aims:

Aim 1: Examine the development of supported and coordinated JE, as well as time spent engaged with objects and unengaged, in HR infants varying in developmental outcomes (HR-ASD, HR-LD, HR-ND) and in infants with no family history of ASD (Low Risk; LR). Although this is the first study to examine these engagement states in the first years of life in ASD, based on the literature reviewed above, we expected that (1) supported JE would not differ across outcome groups; (2) coordinated JE would increase across time for typically developing infants but not for infants later diagnosed with ASD; and (3) infants later diagnosed with ASD would spend a higher proportion of time engaged with objects and unengaged.

Aim 2: Characterize caregiver verbal input during supported and coordinated JE across age and developmental outcome. To our knowledge, caregiver input during JE has not been characterized in HR infants; therefore, this aim is descriptive in nature. However, it will be an important first step in understanding the nature of this input in relation to language development.

Aim 3: Examine caregiver verbal input, including contingent input and labels, during episodes of coordinated and supported JE in relation to measures of receptive and expressive language ability in toddlerhood. Based on research with both typically developing infants and toddlers and young children with ASD (Adamson et al., 2004; Adamson et al., 2009; Bottema-Beutel, Yoder, Hochman, & Watson, 2014; Trautman & Rollins, 2006), we predicted that caregiver verbal input during episodes of supported JE would uniquely predict language abilities in toddlerhood across outcome groups.

2.0 METHODS

2.1 PARTICIPANTS

The present study included 43 infant siblings of children with ASD (26 male) who are at heightened risk for a later ASD diagnosis (HR infants; Ozonoff et al., 2011) and 14 low risk (LR; 10 male) infants without a family history of ASD. HR infants were followed in a longitudinal study investigating early communication and motor development. Families were recruited through the Autism Research Program at the University of Pittsburgh, as well as through parent support organizations, local agencies and schools serving children with ASD. Prior to enrollment in the study, the older sibling's ASD diagnosis was confirmed by a trained clinician using the Autism Diagnostic Observation Schedule (ADOS-G; Lord et al., 2000). At 36 months of age, HR infant participants were classified into three outcome groups (described in detail below). LR infants were followed as part of a separate ongoing longitudinal study investigating motor development and were recruited through a university research registry and word of mouth.

Infants from both the LR and HR groups were eligible if they had an older sibling (with or without ASD, depending on risk status), were from full-term, uncomplicated pregnancies, and came from monolingual English-speaking homes. Demographic information for the sample is reported in Table 1. Mothers and fathers of HR infants were significantly older than mothers and fathers of LR infants; this is consistent with prior research demonstrating a higher risk for ASD with parental age (e.g., Croen, Najjar, Fireman, & Grether, 2007). Descriptive statistics characterizing the sample are reported in Table 2, including measures of receptive and expressive language, as well as visual reception, which is considered a measure of non-verbal cognitive ability (e.g., Bishop, Guthrie, Coffing, & Lord, 2011).

Table 1. Demographic Information for High Risk (HR) and Low Risk (LR) groups

	HR (n=43)		LR (n=14)	
Racial or ethnic minority (%)	7	(16%)	1	(7%)
Mean age for Mothers* (SD)	34.12	(3.88)	31.07	(4.50)
Mean age for Fathers* (SD)	37.12	(5.13)	32.36	(4.52)
Mean Parent Education[a] (SD)	1.20	(0.54)	1.43	(0.43)

* HR and LR groups significantly differ ($p < 0.05$)
[a] Parent education based on averaging education scores for mothers and fathers.
0 = High school, 1 = Some college or college degree, 2 = Graduate or professional school.

Table 2. Descriptive statistics characterizing each outcome group at 12, 18, 24 and 36 months

		Low Risk			HR – No Diagnosis			HR – Language Delay			HR – ASD		
Measure	Month	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
CDI: Words Understood	12	13	33.5	26.5	14	17.5	16.6	17	17.6	17.9	12	6.67	6.85
CDI: Words Produced	12	13	48.8	19.6	14	42.5	12.4	17	35.3	17.0	12	34.2	12.2
	18	12	26.3	24.5	14	31.4	19.9	17	7.60	12.3	12	6.67	9.37
	24	11	46.4	25.5	12	46.7	22.2	17	16.2	17.5	11	2.73	4.67
	36	8	25.6	22.3	13	27.3	29.6	17	4.12	4.41	11	0.00	0.00
MSEL: Receptive Language	12	14	41.6	7.75	14	36.7	9.23	17	38.3	9.23	12	33.0	13.6
	18	14	40.4	12.4	14	42.6	16.9	17	34.5	12.0	12	28.4	14.6
	24	10	53.9	12.2	13	56.3	5.12	17	41.2	14.3	9	25.6	8.23
	36	7	51.3	6.78	14	55.1	8.87	17	45.0	7.60	9	29.6	10.3
MSEL: Expressive Language	12	14	53.4	11.0	14	44.1	11.0	17	38.6	10.4	12	35.9	9.52
	18	14	50.9	8.64	14	47.7	7.46	17	38.7	6.70	12	34.3	13.0
	24	10	54.7	10.2	13	55.1	5.33	17	43.9	8.65	11	28.8	10.7
	36	7	52.7	13.7	14	59.7	8.45	17	50.2	7.47	10	31.1	11.3
MSEL: Visual Reception	12	14	54.9	11.3	14	53.1	9.43	17	52.4	8.70	12	47.8	14.5
	18	14	48.9	8.60	14	47.6	6.93	17	40.9	8.76	12	36.3	12.7
	24	11	52.4	11.7	13	50.5	9.41	17	45.6	7.93	10	38.7	8.42
	36	8	66.6	6.89	14	60.4	9.37	17	53.1	13.2	9	31.6	13.3

Note: CDI = MacArthur-Bates Communicative Development Inventory, CDI percentile scores are reported; MSEL = Mullen Scales of Early Learning, MSEL standardized T-scores are reported.

2.2 PROCEDURE

Infants in the HR group were observed during monthly home visits from 5-14 months of age, with follow-up visits at 18, 24 and 36 months. Infants in the LR group were observed every other week from 2.5 months until one month after onset of unsupported sitting (mean = 7.5 months), with follow-up visits at 12, 18, 24, and 36 months. Data collection is complete for the HR group but ongoing for the LR group. For both groups, additional infants were excluded if they did not have a visit at both 12 and 18 months or had unusable video data (LR: n=4, HR: n=10), withdrew from the study/were lost to follow-up prior to 18 months (LR: n=1, HR: n=7), or had not yet reached 18 months during data coding and analyses (LR: n=4).

At each visit for both groups, videotaped observations of the infant were completed in several different settings, including naturalistic toy play with a primary caregiver. These visits were scheduled to occur at a time convenient for parents and when they thought infants would be most alert and playful.

The present study uses data collected during the naturalistic toy play observations from the 12- and 18-month visits, as these ages span the period when coordinated JE begins to emerge in typical development (Bakeman & Adamson, 1984). From each of these visits, a 3- to 6-minute segment was coded, during which the infant and a primary caregiver were asked to play on the floor together with a standard set of age-appropriate toys (teddy bear, brush, washcloth, cup, spoon, and bowl). The caregiver participating in the toy play observation was consistent across visits for 54 infants (50 mothers, 4 fathers); for 3 infants, mother participated at one visit and father at the other due to visit scheduling constraints. The infant wore a cloth vest holding a microphone to enhance audio recordings, and the dyad was video-recorded by an assistant trained to keep the infant and parent in view.

2.3 MEASURES

2.3.1 MacArthur-Bates Communicative Development Inventory (CDI)

The CDI is a parent-report measure of communication and language widely used with both typically and atypically developing populations (e.g., Fenson et al., 1993; Mitchell et al., 2006). The CDI is regarded as a reliable and valid measure of communicative ability, with high levels of internal consistency, test-retest reliability, and validity with experimenter-administered measures (Fenson et al., 1994). In the present study, parents completed the CDI at each visit. The CDI-I was collected at 12 months; this form includes a 396-word vocabulary checklist for which parents indicate words their child understands, or both says and understands. The CDI-II was used at 18 and 24 months; this form is normed for children 18 to 30 months of age and includes a 680-word checklist for which parents indicate words their child says. The CDI-III was used at 36 months; this is a brief form designed for children 30 to 37 months and includes a 100-item vocabulary checklist. For the present study, age and gender-normed CDI percentile scores from the 24- and 36-month visits contributed to our composite measure of language ability in toddlerhood.

2.3.2 Mullen Scales of Early Learning (MSEL)

Participants also completed the MSEL (Mullen, 1995), which is a normed, standardized assessment of cognitive functioning designed for infants and young children. The MSEL is widely used in HR sibling studies (e.g., Jones et al., 2014), and has good convergent validity with other measures (Bishop, et al., 2011). The MSEL is administered by an experimenter and includes scales for visual reception, fine and gross motor skills, and receptive and expressive language. The MSEL was collected for both LR and HR infants at 6, 12, 18, 24, and 36 months of age. For the present study, the Receptive Language and Expressive Language T-scores from the 24-, and 36-month visits contributed to our composite measure of language in toddlerhood.

2.4 OUTCOME CLASSIFICATION

All HR infants were classified into one of three mutually exclusive outcome categories at 36 months of age: Autism Spectrum Disorder (ASD), Language Delay without ASD (LD), and No Diagnosis (ND). While LR infants did not receive a formal evaluation, a primary caregiver for each LR infant completed the M-CHAT (Modified Checklist for Autism in Toddlers; Robins, Fein, Barton, & Green, 2001) at 18 and 24 months. All scored negative for ASD. One infant did not have M-CHAT data at either age. The three HR outcome groups are defined as follows:

HR-ASD. All HR infants were evaluated for ASD at their 36-month visit, with the exception of one infant who was evaluated at 24 months and received an ASD diagnosis prior to withdrawing from the study. Infants completed the ADOS-G, which is a widely used structured play schedule designed to probe symptoms of ASD, and reliably distinguishes ASD from other developmental disorders (Lord et al., 2000). Infants received a diagnosis if they met or exceeded ADOS-G algorithm cutoffs for ASD *and* had this confirmed using DSM-IV-TR criteria by a trained clinician blind to previous study data. Using these criteria, 12 infants (9 male) were diagnosed with ASD.

HR-LD. Language delay was assessed using the CDI and the MSEL at 18, 24, and 36 months. While ASD is of primary interest in this study, inclusion of the language delay group allows us to parse out some of the considerable variability in outcomes for the HR population (e.g., Landa, Holman, & Garrett-Mayer, 2007; Messinger et al., 2013), and provides an additional comparison group to determine whether differences in both types of JE are specific to infants later diagnosed with ASD, or more generally characteristic of communicative delay.

HR infants were classified as LD if they *were not* diagnosed with ASD and either (1) had standardized CDI scores at or below the 10^{th} percentile at more than one administration between 18 and 36 months (Heilmann, Weismer, Evans, & Hollar, 2005); and/or (2) had standardized CDI scores at or below the 10^{th} percentile *and* standardized MSEL receptive and/or expressive language scores greater or equal to 1.5 standard deviations below the mean at 36 months (e.g., Ozonoff et al., 2010). Using these criteria, 22 infants (13 male) were classified as LD; 17 of these infants (10 male) had usable video observations at both 12 and 18 months and were included in the present study.

HR-ND. The remaining 39 HR infants (20 male) who completed the study were classified as having No Diagnosis. For the purposes of the present study, 14 (7 male) of the 34 HR-ND infants with usable videos at both 12 and 18 months were randomly selected for inclusion by an individual not otherwise involved in the study.

2.5 CODING OF PARENT-CHILD INTERACTION

Video recordings of the caregiver-child toy play interaction were coded using a time-linked multimedia annotation program (ELAN; Brugman & Russel, 2004). Coding was completed by the first author, who was naive to outcome classification, and four secondary coders, who were naive to risk status, outcome, and study objectives. The entire toy-play observation was coded into mutually exclusive engagement states, such that the end of one code signified the beginning of another code. An additional coding scheme focused on verbal input from the caregiver during the interaction. These codes are defined below.

2.5.1 Engagement States

Joint engagement coding for the present study was based on a coding scheme developed by Adamson and colleagues (Bakeman & Adamson, 1984; Adamson et al., 1998; 2004; 2009) that differentiates six engagement states, including supported and coordinated JE, object engagement, and unengaged (described below).

Supported joint engagement. For both forms of JE, the infant must be actively involved with the same object as the caregiver. The caregiver's attention is often shown through their active manipulation of the object (e.g., a mother demonstrates how to use a toy while the infant actively attends, then they play with the toy together). The caregiver's involvement must appear to influence the infant's experience with the object. For the code to be classified as *supported* JE, the child does not visually acknowledge the caregiver despite being jointly engaged with the same object (i.e., s/he does not glance up at the caregiver to coordinate attention between the object and the caregiver).

Coordinated joint engagement. For coordinated JE, the infant and caregiver must be actively involved with the same object, as in supported JE. However, in this state, infants coordinate their attention between objects and people, visually acknowledging the caregiver's role in the interaction. This is typically evidenced by the infant glancing towards the caregiver's face. For example, the infant and caregiver might be pushing a toy truck around on the floor, and the infant looks back and forth between the caregiver's face and the truck.

Object engagement. To code object engagement, the child must be exploring or playing with object(s) by him/herself. While the partner may attempt to engage the child, the child ignores him/her. This code does not include segments in which the child is merely in contact with a toy, for example, when the child "absent-mindedly" holds a toy while scanning the room.

Unengaged. The unengaged code was defined by no apparent engagement with a specific person or object. The child may be unoccupied, scanning the environment, or may be flitting between different foci without committing to any. This code was used until the child displayed clear interest in a specific object and/or person. Also included in this code were segments in which the child was involved with food (e.g., munching a cookie while looking around), segments when the child was crying or having a tantrum without a focus on an object, and segments when the child was wandering around the room without a particular focus.

Other. Adamson and colleagues (2004; 2009) designate two additional engagement states (i.e. infant's attention only to the caregiver without objects, or on-looking without being actively involved). These engagement states were coded to ensure accurate distinction between states but were collapsed into the *other* category for analyses.

Uncodable. An additional code was included for segments of the observation in which the movement of the child or the camera gave an inadequate view of the child's activities. For example, this code was used when the child was off camera or was engaged with a toy off screen where the coder was unable to determine their focus. As described below, these segments were excluded from analyses.

Additionally, to avoid micro-coding very brief fluctuations in attention, a 3-second rule was applied. Thus, if the infant briefly looked away from the interaction for less than three seconds towards another object, towards an accidental noise from the recording assistant, or another brief fluctuation, this was not coded as changing engagement state. However, if there was a clear switch from one behavioral state to another (i.e. the infant is in supported JE, wanders away for 5 seconds, then enters supported JE again), that fluctuation was coded as *unengaged*, between two episodes of *supported JE* (Adamson et al., 2004).

2.5.2 Caregiver Verbal Input

An additional coding scheme was used to classify caregiver verbal input throughout the interaction. This scheme distinguished between utterances that discussed the child's current object of focus, and further classified whether each utterance was contingent (i.e., the child was focused on the referent within the two seconds prior to the utterance) and whether it contained a label (i.e., contains a noun naming the object). This scheme was adapted from work by Trautman & Rollins (2006) but expands on this scheme to include labels. Definitions for each code, including additional verbal input codes not included in analyses, are provided in Table 3.

Table 3. Caregiver Verbal Input Coding Scheme

Verbal Input Code	Definition	Examples
Total utterances	Caregiver utterances are defined as speech with phonation. The boundary between utterances is defined by a change in intonation, a pause or a breath in speech, and/or a change in subject.	Also includes whispered words without phonation. Does *not* include gasps, smacking, etc.
Object of Focus (OF)	Object of Focus includes utterances that *clearly* refer to and/or describe a *distinct* object or event in the immediate environment that the child attends to within a period extending two seconds before and/or after the utterance.	"Hey, what's this" (Child immediately looks at a washcloth mom is holding up for the child to see.)
OF: Contingent	Utterances regarding the object of focus are classified as contingent if the child is attending to the referent of the utterance within the two seconds *before* the utterance begins.	"Aww you found the teddy bear!" (Child is attending to bear during *and before* the utterance.)
OF: Label	Utterances regarding the object of focus are classified as labels if they contain a noun that clearly *names* the object. Action words alone (e.g., "are you drinking") do not count.	"Aww you found *the teddy bear*!" "We drink with *the cup*." "Brush *his hair*."
Other Object	Other Object includes utterances that refer to and/or describe a distinct object or event in the immediate environment that the child *does not* attend to within two seconds before or after the utterance.	"Hey, what's this" (Mom holds up a washcloth, child is playing with bear and doesn't look up.)
Praise/Scolding	This code includes utterances that praise or scold the child's actions	"Oh thank you", "That was nice", "No don't run off!"
Other Comment	Other Comment includes sound effects, other exclamations and social routines, and comments *involving* objects for which the *specific* referent is unclear	"Aww", "yum yum", "haha", "bye-bye", "Hey [child's name]", "okay", "let's pack up", "let's see"
Uncodable	Utterances are considered uncodable if the caregiver is not audible enough to determine what they are saying, or if the utterance is not classifiable due to problems with the camera angle.	

2.5.3 Reliability

To assess inter-coder reliability, approximately 21% of the videos (n=24) were independently coded by the first author and a secondary coder (two secondary coders on engagement states; two on caregiver verbal input). Reliability sessions were chosen at random with the constraint that each outcome group and age was equally represented. For the joint engagement scheme, reliability was assessed by creating one-second bins for each video and calculating a Cohen's kappa statistic on the number of matching bins between two coders. Using this procedure, coders were trained to a criterion of a Cohen's kappa of at least 0.70 with a master coder (the first author) for three consecutive videos prior to independent coding. Mean Cohen's kappa statistic for engagement state (7 possible codes) was 0.75 (range 0.63 to 0.92). Disagreements were resolved through discussion, and three videos with low reliability (Kappa < .70) were examined in detail and coded by consensus.

For caregiver verbal input coding, percent agreement with a criterion of 85% agreement on all variables for at least three consecutive videos was used for training purposes. To assess inter-coder reliability, percent agreement was calculated for identification of utterances; mean percent agreement was 92.5% (range: 80-97.1%). Cohen's kappa statistic was calculated for identification of utterance type (Object of Focus, Other Object, Praise/Scolding, and Other Comment), contingency (contingent or not contingent), and labels (label or no label). Mean Cohen's Kappa was .80 (range .70 to 1.0) for utterance type and .87 (range .63 to 1.0) for labels. For contingency, mean Cohen's kappa was .62 (range .29 to .91). However, the low prevalence of non-contingent utterances (15%) is likely to cause kappa estimates to be unrepresentatively low (e.g., Hallgren, 2012). As another measure of inter-coder reliability for contingency, utterances across all reliability videos were combined and an intraclass correlation coefficient (two-way random effects, average-measures) was calculated; this was .802 (95% CI: .77 to .83).

3.0 RESULTS

The present study aimed to examine the development of supported and coordinated JE, as well as time spent engaged with objects and unengaged, in HR infants who varied in developmental outcome at 36 months (ASD, LD, ND) and in infants with no familial ASD risk (LR). Additionally, this research aimed to characterize caregiver verbal input during supported and coordinated JE across age and developmental outcome, and to explore features of this caregiver input in relation to language abilities in toddlerhood. Preliminary analyses and results for each aim are presented in turn below.

3.1 AIM 1: ENGAGEMENT STATES

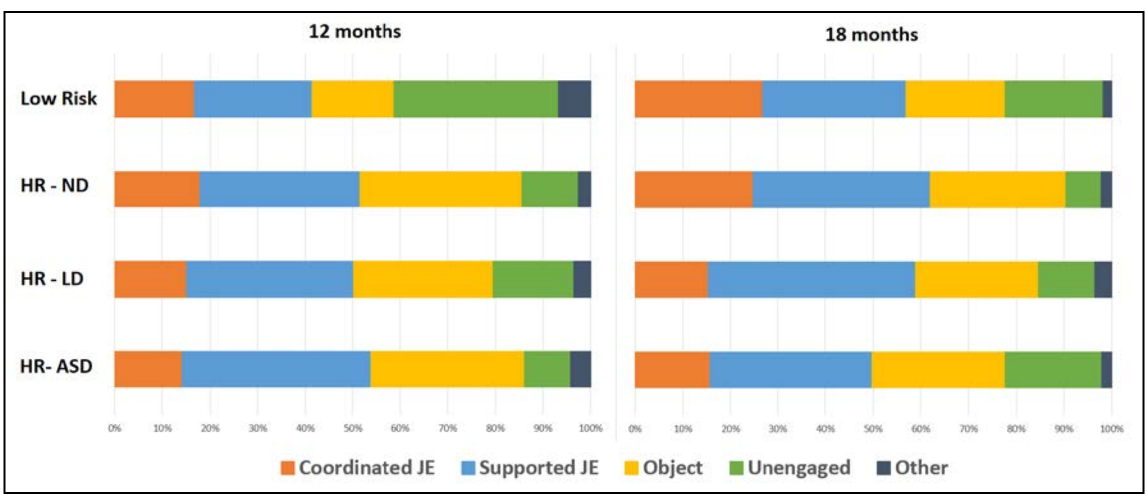
Prior to conducting analyses related to the first aim of the study, the proportions of each observation considered *uncodable* (i.e., there was not an adequate view of the child's activities to code engagement) were examined in a repeated-measures mixed ANOVA with age (12 and 18 months) as a within-subjects factor and outcome (LR, HR-ND, HR-LD, and HR-ASD) as a between-subjects factor. There were no significant effects; thus, these segments were excluded from further analyses, and engagement variables were based on observation durations excluding *Uncodable* segments.

Descriptive statistics, including means and standard deviations for the proportions of time spent in each engagement state by age and outcome group, are presented in Table 4, with a visualization of these proportions provided in Figure 1. Visual inspection of the engagement data using Q-Q plots revealed significant problems with positive skew and kurtosis. Therefore, non-parametric statistics were used for analyses of the proportions of time spent in *supported JE*, *coordinated JE*, *object engagement*, and *unengaged* reported below.

Table 4. Mean Proportions and Standard Deviations of Observation Time in Engagement States for Each Outcome Group at 12 and 18 months

		Low Risk (n=14)		HR – ND (n=14)		HR – LD (n=17)		HR – ASD (n=12)		Kruskal-Wallis Test	
	Age	Mean	SD	Mean	SD	Mean	SD	Mean	SD	*H*	*p*
Supported Joint	12	0.246	0.124	0.336	0.194	0.351	0.146	0.396	0.266	4.17	0.243
	18	0.302	0.188	0.374	0.188	0.433	0.152	0.341	0.205	4.91	0.179
Coordinated Joint	12	0.167	0.135	0.178	0.164	0.150	0.129	0.141	0.193	1.34	0.720
	18	0.266	0.231	0.246	0.225	0.152	0.169	0.157	0.127	3.45	0.328
Object	12	0.173	0.077	0.341	0.179	0.294	0.153	0.324	0.191	10.9	0.012
	18	0.209	0.137	0.284	0.100	0.255	0.113	0.279	0.157	3.95	0.267
Unengaged	12	0.345	0.116	0.119	0.126	0.170	0.119	0.097	0.074	23.3	<.001
	18	0.205	0.160	0.073	0.083	0.117	0.083	0.202	0.238	7.56	0.056

Figure 1. Mean Proportions of Observation Time in Engagement States for Each Observation Group at 12 and 18 months (JE = Joint Engagement)



3.1.1 Supported JE

Based on prior literature (e.g., Adamson et al., 2009), supported JE was not expected to differ across outcome groups. As can be seen in Table 4 and Figure 1, a substantial portion of the observation was spent in supported JE for each outcome group, with a high degree of individual variability. Means ranged from 25 to 43% of the observation, with slight increases from 12 to 18 months apparent in the LR, HR-ND, and HR-LD groups. Kruskal-Wallis tests, reported in Table 4, were used to examine differences between outcome groups at 12 and 18 months. Consistent with hypotheses, the proportions of time spent in supported JE did not differ across groups at either 12 ($H(3) = 4.17$, $p = 0.243$) or 18 months ($H(3) = 4.91$, $p = 0.179$).

3.1.2 Coordinated JE

In contrast to supported JE, coordinated JE was expected to increase across time for the LR and HR-ND groups, but not for infants later diagnosed with ASD. As can be seen in Figure 1, increases in coordinated JE from 12 to 18 months were apparent in the LR and HR-ND groups, with increases from 16.7 to 26.6% and 17.8 to 24.6% of the observation respectively. However, both the HR-LD and HR-ASD groups remained low and stable in coordinated JE across time (14.1 to 15.7%). Differences across outcome groups were not significant at 12 ($H(3) = 1.34$, $p = 0.720$) or 18 months ($H(3) = 3.45$, $p = 0.328$).

To further explore apparent differences between groups, planned contrasts were completed using Mann-Whitney U tests. Outcome groups were collapsed into typically developing (LR, HR-ND) and non-typically developing (HR-LD, HR-ASD). Using this two-group split, contrasts revealed no significant differences at 12 months ($U = 354.0$, $p = 0.404$). By

18 months, however, there was a nearly significant tendency for typically developing infants to spend more time in coordinated JE than non-typically developing infants ($U = 293.5$, $p = 0.069$).

To examine the hypothesis that coordinated JE would increase across time for typically developing (LR, HR-ND) but not for non-typically developing (HR-LD, HR-ASD) infants, related-samples Wilcoxon signed rank tests were run separately for the two groups. While visual inspection of the data suggests an increase from 12 to 18 months for LR and HR-ND infants (Means 16.7 to 26.6% and 17.8 to 24.6%, respectively), it did not reach statistical significance ($Z = 1.64$, $p = 0.101$). Coordinated JE did not change across time for non-typically developing (HR-LD and HR-ASD) infants (Means .141 to .157; $Z = 0.05$, $p = 0.96$).

3.1.3 Object Engagement

Based on prior literature, HR-ASD infants were expected to spend more time in object engagement and unengaged than their typically developing peers. As can be seen in Figure 1, LR infants spent an average of 17.3% of the observation at 12 months engaged only with objects, while all HR groups were engaged with objects for an average of 29.4 to 34.1% of the observation. Differences appeared to be smaller by 18 months of age, with LR infants spending 20.9% and HR-ND, LD, and ASD infants spending 28.4, 25.5, and 27.9% of the observation engaged with objects. This pattern of results was confirmed statistically, with a Kruskal-Wallis test revealing differences between groups at 12 ($H(3) = 10.9$, $p = 0.012$) but not 18 months ($H(3) = 3.95$, $p = 0.267$). Pairwise comparisons between groups at 12 months were conducted to explore these differences further. LR infants spent significantly less time in object engagement than each HR outcome group ($ps < 0.01$ for HR-ND and HR-ASD, $p = 0.023$ for HR-LD).

3.1.4 Unengaged

Interestingly, LR infants spent substantially *more* time unengaged at 12 months of age than any of the HR groups, as can be seen in Figure 1. In fact, the proportion of time spent unengaged was more than double that of the other groups (34.5% vs. 11.9, 17.0, and 9.7% of the observation for HR-ND, HR-LD, and HR-ASD infants). This difference between groups was significant at 12 months ($H(3) = 23.3$, $p < 0.001$), with pairwise comparisons between groups showing significant differences between LR infants and each HR outcome group ($ps < .001$ for HR-ND and HR-ASD; $p = .004$ for HR-LD). Time spent unengaged did not significantly differ between groups at 18 months ($H(3) = 7.56$, $p = .056$).

3.2 AIM 2: CAREGIVER VERBAL INPUT DURING SUPPORTED AND COORDINATED JOINT ENGAGEMENT

Due to differences in observation durations (approximately 3 to 6 minutes), all verbal input variables are reported as rates (number of utterances per minute). Descriptive statistics for caregiver verbal input during the overall observation and during coordinated and supported JE are reported in Table 5. Rates of caregiver verbal input during supported or coordinated JE include utterances that fell entirely within a period of supported/coordinated JE, and utterances for which the onset of the utterance occurred prior to the transition to a new engagement state.

To characterize caregiver verbal input for the sample, a series of repeated-measures mixed ANOVAs were conducted on each variable of interest to determine whether differences existed in caregiver input across age (12 and 18 months) and/or outcome (LR, HR-ND, HR-LD, HR-ASD, with post-hoc comparisons between groups) for the overall observation and during supported and coordinated JE. As can be seen in Table 5, the rates of total utterances, utterances regarding the object of focus (OF), contingent utterances (OF: Contingent), and labels (OF: Labels) were similar at 12 and 18 months. There were no significant effects of age or outcome for these variables during the overall observation *or* during supported JE (*p*s = *ns*).

Table 5. Rates (number/minute) of Caregiver Verbal Input during the Overall Observation, during Coordinated Joint Engagement, and during Supported Joint Engagement

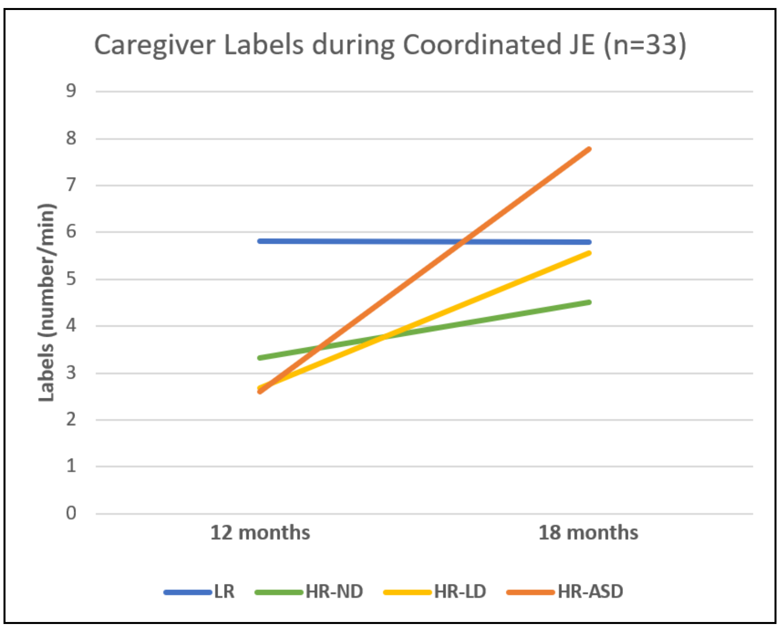
		Overall Trial (n=57)		Coordinated JE (n=45; 41)		Supported JE (n=57)	
Verbal Input Type	Age	Mean	SD	Mean	SD	Mean	SD
Total utterances	12	17.30	6.05	17.90	8.34	17.90	6.46
	18	17.60	5.64	19.60	6.20	18.90	6.09
Object of Focus (OF)	12	8.36	3.54	9.48	6.48	10.40	4.56
	18	8.61	3.50	11.20	4.94	10.80	4.99
OF: Contingent	12	6.70	3.12	8.41	5.82	9.02	4.24
	18	7.00	2.94	9.55	3.74	8.78	4.24
OF: Label	12	4.25	2.13	4.05	4.23	5.43	3.04
	18	4.77	2.31	5.64	3.09	5.62	3.45
Other Object	12	0.82	0.66	0.17	0.48	0.31	0.60
	18	0.68	0.74	0.50	1.32	0.55	0.87
Praise/Scolding	12	0.79	0.68	1.13	2.34	1.15	1.37
	18	1.15	0.71	1.35	1.36	1.42	1.11
Other Comment	12	6.82	2.89	6.64	4.79	5.61	2.93
	18	6.40	2.73	5.73	3.36	5.40	2.97
Uncodable	12	0.55	0.55	0.52	1.07	0.45	0.60
	18	0.72	0.68	0.78	1.43	0.75	1.14

Note: JE = Joint Engagement; Caregiver Verbal Input rates during Coordinated JE are based on the sample of infants who spent *some* time in coordinated JE at 12 (n=45) or 18 months (n=41).

Of note, rates of caregiver verbal input variables during coordinated JE could only be calculated for infants who spent *some* time in coordinated JE. Four infants (one in each outcome group) spent 0% of the observation at *both* 12 and 18 months in coordinated JE. An additional 8 infants (2 LR, 2 HR-ND, 0 HR-LD, 4 HR-ASD) at 12 months and 12 infants (1 LR, 2 HR-ND, 7 HR-LD, 2 HR-ASD) at 18 months spent 0% of the observation in coordinated JE. No significant effects emerged for age or outcome (n=33; *p*s = *ns*) for total utterances, utterances regarding the object of focus, or contingent utterances. However, there was a significant main effect of age for labels during coordinated JE (p = .002), with a higher rate of labels at 18 months (5.7/min vs. 3.8/min for the 33 infants with coordinated JE at both time points). There was no main effect of outcome for labels during coordinated JE (p = .193).

Interestingly, the effect of age appeared to be driven by caregivers of HR-ASD and HR-LD infants (see Figure 2), though this interaction did not reach significance (p = .085). Pairwise comparisons for each group showed a significant effect of age for the HR-ASD (p = .005) and HR-LD (p = .03) groups, but not for the LR and HR-ND groups (*p*s = .986, .360, respectively).

Figure 2. Rates (number/min) of Caregiver Labels during Coordinated Joint Engagement at 12 and 18 months, Moderated by Outcome Group



3.3 AIM 3: CAREGIVER VERBAL INPUT AND ITS RELATION TO LANGUAGE

The third aim of this study was to examine caregiver verbal input, including contingent utterances and labels regarding the child's object of focus, in relation to later language abilities. Based on prior literature (Adamson et al., 2009; Trautman & Rollins, 2006), we expected contingent input during supported JE would be predictive of language ability in toddlerhood, with higher rates of contingent input and labels at 12 and 18 months contributing to higher language scores across outcome groups. Since caregiver verbal input variables during supported JE did not differ between 12 and 18 months, mean rates (collapsed across age) were used in analyses. For caregiver verbal input during coordinated JE, mean rates were used for contingent utterances, with 53 infants having data (i.e., *some* time spent in coordinated JE) for at least one visit. Due to differences across age in the rate of labels during coordinated JE, these are examined separately at 12 (n=45) and 18 (n=41) months in relation to language.

To examine caregiver verbal input in relation to language, a composite measure was created using standardized scores from the 24- and 36-month CDI and MSEL to obtain a continuous measure of language ability in toddlerhood. To create the composite, we standardized into z-scores and averaged together the CDI Words Produced percentile scores, the MSEL Receptive Language T-scores, and the MSEL Expressive Language T-scores from both 24 and 36 months. LR and HR infants were included in this measure, though 3 out of 14 LR infants did not have 24 or 36 month data due to withdrawal from the study (n=1) or ongoing data collection (n=2). Thus, 11 LR infants had 24-month data, and 8 of these LR infants had 36-month data. A high level of internal consistency for this composite measure was found in prior studies (Northrup & Iverson, 2015), and in the present sample (Cronbach's alpha = .861).

Bivariate correlations between each verbal input variable during both coordinated and supported JE and the language composite (hereafter, Language) are reported in Table 6. Contrary to hypotheses, neither contingent verbal input nor labels were positively related to Language. Separate linear regressions were completed for each variable of interest with Language as the dependent variable. Neither mean contingent utterances nor mean labels during supported JE were significantly predictive of Language (*B* = -0.012, t(52) = -0.352, p = .726; *B* = 0.006, t(52) = .128, p = .899, for mean contingent utterances and labels, respectively). Mean contingent utterances and 12-month labels during coordinated JE were also not predictive of Language (*B* = .001, t(48) = .027, p = .979; *B* = .017, t(40) = .561, p = .578, for mean contingent utterances and 12-month labels, respectively). Surprisingly, caregiver labels at 18 months showed a negative relationship and were predictive of Language (*B* = -0.097, t(36) = -2.03, p = 0.05), with higher rates of labels at 18 months predicting *lower* Language in toddlerhood.

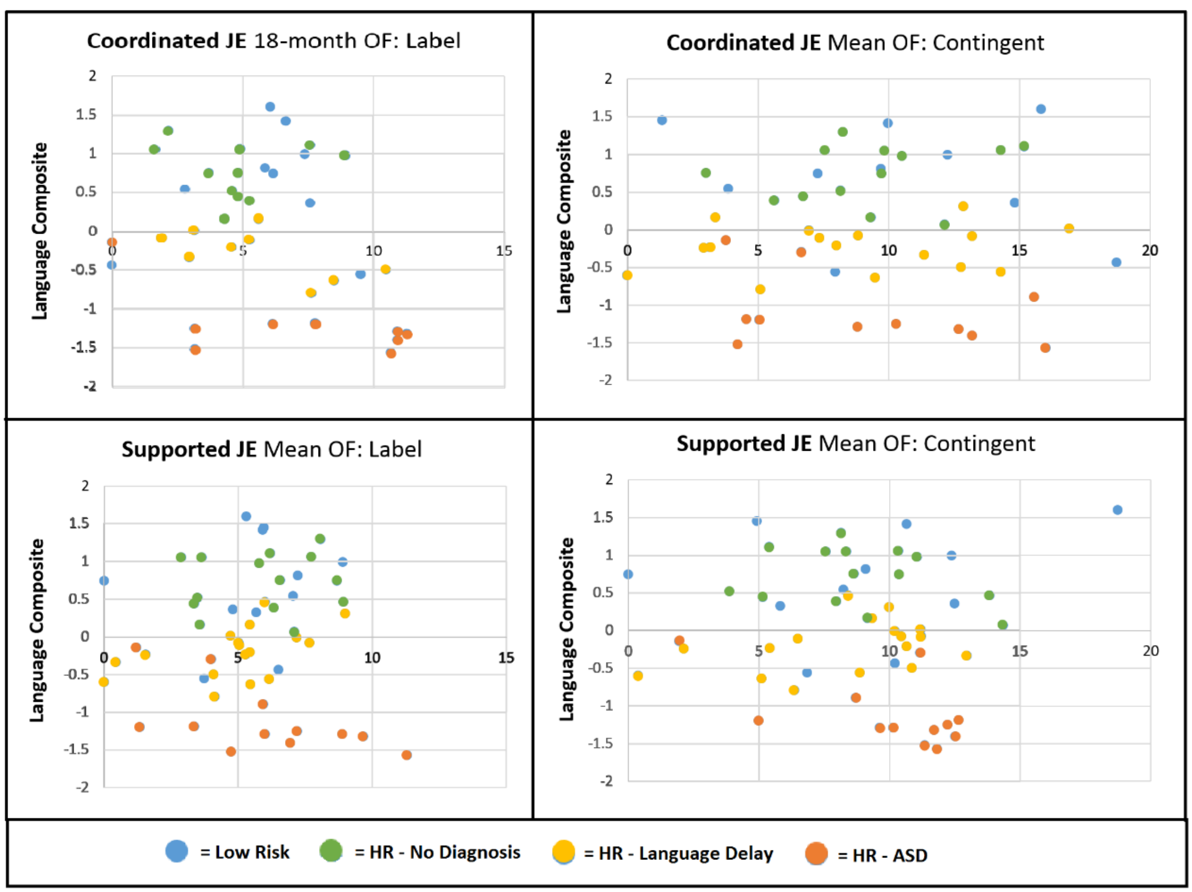
Table 6. Correlations between Toddler Language Composite and Caregiver Verbal Input during Coordinated and Supported Joint Engagement

Verbal Input Type	*r*
Coordinated JE	
Mean Total Utterances	0.092
Mean Object of Focus (OF)	0.002
Mean OF: Contingent	0.004
12-month OF: Label	0.088
18-month OF: Label	-0.32*
Supported JE	
Mean Total Utterances	0.028
Mean Object of Focus (OF)	0.006
Mean OF: Contingent	-0.049
Mean OF: Label	0.018

* *p* = .050

To determine whether the relation between caregiver verbal input and Language differed by outcome group, we conducted regression analyses for each variable of interest with outcome classification (LR, HR-ND, HR-LD, HR-ASD) added as a moderating variable. Examination of the verbal input data in relation to language suggested that while there was substantial variability, differences may exist between outcome groups. In particular, a cluster of infants with the lowest language scores in toddlerhood (primarily in the HR-ASD group) had high rates of contingent caregiver utterances during supported JE, and high rates of caregiver labels at 18 months during coordinated JE (see Figure 3).

Figure 3. Rates (number/min) of Contingent Utterances and Labels during Supported and Coordinated Joint Engagement in Relation to Language by Outcome Group



Results from moderation analyses for contingent utterances and labels during supported JE are reported in Table 7. Consistent with our initial analyses, verbal input during supported JE was not significantly associated with Language (*B* = .038, p = .208; *B* = .047, p = .465, for contingent utterances and labels, respectively) with outcome group included in the model. However, this relationship depended on (i.e., was moderated by) whether the infant was in the HR-ASD outcome group for contingent utterances during supported JE (interaction coefficient = -0.119, p = .025). A similar but non-significant pattern of results emerged for labels during supported JE (interaction coefficient = -0.133, p = .094). To explore this further, we calculated the conditional effects of contingent utterances and labels on Language for each outcome group using PROCESS (Hayes, 2013). These results are also presented in Table 7. While there was no significant association between caregiver input during supported JE and Language for LR, HR-ND, and HR-LD infants, there was a nearly significant trend for a negative association between caregiver input during supported JE and Language for HR-ASD infants. This trend was apparent for both caregiver contingent utterances and labels (*B*s = -0.081, -0.086, ps = .059, .058).

Table 7. Moderation of Caregiver Verbal Input's effects during Supported JE on Language Composite by Outcome Group

	VI = Mean OF: Contingent			VI = Mean OF: Label		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Constant	0.314	0.303	0.306	0.397	0.381	0.302
VI: [Caregiver verbal input variable]	0.038	0.030	0.208	0.047	0.064	0.465
HR-ND	0.701	0.497	0.165	0.215	0.534	0.689
HR-LD	-0.830	0.424	0.056	-0.950	0.462	0.046
ASD	-0.623	0.531	0.247	-1.01	0.480	0.041
HR-ND*(VI)	-0.071	0.052	0.174	-0.029	0.088	0.744
HR-LD*(VI)	0.000	0.045	0.999	0.025	0.080	0.757
HR-ASD*(VI)	-0.119	0.052	0.025	-0.133	0.078	0.094
Model Summary	R^2 = .751		<.001	R^2 = .748		<.001
R^2 increase due to interaction	R^2 change = .039		0.078	R^2 change = .036		0.101
	VI = Mean OF: Contingent			VI = Mean OF: Label		
Conditional effects by Outcome	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
LR	0.038	0.030	0.208	0.047	0.064	0.465
HR-ND	-0.033	0.042	0.434	0.018	0.060	0.763
HR-LD	0.038	0.033	0.259	0.072	0.049	0.146
HR-ASD	-0.081	0.042	0.059	-0.086	0.044	0.058

Results from moderation analyses for contingent utterances and labels during coordinated JE are reported in Table 8. With all four outcome groups included in the model, neither mean contingent utterances nor 12- and 18-month labels are significantly associated with Language. No interaction terms were significant. Due to apparent differences in the proportions of time spent in coordinated JE at 18 months for typically-developing (LR and HR-ND) and non-typically developing (HR-LD and HR-ASD) infants described above, we decided to explore the negative relationship between 18-month caregiver labels and Language by conducting a moderation analysis with outcome collapsed into these two groups. The results of this moderation analysis are presented in Table 9. As can be seen in the table, 18-month labels during coordinated JE were no longer significantly predictive of Language with combined outcome included in the model (*B* = .018, p = .728). While the interaction term did not reach statistical significance (*B* = -0.111, p = .089), examination of conditional effects suggests there was a significant negative association between 18-month labels and Language for HR-LD and HR-ASD infants (*B* = -0.093, p = .017), but *not* for LR and HR-ND infants (*B* = 0.018, p = .728).

Table 8. Moderation of Caregiver Verbal Input's effects during Coordinated JE on Language Composite by Outcome Group

	VI = Mean OF: Contingent			VI = 12-month OF: Label			VI = 18-month OF: Label		
	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*	Coeff.	*SE*	*p*
Constant	1.03	0.339	0.004	0.578	0.297	0.06	0.325	0.381	0.401
VI: [Caregiver verbal input]	-0.033	0.03	0.267	0.027	0.041	0.516	0.049	0.06	0.422
HR-ND	-0.527	0.53	0.325	0.082	0.371	0.826	0.476	0.535	0.380
HR-LD	-1.376	0.422	0.002	-0.795	0.328	0.021	-0.206	0.529	0.700
ASD	-1.780	0.476	<.001	-1.840	0.392	<.001	-1.080	0.502	0.039
HR-ND*(VI)	0.059	0.051	0.257	-0.008	0.067	0.909	-0.055	0.094	0.561
HR-LD*(VI)	0.045	0.039	0.258	-0.035	0.047	0.464	-0.120	0.085	0.166
HR-ASD*(VI)	-0.005	0.044	0.911	0.010	0.063	0.873	-0.112	0.072	0.130
Model Summary	R^2 = .734		<.001	R^2 = .741		<.001	R^2 = .784		<.001
R^2 increase due to interaction	R^2 change = .018		0.433	R^2 change = .009		0.765	R^2 change = .022		0.409

Table 9. Moderation of 18-month Caregiver Labels during Coordinated JE on Language Composite by Combined Outcome (LR & HR-ND compared to HR-LD & HR-ASD)

	Coeff.	*SE*	*p*
Constant	0.603	0.295	0.049
VI: 18-month OF: Labels	0.018	0.051	0.728
HR-LD *and* HR-ASD combined	-0.759	0.398	0.065
HR-LD/HR-ASD*(VI) interaction	-0.111	0.063	0.089
Model Summary (N=38)	R^2 = .683		<.001
R^2 increase due to interaction	R^2 change = .029		0.089
Conditional Effects by Combined Outcome	Coeff.	*SE*	*p*
LR *and* HR-ND combined	0.018	0.051	0.728
HR-LD *and* HR-ASD combined	-0.093	0.037	0.017

4.0 DISCUSSION

This research examined the development of supported and coordinated JE, as well as time spent engaged with objects and unengaged, in infants with a heightened genetic risk for ASD who varied in developmental outcomes and in infants with no familial ASD risk (LR). It also characterized caregiver verbal input during supported and coordinated JE and explored features of this input in relation to language abilities in toddlerhood. There were four main sets of findings. First, differences in supported and coordinated JE were generally consistent with prior literature, though with *both* HR-LD and HR-ASD infants deviating from their typically developing peers in coordinated JE by 18 months. Second, HR infants as a group spent *more* time engaged with objects and *less* time unengaged than their LR peers. Third, caregivers provided similar rates of contingent input and labels across outcome groups, though with an increase in labels during coordinated JE from 12 to 18 months for HR-ASD and HR-LD infants. Finally, counter to predictions, caregiver verbal input was not positively associated with language ability, but this was qualified by developmental outcome. For HR-ASD infants, higher rates of caregiver verbal input were associated with *lower* language scores in toddlerhood. Each of these findings will be discussed in turn.

4.1.1 Supported and Coordinated Joint Engagement

Based on prior work with young children and toddlers with ASD (Adamson et al., 2009), we expected HR and LR infants, regardless of 36-month outcome, to spend substantial proportions of toy play interactions in *supported* JE, a state in which the caregiver and infant are actively involved with the same object *without* eye contact. This was supported by the data; although there was a high degree of variability, infants spent on average 25 to 43% of the observation in supported JE during our first observation at 12 months and this did not differ across outcome groups.

Based on a large body of work examining *coordinated* JE in toddlers with and without ASD and in HR infants (e.g., Adamson et al., 2009; Rozga et al., 2011; Sullivan et al., 2007), we expected HR-ASD infants to spend less time in coordinated JE, a state which required eye contact, than their typically developing peers. We also expected LR and HR-ND infants to increase in coordinated JE from 12 to 18 months. These hypotheses were partially supported by the data. Although LR and HR-ND infants generally increased in coordinated JE, there was substantial individual variability and the increase was not significant. Of note, LR and HR-ND infants were already spending on average 16-18% of the observation in coordinated JE by 12 months. Future work should examine coordinated JE earlier and with more frequent sampling to better characterize its development in HR infants.

Interestingly, by 18 months of age, there was a trend for both HR-ASD *and* HR-LD infants to spend less time in coordinated JE than their LR and HR-ND peers. This was consistent with hypotheses for HR-ASD infants, but prior work has not examined coordinated JE in HR infants with non-ASD language delays. This similarity between HR-ASD and HR-LD infants highlights the immense challenge of discriminating subtle differences in social communicative behaviors prior to two years of age (Camarata, 2014). This finding is also consistent with recent work showing broad differences in JE for toddlers who screened positively for ASD but were diagnosed with other developmental delays (Adamson et al., 2017).

Taken together, these findings highlight the importance of investigating supported and coordinated JE in HR siblings. Since *all* infants spent a substantial proportion of time in supported JE, this engagement state may provide a key context for early interventions. In fact, an emerging literature targeting JE in interventions for toddlers with ASD has shown promising effects (e.g., Kasari, Gulsrud, Wong, Kwon, & Locke, 2010). Furthermore, these findings highlight the importance of considering the extensive heterogeneity in HR infants when thinking about communicative delays in this population. Language and nonverbal communicative behaviors, including eye contact, are closely intertwined. Much of the HR literature examining HR-LD infants reports that they fall somewhere in between HR-ND and HR-ASD peers in their development of a number of verbal and nonverbal communicative behaviors (e.g., Parladé & Iverson, 2015; Iverson et al., 2018). Differences in coordinated JE, which involves eye contact, by 18 months of age suggests continued monitoring of both groups is necessary to disentangle subtle emerging signs of ASD from communicative delays more generally. Examining how these differences in coordinated JE culminate in a wide array of outcomes will be an important avenue for future research.

4.1.2 Object Engagement and Time Spent Unengaged

While *joint* engagement was of primary interest in the present study, exploration of time spent in object engagement and unengaged was also warranted given differences in these engagement states among young children with ASD (Adamson et al., 2009). In line with expectations, HR-

ASD infants spent more time engaged solely with objects than did their LR peers. However, these differences were not limited to infants later diagnosed with ASD. At 12 months, all HR infants spent nearly a third of the interaction in object engagement (compared to 17% for LR infants), with HR-ND and HR-LD infants also differing significantly from their LR peers. These findings are consistent with studies of HR siblings showing that infants and toddlers later diagnosed with ASD are less engaged with social partners (Campbell et al., 2018), and exhibit decreased social attention in the first year of life (Jones & Klin, 2013; Jones et al., 2016; Chawarska, Macari, & Shic, 2013). Increased object engagement for HR infants without a later ASD diagnosis as well as HR-ASD infants may reflect an underlying propensity for decreased social attention in HR infants as a group that is attenuated for some infants by 18 months, though replication with a larger sample is needed.

In contrast to work with young children with ASD (Adamson et al., 2009), HR infants spent *less* time unengaged than their LR peers at 12 months of age, though this difference was not robust by 18 months. It is important to note that our visits occurred in the home; while this is a strength of the study in observing infant behavior in a naturalistic setting, home observations also inherently come with an array of distractions from a standard toy-play interaction. While these distractions are unlikely to differ substantially between groups, they provide an ideal setting for increasingly mobile infants to disregard caregiver attempts to keep them engaged in the interaction. Anecdotally, *unengaged* coding frequently included moments in which the infant spent time standing up and wandering away from the toy set. Since motor delays are common in HR infants (Bhat, Galloway, & Landa, 2012; Iverson & Wozniak, 2007; Leonard, Elsabbagh, Hill, & the BASIS team, 2014) one potential explanation for this unexpected finding is that HR infants are simply less likely to get up and walk away from the task at 12 months. Another, somewhat related, explanation may be that caregivers of HR infants, who already have a child with ASD, are more likely to direct their infant back to the task at hand when they become unengaged (e.g., Wan et al., 2012), while caregivers of LR infants may allow them to wander away from the task. Future work examining the nature of these unengaged episodes in more detail will be beneficial in understanding these differences.

4.1.3 Caregiver Verbal Input During Supported and Coordinated Joint Engagement

The second aim of this study was to characterize caregiver verbal input during supported and coordinated JE across age and developmental outcome. Consistent with prior work examining maternal responsiveness in LR and HR infants (Leezenbaum, Campbell, Butler, & Iverson, 2014), caregiver input did not differ across outcome groups for the overall observation. Furthermore, rates of caregiver verbal input *during* supported and coordinated JE did not differ across outcome. Although there was a high degree of variability, these findings suggest that caregivers of infants across a range of developmental outcomes are generally similar in the extent to which they follow into the child's object of focus and provide contingent input and labels.

Regarding change over time, caregiver verbal input during coordinated and supported JE was generally stable over the period from 12 to 18 months of age, with one exception. Caregiver labels regarding the infant's object of focus during coordinated JE increased over time, particularly for HR-ASD (and to a lesser extent, HR-LD) infants. It is important to note that rates of verbal input during coordinated JE were only available for infants who spent *some* time in coordinated JE; thus, this finding is based on a limited sample. However, this finding suggests that differences are emerging over time in the input received by infants with later communicative delays. Interestingly, this increase was only apparent during *coordinated* JE, in which HR-ASD and HR-LD infants spent less time in by 18 months compared to their typically developing peers. One potential explanation for this finding is that parents are capitalizing on these few moments of coordinated JE, increasing the number of labels they provide in an effort to scaffold language development for their infants who are beginning to show delays in language (e.g., Talbott, Nelson, & Tager-Flusberg, 2015). This possibility will be discussed in more detail below in the context of its relation to language ability in toddlerhood.

4.1.4 Caregiver Verbal Input in Relation to Language

Based on prior work, we expected caregiver input during supported JE to be predictive of language ability in toddlerhood for infants with varied developmental outcomes (Adamson et al., 2009; Adamson et al., 2017, Bottema-Beutel et al., 2014, Trautman & Rollins, 2006). Contrary to predictions, neither contingent input nor labels during supported or coordinated JE were positively associated with toddler language ability. Given the substantial literature showing that caregiver input is positively related to language abilities, particularly within episodes of JE (e.g., Tomasello & Farrar, 1986), this lack of a positive relationship must be considered with a few limitations in mind. First, while caregiver-infant interactions with a standard set of toys are commonplace in prior research, the present study used a brief interaction (only 3 to 6 minutes) with a small set of toys (teddy bear, bowl, spoon, cup, washcloth, and brush). It is possible that this limited interaction may not provide sufficient time and breadth to generate enough variability in caregiver input to predict language ability in toddlerhood. Second, our analyses of verbal input in relation to language included a very small sample of LR infants; only 11 had available language data in toddlerhood.

Unexpectedly, caregiver labels during coordinated JE at 18 months were *negatively* related to language in toddlerhood. Of course, this does not suggest that caregiver labeling during coordinated JE inhibits language development; closer inspection of the data reveals a more nuanced picture. While moderation effects by outcome for this association did not reach statistical significance, labels were negatively associated with language for HR-ASD and HR-LD infants, but not for their typically developing HR and LR peers. This pattern of negative associations between verbal input and language ability for HR-ASD infants was further demonstrated by moderations in contingent utterances and labels during supported JE. At face value, these negative associations may be disheartening – in contrast to prior work suggesting caregiver input during supported JE may be especially facilitative of language development for toddlers and young children with ASD (Adamson et al., 2009; Bottema-Beutel et al., 2014), the present findings suggest this may not be the case for HR infants.

Notably, the 10 lowest toddlerhood language scores fell in the HR-ASD group, and by definition, many of the next lowest scores were HR-LD infants. Visual inspection of the data (see Figure 3) revealed an interesting pattern of caregiver input – a cluster of infants (primarily in the HR-ASD group) with the lowest language scores in toddlerhood received particularly high rates of caregiver input in the second year of life. As demonstrated in a larger study with a partially overlapping sample, HR-ASD infants are already beginning to fall behind their typically developing peers in language by 12 months of age (Iverson et al., 2018).

One potential explanation for this negative association between verbal input and language is that caregivers are picking up on subtle delays in language in the second year of life and providing *more* input to help their infants "catch up". This is consistent with our findings that caregiver labels during coordinated JE increased the most over time for HR-ASD and HR-LD infants. Early differences in infant behavior can have cascading effects on the dynamic exchange between infants and their caregivers, leading to alterations in their communicative environments (e.g., see Iverson & Wozniak, 2016, for a review). For example, maternal communicative behavior may be influenced by perceptions of the infant's communicative ability (Talbott et al., 2015). Caregivers who already have a child diagnosed with ASD (i.e., caregivers of HR infants) may be especially attuned to even mild developmental delays, and frequently report language concerns in the first two years of life (Herlihy, Knoch, Vibert, & Fein, 2015, Hess & Landa, 2012, Sacrey et al., 2015).

While caregivers may be picking up on early concerns and providing high rates of verbal input during episodes of JE, it may be that *more* contingent input and labels in response to early signs of language delay, at least in the second year of life, is simply not effective. A recently proposed theoretical model of contingency detection suggests that difficulties making sense of complex social contingencies may lead to decreased learning from the social environment for infants later diagnosed with ASD (Northrup, 2017). Perhaps the contingent responses provided, at least at 12 and 18 months, are too complex for effective language learning in some HR infants. Consistent with this idea, varying aspects of caregiver input are most beneficial at different points in development and at different levels of language ability for typically developing infants (Rowe, 2012). This has implications for early interventions with infants at risk for ASD; if just providing more contingent input and more labels in the second year of life is not predictive of increased language development, a critical direction for future research will be to examine what types of input *are* most effective for language learning in HR infants.

4.1.5 General Conclusions and Clinical Implications

In sum, the present study extended prior work investigating supported and coordinated JE in young children with ASD to the HR infant population. Findings suggest that even in the second year of life, infants later diagnosed with ASD and non-ASD language delays are spending comparable proportions of time in supported JE as their typically developing peers. Consistent with prior work, HR-ASD infants spent less time in coordinated JE, though HR infants with non-ASD language delays showed a similar pattern. Additionally, HR infants as a group spent more time engaged solely with objects and less time unengaged. Furthermore, early differences in HR-LD and HR-ASD infants may impact their communicative environment; caregivers of these infants increased in the rate of labels they provided during coordinated JE. However, this caregiver input was negatively associated with language ability in toddlerhood, suggesting it may not be sufficient to bolster language development when infants may already be on a path to communicative delays. Since prior work does show a positive effect of caregiver verbal input during supported JE on language ability for young children across a range of diagnostic outcomes (Adamson et al., 2009; Bottema-Beutel et al., 2014), an important goal for future research will be to determine what aspects of caregiver input, at what points in development, are most effective for language learning in HR infants.

Taken together, these findings have implications for clinical applications. The present study was the first to our knowledge to take a novel approach to studying joint engagement in HR infants by including forms of JE *without* eye contact and examining these states in a naturalistic environment. Early intervention researchers have begun to take this approach; a study targeting toddlers with ASD (age 21 to 36 months) found increases in JE and decreases in object engagement following an 8-week parent-mediated intervention that taught parents to scaffold JE (Kasari et al., 2010). Researchers have also begun to examine the utility of pre-emptive parent-mediated interventions for HR infants with some promising effects (Green et al., 2017). By examining coordinated and supported JE in HR infants, and beginning to characterize their communicative environment in a naturalistic setting, the present study provides a first step towards understanding what strengths might be built upon in future interventions for infants at risk for ASD.

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