THE DEVELOPMENT OF MULTIMODAL SOCIAL COMMUNICATION IN INFANTS AT HIGH RISK FOR AUTISM SPECTRUM DISORDERS

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Submitted to the Graduate Faculty of

the Kenneth P. Dietrich School of Arts and Sciences

in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2012

UNIVERSITY OF PITTSBURGH

THE KENNETH P. DIETRICH SCHOOL OF ARTS AND SCIENCES

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In addition to impairments in gaze, facial expression, gesture, and sound, children with autism spectrum disorders (ASD) have difficulty producing these behaviors in coordination. Two studies were designed to evaluate the extent to which delayed and/or atypical development in the production or coordination of social communication behaviors can identify children eventually diagnosed with ASD. This research was grounded in Dynamic Systems Theory (DST), which proposes that changes in development depend on the interaction of multiple subsystems within the child, the environment, and the demands of the task; and that instability in one component can translate into varied developmental courses. A prospective longitudinal design was used to compare 9 infants at high familial risk for ASD (HR) later diagnosed with ASD, with 13 HR infants with language delay, 28 HR infants with no diagnosis, and 30 low risk (LR) infants. Participants were observed at home during naturalistic play with a primary caregiver at 8, 10, 12, 14, and 18 months. Frequencies of gestures, words, non-word vocalizations, eye contact, and smiles, and instances in which behaviors overlapped in time, were coded from videotape. Study 1 revealed that, while all infants demonstrated similar levels of communicative behavior at 8 months, ASD infants exhibited significantly slower growth in coordinations involving pre-speech vocalizations and those involving gestures used for joint attention than all other infants, even those exhibiting language delays. Study 2 demonstrated that information gathered on social communication skills during a natural setting improved prediction of diagnostic outcome when combined with standardized assessments and parent report; and the setting, method of measurement, and frequency of assessment were important factors in determining risk. Across both studies, variability was detected between and within infants. Results suggest that behavioral signs of ASD emerge over time in specific areas of communication. Disruption in the coordination of pre-speech vocalizations may result in negative cascading effects that have important implications for later social and linguistic development. Findings emphasize the importance of examining a wide range of communicative behavior in HR infants across contexts repeatedly over time and that DST offers a valuable framework with which to better understand their development.

Keywords: autism spectrum disorders, Dynamic Systems Theory, communication, development, coordination

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PREFACE

This dissertation project was supported in part by an Autism Speaks Sir Dennis Weatherstone Predoctoral Fellowship, an American Psychological Association Dissertation Research Award, and an A. David Lazovik Research Award from the Department of Psychology at the University of Pittsburgh awarded to Meaghan V. Parladé. This study was also supported by grants from the National Institute of Health (R01 HD41677 and R01 HD054979) to Jana M. Iverson. Portions of these data were presented at the 2011 annual International Meeting for Autism Research, San Diego, CA, and the 2012 annual International Meeting for Autism Research, Toronto, Canada

This project, and the long and arduous (yet rewarding) journey towards my Ph.D., would not have been possible without the continued professional and personal support of a number of people. First, I would like to thank my graduate advisor, Dr. Jana Iverson, for her guidance and support over the years. You have made a deeply meaningful contribution to my development both as a scientist and as a person. I am eternally grateful to you for providing me with opportunities to explore and refine my own interests, and for sharing your own passion with research. I cannot thank you enough for your support throughout this process; your enthusiasm for this study, unwavering confidence in my ability to complete it (even when I was wrought with doubt myself), and spoken and unspoken words of encouragement (particularly at the end) were essential to its completion. I am lucky to have worked with you and am proud to call you my “academic mother.”

I also owe thanks to the members of my committee, all of whom played a formidable role in the development and implementation of this project, as well as my overall academic development. First, special thanks go to Dr. Sue Campbell for supporting my research and my personal growth the past several years and for helping me to develop a strong foundation in theories and methods of developmental psychology. Dr. Celia Brownell, your thought-provoking questions (and the avid discussions they fostered), have continually pushed me to a higher level of contemplation and stimulated my overall intellectual development, and for that I am forever grateful. Many thanks to Dr. Elizabeth Votruba-Drzal for your strong statistical guidance throughout this project, for always welcoming even the most minor questions, and for showing me that a work-life balance is indeed possible to achieve. Thanks also go to Dr. Diane Williams for sharing your knowledge and expertise from a separate but integrally related discipline, and for your willingness to embark on an intellectual collaboration, one in which I hope to return in the future. And finally, my appreciation goes to Dr. Michael Pogue-Geile for offering insightful comments and a fresh perspective, and for guiding me and my peers through a rigorous academic program as the Clinical Psychology Program Chair.

Additionally, I would like to extend special thanks to the infants and their families without whose enthusiastic participation the research could not have been completed. I especially appreciate the way these families opened their homes and shared their lives with us; and how deeply committed they are to advancing science and knowledge of autism spectrum disorders. I also thank Drs. Nancy Minshew and Diane Williams for their help with recruitment and diagnostic assessments. To the members of the Infant Communication Lab, thank you for your smiles and laughter and of course, your dedication and enthusiasm during data collection. I will always have fond memories of lab meetings, the coding room, and the not so occasional

Saturday morning home visit. I owe particular thanks to Jonni Johnson, Lindsay Nickel, and Laura Ayer for coordinating such an amazing team of people.

I am eternally grateful to my coding team, Kaitlin Schuessler, Allison Rosenthal, and Nina Leezenbaum, for devoting countless hours to this project, for always responding so gracefully to my frantic calls and emails, and for meeting those very important deadlines; this project would not have been possible without you. Nina, your thoughtful feedback, help, and kindness never went unnoticed. I would also like to thank Julija Hetherington for being a master data manager and for always running "just one more query, I promise." Special thanks go also to Dr. Eve Sauer LeBarton for her enthusiastic, intellectual contributions to my research. I have enjoyed getting lost in deep discussion during conference poster sessions (even after the session has long since ended).

I have been privileged to study and grow alongside my fellow classmates, labmates, and friends, particularly Dr. Erin Koterba, Dr. Keiran Rump, and Dr. Anna Craig. Erin, you were there from the beginning and were as much a mentor to me as a friend. I look forward to many years of continued friendship and collaboration. Keiran, you were my partner in autism research; in many ways you paved the course for me to follow (e.g., Mailman). Anna, I have so valued your support and friendship throughout the years, especially during that first year of graduate school. I will always treasure all of the many friendships I have made in Pittsburgh and the memories we have shared, especially the writing days at Coffee Tree, Crazy Mocha, and Make Your Mark; the celebrations at Point Brugge; and not one, but two, Steelers' championships.

To my family – my parents, Jean and Larry, my sister, Kym, and my brother, Nick – thank you for your unwavering support throughout my life and most especially during graduate school. I always felt your love and encouragement even though we were physically hundreds of miles apart. I also thank my in-laws, the Parlades, for being the “village” to my son and providing countless evening and weekend hours of child care throughout this past year. Your support has also meant the world to me.

I would like to thank my son, my love, my Justin, for giving me hope. There is nothing like the unconditional love of a child to bring out the strongest determination to succeed. It was your silly, smiling face that pulled me out of many intervals of depression. I thank you for exerting your two-year-old version of patience with me every time I had to reply “No, I’m sorry.” to your requests that “Mommy, no work. Come on, Mommy, play.” Sweetie, now, I’m yours.

Finally, to my husband, AJ, I would like to extend my deepest and most heartfelt thanks. You have lived every moment of this experience with me and have made so many sacrifices in the name of my graduate career. From leaving the only home you had known in Miami and enduring four long years in rural Pennsylvania (snow and all), to becoming a “single dad” during the final 6-month push. No words can express how much your own dedication to my career has meant to me. This is for you.

1.0 INTRODUCTION

Neurobehavioral disorders that fall within the general autism spectrum (i.e., autism spectrum disorders; ASD) can be some of the most devastating disorders of childhood. ASD is present early in life but a reliable and stable diagnosis is rarely given before the age of 2 or 3 (Charman et al., 2005; Lord, 1995; Stone et al., 1999; Turner, Stone, Pozdol, & Coonrod, 2006). Thus, research efforts have begun to focus on the identification of early behavioral markers of risk for a later ASD diagnosis. Recent research indicates that infants with an older sibling who has a confirmed diagnosis of ASD are at an elevated risk for ASD and related social, communication, and behavioral difficulties (e.g., Zwaigenbaum et al., 2005; see also Rogers, 2009, for a review). Thus, the prospective study of these high risk infants (High Risk; HR) may permit the delineation of subtle risk markers in the first year of life. Social communicative behaviors are of particular interest because they lie at the heart of an ASD diagnosis (*Diagnostic and Statistical Manual-IV-TR*; American Psychiatric Association, 2000), and are among the best predictors of developing the disorder (Sigman, Dijamco, Gratier, & Rozga, 2004). This research was designed to describe developmental trajectories of the production and coordination of infant social communicative behaviors in HR infants and a group of comparison infants with low ASD risk (Low Risk; LR), and to evaluate the extent to which delayed and/or atypical patterns of these behaviors, prospectively observed, can be used to identify children eventually diagnosed with ASD.

Measurement of social communication behaviors in multiple contexts, including more naturalistic contexts, has the potential to inform our understanding of the range of children's social communicative behaviors and to facilitate the comparison of these behaviors across clinical and typical populations. In other words, evaluating social communicative behaviors under varying contextual constraints increases the probability of obtaining a valid index of these skills. Therefore, a second goal of the current study was to provide an initial comparison between fine-grained measurement of social communicative behaviors coded within a naturalistic play context and more macro-level quantification of similar behaviors coded within commonly used structured assessments.

These goals are grounded in work pointing to deficits in social communication behaviors and their coordination in children diagnosed with ASD and conceptualized within a theoretical framework derived from Dynamic Systems Theory (DST; Thelen & Smith, 1994). Following a brief overview of ASD and current approaches to the early identification of ASD, I describe what is currently known about the development of social communication skills in typical development; this is followed by a review of findings from studies examining social communication deficits present in children and infants with ASD, with particular emphasis on multimodal communication difficulties. I then outline the theoretical framework for the current research and its application to infants at risk for ASD.

1.1 AUTISM SPECTRUM DISORDERS

ASD is an umbrella term for a collection of developmental disorders known in the *DSM-IV-TR* as Pervasive Developmental Disorders (PDD; APA, 2000). There are three primary subgroups of disorders under the overall category of PDD that involve severe and persistent impairments in social interaction, delay and deviance in communication, and restricted and repetitive patterns of interest and behaviors. These subgroups are defined on the basis of the number and severity of symptoms that can vary widely and manifest in many different ways, and include Autistic Disorder, Asperger's Disorder, and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS).[1] For example, a qualitative impairment in communication may range from a total lack of spoken language with parallel deficits in the use of nonverbal forms of communication to relatively intact vocabulary, grammatical knowledge, and articulation skills but an inability to integrate language with gestures or other nonverbal behaviors (Lord & Paul, 1997).

The prevalence of ASD has increased over the past 30 years, and recent data indicate that 1 per 88 children are likely to be identified as having some form of ASD (Baio, 2012). Although its etiology is still unknown, ASD is recognized as a genetically-based neurobiological condition most likely involving multiple genes (Bailey, Phillips, & Rutter, 1996; Rutter, Bailey, Simonoff, & Pickles, 1997). Family studies have demonstrated a sibling recurrence risk of 2-6% in families with one child with ASD (Rutter, Silberg, O'Connor, & Siminoff, 1999). These rates are greatly increased over the general population risk, which even at its highest estimate is still less than 1% (Chakrabarti & Fombonne, 2001, 2005; Yeargin-Allsopp et al., 2003).

The existence of a "broader autism phenotype" (BAP) commonly seen in nonautistic family members of an individual with ASD is another indication of the disorder's strong heritability (see Bailey, Palferman, Heavey, & Le Couteur, 1998 for a review). The BAP involves milder, subclinical characteristics related to one or more of the three areas that are impaired in ASD: social responsiveness, communication, and limited interests/stereotyped

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[1]Although children diagnosed with Rett Disorder and Childhood Disintegrative Disorder are included under the classification of Pervasive Developmental Disorders by the DSM-IV-TR, these disorders are not generally included in the term ASD.

behaviors. These difficulties often occur at an elevated rate in first-degree relatives of individuals with ASD (Constantino et al., 2006; Constantino & Todd, 2000; Pickles et al., 2000; Rutter, 2000). While several studies have documented social and communication differences in the infant/toddler-aged younger siblings of children with ASD, the precise presentation of BAP in infancy and its relation to later development remains unclear (see Rogers, 2009, and Zwaigenbaum et al., 2009 for reviews).

As yet, ASD cannot be prevented and cannot be cured. Parents often report autism symptom recognition by the time their child is 18 months (Chakrabarti & Fombonne, 2005; Ozand, Al Odaib, Merza, & Al Harbi, 2003; Spitzer & Siegel, 1990; Volkmar, Stier, & Cohen, 1985) and many suspect developmental difficulties within the first year of life (Coonrod & Stone, 2004; Ornitz, Guthrie, & Farley, 1977; Zwaigenbaum et al., 2005). However, children are not usually given a clinical diagnosis of autism until after they reach age 4 (Baio, 2012). The median age of diagnosis is somewhat earlier for autistic disorder (48 months) than for children with the more broadly-defined PDD-NOS (53 months), and diagnosis is much later for children with Asperger's Disorder (75 months; Baio, 2012). Diagnosis for ethnic minority groups and children in rural settings occurs even later (Mandel, Listerud, Levy, & Pinto-Martin, 2002).

Thus, a major goal of contemporary autism research is the identification of infant markers of an eventual ASD diagnosis. This is potentially valuable for at least two reasons. First, and perhaps most importantly, early diagnosis is prerequisite to early intervention; and children who receive intervention by 2-3 years of age generally have more positive outcomes, specifically in terms of language development and school placement (Fenske, Zalenski, Krantz, & McClannahan, 1985; Rogers, 1996). Evidence also suggests that treatment yields diminishing returns as children get older (Mandell et al., 2005). Second, early detection permits the characterization of the early life of children with autism, which will broaden our understanding of the disorder and its development. Consequently, a large research effort has commenced that focuses on identifying early signs and symptoms of ASD.

1.2 RESEARCH APPROACHES TO EARLY IDENTIFICATION

Initial research on the early manifestations of ASD was primarily restricted to parents' retrospective reports in large-scale screening studies (Baird et al., 2000) and observations from early home videos (for a review, see Palomo, Belinchon, & Ozonoff, 2006). Although these studies have provided valuable hints regarding potential early behavioral identifiers of infants eventually diagnosed with ASD (e.g., Adrien et al., 1991, 1992; Baranek, 1999; Osterling & Dawson, 1994; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998; Werner, Dawson, Osterling, & Dinno, 2000), they have been limited in a number of ways. Reliance on parental report is problematic because of potential bias in recall. That is, the accuracy with which family members could recall behaviors in the past (sometimes years earlier), and the fact that the information was gathered after the children had been diagnosed with ASD may have biased the parents' views of what their children were like at younger ages. In home video studies, data are typically available from only a single occasion, clips tend to be relatively brief (as short as 3 min in some cases) and widely variable in length, and the social and physical contexts of the recordings vary widely from child to child, even in situations specifically chosen to be generally comparable across children (e.g., first birthday parties; Osterling & Dawson, 1994).

The most promising approach to early identification involves the *prospective* observation of infants at heightened risk for ASD and other forms of impairment (Zwaigenbaum et al., 2007).

Prospective studies of children at heightened genetic risk for a particular disorder are also utilized in research on mental illnesses such as schizophrenia and depression (e.g., Asarnow, 1988; Avenevoli & Merikangas, 2006; Thompson, Watson, Steinhauer, Goldstein, & Pogue-Geile, 2005), and medical illnesses such as breast cancer, diabetes, and heart disease (e.g., Bingley & Gale, 1989; Weinberg, Shore, Umbach, & Sandler, 2007); but this design is relatively new in autism research (Yirmiya & Ozonoff, 2007). The later-born siblings of children already diagnosed with ASD have an ASD recurrence risk of approximately 18.7% (Ozonoff et al., 2011). Thus, their inclusion in research greatly increases the probability that children who will eventually receive an ASD diagnosis are sampled.

Studies utilizing this type of prospective design systematically collect measures of behavior early in development, with assessments for ASD conducted at 24 to 36 months, when more reliable diagnoses are possible (Zwaigenbaum et al., 2009). The early behaviors of the children who do and do not develop ASD can then be contrasted with one another and typically-developing (TD) infants. Initial studies report that an estimated 25% of these later-born siblings who do not meet ASD diagnostic criteria nevertheless demonstrate other, more subtle social and cognitive abnormalities, including expressive language delays (Gamliel, Yirmiya, & Sigman, 2007; Landa & Garrett-Mayer, 2006; Sullivan et al., 2007; Yirmiya et al., 2006; Zwaigenbaum et al., 2005). Further, expressive language delays have been shown to be related to other difficulties in preverbal communication and social behavior (e.g., play; Thal, Tobias, & Morrison, 1991; Thal & Tobias, 1994; Whitehurst, Smith, Fischel, Arnold, & Lonigan, 1991). Research has also shown that while some early delays in cognition remit by preschool (Warren et al., 2012), expressive and language delays remain in a portion of these infants through the school age years (Gamliel et al., 2007; Gamliel, Yirmiya, Jaffe, Manor & Sigman, 2009), Thus, expressive language delays are present among many HR infants, including infants who later receive an ASD diagnosis and infants who do not. Therefore, if early behavioral markers of ASD identified in high risk samples are to be useful in guiding screening efforts for early diagnosis in the general population or clinically referred samples, it is important to know not only whether these markers can distinguish ASD from TD, but also whether they distinguish ASD from language delays (see Zwaigenbaum et al., 2007 for further discussion). At present, relatively few infant sibling studies include a clinical comparison group (e.g., infants with developmental or language delays) for the purpose of determining specificity. The inclusion of a high risk group that develops non-ASD difficulties is necessary to begin to determine whether observed deficits in social communication skills among ASD infants are both *sensitive* and *specific* to ASD, and not just a sign of more general delay. This is the approach that was adopted in the present study.

1.3 SOCIAL COMMUNICATION SKILLS AS AN IDENTIFYING FEATURE OF ASD

Social skill dysfunction is one of the most salient markers of ASD (Siegel et al., 1988; Volkmar et al., 1994) and has become a particularly fruitful area of inquiry in early identification studies (e.g., Cassel et al., 2007; Landa & Garret-Mayer, 2006; Yirmiya et al., 2006; Yoder et al., 2009; Zwaigenbaum et al., 2005). Indeed, the diagnostic criteria for ASD of the DSM-IV-TR (APA, 2000), and the International Classification of Diseases-10 (ICD-10; World Health Organization, 2002) both include qualitative impairments in social interaction and communication. The production and integration of communicative behaviors are also flagged as a diagnostic feature of ASD in gold standard assessment tools such as the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000) and the Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003). An impressive amount of research on the social communicative deficits in children with ASD has taken place over the past few decades. Before proceeding to a discussion of that work, however, I will provide a brief overview of current methods for evaluating these skills in young children, and their normative development.

1.4 METHODS FOR STUDYING THE DEVELOPMENT OF SOCIAL COMMUNICATION

Measurement of social communication poses a challenge for researchers because it is influenced by many variables, including the social partner, the interactive context, the source of information, and psychometric features of the measurement scale (Wetherby, 2006). Several research strategies have traditionally been employed in studies of social communication development in young children with and without communicative delay. These include semi-structured interactive sampling in a laboratory or clinical setting, information reported by parents or teachers familiar with the child, and observation in the natural environment.

1.4.1 Semi-structured interactive sampling methods

Semi-structured play instruments provide an index of children’s communicative competence by assessing frequencies of behaviors and describing their form (e.g., gestures, eye gaze) and function (e.g., joint attention, behavior regulation, social interaction; Kasari, Sigman, Mundy, & Yirmiya, 1990; Mundy, Sigman, Ungerer, & Sherman, 1986; Phillips, Gomez, Baron-Cohen, Laa, & Riviere, 1995; Stone, Ousley, Yoder, Hogan, & Hepburn, 1997; Wetherby et al., 2004). One advantage of experimenter-child interactions is that they minimize the possible variability that caregivers may contribute to the display of communication skills among children (i.e., by scaffolding production of target behaviors).

One of the most widely used instruments is the Early Social-Communication Scales (ESCS; Seibert, Hogan & Mundy, 1982). The ESCS was designed to measure nonverbal communication skills in TD toddlers (Morales et al., 2000; Mundy & Gomes, 1998; Mundy & Willoughby, 1998) and was later utilized with children with ASD and other developmental delays (Mundy, Kasari, Sigman, & Ruskin, 1995; Mundy, Sigman, & Kasari, 1990). It involves a series of face-to-face, structured interactions between an examiner or clinician and a child, in which a variety of toys and social prompts are employed in order to elicit social communicative bids. Thus, a potential limitation of this method is that it involves interaction with an unfamiliar adult in an unfamiliar setting, factors that may well impact the performance of at least some children (Wetherby, 2006). It is therefore not yet clear whether and to what extent observed differences in infant behavior under standardized conditions are characteristic of the child in the everyday environment.

1.4.2 Parent report measures

A second approach to measuring social communication skills is to use information reported by adults familiar with the child's social communication in natural environments gathered in questionnaire or interview format. Of the currently available assessment tools, the Words and

Gestures form of the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2002) documents the largest number of early and later emerging social communication skills. Parents are provided with a list of common vocabulary words and asked to indicate those that their child understands or understands and says. The CDI also includes a list of common early gestures (e.g., giving, showing, pointing) and social actions (e.g., games and routines, pretend play), and parents are asked to check whether the child has (either commonly, sometimes, or not yet) displayed each behavior. Parent report measures capitalize on the knowledge of a familiar person who interacts with the child on a daily basis. One limitation to the CDI, however, is the lack of specific information related to the frequency with which each behavior is produced and the developmental order of emergence of behaviors.

1.4.3 Naturalistic observation

Finally, for very young children with or without developmental delay, frequency, type, function, and complexity of social communicative behaviors can be sampled in interactive play contexts with caregivers and other adults. Naturalistic observation of a child with a familiar communicative partner over an extended period of time may capture the child's repertoire of skills and provides an ecologically valid measure of the child's spontaneous use of social communication in natural settings. Typically, this approach involves videotaping the child in the home interacting with a parent (Capirci, Iverson, Pizzuto, & Volterra, 1996; Iverson, Capirci, & Caselli, 1994). Observation in this type of context is a standard and reliable method that has been widely and successfully employed in numerous studies of early communicative development (e.g., Butcher & Goldin-Meadow, 2000; Iverson et al., 1994; Iverson & Goldin-Meadow, 2005).

The primary advantage to naturalistic home observation as the primary means for measuring social communication skills is that many of these behaviors (e.g., vocalizations, gestures, and speech) are maximally likely to occur when infants are in familiar surroundings and engaged in familiar activities with familiar adults. TD infants are known, for example, to vocalize more frequently and their vocalizations are more likely to contain syllables when they are in the home than when they are in the laboratory (Lewedag, Oller, & Lynch, 1994). Similarly, rates of gesture production among toddlers are nearly twice as high in the home as they are in laboratory play sessions (Iverson et al., 1994; Thal & Tobias, 1992).

In sum, each of the methodologies described above has provided valuable information about the development of early social communication skills in young children; however, each also has its limitations. Therefore, sampling procedures that incorporate structured evaluation, parent report, *and* measures derived from naturalistic interactions may provide a more complete picture of infants' communicative repertoires (Tager-Flusberg et al., 2009; Crais, Watson, & Baranek, 2009). The current research employed this strategy in order to provide an initial, exploratory description of the range of social communication skills in children who are at risk for delays in this domain.

1.5 THE DEVELOPMENT OF SOCIAL COMMUNICATION IN TD CHILDREN

Social communicative competence in typical development is a progression of developmental achievements that involve the ability to engage in social exchanges with a communicative partner (e.g., caregivers) using a broad array of verbal and nonverbal behaviors (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bates, O'Connell, & Shore, 1987). Long before TD infants begin to speak, they communicate nonverbally through a collective system of behaviors such as facial expressions, eye gaze, communicative non-word vocalizations (NWVs), and gestures (Parlade & Iverson, 2010, 2011; Trevarthen & Hubley, 1978). Longitudinal and cross-sectional research on TD children has documented a developmental sequence of emergence of social communicative skills over the first year of life (e.g., Bakeman & Adamson, 1984; Bates, 1976; Bates et al., 1979; Bruner, 1975; Carpenter, Nagell, & Tomasello, 1998).

Over time, social communication becomes more varied and complex (Bates et al., 1979; Wetherby, Cain, Yonclas, & Walker, 1988), particularly as a result of the development of increasingly sophisticated and explicit gestures (Iverson & Thal, 1998). For example, rate of communication increases, communicative functions become more differentiated, and most important for purposes of the present study, infants begin to combine and coordinate multiple communicative cues within a single utterance. Indeed, the ability to coordinate communicative behaviors into a single, seamless act is a crowning achievement in the development of social communication (e.g., Crais et al., 2009; Stone et al., 1997).

A rich body of work has described the developing co-production of communicative behaviors throughout infancy. Thus, for example, as early as 3 months of age, infants coordinate facial expressions (smiles and frowns) with NWVs at greater than chance levels (Yale, Messinger, Cobo-Lewis, Oller, & Eilers, 1999; Yale, Messinger, Cobo-Lewis, & Delgado, 2003). At around 12 months, positive facial expressions frequently accompany pointing and showing gestures (Adamson & Bakeman, 1985; Kasari et al., 1990; Messinger & Fogel, 1998; Mundy, Kasari, & Sigman, 1992). With increasing age, the use of gestures or NWVs alone decreases as gesture-NWV combinations increases until a point when they predominate at 15 months (Carpenter et al., 1998; Wetherby et al., 1988). By the second birthday, gestures and words are tightly coordinated; gestured and spoken elements in coordinated communications are both semantically coherent and temporally synchronous (Butcher & Goldin-Meadow, 2000; Pizzuto, Capobianco, & Devescovi, 2005). Findings such as these point to close, time-linked relationships between the facial, manual, and vocal modalities in the development of an integrated communicative system.

Thus, as communicative development continues to unfold over the first two years, the child's ability to combine communicative behaviors from different modalities grows, even as the individual components of the infant's communicative repertoire are themselves undergoing significant development (Bates, 1976; Bates et al., 1979; Desroches, Morisette, & Ricard, 1995; Wetherby et al., 1988). For example, after the onset of the vocabulary spurt, a major transition in language development, the frequency with which communicative behaviors such as gestures, smiles, NWVs, and words appear in coordination increases significantly (Parlade & Iverson, 2010). Further, developmentally earlier forms of communication (e.g., smiles, NWVs) continue to be produced during the transition period; however, the degree to which these behaviors appear in coordination decreases after the onset of the spurt. Meanwhile, words are increasingly produced in coordination during this time. This ultimately results in the child's ability to coordinate behaviors flexibly and to modify communicative signals as needed (Bates et al., 1979; Wetherby et al., 1988).

Not only is multimodal coordination an index of the relative strength of the communicative system, it plays an important role in social interaction. For example, the co-production of communicative behaviors has been shown to increase the salience and interpretability of the communicative act and increase the probability of a social partner responding to the communication (Martinsen & Smith, 1989; Yoder, Warren, Kim & Gazdag, 1994). Thus, when a child is attending to an object then vocalizes about such object, the likelihood that the caregiver's attention will be attracted to the object of interest to the child is greatly enhanced when the vocalization is combined with a gesture or alternating eye gaze. The state of shared attention between the child and caregiver that has resulted now provides an occasion for the caregiver to provide relevant linguistic input. In fact, joint attention has long been thought to provide a foundation for language development (Bates et al., 1979; Tomasello & Farrar, 1986). Recent research demonstrates this relationship more specifically by showing that mothers increase the length of their responses selectively to certain types of gesture-speech combinations (Goldin-Meadow, Goodrich, Sauer & Iverson, 2007).

Thus, communicative coordinations appear to elicit important input from a social partner, which in turn, may facilitate language development. Indeed, the coordination of communicative behaviors is a predictor of later linguistic as well as socio-emotional development. For example, the production of gestures in combination with words reliably predicts the transition to two-word speech, a significant achievement in language development (Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005; Rowe & Goldin-Meadow, 2009; see also Capirci et al., 1996). Moreover, the temporal coordination of eye gaze and smiling during joint attention episodes between 9 and 12 months has been found to correlate positively with emotional expressivity and social competence at 30 months (Parlade et al., 2009). These findings suggest that the coordination of communicative signals is an important form of infant behavior that relates uniquely to later social competencies.

Surprisingly, this ability to coordinate communicative behaviors from multiple modalities remains relatively unexplored in research on social communication in infants at risk for delays. It is perhaps even more surprising in light of the fact that a) multimodality is a key component in typical communication; b) communicative coordinations are a powerful social stimuli that have the potential to redirect caregiver attention (e.g., Goldin-Meadow, et al., 2007; Martinsen & Smith, 1989; Yoder et al., 1994); and c) young children’s ability to coordinate behaviors is predictive of later language skill and social competence (e.g., Parlade et al., 2009; Rowe & Goldin-Meadow, 2009). Given that social and language behaviors are known to be impaired in older children with ASD (see below), multimodal communication may therefore be a potential prognostic indicator in infants at-risk for ASD.

1.5.1 Defining Social Communication Deficits in Children with ASD

Children with ASD often have tremendous difficulty participating in the verbal and nonverbal aspects of normal social interaction. These impairments are marked and sustained and affect facial, manual, and vocal modalities. Thus, for example, children with ASD show difficulty using eye contact to share experiences with others (Mundy, Sigman, & Kasari, 1994; Osterling & Dawson, 1994; Sigman & Ruskin, 1999), increased difficulty with gesture production (Landry & Loveland, 1988; Mitchell et al., 2006; Smith & Bryson, 2007), atypicalities in facial expression of emotion (Celani, Battachi, & Arcidiacono, 1999; Loveland et al., 1994; Yirmiya, Kasari, Sigman, & Mundy, 1989), and disturbances in preverbal speech sounds (i.,e., NWVs; De Giacomo & Fombonne, 1998; Kuhl, Coffey-Corina, Padden, & Dawson, 2005; Sheinkopf, Mundy, Oller, & Steffens, 2000) and in aspects of receptive and expressive language development (Lord & Paul, 1997; Tager-Flusberg, Paul, & Lord, 2005; Zwaigenbaum et al., 2005).

The social behaviors just described can be further distinguished on the basis of function, or the purpose of the communicative message. Bruner (1981) proposed that young children's early communicative acts can be divided into at least three broad functional categories: a) behavior regulation (acts used to regulate another's behavior, e.g., requesting or protesting objects and actions); b) social interaction (acts used to gain or maintain another's attention to self, e.g., greeting or showing off); and c) joint attention (acts used to direct another's attention to an object or event, e.g., showing objects and actions). TD children show an increase in the number of specific communicative functions used within these three major areas with age and advancing language skills (Crais, Douglas, & Campbell, 2004; Dore, 1979; Wetherby et al., 1988). However, behavior regulation acts are often the main mode of responding in younger children with ASD (Mundy et al., 1994; Wetherby, 1986; Wetherby et al., 2004; see below). They also tend to utilize atypical forms of this behavior (e.g., placing an adult's hand on a desired object) rather than more conventional behaviors (e.g., pointing or showing) to communicate their needs (Paul, Chawarska, Klin, & Volkmar, 2007).

An overwhelming majority of studies to date have assessed the form and function of social communication skills in semi-structured assessments with an examiner (e.g., ESCS) in the laboratory or clinic (e.g., Kasari et al., 1990; Mundy et al., 1986; Phillips et al., 1995; Stone et al., 1997; Wetherby et al., 2004). However, there is evidence to suggest that the spontaneous communication of children with ASD may be more limited in unfamiliar situations. For example, McHale and colleagues (1980) found that children with ASD demonstrated more social communicative initiatives in the presence of their teachers than in the presence of unfamiliar adults. Therefore, the communicative behaviors of children with ASD captured during a novel social situation in an unfamiliar setting with an unknown adult may not be entirely representative (Wetherby, 1986).

Although the extant literature characterizing communicative deficits in ASD has documented widespread social communication abnormalities in early childhood, the nature of these deficits in infants and toddlers with ASD is less clear, and the extent to which they may be evident in infants at risk for ASD has not yet been determined. For example, some prospective studies of HR infant siblings report differences between HR and LR groups in the duration of gaze or affect expression during face-to-face interaction at 4 and 6 months of age (Ibanez, Messinger, Newell, Lambert, & Sheskin, 2008; Merin, Young, Ozonoff, & Rogers, 2007; Yirmiya et al., 2006). Delays in verbal and gestural communication development beginning at 12 months have been reported in HR infants who develop ASD in a number of studies (Landa & Garret-Mayer, 2006; Yirmiya et al., 2006; Yoder et al., 2009). In addition, reduced variety of gesture types in 9-12 month olds is a strong predictor of a later ASD diagnosis (Colgan et al., 2006). However, others have found no differences in measures of affect sharing, joint attention, social interaction, or use of conventional gestures in the first year of life (Toth, Dawson, Meltzoff, Greenson, & Fein, 2007; Zwaigenbaum et al., 2005).

Although difficulties in social communication skills are somewhat more pronounced for those HR infants who go on to develop ASD (Bryson et al., 2007; Dawson, Osterling, Meltzoff, & Kuhl, 2000; Landa, Holman, & Garrett-Mayer, 2007; Sullivan et al., 2007; Wetherby et al., 2004), there still appears to be variability in the onset and precise nature of these signs (Rogers, 2009; Zwaigenbaum et al., 2009). Studies that have reported differences in the social communicative behaviors of HR versus LR infants indicate that such differences are evident by 12 months (but not at 6 months) and become more apparent with age (see Rogers, 2009, for a review). However, many of these studies sample behavior relatively infrequently (e.g., target ages 6, 14, and 24 months) which may contribute to an incomplete portrayal of the pattern of developmental change (for an excellent discussion of this issue, see Adolph, Robinson, Young, & Gill-Alvarez, 2008).

Because an accurate characterization of developmental trajectories depends on the frequency with which target behaviors are sampled, the present research investigated communicative behaviors at regular and frequent intervals from 8 to 18 months. This will provide a more comprehensive indication of the repertoire of behaviors that are involved in social communication and the interrelationships among them, and shed additional light on the extent to which the development of these behaviors may be delayed or atypical in infants at risk for ASD.

1.5.2 Multimodal Communication in Children with ASD

While TD children frequently and flexibly coordinate multiple communicative behaviors in time well before the first birthday (e.g., Bates, 1976), children with ASD tend to rely on isolated communicative signals during social interactions (e.g., Camaioni, Perucchini, Muratori, & Milone, 1997; for a recent review, see Parladé, 2012). Relative to TD children and children with mental retardation and other developmental disabilities, children with ASD demonstrate a significant delay in temporally coordinating positive affect expressions with eye contact, gestures with eye contact, and gestures with vocalizations (Adrien, Ornitz, Barthelemy, & Sauvage, 1987; Buitelaar, van Engeland, de Kogel, de Vries, & van Hooff, 1991; Kasari et al., 1990; Wetherby, Yonclas, & Bryan, 1989). And even when levels of overall communication (indexed by production of verbalization, eye contact, or gesture taken singly) are similar to those of comparison samples, children with ASD show reduced frequency of coordination of these behaviors. Moreover, children with ASD are less apt to produce utterances involving the combination of *more than two* communicative behaviors (e.g., co-production of gesture, vocalization, and eye gaze) than comparison children (Stone et al., 1997; Wetherby et al., 2004).

For children with ASD, the production of temporally co-occurring communicative signals appears to be less apparent in triadic communicative contexts as opposed to dyadic, face-to-face situations (Adrien et al., 1987; Mundy et al., 1986; Phillips et al., 1995). Moreover, children with ASD have increased difficulty producing these coordinations for joint attention as opposed to behavior regulation purposes (Kasari et al., 1990; Mundy et al., 1986; Stone et al., 1997; Wetherby et al., 2004). Although most of the research in this area has been conducted using semi-structured interactive assessments (e.g., ESCS), these difficulties appear to persist across situational contexts, including social interactions with caregivers (Dawson, Hill, Spencer, Galpert, & Watson, 1990; Joseph & Tager-Flusberg, 1997). However, investigations examining the coordination of smiles and eye gaze in situations where the adult provides more support in facilitating the social interaction typically demonstrate higher levels of multimodal coordination. For example, Sigman and colleagues (1986) found that as compared to free play situations, interactions in which caregivers played a social game (e.g., pat-a-cake or peek-a-boo) were the only ones in which the children with ASD showed as much mutual eye gaze with smiling as TD and developmentally delayed children. They note that social games are by nature highly regulated by the caregivers and involve a high degree of physical contact (i.e., caregivers physically held their children in these play episodes).

Research examining these more intricate social communicative processes in infancy is limited. Retrospective home video studies of infants eventually diagnosed with ASD indicate severe and persistent difficulties with more developmentally advanced communication skills, including the use of gestures for joint attention and behavior regulation and the production of gestures combined with eye gaze (e.g., Adrien et al., 1991, 1992; Baranek, 1999; Osterling & Dawson, 1994; Teitelbaum et al., 1998; Werner, Dawson, Osterling, & Dinno, 2000). Evidence of impairments in less complex communication skills, such as the use of eye gaze alone and the coordination of eye gaze and smiles during face-to-face interactions is less clear. Two of the three known studies examining these earlier emerging skills reported difficulties in combining eye gaze with smiles (Adrien et al., 1993; Werner et al., 2000) while one did not (Clifford & Dissanayake, 2008). However, a number of methodological limitations (e.g., wide age ranges, variation in the length of movies and the events filmed) make it difficult to interpret these findings.

In a series of prospective studies examining social communication skills in infants and toddlers (*M* = 21 months; age range = 13.0-26.9 months) determined to be at heightened risk for communication delays during a general population screening, Wetherby and colleagues (2004, 2007) rated a videotaped sample of behavior during a semi-structured play assessment (Communication and Symbolic Behavior Scales Developmental Profile; CSBS-DP; Wetherby & Prizant, 1993, 2002). The HR children later diagnosed with ASD were distinguished from the DD and TD comparison groups on the basis of lack of coordination of gaze, facial expressions, gesture, and sound, lack of smiles coordinated with gaze, lack of sharing interest (i.e., joint attention; Wetherby et al., 2004). In a follow-up study employing a larger sample, those toddlers who eventually received an ASD diagnosis sored significantly lower than a TD group on social communication measures including shared positive affect and inventory (i.e., number of different types) of gestures, NWVs and words. However, inventory of gestures was the only one of these variables for which the ASD group also scored significantly lower than the DD group (Wetherby, Watt, Morgan, & Shumway, 2007).

Only two known studies have reported data on multimodal communication in HR infant siblings (Ozonoff et al., 2010; Winder, Poulos-Hopkins, Parladé, Wozniak, & Iverson, in press). Using the Mullen Scales of Early Learning (MSEL; Mullen, 1995), administered at 6, 12, 18, 24, and 36 months, Ozonoff and colleagues measured the frequency of “early emerging” coordinations (i.e., eye gaze combined with smiles or vocalizations) in a group of HR infants later diagnosed with ASD and a gender-matched LR group later determined to have typical development (TD). Of note, they only reported data for the HR infants who met criteria for an ASD outcome; they did not include the HR infants who did not develop ASD in the study.

The authors found that HR infants later diagnosed with ASD exhibited declining trajectories in “early emerging” coordinations The frequencies of social smiles and vocalizations to others (i.e., directed vocalizations) were highly comparable at 6 months of age, but differences between ASD and TD infants were significant by 12 months for directed vocalizations and by 18 months for social smiles, and became more pronounced with age. However, as mentioned above, this study did not include a high risk comparison group; without the inclusion of a comparison group to control for potential confounding variables, it is difficult to determine whether these differences observed are specific to ASD or indicators of early developmental delay (Zwaigenbaum et al., 2007). Further, the data gathered in this study was generated from infant-experimenter interaction during the MSEL and took place in the laboratory/clinic setting. As noted above, it is not yet clear to what extent observed differences in infant behavior under standardized conditions are characteristic of the child in the everyday environment.

In a recent study, HR and LR infants were observed longitudinally at 13 and 18 months (Winder et al., in press). Spontaneously produced communicative behaviors including gestures, NWVs, and words (singly and in combination) were coded during naturalistic in-home interaction and semi-structured play with caregivers. Results indicated that HR infants (including 3 infants later diagnosed with ASD) produced gesture-speech combinations at a significantly lower rate than LR infants at 18 but not 13 months of age. HR infants also demonstrated a more restricted repertoire of gesture-speech coordinations; specifically, HR infants produced significantly fewer vocal utterances (NWV and words) coordinated with point gestures. While results are promising, it is unknown whether and to what extent reduction in early preverbal communicative behavior of this sort is specific to infants at heightened risk for ASD rather than being a more general marker of potential language delay regardless of ASD-risk status. Further, while this study adopted a longitudinal approach, more frequent observations of both early emerging and developmentally advanced coordinations in familiar, everyday environments may shed additional light on the early communicative repertoires of HR infants.

In general, research to date suggests that infants and children with ASD demonstrate specific difficulty integrating multiple behavioral signals into a single, organized communicative act. It is therefore surprising that little work to date has specifically examined *coordinations* in prospective studies of infants at risk for ASD. Thus, Study 1 in the present research focused on multimodal communicative coordinations in general, specifically examining developmental trajectories of HR infants who develop ASD, those who do not receive an ASD diagnosis but may (or may not) experience other types of delays, and comparison infants with no family history of ASD.

Further, although the literature to date suggests that contextual factors influence communicative performance for children with ASD as well as TD children, little known is about the influence of context variation on the expression of social communicative skills in infants at risk for ASD. Study 2 was therefore designed to provide an initial evaluation of the way in which interactive context may influence social communicative behaviors in infants at risk for ASD.

1.6 A THEORETICAL MODEL OF THE DEVELOPMENT OF SOCIAL COMMUNICATIVE COORDINATION

Dynamic systems theory (DST; Thelen & Smith, 1994) provides a useful framework for understanding the progression of communicative development in TD children and can help elucidate instances in which development goes awry, as in ASD. A central tenet of DST is that complex phenomena (e.g., communication) cannot be fully understood by dissecting the system into its constituent parts because the individual components and their associated functions are embedded within the fabric of the whole system. Accordingly, understanding typical and atypical communicative development requires investigations of multiple modalities, the use of multiple methods and contexts, and assessments of interactions as they unfold over time (Iarocci & McDonald, 2006).

From a DST perspective, the foundations of complex thought and behavior are built upon a continual interplay between perceptual and behavioral processes that interact with the broader social environment (Thelen, 2004). Unlike many existing theories of ASD (albeit similar to a developmental psychopathology perspective; Cicchetti & Cohen, 1995; Sroufe & Rutter, 1984), DST is concerned with issues of underlying processes, universal mechanisms, and variable outcomes, and more specifically, with the question of how complex organisms, including developing infants, produce behavioral patterns that evolve over time.

DST views development as both continuous and dynamic—moving all the time. Throughout development, and over different timescales (e.g., seconds, minutes, days, weeks, months, years), there are circumstances in which behavioral options are more constrained and circumstances in which systems are primed to explore new options and new behaviors are likely to emerge. Disordered behavior, then, can be best understood as the emergent product of multiple, nonlinear interactions that occur in real time and involve a large number of variables, including the history and individual characteristics of the child, the demands of the current task, and various social and environmental constraints (Thelen & Smith, 1994).

1.6.1 Complexity

Developing organisms are complex systems comprised of multiple interacting parts that self-organize to produce coherent patterns (Thelen & Smith, 1994; Thelen, 2004, 2005). These components operate collectively without any overarching program or recipe; the order of the system is generated solely in the relationships between behaviors. The specific relationship between individual components is continually adaptable and flexible; and it is in the mutual interactions and shifting coordination of these co-existing parts that we can observe the very process of change (Thelen, Schoner, Scheier, & Smith, 2001).

Self-organization also means that no single element has causal priority; rather, any component has the potential to disrupt or reorganize the system (Smith & Thelen, 2003). Behavior is therefore multiply determined; and because development is the result of interactions among the constituents of a system, it is inherently nonlinear. Consequently, the *relationships among components* are a primary source of systemic change (Thelen & Smith, 1994).

One index of the strength of these intra-component relationships is the relative degree of temporal coordination between component behaviors. Thus, for example, learning to reach involves the coordination of arm movement and patterns of muscle activation in order to obtain a desired object. As infants become more skilled at each of these component behaviors, they unfold in a tightly timed, well-coordinated reaching action (Iverson & Thelen, 1999; Thelen, 2001, Thelen, Corbetta, & Spencer, 1996). A similar scenario has been described in the communicative system; in general, production of gesture-NWV combinations in which the two elements are synchronous increases with development (Pizzuto et al., 2005).

1.6.2 Soft assembly

Soft assembly is the notion that behavior is inherently flexible, and that a myriad of behavioral modes or coordinations are possible depending on the status and relative influence of each component of the system at any given time (Gershkoff-Stowe & Thelen, 2004; Iverson & Thelen, 1999; Thelen & Smith, 1994). In typical development, systems continually move in and out of a state of flux. As this happens, patterns dissolve and evolve, shifting from one preferred state to another (Smith & Thelen, 2003). Importantly, however, earlier behavioral patterns do not disappear and may emerge again under certain circumstances. Because patterns involving well-established behavioral forms are likely to be stronger and more stable than newer patterns, they may guide the system during times of instability.

Further, the many individual elements of the system are embedded within and open to influence from a complex environment (Smith & Thelen, 2003). As a result, small differences in any one aspect of the system will engender changes in the way the system as a whole is organized. An important implication of this view is that instability in one component (e.g., the introduction of a new skill or transformation of an existing one) will engender changes in the way the system as a whole is organized (see Parlade & Iverson, 2011 for an example of this phenomenon in TD language development). For example, children who experience rapid growth in vocabulary during the vocabulary spurt demonstrate a significant reduction in the frequency with which gesture, affect, NWVs, and words were produced in coordination. They also showed a preference for coordinations comprised of well-established behaviors (e.g., affect, NWVs) while words were rarely produced in coordination (Parlade & Iverson, 2011).

This temporary decoupling of behavioral components of the communicative system during transition – evidenced by the reduction in communicative coordinations – illustrates the way in which the communicative system shifts and reorganizes to allow for continued growth. Further, the introduction of a relatively weak component (i.e., words) to the system introduced a significant amount of instability and encouraged a reliance on more stable, well-patterned coordinations. Development, therefore, can be thought of as a series of evolving and dissolving patterns of varying stability, rather than a systematic progression toward a final end (Smith & Thelen, 2003; Thelen & Smith, 1994; Thelen, 2004).

1.6.3 Application of DST to the Study of HR Infants

The DST view of communicative development involves a collective system with dynamic interplay among multiple components that self-organize to produce a potentially very large set of behavioral combinations. Moreover, because development is holistic, some degree of influence from any one element of the communicative system may profoundly alter the way in which component behaviors work together (i.e., are coordinated). For the most part, communicative abilities generally emerge and develop in a similar fashion across children, with temporary deviations as new skills emerge and are consolidated with old skills. However, for some children, variability in the course of communicative development may deviate from the norm due to characteristics of the child and/or the environment.

HR infants at risk for ASD may show a different pattern of development that could manifest in at least three ways. First, DST places a strong emphasis on the dynamic interplay between a myriad of forces on the developing system and the relative stability of component behaviors. The literature reviewed above suggests that relative to TD children, the communicative systems of infants with ASD are characterized by greater instability. In addition to some reports of lower frequency of communicative behaviors in children with ASD (e.g., Landry & Loveland, 1988; Mitchell et al., 2006; Mundy et al., 1986; Sigman & Ruskin, 1999; Stone & Caro-Martinez, 1990; Wetherby et al., 2007; Zwaigenbaum et al., 2005), communicative performance appears to be more strongly influenced by contextual variations than that of TD children (e.g., Lewy & Dawson, 1992; Sigman et al., 1986). This "hypersensitivity" to input from the external and internal worlds may interfere with the formation of coherent and stable behavioral patterns, and communicative behavior may thus appear to be highly variable. This instability also has implications for the ability to coordinate multiple communicative behaviors in a single, tightly timed message. As previously described, behavioral components are more susceptible to decoupling in the face of instability. Thus, infants with ASD may exhibit a specific difficulty with packaging multiple behaviors into a single communicative act.

Second, TD children have a number of communicative strategies available to them and are able to coordinate these behaviors temporally such that the initial coordinations can disassemble and reassemble into more effective configurations if modifications are needed (e.g., an unresponsive partner, excess background noise). In this case of infants with ASD, a lack of behavioral variability and flexibility in communicative performance may occur. A consequence of limited behavioral options may be a lack of diversity in the repertoire of communicative coordinations (e.g., communicating through eye contact plus smiles only or NWVs plus eye contact only). This inflexibility may also place limits on the ability to adapt to relative increases in processing demands placed on the system. For example, young children with ASD have greater difficulty with highly complex communicative acts that involve the integration of three or more behaviors (e.g., Stone et al., 1997). Therefore, infants with ASD may experience the most widespread difficulties organizing multiple communicative behaviors into a single act.

Finally, the communicative systems of children with ASD may get "stuck" in developmentally prior states. Typically, the early-appearing dyadic behaviors of eye gaze and smiling are produced and perceived with relative ease. These behaviors are initially governed by simple reciprocity and contingency processes (Stern, 1985) and occur in interactions that are highly repetitive and very well structured by the caregiver. It is possible that these behaviors develop "normally" in children with ASD (at least initially) and, with repetition, become the preferred behavioral mode (Thelen & Smith, 1994) in early infancy. The more children repeat them, however, the stronger and more entrenched the patterns become. Then, when new circumstances arise, the communicative system may not adapt to produce a new behavioral configuration and may instead continue to fall back on pre-existing patterns (see also Thelen, 2005). That is, patterns that are initially adaptive may become so habitual that children have greater difficulty transitioning into a new behavioral mode (e.g., triadic communication).

To summarize, DST provides a new and sophisticated theoretical foundation particularly well-suited for evaluating the social communication profiles of infants with ASD. It also raises a number of questions to consider regarding the development of multimodal communication in infants *at risk* for ASD. Will these aberrant processes also be evident in the development of social communicative behaviors in HR infants who do not receive an ASD diagnosis (including those with language delays)? Is there a specific point in development or certain conditions under which behavior appears more or less integrated? Might a disturbance in one component of communication alter the way in which all behaviors work together? The present study was therefore designed to address questions such as these by evaluating a set of hypotheses derived from this theoretical model. These are detailed below.

1.7 THE PRESENT STUDY

This research is comprised of two studies designed to examine the development of social communicative behaviors and coordinations in infants at risk for ASD. First, although communicative behaviors are often examined separately for practical purposes, it is important to acknowledge the dynamic and interactive associations among components as well as their transactions with the contexts surrounding them (Mitchell, 1995). As noted above, because the vast majority of studies concerned with communicative development in infants at-risk for ASD have focused on individual communicative behaviors despite the known impairment in coordinating communicative behaviors manifested by older children with ASD, there is a need to examine the broad constellation of social communicative behaviors and their coordinations in infants at heightened risk for ASD. The goal of Study 1 was therefore to examine HR infants' social communication skills by identifying developmental trajectories of individual communicative behaviors and their respective coordinations at *multiple time points* and compare them to those of LR infants.

Second, examination of developmental profiles may improve screening predictions in high risk populations (Darrah, Hodge, Magill-Evans, & Kembhavi, 2003). Study 2 is an initial, descriptive study designed to explore factors that could be important in informing clinical practice, namely, the assessment of ASD in HR infants. Tager-Flusberg et al. (2009) have recently argued that "in order to capture the communicative abilities of young children with ASD and to avoid sampling effects, assessments in this domain should include measures derived from multiple sources. These sources should ideally include (a) natural communicative samples, (b) parent report, and (c) direct standardized assessments" (p. 645). Therefore, this study examined profiles of communication development in HR infants *across multiple contexts over time*. At issue here was whether HR infants demonstrate variation in social communication abilities when skills are assessed in a structured versus naturalistic setting. In addition, this study asked whether an examination of patterns of change in infants' communication skills can improve the accuracy with which ASD infants are identified. Also of interest was whether communicative development profiles that include information about the relative use of *multimodal communication* with other communicative skills improve prediction of diagnostic outcome in HR infants.

2.0 STUDY 1

The aims of Study 1 were to: a) describe developmental trajectories in the production and temporal coordination of social communicative behaviors from 8 to 18 months in HR and LR infants, and evaluate the extent to which developmental delay or impairment in these communicative behaviors predicts a later ASD or Language Delay diagnosis in HR infants; b) test a set of hypotheses guided by DST (Thelen & Smith, 1994) regarding the effects of instability on the communicative system and the consequences for the development of social communication skills; and c) determine whether delays or deviance in the development and coordination of communicative behaviors are specific to ASD –and therefore could be considered a viable candidate for a behavioral marker of the disorder – or merely indicative of general communicative delay.

The DST notion of soft assembly suggests that behavioral patterns are assembled and maintained flexibly, online, and in response to a particular context (Thelen, 2005). As such, the cohesiveness of the communicative system (i.e., the degree to which individual behaviors such as eye gaze, affect, gestures, or vocalizations are tightly timed in production) may be affected by instability related to a variety of factors (e.g., onset of a new skill, task demands, biological characteristics). The study predictions outlined below are based on the notion that HR infants (and particularly those eventually diagnosed with ASD) are particularly susceptible to instability in the communicative system, which may lead to the delayed or atypical development of communicative coordinations (e.g., reliance on one mode of communication versus the flexible, integrated use of multiple communicative modalities). Based on the evidence reviewed above, the following predictions have been generated.

1. Based on the DST notion that behavioral components are more susceptible to decoupling in the face of instability, and the assumption that the communicative systems of HR infants may be characterized by instability, it was predicted that, over and above any difficulties in producing communicative behaviors alone, HR children as a group, and particularly those later diagnosed with ASD, will produce fewer instances of multimodal communicative coordinations (i.e., more than one behavior produced in a single communicative act).

2. (a) An additional indicator of instability may be reflected in a difficulty with production of different behavioral configurations as the demands of the situation change. For example, the child who, after saying "cup" to request more juice, realizes that her mother is unresponsive, and is then able to again say the word "cup" but this time also points to the cup and makes eye contact with her mother, demonstrates the flexible use of multiple communicative signals. It was predicted that relative to LR infants, HR infants will demonstrate less flexibility in their communicative repertoire, as indicated by restricted variety in type(s) of communicative coordinations.

(b) As indicated above, infants later diagnosed with ASD may demonstrate the most widespread impairments with the organization of multiple communicative signals (e.g., Stone et al., 1997). Based on this study and more recent literature pointing to delays in higher-level aspects of social communication in HR infants (e.g., Colgan et al., 2006; Landa & Garret-Mayer, 2006; Yirmiya et al., 2006; Yoder et al., 2009), it was expected that HR infants will produce less complex communicative coordinations (i.e., coordinations comprised of two distinct behaviors as opposed to three or four behaviors) compared to LR infants.

3. Under conditions of systemic instability, patterns involving developmentally prior behavioral forms are likely to be stronger and therefore more frequently produced (Thelen, 2004; Thelen & Smith, 1994). If the communicative system of the HR infant is predisposed to instability, then coordinations involving well-established, pre-existing behaviors may be more frequent. Thus, it was expected that when HR infants produce communicative coordinations, they will more likely be comprised of highly practiced, older behavioral forms, i.e., those that are typically utilized for social communication in early infancy (eye contact and smiles; Fogel, 1993).

2.1 METHOD

2.1.1 Participants

Two groups of infants participated in the current study. The first consisted of 50 infants with an older sibling diagnosed with Autistic Disorder and therefore at heightened biological risk for an ASD diagnosis (HR infants; e.g., Ozonoff et al., 2011). Of these 50 infants, 20 (7 males) were followed longitudinally as part of a completed pilot study; the remaining 30 (15 males) were followed as part of an ongoing longitudinal study. Demographic information for HR and LR infants is presented in Table 1. Infants were recruited from western Pennsylvania by flyer, professional referral, and word of mouth through the Autism Research Program at the University of Pittsburgh, parent support groups, and local agencies and schools serving children with ASD.

Eligible HR infants were full-term, from uncomplicated pregnancies and deliveries, had 5-minute neonatal Apgar scores within the normal range (9 or better; Apgar, 1953), were from monolingual, English-speaking homes, and had an older full biological sibling diagnosed with Autistic Disorder (AD). In order to guarantee that infants met this last criterion, the diagnostic status of the older sibling with AD was verified via administration of the ADOS-G prior to the infant's enrollment in the study. For an infant to participate, the older sibling must have met DSM-IV-TR criteria for AD *and* scored above the Autism threshold on the ADOS-G. Informed consent was obtained prior to the first home visit.

The full HR sample was 86% European-American, 12% Hispanic-American, and 2% Asian-American. Twenty-four infants were second born and 26 were later than second born. Ten percent of the HR sample were from multiplex families (i.e., had more than one sibling with an ASD diagnosis). Mean maternal age at enrollment was 34.10 years (SD = 4.43) and mean paternal age was 35.70 years (SD = 4.30). Thirty percent of mothers had some graduate or professional school experience, 66% had some college or a college degree, and 4% had completed high school only. For fathers, 36% had some graduate or professional school experience, 54% had some college or a college degree, and 6% had completed high school only. Educational information was unavailable for 4% of fathers. Although information on family income was unavailable, parental occupations were identified for the purpose of providing a general index of social class. Because almost half of the mothers (46%) were home raising their children, Nakao-Teas occupational prestige scores (Nakao & Teas, 1994) were calculated for fathers' occupation. For five cases, it was impossible to identify the father's occupation with enough precision to assign a prestige score. Results from the remaining families indicated that the mean prestige score was 60.40 (*SD* = 14.96), and generally fell within the managerial/ professional range.

The second group of infants consisted of 30 infants (14 males) with a negative family history of ASD (LR infants). These infants were followed longitudinally as part a separate, completed study of vocal-motor coordination in infancy (e.g., Iverson, Hall, Nickel, & Wozniak, 2007). LR infants were recruited through published birth announcements and word of mouth. Eligible families were contacted by letter and follow-up phone call. Informed consent was obtained from parents upon enrollment.

All of the LR infants were from full-term, uncomplicated pregnancies with normal deliveries, had 5-minute neonatal Apgar scores within the normal range (9 or better; Apgar, 1953), and came from monolingual, English-speaking households. Ninety-three percent of infants were European-American and 7% were Asian-American. Twelve of the infants were first born and 18 had at least one older (TD) sibling (4 infants had more than one older sibling). Mean maternal age at enrollment was 31.77 years (*SD* = 4.58) and mean paternal age was 32.83 years (*SD* = 4.21). Fifty-three percent of mothers had some graduate or professional school experience, 43% had some college or a college degree, and 3% had completed high school only. For fathers, 40% had some graduate or professional school experience, 50% had some college or a college degree, and 10% had completed high school only. As with the HR group, Nakao-Teas occupational prestige scores were calculated for the LR fathers (33% of mothers stayed home with their children). It was not possible to assign prestige scores for four of the LR fathers due to lack of sufficient detail provided. The mean occupational prestige score for the remaining LR fathers was slightly lower than the HR infants (*M* = 57.79, *SD* = 12.00), but still fell within the same general category.

2.1.2 Procedure

Infants in both groups were observed at home with a primary caregiver for approximately 30-45 minutes at regular intervals as part of the larger studies. LR infants were followed bimonthly from 2 to 19 months of age. Data collection for the HR group began when infants were 5 months old and continued monthly to the age of 14 months, with 18-, 24-, and 36-month follow-up visits. Several standardized instruments designed to assess cognitive, social, behavioral, and communicative functioning were administered to HR infants at each follow-up visit. At 36 months, HR infants were brought by a parent to the University of Pittsburgh Autism Research Program for a final diagnostic assessment and classification using gold-standard assessments and clinical judgment.

The present study utilized data obtained during the 25-minute naturalistic and semi-structured play segments at the monthly home observations at 8, 10, 12, 14, and 18 months and from standardized assessments at the HR infants' 24- and 36-month follow-up visits. For all infants, observations occurred within three days of the monthly anniversary of the infant's birth and at times when parents thought the infant would be most alert and playful. All home visits were video- and audio-recorded. To enhance the quality of audio recording, infants wore a small wireless microphone housed in a cloth vest and clipped at shoulder level.

A staff of seven full-time research assistants and graduate students conducted the home observations. They were assigned to follow the same infants for the duration of the study. Before data collection began, they received extensive training on study measures; reliability and quality control checks were also completed on a monthly basis. Data collection teams also included an assistant who operated the recording equipment. When necessary, a third staff member was assigned to play with any siblings who were at home at the time of the session so that they neither appeared on camera nor interfered in any other way with the recording.

2.1.2.1 Naturalistic and play segments. At all ages, infants were videotaped in the home for at least 25 minutes in two major settings. The same fixed order of observational contexts was employed for all infants at all sessions. Prior to initiating the period of observation, caregivers were asked to turn off the television and to allow the child to be free to move about the observation space. The first segment consisted of 15 minutes of unstructured, naturalistic observation. Caregivers were asked to continue their normal activities and infants were observed in contexts and activities typical of the time of day at which the visit took place. During the first segment, infants typically played on the floor with the caregiver present but not specifically initiating involvement with the infant. The unstructured nature of these segments makes them appropriate for infants across a wide range of ages (e.g., see Thelen, 1979).

The second segment consisted of 10 minutes of free play and social interaction between the primary caregiver and infant. Observation during play with a caregiver is a standard and reliable method of eliciting social communicative behaviors (e.g., Iverson & Goldin-Meadow, 2005). During this segment, caregivers and infants were seated on the floor and asked to "play as you normally would;" otherwise, there was no attempt to structure this segment in any way.

2.1.3 Measures

2.1.3.1 Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000). The ADOS-G was administered to all HR infants as part of a formal diagnostic assessment that was scheduled around the time of the final 36-month home visit. The ADOS is a structured play schedule designed to elicit behaviors diagnostic of ASD (Lord et al., 2000). It provides systematic probes for symptoms of autism in social interaction, communication, play, and repetitive behaviors, and has standard administration and scoring schema. An algorithm is provided with the ADOS-G, and permits diagnostic classification of ASD or Autism when domain scores meet instrument thresholds. It reliably distinguishes children with ASD from TD children and children with other non-ASD developmental disorders (Lord et al., 2000). All ADOSs were administered by a research reliable evaluator who was blind to all previous study data.

2.1.3.2 Mullen Scales of Early Learning (MSEL; Mullen, 1995). The MSEL was administered at the 18-, 24-, and 36-month outcome visits for all HR infants. The MSEL provides a comprehensive measure of general cognitive functioning that is administered to individual children from 0-68 months (Mullen, 1995). It consists of five subscales: Visual Reception, Receptive Language, Expressive Language, Fine Motor, and Gross Motor. Internal consistency ranges from .83 to .95. Verbal requirements for items range from none, to one to three word responses, to repeating sentences. Items involve presenting the child with structured tasks, asking questions, and observation of reaction to stimuli. The MSEL was administered by the same examiner who conducted all previous home visits.

2.1.3.3 MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2002). At each session, parents were asked to complete the CDI. The CDI is a reliable and valid parent report measure of language and communication development and has been used extensively in research with infants and children with typical development, specific language impairment, and Down syndrome (Dale, Bates, Reznick, & Morisset, 1989; Fenson et al., 1993, 1994; Heilmann et al., 2005; Miller, Sedey, & Miolo, 1995; Thal, O'Hanlon, Clemmons, & Fralin, 1999). It has also been used with small samples of children with ASD (Charman, Drew, Baird, & Baird, 2003; Luyster, Lopez, & Lord, 2007; Luyster, Qui, Lopez, & Lord, 2007; Mitchell et al., 2006).

Beginning at 8 months and continuing monthly to 14 months, parents completed the Words and Gestures form of the CDI (CDI-WG; Fenson et al., 2007). The CDI-WG is for use with children between the ages of 8 and 16 months and has well-established reliability and validity. It is organized into two parts. Part I consists of a 396-item vocabulary checklist organized into 19 semantic categories. Parents are asked to check: a) items that their child *only understands*; and b) those that s/he *both says and understands*. Part II of the CDI-WG focuses on early gestures (e.g., giving, showing, pointing) and actions (e.g., games and routines, pretend play); parents indicate those performed by their child. The CDI-WG was scored according to manualized procedures (norms are based on age and gender; Fenson et al., 2007).

Caregivers of LR infants were administered the CDI-WS (Words and Sentences Form) at the 18-month observation. The CDI-WS, which is normed for children from 18 to 30 months, consists of two parts: a 680-word vocabulary checklist organized into 22 semantic categories (parents indicate words that their child says) and a section on children's use of English morphology and syntax. Caregivers of HR infants completed either the CDI-WG or the CDI-WS at 18 months depending on the child's general language level.[2] Thus, if a child was producing relatively few words (as indicated by the primary caregiver and observed by the experimenter)

[2]The rationale for the decision to use children's language level (rather than age) as a criterion for determining transitions to more advanced CDI forms was based on our observations that: a) many parents of HR infants expressed heightened concern about their children's language development, and they tended to become worried that their child was producing relatively little language when presented with a lengthy list of words and questions about grammar (even at ages when such production would not yet have been expected); and b) parents of HR infants whose communicative and language development was proceeding at a slower pace became overwhelmed by questions about more advanced forms. To ensure their continued cooperation with completion of the CDI, we opted to continue to give parents of such children forms that were more appropriate to their child's current abilities.

and had no two-word combinations at 18 months, the CDI-WG was administered. If a child had a significant productive vocabulary and some word combinations, the CDI-WS was administered. All caregivers were administered the CDI-WS at the 24-month session.

At the final (36 month) observation, caregivers completed the CDI-III, which is designed for children aged 30-37 months (Fenson et al., 2007). It consists of three parts: a 100-item vocabulary checklist, 12 sentence pairs assessing grammatical complexity, and 12 yes/no questions concerning semantics, pragmatics, and comprehension.

2.1.4 Diagnostic Assessment and Classification

In this paper, results are reported on HR infants who met criteria for an ASD outcome. In addition, a subset of HR children with communication delays was identified to serve as a clinical comparison group. Previous research has demonstrated that children with persistent language delays show early disturbances in other aspects of communication such as comprehension (Ellis Weismer, 2007; Thal et al., 1991; Thal & Tobias, 1992), NWVs (Whitehurst et al., 1991), and use of communicative gestures (e.g., Thal et al., 1991; Thal & Tobias, 1994). As many children with ASD also have delayed language, inclusion of this comparison group provided an opportunity to determine whether any differences observed between HR infants who were versus were not diagnosed with ASD were specific to ASD or a reflection of general communicative and language delay. Thus, HR infants were also assessed for the presence of a language delay (without an ASD diagnosis). Final diagnostic outcome was assessed for HR infants at the 36-month follow up visit using the ADOS-G and the MSEL, and at the 18- and 24-month follow up visits using the CDI. Table 2 contains scores from the standardized assessments at the 18-, 24-, and 36-month visits.

2.1.4.1 Outcome groups. Using the standardized measures described above, HR infants were classified into one of three diagnostic outcome categories: a) *ASD*, b) *Language Delay without ASD*, and c) *No Diagnosis*. While LR infants did not undergo a formal evaluation process to confirm typical development, there were never any developmental concerns noted by caregivers or research staff. Further, no LR infant received early intervention services.

A clinical referral for further evaluation was made at the 36-month evaluation if the child received a diagnosis of ASD or Language Delay (LD). In addition, HR infants were given a clinical referral at any time during the course of the study if parents indicated concern about their infant's development and asked for a referral, or the infant scored above diagnostic cutoffs on the Modified Checklist for Autism in Toddlers (M-CHAT; Robins et al., 2001) administered at the 18- and 24-month follow-up visits. Infants referred for evaluation and possible intervention were retained in the sample, and types and frequency of services received were documented. None of the parents in any group was systematically involved in a parent training regimen. Table 3 provides a detailed summary and description of the referrals, evaluations, and early intervention services for all HR infants by outcome group.

2.1.4.2 ASD. A diagnosis of ASD was given if HR infants met or exceeded algorithm cutoffs for ASD or AD on the ADOS *and* received confirmation by clinical judgment using DSM-IV-TR criteria by a trained clinician.

Nine HR infants received a diagnosis of ASD at the 36-month evaluation (6 males; HR-ASD). Seven HR-ASD infants (all males) were referred for a developmental evaluation before the 36-month visit. Four infants were contacted by research staff and referred as a result of receiving low and/or concerning scores on standardized study measures (SNs 12417, 19521, 19576, 17438); five infants were self-referred as early as 10 months due to parental concerns

(SNs 36575, 36578, 36579, 24909, and 16694). Of these 9 infants, three (SNs 12417, 16694, and 17438) received provisional diagnoses of ASD at 22, 24, and 30 months, respectively (36-month diagnostic evaluations confirmed the diagnosis). Seven HR-ASD infants received early intervention services consisting of a combination of occupational therapy (OT), physical therapy (PT), speech and language therapy (SLT), and child developmental therapy (CD). The mean age of initiation of services was 17.57 months (age range = 11 months-24 months).

2.1.4.3 Language Delay without ASD. HR infants were assigned to the LD subgroup if they meet one of the following criteria and *did not* receive a diagnosis of ASD (many of the children classified with ASD also exhibited delayed language):

1) Standardized scores on the CDI-II and CDI-III at or below the 10th percentile at *more than one* time point between 18 and 36 months (e.g., Ellis Weismer, & Evans, 2002; Gershkoff-Stowe, Thal, Smith, & Namy, 1997; Heilmann et al., 2005; Robertson & Ellis Weismer, 1999).
2) Standardized scores on the CDI-III at or below the 10th percentile ***and*** standardized scores on the Receptive and/or Expressive subscales of the MSEL equal to or greater than 1.5 standard deviation below the mean (e.g., Landa & Garrett-Mayer, 2006; Ozonoff et al., 2010).

Using these criteria, 13 HR infants were classified as Language Delayed (HR-LD). Two HR-LD infants were referred for services after the 36-month diagnostic assessment; one infant was referred due to poor articulation (SN 24843), and the other infant was referred due to language difficulties inaccurately inflating scores on the ADOS-G (SN 16640). Eight infants were referred for a developmental evaluation prior to the 36-month outcome visit (see Table 3). Two infants (SNs 26375 and 23494) were referred for a speech and language evaluation because their CDI and/or MSEL scores were low; however the parents never followed through with the referral (one parent cited improved language abilities as the reason). Another HR-LD infant (SN 15000) received a speech and language evaluation at 20 months, was diagnosed with expressive-receptive language disorder, and therefore received SLT and CD intervention services until 36 months of age. One infant was evaluated at 16 months and diagnosed with speech apraxia (SN 59423); she subsequently received SLT services from 16 to 33 months. Another infant began receiving SLT at 9 months after a self-referral due to parental concern (SN 17811). Two additional infants were evaluated at 18 months; one infant received OT, PT, CD, and SLT services through 24 months of age (SN 25042), and the other received SLT and CD also though 24 months of age (SN 21717). One HR-LD infant was evaluated for a speech delay at 30 months but results were reportedly within normal limits (SN 61218). The remaining three HR-LD infants (SNs 12655, 13856, and 14578) were offered a referral but refused, and did not receive early intervention services. The mean age of initiation of services for HR-LD infants was 17.00 months (age range = 9 months-20 months).

2.1.4.4 No Diagnosis (ND). The remaining 28 HR infants did not meet any of the above criteria for ASD or LD (HR-ND).[3] Despite not meeting diagnostic criteria, seven parents reported concerns with their child's development at some point during the course of the study (see Table 3). While parents may have consulted with research staff about their concerns, no formal referral was initiated. However, six parents self-referred their children for developmental evaluations for a variety of reasons (see Table 3). Two infants were evaluated for gross motor delays around 12

[3]Two HR-ND infants demonstrated nonspecific developmental delays ("other delay") as indicated by MSEL standard scores at or below 1.5 SD from the mean on one or more non-language subscale (e.g., Fine Motor) and/or elevated scores (albeit below clinical cut-off) on the ADOS-G. Neither of these infants' parents reported concern, nor did they receive early intervention services. Further, visual inspection of the data suggested that communicative patterns for HR-ND "other delay" infants were not substantially different from other HR-ND infants; thus, the decision was made to retain them in this category.

months of age and both received PT initiated at 13 months (SN 15495 and 18445). One infant was evaluated at 10 months for feeding difficulties and later received OT and a feeding intervention (SN 23958). Another infant was assessed at 10 months and subsequently received OT, PT, and SLT, beginning at approximately 11 months (SN 34056)[4]. Finally, one infant was evaluated at 30 months due to concerns regarding behavior (e.g., tantrums; SN 38940), and one infant was evaluated at 33 months for stuttering (SN 35548); neither received intervention services. The mean age of initiation of services for HR-ND infants was 12.60 months (age range = 10 months-16 months).

2.1.5 Observational Behavior Coding

All non-elicited infant communicative behaviors[5] (eye contact, gestures, facial affect expressions, communicative non-word vocalizations, words) and temporally coordinated combinations of these behaviors produced during the 25-minute observation were coded. Because infant-initiated communications were the focus of this study, all behaviors that were explicitly directed by an adult—e.g., caregiver says "give me the ball" and child picks up the ball and hands it to her; caregiver says "Say ball" and child says "ball" were not coded. Each

[4]This particular infant had a highly concerned mother and nonspecific early motor delays which motivated an outside developmental evaluation and subsequent initiation of EI services. However, all scores on the MSEL, CDI, and ADOS-G administered during the study were well within the normal range.

[5]In order for an act to be considered communicative, it must have been produced when the child was in the presence of a potential communicative partner (e.g., caregiver, camera person, or team leader). Communicative acts are indexed by some attempt on the part of the child to direct the communicative partner's attention or behavior as indicated by: a) eye gaze, body orientation, or physical contact, b) awaiting a response from the communicative partner as indicated by looking at the partner, hesitating, repeating the same behavior or modifying the behavior. This does not mean that every communicative act needs to be accompanied by eye contact to be considered communicative, but it should involve some apparent awareness of another person's presence and some kind of goal-oriented behavior. For example, smiling and vocalizing at a toy is not coded as communicative if the child would likely act in the same way if they were alone. Self-directed actions are *not* coded as communicative (e.g., vocalizing while wandering around aimlessly).

communicative act was further classified according to function (i.e., joint attention, behavior regulation, social interaction).

Coding procedures were based on coding schemes developed for social communication behaviors in children with ASD (Stone et al., 1997; Wetherby & Prutting, 1984; Drew, Baird, Taylor, Milne, & Charman, 2007) and speech and gestures (e.g., Iverson, Capirci, & Caselli, 1994; Iverson & Goldin-Meadow, 2005) and facial expressions (babyFACS, Oster, 2000) in very young TD children. The coding categories and definitions for communicative behaviors in each category are presented below (for further details, see Appendix A, Tables A1 and A2). To facilitate analysis of the relative timing of communicative behaviors, coding was completed using a time-linked, computer-based video interface system (The Observer Video-Pro version XT, Noldus Information Technologies).

2.1.5.1 Gestures. Several criteria were instituted to ensure that a hand movement qualified as a gesture. First, the infant had to make a clear effort to direct the caregiver's attention (e.g., through use of eye contact, vocalization, postural shift, or repetition) for a gesture to be considered communicative (e.g., Iverson, Capirci, Volterra, & Goldin-Meadow, 2008; Iverson & Goldin-Meadow, 2005; Thal & Tobias, 1992). Second, the gesture itself must not have been a direct manipulation of some relevant person or object (e.g., using the index finger to activate a button on a toy would not be considered a pointing gesture). Finally, the gesture must not have been part of a ritual act (e.g., blowing a kiss to someone) or game (e.g., patty cake).

Gestures were classified into two main categories. *Deictic gestures* (pointing, reaching, giving, and showing) expressed intent to request or declare (e.g., Bates et al., 1979). These gestures indicated referents (i.e., object, location, event) in the immediate environment, and their meanings were thus context-bound. *Representational gestures* (e.g., nodding the head "yes;"

raising the arms high for “tall”) referred to an object, person, location, or event through hand movement, body movement, or facial expression. These gestures differed from deictic gestures in that they represented specific referents and their basic semantic content did not vary with the context (e.g., Iverson, Capirci, & Caselli, 1994).

2.1.5.2 Vocal utterances. All infant vocal utterances were coded in a manner consistent with previous work examining the gesture-speech relationship in infants and young children (e.g., Harding & Golinkoff, 1979; Gros-Louis, West, Goldstein, & King, 2006; Iverson & Goldin-Meadow, 2005; Stoel-Gammon, 1992). Vocal utterances were classified into three major categories: *Words, non-word vocalizations,* and *affective/other vocalizations*. *Words* involved use of the same sound pattern to refer to a specific referent on multiple occasions or in different contexts. They were either actual English words (e.g., “cat,” “duck,” “hot”) or sound patterns that were consistently used by a particular child to refer to a specific object or event (e.g., using “bah” to refer to a bottle in a variety of different contexts). As indicated above, words that were purely imitative (i.e., words repeated immediately after being spoken by another person) were not coded.

All uninterpretable strings of speech sounds (with the exception of sneezing, coughing, breathing, and other vegetative noises) were coded as *non-word vocalizations (NWVs)*. Non-word vocalizations included vowel strings (e.g., [eeaa]), reduplicated babbling (e.g., [gaga]), and variegated babbling (e.g., [bama]). *Affective/other vocalizations* consisted of vocal sounds directly expressing an affective or bodily state (e.g., laughing, squealing, fussing, whining, crying, grunting). They were distinguished from NWVs on the basis of situational context (e.g., [aaaaah] as a non-word vocalization was distinguished from [aaaaah] as a whine based on the vocalization's occurrence during an episode of infant noncompliance). Affective/Other vocalizations were excluded from further analysis.[6]

2.1.5.3 Eye gaze. Instances in which the infant's eye gaze was directed toward another person were coded as either *eye contact* or *gaze switch. Eye contact* involved a directed and relatively extended look to the person's face/head and did not include fleeting eye contact (i.e., extremely brief glances toward another person). *Gaze switch* required the alternating eye gaze from an object, to the person's face, back to the object, *or* from the person's face, to an object, and back to the person's face. However, due to low frequency and therefore low inter-coder reliability (see below), *gaze switch* was excluded from all analyses.

2.1.5.4 Smiles. Based on research examining infants' early attempts at nonverbal communication, facial expressions classified as *smiles* were also coded (e.g., Adamson & Bakeman, 1985, Messinger & Fogel, 1998; Yale et al., 2003). *Smiles* involved the upward turning of the corners of the lips *often* accompanied by narrowed/crinkled eyes (i.e., eye constriction) and a widened mouth (Oster, 2000).

2.1.5.5 Coordinations. In addition to coding individual vocal, gestural, affective, and eye gaze behaviors (i.e., those produced in isolation), instances in which communicative behaviors co-occurred in time were identified (i.e., *Coordinated Bout*). A communicative act was coded as a *Coordinated Bout* when two (or more) behaviors overlapped temporally with one another. For example, a child points at a car and holds the point while saying "car". *Coordinated Bouts* were

[6]Because previous research demonstrates that speech-like vocalizations become more frequent in infants' vocal repertoires after 2 months of age (e.g., Oller, 1980, Stark, 1978; Stark, Rose, & McLagen, 1975) and continue to increase when infants transition to triadic communication (Hsu & Fogel, 2001), our coding and analysis focused on vocalizations containing speech-like sounds.

further described in terms of their *complexity* (i.e., the number of individual behaviors that were involved in each coordination), and *composition* (i.e., identifying individual behavioral forms appearing within a given coordination).

2.1.5.6 Function. The apparent purpose of each communicative gesture[7] (i.e., single behaviors and Coordinated Bouts), or what the child was attempting to communicate was coded as *Joint Attention*, *Behavior Request*, or *Social Interaction*. *Joint Attention* was coded when a behavior was produced to direct another's attention to indicate interest about an object or event. Joint attention/comment behaviors had no obvious instrumental function (e.g., trying to get or activate a toy) but seemed to be more to *share* experiences or objects with others or to declare (e.g., "look at that!"). A showing gesture is prototypical of this type of behavior. *Behavior Request* acts elicited supportive action or aid from the communicative partner in obtaining objects or events. They differed from *Joint Attention* behaviors in that they seemed to communicate a want or desire (e.g., nodding head "yes" when a game is suggested) rather than a comment (e.g. saying "uh-oh when a toy is knocked over). Giving in order to obtain aid in opening or activating a toy is a prototypical *Behavior Request* behavior. Gestures that were purely focused on face-to-face interaction were considered *Social Interaction*. For example, this includes the use of a give gesture to elicit and maintain turn-taking with objects such as offering objects back and forth with a social partner.

[7]The decision to code function for gestures only was based on both theoretical and practical reasons. First, some have reasonably argued that a better indicator of joint attention development and associated aspects of social cognitive development may be infants' later developing capacity to coordinate social attention with conventional gestures, such as showing and pointing (Tomasello, 1995). Second, because observation of infants was primarily unstructured, it was difficult to capture instances of alternating eye contact between an object of interest and a social partner with enough consistency and specificity to make decisions about the function of that behavior.

2.1.5.7 Reliability. In order to assess reliability, 58 videotapes of the naturalistic observation (15%) were chosen at random and independently scored by 3 raters, blind to one another's codes. Equal numbers of videos (i.e., 29) were drawn from the HR and LR samples. One rater (first author) had some knowledge about which group the tapes were from but was blind to infant diagnostic outcome classification. The second and third raters were blind to both study and diagnosis. Prior to commencing data coding for the current study, the secondary coders were trained to at least 80% agreement on all categories. Reliability meetings were held on a regular basis to prevent coder drift and allow for the estimation of reliabilities. Disagreements were resolved by joint viewing of the clips and discussion. Reliability analyses reflect the original codes.

Intraclass correlation coefficients (ICCs) between the raw total counts of the three raters on each variable were calculated as an index of agreement. The ICCs are shown in Table 4. For the majority of variables inter-rater reliability was good (> 0.60) or excellent (> 0.80), although for other variables it was moderate (.40-.60) or low (<.40). Low reliability scores were primarily due to the fact that behaviors occurred very infrequently (e.g., representational descriptive gestures). Therefore, findings from variables where inter-rater reliability was low (<.40) are not reported.

2.1.6 Data Reduction and Analysis

Study 1 was designed to explore developmental trajectories in the production of gestures, vocalizations, words, smiles, eye gaze, and the content of communicative coordinations in HR and LR infants. Data from observations across the 8 to 18 month period were utilized for this purpose, and resulted in a total of 387 observations and 9,624.32 minutes of coded data. As noted above, the study protocol consisted of 15 minutes of naturalistic observation and 10 minutes of interactive play segments per session, which resulted in a total of 25 minutes of observation coded for each participant.

Average session lengths were highly similar across ages and outcome groups (at 8 months, LR = 24.92; HR-ND = 23.41; HR-ASD = 24.99; HR-LD = 23.68; at 10 months, LR = 24.83; HR-ND = 25.12; HR-ASD = 24.93; HR-LD = 24.68; at 12 months, LR = 25.00; HR-ND = 24.85; HR-ASD = 25.15; HR-LD = 25.08; at 14 months, LR = 25.02; HR-ND = 25.08; HR-ASD = 25.22; HR-LD = 25.11; at 18 months, LR = 25.22; HR-ND = 25.03; HR-ASD = 25.10; HR-LD = 25.13). However, because session length sometimes varied slightly among participants, all frequency variables were converted to rates per 10 minutes by dividing total frequency by length of observation in minutes, then multiplying by 10. Because of missing visits (e.g., infant not yet enrolled in study; visit missed due to illness or other unanticipated family events) and/or unusable video (e.g., malfunction of sound equipment), 8-month data were available for n = 74, 10-month data for n = 78, 12-month data for n = 77, 14-month data for n = 79, and 18-month data for n = 79 infants.[8]

2.1.6.1 Analytic Approach. Hierarchical Linear Modeling (HLM; Bryk & Raudenbush, 1992) was utilized to examine developmental trends with respect to the overall production of specific communicative behaviors and the frequency, variety, and complexity with which behaviors were produced in coordination during the 25-minute naturalistic and toy play context over the observation period. Multilevel modeling techniques were chosen because of the nested, hierarchical nature of the data. The data are nested because they contain repeated sessions within

[8]There were 6 missing sessions at 8 months (all HR); 2 missing sessions at 10 months (all HR); 3 missing sessions at 12 months (2 HR, 1 LR); 1 missing session at 14 months (HR); and 1 missing session at 18 months (LR).

infants; they are hierarchical because they contain data at two levels (sessions and infants). Nested, hierarchical data violate assumptions of independence required in traditional regression analyses. Violating assumptions of independence can result in downwardly biased (smaller) standard errors and alpha inflation. Thus, failure to account for nested and hierarchical levels can result in more frequent, incorrect, rejections of the null hypothesis and false positive results.

Another advantage of multilevel models is that they can be used in longitudinal designs to describe patterns of change over time and the shape of change in growth trajectories. In addition, this type of analysis permits identification of variations in trajectories as a function of individual difference variables (e.g., gender, diagnostic classification). Multilevel models can also accommodate multiple waves of data in longitudinal designs, unequally spaced data-collection occasions, different data collection schedules, and missing data (Huttenlocher, Haight, Bryk, Seltzer, & Lyson, 1991; Singer, 1998; Willett, Singer, & Martin, 1998). Thus, multilevel models both accommodate nested, hierarchical data and take appropriate advantage of all observations, resulting in greater power for the detection of effects (Raudenbush & Bryk, 2002; Singer & Willett 2003).

Measurement precision and reliability (smaller standard errors of estimated growth parameters), are improved by multiple waves of data (Willett et al., 1998). In this study, analysis of five data points per infant permitted exploration of linear, quadratic, and cubic growth models. The developmentally- and prediction-driven analyses described below all utilized HLM. The data in this study contributed to a two-level hierarchical structure. Observation sessions nested within individual infants were considered Level 1 data, and differences between individual infants were considered Level 2 data. A Level 1 growth model was used to model within-person variation. Level 2, or between-person, models were used to model inter-individual variation (Singer, 1998; Willett et al., 1998).

Thus, for each analysis, the variable of interest was entered at Level 1 to detect whether the growth trajectories of individual children varied significantly from one another; and diagnostic outcome (HR-ASD, HR-LD, HR-ND) was entered as a predictor variable at Level 2 to determine whether any individual differences detected in Level 1 could be predicted or explained by these factors, after for controlling for other potential influences (e.g., gender). All models were estimated in HLM 6.08 using Full Information Maximum Likelihood estimation (FIML; Raudenbush et al., 2001).

2.1.6.2 Modeling strategies. As typically recommended, two types of preliminary multilevel models were tested for each dependent measure: an unconditional means model, and several unconditional growth models (Raudenbush & Bryk, 2002; Singer & Willet, 2003). These models provide useful information for determining proper model specification and serve as a baseline for subsequent model comparisons. Thus, for each dependent variable in this study, unconditional means and unconditional growth models provided a description of the general pattern of change in each communicative behavior over the 8 to 18 month period.

Unconditional models also indicate whether significant variability exists between children in the initial production and developmental progression of communicative behaviors (Raudenbush & Bryk, 2002). Therefore, when significant variability was present, additional analyses included predictor variables that were introduced in an attempt to account for additional variance. The only predictor of Level 1 variance (within sessions) considered in this study was *TIME*. At Level 2 (between-child) were time-invariant predictors (i.e., a predictor that remained constant across observations for a given infant) which included outcome group (i.e., LR, HR-

ND, HR-ASD, and HR-LD) and gender. As a result, these analyses explicitly examined differences in growth trajectories among outcome groups after controlling for infant gender.

Although details of the modeling process differed slightly for each dependent variable, the same general procedure was used for all of the measures considered. The process began with an unconditional means model (without predictors). Model building continued with testing of functional form fit for unconditional growth models by computing linear, quadratic, and cubic growth models for each of the main variables. Further assumptions underlying statistical models were checked by assessing normality and homoscedasticity.[9] In cases where homoscedasticity assumptions were violated, robust standard errors are reported instead. Robust standard errors are standard errors that are relatively insensitive to misspecification at the levels of the model and the distributional assumptions at each level and can be used if heteroscedasticity is an issue or a distributional problem is found and cannot be addressed by adding Level 1 predictors (Raudenbush & Byrk, 2002). Finally, outliers were identified by inspecting the Mahalanobis distance plots. This statistic measures the distance between the residual estimates for each group relative to the expected distance based on the model (Raudenbush & Bryk, 2002). Extreme values were removed and models were fitted again. In all cases, normality improved but results remained unchanged (although significance levels may have attenuated or strengthened).

As noted, while some variation in model building was necessary (e.g., fixing the random Level 2 variation in intercept when no between-child differences were detected in Level 1), model building followed two general patterns. Thus, dependent variables involving pre-verbal communicative behaviors (i.e., smiles, eye contact, gestures, NWVs) were best modeled using a linear trajectory. For these basic linear growth models, at Level 1 were repeated measures of

[9]As suggested by Singer & Willet (2003), assumptions were analyzed for several initial models and then again for any model that was explicitly interpreted.

early communication (e.g., NWVs), which were nested within individual infants at Level 2. The Level 1 model is shown in Equation 1:

$$(1)\ Y_{it} = \pi_{0i} + \pi_{1i}(age_{it} - 8) + \varepsilon_{it}$$

Here, repeated assessments of communicative development were modeled as a function of time-varying measures of age (age_{it}), where Y_{it} was the rate of production of NWVs for child i at t months, and ε_{it} was the deviation of child i from his or her growth trajectory at time t. The ε_{it} are assumed to be normally distributed with mean 0 and variance σ^2. Time was measured in months and was centered at the individual level at the initial data collection point (8 months). Thus, π_{0i} (intercept) represents the production of NWVs of child i at 8 months, and π_{1i} (slope) represents the linear growth rate of NWVs for child i.

In some cases, however, a quadratic model was determined to be the best fit for the data. For example, a quadratic function of age was chosen to represent individual growth in word production (e.g., Huttenlocher et al., 1991). Equation 2 represents word production as a quadratic function of age.

$$(2)\ Y_{it} = \pi_{0i} + \pi_{1i}(age_{it} - 8) + \pi_{2i}(age_{it} - 8)^2 + \varepsilon_{it}$$

On the basis of past research, it was expected, however, that the average value of π_{0i} (intercept) and π_{1i} (slope) would be close to zero at age 8 months. That is, spoken words do not appear in typical development until after 12 months ($\pi_{0i} \approx 0$), and the acquisition of new words is also slow initially ($\pi_{1i} \approx 0$). In fact, preliminary HLM analyses using Equation 2 indicated that mean status at 8 months for the whole sample was not significantly different from zero and that the observed variability in π_{1i} could be attributed entirely to sampling variance, rather than true differences in the π_{1i}. These analyses also revealed that the average instantaneous growth rate π_{1i} at 8 months was not significantly different from zero. Results indicated that a one-parameter quadratic model adequately represented the individual growth data collected for word production. Thus, a reduced version of Equation 2 was used to model overall word production and combinations involving words where π_{2i} represents the acceleration (i.e., curvature) in word growth for child *i* (see Equation 3).

$$(3)\ Y_{it} = \pi_{2i}(age_{it} - 8)^2 + \varepsilon_{it}$$

This pattern of acceleration in vocabulary size in the second year of life is consistent with previous research modeling vocabulary growth trajectories (Huttenlocher et al., 1991). Overall, model adequacy and fit were determined by this type of theoretical consideration and measures of model fit.[10]

Between-child associations between diagnostic classification and children's average level and growth in communication were considered separately at Level 2 in conditional growth models. For all of the communication variables that demonstrated significant reliability of and variability on the intercept and slope parameters, intercepts and linear growth terms were estimated as random effects at Level 2. All Level 2 variables were centered on the grand mean of the sample.

In light of previous research indicating differences in early communication and coordination development between HR children later diagnosed with ASD and TD children (e.g., Bryson et al., 2007; Dawson et al., 2000; Landa et al., 2007; Sullivan et al., 2007; Wetherby et al., 2004), we considered whether developmental trajectories in communication and language varied as a function of diagnostic classification (LR, HR-ND, HR-ASD, and HR-LD). Variability

[10]More specifically, a linear model was determined to be the best fit using a combination of the following criteria: the acceleration term was not significantly different from zero, the reliability estimates were higher and deviance statistics were lower for the linear model, and chi square analyses comparing models were significant for the linear model. In some cases, the deviance statistics were slightly lower for the quadratic term; however, the simpler model was chosen in an effort to avoid over-fitting the data. Thus, although the resulting equation was a simple growth model, it both fit the data well and parameterized the key aspect of the growth phenomenon that is of interest in this study—individual differences in growth rate over time.

in the intercept and linear growth terms in the Level 1 equation was modeled using Equations 4 and 5:

$$(4)\ \pi_{0i} = \beta_{00} + \beta_{01}(MALE_i) + \beta_{02}(HRND_i) + \beta_{03}(HRLD_i) + \beta_{04}(HRASD_i) + r_{0i}$$

$$(5)\ \pi_{1i} = \beta_{10} + \beta_{11}(MALE_i) + \beta_{12}(HRND_i) + \beta_{13}(HRLDD_i) + \beta_{14}(HRASD_i) + r_{1i}$$

In these models, variation in mean levels of observed communication and language abilities (Equation 2)[11] and in the growth of these abilities over time (Equation 3) was explained with infant gender (*MALE*) and diagnostic classification. The LR group was used as the comparison group and the three remaining diagnostic classification groups (HR-ND, HR-LD, HR-ASD) were entered as predictors at Level 2. Thus, coefficients reflect deviations in initial level and slope from the average LR participant in the sample. For each analysis, a series of post-hoc comparisons was conducted to examine potential differences between the HR-ND, HR-LD, and HR-ASD groups by systematically rotating the comparison group. Additional post-hoc analyses were performed by re-centering time at each observation point to determine the point at which the divergence of developmental trajectories between outcome groups became statistically significant.

2.2 RESULTS

The purpose of this research was to investigate developmental change in infant communicative behaviors and the coordination of behaviors in early infancy (i.e., between 8 and 18 months) as

[11]For many of the models, particularly those estimating the developmental emergence of communicative behaviors (e.g., gestures), significant variation in intercept (i.e., starting point) was not statistically significant nor was the parameter significantly different from zero. In this case, the Level 2 variance for the intercept parameter was fixed, or the intercept term was removed entirely from the model. For example, as gestures are not expected to appear in typical development until after 8 months of age, variance in gesture production at 8 months was neither expected nor particularly meaningful.

assessed in a naturalistic home setting. Data analyses were focused on addressing three main research questions. First, what is the nature of the communicative landscape between 8 and 18 months of age? Second, do infants with and without risk for ASD demonstrate differences in developmental trajectories of social communicative behaviors that are observable during this time period? And third, to what extent does developmental delay or impairment in social communicative behaviors predict a later ASD or LD diagnosis in HR infants?

In order to address these questions, I begin by presenting preliminary analyses focusing on potential effects of differences in birth order, early intervention services, and level of cognition. Next, two sets of analyses regarding the nature of infants' communication patterns during the 8- to 18-month period are performed. The first focused on estimating growth in overall production of communicative behaviors over time; and the second examined growth in communicative behaviors produced within Coordinated Bouts over time. For each set of analyses, developmental trajectories of communicative behaviors were estimated first for the sample as a whole (i.e., with HR and LR groups combined). This was to provide a general picture of infant communication skills in early infancy, and to determine if variability in the course of development for these behaviors exists. Then, if variability was detected, developmental trajectories were modeled using outcome group as a predictor to evaluate potential group differences. Following these analyses, data relevant to the three main study predictions will be presented in turn. Prediction-driven analyses were conducted by examining overall frequencies of communicative behaviors produced in *coordination* and relative frequencies, diversity, and complexity of coordinations during the 8- to 18-month period.

2.2.1 Preliminary Analyses

First, potential effects of birth order and early intervention were examined by analyzing the mean rate of communicative attempts (i.e., a behavior produced alone or a single coordinated bout) and the mean rate of Coordinated Bouts (i.e., communicative utterances in which two or more behaviors overlapped in time). Mann-Whitney *U* tests revealed no effects of birth order (first born versus later born) or EI services (yes versus no) on the rate of communicative acts or the rate of Coordinated Bouts at any age.

Next, potential differences in level of cognitive functioning for infants in the three HR outcome groups was examined using the 36-month MSEL Visual Reception (VR) scores. Scores indicated that 44/50 (88%) of HR infants were within the normal range (within 2 SD of the normative mean; Danaher; 2007), with regard to non-verbal cognitive ability. Three infants with VR scores 2 SDs below the mean were diagnosed with ASD, one infant was classified as Language Delay, and two were in the HR-ND outcome group. A Kruskal-Wallis one-way analysis of variance (ANOVA) revealed that MSEL VR T-scores differed significantly across outcome groups (χ^2 (2, N = 46) = 7.61, p =.022). Follow-up Mann-Whitney *U* tests indicated that the HR-ASD group scored significantly lower than both the HR-ND group (U = 18.00, p = .006), and the HR-LD group (U = 13.50, p = .049). The HR-ND and HR-LD groups did not differ from one another in terms of non-verbal cognitive ability (U = 140.00, *ns*). Although it is difficult to assess the impact of low nonverbal cognitive ability on the development of spontaneous communication, it is clearly the case that the HR-ASD infants differed from other HR infants in terms of cognitive delay.

2.2.2 Analyses Examining Development in Social Communication

2.2.2.1 Estimating growth in production of communicative behaviors over time (unconditional models). Descriptive statistics for all communicative behaviors by form and function for the full sample are presented in Table 5 (for a more detailed breakdown of specific behaviors produced overall, see Appendix B, Table B1, and for descriptive information by age for each outcome group see Appendix C, Tables C1-C4).

2.2.2.2 Overall production of communicative behaviors. To provide general indices of communication across the 8- to 18-month period, unconditional growth models were first estimated for: a) rate (per 10 minutes) of total communicative acts (i.e., all behaviors produced alone and all Coordinated Bouts); and b) rate of single communicative behaviors (i.e., communicative acts consisting of one communicative behavior, e.g., eye contact). Results are presented in Table 6 and Figure 1.

In terms of the overall production of communicative acts, the initial frequency of all communicative acts at 8 months (i.e., intercept) was high, indicating that infants were spontaneously producing communicative acts at a rate of approximately 13 acts per 10 minutes ($p < .001$). The frequency with which infants produced communicative acts grew steadily as the rate of production increased by 2.47 acts per month ($p < .001$). The mean rate of single communicative acts (i.e., behaviors produced alone) followed a similar developmental pattern. The initial rate of production at 8 months was slightly lower and estimated at approximately 9.48 acts per 10 minutes ($p < .001$). The rate of increase over time was also significant and comparable to all communicative acts ($p < .001$).

2.2.2.3 Forms of communicative behaviors. To provide an understanding of the general frequency with which various communicative behaviors are produced between 8 and 18 months, ,this set of analyses examined the developmental progression of communication separately for eye contact, smiles, NWVs, gestures, and words. Thus, all occurrences of each behavior were included, without regard to whether they were produced singly or in coordination. Results for unconditional growth trajectories for mean rates of each of the five forms of communicative behaviors are presented in Table 7 and depicted in Figure 2.

Regarding early-emerging communicative behaviors (top panel of Figure 2), the rates of eye contact, smiles, and NWVs were significantly different from zero at 8 months, suggesting that these behaviors are established components of infants' communicative repertoires at this age. At 8 months, NWVs were produced with greatest frequency, at a rate of 9.13 vocalizations per 10 minutes. A positive and significant slope term suggests that infants' use of NWVs initially increased at a steep rate of 3.30 units per month; however, a negative acceleration term indicates that the rate of increase attenuated with time resulting in a concave curvature (p = .002). Infants' rate of production of eye contact (p = .006) and smiles (p = .005) showed a modest yet significant increase over time.

Not surprisingly, a different pattern of development was observed for later-emerging communicative behaviors (i.e., gestures and words; see bottom panel of Figure 2). As was expected based on prior literature (Bates, 1976; Bates et al., 1979; Crais et al., 2009; Fenson et al., 1994), rates of production for gestures and words were not significantly different from zero at 8 months. However, gesture production increased significantly in a linear fashion on the order of 0.66 units per month (p < .001). Also consistent with expectation, word production showed an accelerated (quadratic) increase with time so that by 18 months, infants on average were producing approximately 5 words per 10 minutes ($p < .001$).

As can also be seen in Table 7, significant between-child differences were detected in the growth rate of eye contact, smiles, and gestures over time, and in the initial growth rate and the speed of growth (i.e., acceleration) of NWVs and words over the 8 to 18 month period. This suggests that sources of variability should be examined in individual growth parameters at Level 2 (see below).

2.2.2.4 Functions of gestures. Unconditional growth models for the rates of gestures (i.e., both those produced alone and those coordinated with other communicative behaviors) coded as Joint Attention, Behavior Request, and Social Interaction bids are presented in Table 8 and Figure 3.

As expected, initial frequency did not differ from zero as gestures are a low frequency behavior at 8 months. However, the positive and significant slope term for Joint Attention bids indicates that the frequency with which infants used gestures to initiate joint attention increased steadily over time ($p < .001$). The growth trajectory for Behavior Requests followed a quadratic growth trajectory, such that the initial rate of production was positive and significant (p =.022), and the acceleration in growth trended toward significance ($p = .078$). Social Interaction gestures were produced less frequently than Joint Attention and Behavior Request gestures overall, and these types of bids did not increase significantly over time. Again, significant variance was detected in the growth rate for each function (see Table 8) indicating that analyses should proceed to modeling conditional growth models using Level 2 (between-child) predictors.

2.2.2.5 Overall production of communicative behaviors produced in Coordinated Bouts. To examine overall developmental change in coordination of communicative behaviors, an unconditional growth model was estimated for the rate of production of Coordinated Bouts. Descriptive data on rates of Coordinated Bout production, rates of production of individual communicative forms in Coordinated Bouts, and rates of occurrence of different communicative functions for coordinated gestures are presented in Table 9.

Results from the unconditional analysis of Coordinated Bouts are presented in the third column of Table 6 and depicted with all communicative acts and single acts in Figure 1. As can be observed, the rate with which communicative behaviors appeared in coordination was low at 8 months (3.46 bouts per 10 minutes), but still significantly different from zero ($p < .001$), and increased significantly over time on the order of 0.64 units per month ($p < .001$). There was significant variability in the intercepts and slopes for each summary measure, suggesting between-child differences in developmental course (see Table 6).

2.2.2.6 Forms of communicative behaviors produced in Coordinated Bouts. To determine how often individual behaviors are likely to appear in coordination, unconditional growth models were next estimated separately for rates of occurrence of each form of communicative behavior in Coordinated Bouts (e.g., rate of coordinated eye contact; rate of coordinated NWVs). Means, standard deviations, and ranges of coordinated behaviors are presented in Table 9. Descriptive statistics by age for each outcome group can be found Appendix D, Tables D1-D4.

The results of this series of unconditional growth models can be found in Table 10 and are illustrated in Figure 4. Eye contact and smiles were frequently produced in coordination by 8 months of age, as suggested by significant intercept terms; however, coordinated eye contact (estimated at a rate of 4.02 acts per 10 minutes) was produced more frequently than coordinated smiles (estimated at a rate of 1.39 acts per 10 minutes; see top panel of Figure 4). There was a significant increase in coordinated eye contact over time ($p = .001$), and a small but significant increase in coordinated smiles (p = .006). Importantly, a non-significant variance component suggests that the level of coordinated eye contact did not vary meaningfully between children. While significant variation was detected between children for coordinated smiles, further analyses indicated that outcome group did not significantly explain this variation. Thus, Level 2 conditional models will not be estimated for coordinated eye contact or coordinated smiles.

Regarding coordinated NWVs, infant production was significantly different from zero at 8 months, indicating frequent use of NWVs in coordination with other behaviors (i.e., at a rate of 2.52 per 10 minutes). There was also a significant linear increase in the growth rate of this behavior over time ($p < .001$), but not in the intercept. The production of coordinated gestures was not significantly different from zero at 8 months, nor was the production of coordinated words, which was to be expected. However, a significant increase in growth rate (but not acceleration) of coordinated gestures (p = .001), and in acceleration for coordinated words ($p <$ .001) was observed (see bottom panel of Figure 4). Further, significant between-child variability in slope for coordinated NWVs, slope and acceleration for coordinated gestures, and acceleration for coordinated words was detected (ps < .001; see Table 10).

2.2.2.7 Functions of coordinated gestures. The unconditional growth models for coordinated gestures by function are presented in Table 11 and Figure 5. Because gestures did not differ from zero at 8 months, intercepts did not contribute meaningfully to the model and were therefore excluded. In terms of developmental growth, however, rate of production of coordinated Joint Attention gestures increased steadily from 8 to 18 months ($p < .001$). A similar developmental pattern was observed for coordinated Behavior Request gestures, although the growth rate was somewhat slower than that observed for coordinated Joint Attention gestures ($p < .001$). Further, between-child variability in Joint Attention and Behavior Requests was indicated by significant variance components (*p*s < .001). In contrast, no developmental change or between-child differences were observed for the rate of coordinated Social Interaction gestures. Thus, they will not be analyzed further.

2.2.2.8 Predicting trajectories in the development of communicative behaviors: The relation to outcome group (conditional models). The unconditional analyses reported above revealed significant between-child variance in the majority of variables at Level 1. Thus, variation was expected between the four outcome groups in the development of infants' communicative behaviors. Conditional growth models considered between-child associations of outcome group (i.e., LR, HR-ND, HR-LD, and HR-ASD) with initial (i.e., 8-month) rate of communicative behaviors (intercept), growth in communicative behaviors over time (slope), and speed of growth over time (acceleration). Infant gender was included as a covariate in each of the models.

2.2.2.9 Between-group differences in the overall production of communicative behaviors. The first two columns of Table 12 presents results from the conditional HLM analyses for the rates of all communicative acts and all single communicative acts. As noted above, the LR group was entered into all models as a reference group; therefore, the coefficients generated for the HR-ND, HR-LD, and HR-ASD groups reflect deviations in intercept, slope and/or acceleration from the LR group.

The relation of diagnostic outcome to the developmental trajectory for overall production of communicative acts was examined first. Results are illustrated in Figure 6. As noted above, outcome groups did not differ in the initial value of communicative acts; all groups produced communicative acts at a rate of about 13 acts per 10 minutes. As indicated by the overlapping lines, the LR and HR-ND groups were indistinguishable; both showed significantly increasing growth trajectories for the production of communicative acts. The HR-LD group also demonstrated a significant increase in communicative acts over time, but at a slightly lower rate; the difference from the LR group was marginally significant (p = .06). However, the HR-ASD group differed significantly from all other outcome groups. The average rate of change was 2.46 communicative acts per 10 minutes lower than the LR group each month (p < .001), a difference that was magnified across the 8- to 18-month period.

Post-hoc analyses were conducted by re-centering time so that the trajectories' anchor, or intercept, was systematically varied by age (e.g., $age_{it} - 10$, $age_{it} - 12$, $age_{it} - 14$, $age_{it} - 18$). Centering improves the interpretability of the intercept by allowing the "initial status" to vary by age (Singer & Willet, 2003). Centering analyses indicated that the divergence in developmental trajectories between the HR-ASD and all three non-ASD groups became statistically significant at 12 months (p = .004). As statistical significance does not necessarily translate into meaningful (i.e., practical) differences, we adopted the method proposed by Jacobson, Follette, and Revenstorf (1984), in which clinically significant change is defined as 2 SDs difference between clinical groups. Thus, at 10 months, the standard deviation difference between HR-ASD and LR infants was relatively minimal (0.48 SD). By 12 months, HR-ASD infant communicative production fell on average 0.95 SD below that of LR infants; and by 18 months, the difference had more than doubled, with HR-ASD infants producing acts at a rate of 2.38 SD below LR infants.

Additional post-hoc analyses were conducted to examine differences between each of the HR groups. This was done by rotating the reference group (e.g., from LR to HR-ND, HR-LD; see Analytic Approach). Results indicated that the HR-ASD group exhibited a significantly slower growth rate than both the HR-ND (p < .001) and HR-LD groups (p < .001). No other statistically significant group differences were detected.

The influence of diagnostic outcome on the developmental trajectory for single communicative acts was examined next. Results are presented in the middle column of Table 12. The developmental pattern for the rate of production of single behaviors was mirrored that observed for all communicative acts. Specifically, the LR, HR-ND, and HR-LD groups did not differ significantly from one another in growth rate of the production of single acts over 8 to 18 months. However, the HR-ASD group differed significantly from all other outcome groups; the estimated differential in the rate of change in single communicative acts was 1.73 (p < .001). Again, the developmental trajectory for the HR-ASD diverged significantly from the other three groups at 12 months (p = .002).

2.2.2.10 Between-group differences in forms of communicative behaviors. The relation between diagnostic classification and the form communicative behaviors (i.e., produced both alone and in coordination) was modeled next; separate models were estimated for each category of behavior. Results from these analyses are presented in Table 13. As previously mentioned, the coefficients generated for the HR-ND, HR-LD, and HR-ASD groups reflect deviations in intercept and slope from the LR group.

Regarding the frequency of smiles produced by infants from 8 to 18 months, all groups used smiles to communicate at 8 months of age at a rate that was significantly different from zero (p < .001). Further, all groups demonstrated a small but significant increase in the use of smiles over time. In other words, HR infants (including those with ASD) did not differ from LR comparison infants in the initial production or development of communicative smiles.

The developmental course of infants' use of eye contact to communicate, however, varied depending on outcome group (see the second column of Table 13 and the top left panel in Figure 7). While there were no between-group differences in eye contact at 8 months, a *decline* in the use of eye contact to communicate was apparent in the HR-ASD group. The difference in growth rate between the LR and HR-ASD groups was statistically reliable ($p < .001$). Post-hoc analyses revealed that differences in the rate of production of eye contact between HR-ASD and the LR group became significant at the 14 month observation. However, this difference was not necessarily clinically meaningful (Jacobson et al., 1984); at 18 months the HR-ASD was only estimated to fall 0.95 SD below the LR group. Additional post-hoc analyses revealed that the HR-ASD group also differed significantly from both the HR-ND and HR-LD groups in terms of growth rate; however the LR, HR-ND and HR-LD groups did not differ from one another.

Results for the rate of production of NWVs are presented in the third column of Table 13 and the top right panel of Figure 7. Similar to the pattern observed for eye contact, the initial rate of NWVs was not statistically different among groups; however, the developmental patterns of growth did differ by group. As is illustrated in Figure 7 (top right panel), the LR group demonstrated a significant initial growth rate in use of NWVs to communicate ($p = .013$), which was maintained over time as evidenced by a non-significant acceleration (i.e., speed of growth, or curvature). The initial rate of increase in NWVs for the HR-ND group was significantly higher than the LR group ($p = .005$); however, the acceleration term was negative and statistically significant, indicating an eventual peak and then decline in growth rate ($p = .001$; see Figure 7).

Post-hoc analyses indicated that the HR-ASD trajectory diverged significantly from the HR-ND group at 10 months ($p = .011$), and the LR ($p = .048$) and HR-LD ($p = .007$) groups at 12 months. The standard deviation difference between LR and HR-ASD was 0.65 at 12 months, 1.26 SD at 14 months, and a striking 3.03 SD at 18 months. At 18 months, the standard deviation difference between the HR-ASD group and other HR groups was 1.87, a discrepancy that was statistically significant (p = .002) but fell just short of clinically meaningful (> 2 SD).

Regarding the rate of gestures (displayed in the fourth column of Table 13 and the bottom left panel of Figure 7), all groups demonstrated a positive linear increase in gesture production from 8 to 18 months. Relative to the LR comparison group, gestures grew at a comparable rate in the HR-ND group (i.e., there was no significant difference in slope). However, the HR-ASD and HR-LD groups each demonstrated significantly slower growth over time than both the LR and HR-ND groups. Thus, the average rate of change infants for the HR-LD and HR-ASD groups is 0.51-0.57 lower than LR infants and 0.32-0.39 lower than HR-ND infants. As age increases, these differences become magnified. Post-hoc analyses (i.e., intercept centered at 12 months) indicated that group differences became significant at 12 months for both HR-ASD (β_{04} = -1.98, p < .001) and HR-LD (β_{03} = -1.99, p < .001). Over time, this slower growth rate translated into progressively larger standard deviation differences; at 12 months, HR-ASD and HR-LD infants were performing at a level 2.1-4.23 SD below the LR group and at 6.35-5.64 SD below by 14 months. Thus, both ASD and LD infants showed delayed, or attenuated gesture development, as compared to LR and other HR infants.

A similar pattern was observed for word production (see the last column of Table 13 and the bottom right panel of Figure 7). Analyses revealed that all groups demonstrated upward curvature in growth trajectories, such that word production increased more rapidly with time. No statistically reliable differences between the HR-ND and LR groups were detected. However, the speed of acceleration in word production was significantly lower for the HR-ASD and HR-LD groups, compared to both the HR-ND and LR groups (ps < .05). Again, the divergence from the

LR group became more dramatic with age; by 18 months, rate of word production for both groups fell a striking 12 SD below the LR group. The SD difference was even greater when the HR-ASD and HR-LD groups were compared to the HR-ND group.

2.2.2.11 Between-group differences in the functions of gestures. Results from the conditional (between-group) analyses for development in the function of gestures (i.e., both those produced alone and those coordinated with other communicative behaviors) over the 8 to 18 month observation period are presented in Table 14 and illustrated in Figure 8. As can be observed, infants in the HR-ASD and HR-LD groups developed gestures for establishing Joint Attention significantly more slowly than the LR group, a difference that became more apparent with age. Specifically, infants in the HR-LD group on average grew at a rate of 0.30 fewer Joint Attention gestures per observation each month than LR infants ($p < .001$). Similarly, HR-ASD infants grew at a rate of 0.38 fewer Joint Attention gestures per observation each month ($p < .001$). There was no statistically significant difference between the LR and HR-ND groups.

Post-hoc analyses indicated that the HR-ASD ($p = .001$) and HR-LD ($p = .013$) groups also differed significantly from the HR-ND group in terms of growth rate. While group differences were negligible at 8 months, they became statistically reliable at 12 months (ps < .01) and grew considerably larger until 18 months (SD difference ≈ 10).

Regarding Behavior Requests, even though significant variation was detected in the Level 1(unconditional) model, outcome group was not found to be a significant predictor of the initial use (intercept) and growth (slope and acceleration). Social Interaction gestures were not modeled at Level 2 because individual variation in trajectories was not found to be significant at Level 1.

2.2.2.12 Between-group differences in the overall production of Coordinated Bouts. Regarding the rate of production of Coordinated Bouts, unconditional analyses indicated that while the intercept term was significantly different from zero, it did not vary significantly between children; therefore there was no need to examine between-group differences at Level 2. However, the rate of production over time (i.e., slope) differed between children and outcome group was a significant predictor of this variation.[12] These results are presented in the third column of Table 12 and illustrated in Figure 9. Specifically, while the LR comparison group increased in production of bouts on the order of 0.83 bouts (per 10 minutes) per month, the HR-ASD group grew at a significantly slower rate ($p < .001$). In fact, the slope term was close to zero, indicating that infants in the HR-ASD group showed relatively no growth in the production of Coordinated Bouts between 8 and 18 months (see Table 12). Again, the difference between the HR-ASD and LR group in the production of Coordinated Bouts became significant at 12 months of age ($p < .009$).

Similar to the results for communicative acts, post-hoc analyses indicated that the growth rate in Coordinated Bouts for the HR-ASD group also differed from the HR-ND group ($p = .001$), and the HR-LD group ($p = .019$). While group differences between the HR-ASD and HR-ND groups were significant at 12 months ($p = .003$), significant differences between HR-ASD and HR-LD were not observed until 14 months ($p = .02$). By 18 months, the level of Coordinated Bouts in the HR-ASD group was almost 2 SD below that of the LR group. There were no other significant between group differences in production of Coordinated Bouts.

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[12]Differences persist even after controlling for overall communicativeness (see Prediction 1 in prediction-driven analyses presented below). Further, variables of interest were calculated as proportion of total communicative acts and raw data was plotted. Visual inspection of the data suggested that proportion variables followed the same developmental patterns (in terms of both overall developmental pattern and group differences in trajectories) as those calculated as rates.

2.2.2.13 Between-group differences in the forms of communicative behaviors produced in Coordinated Bouts. The next set of developmentally-focused analyses focused on the specific types of behaviors produced in coordination. As reported above, no between-child variation was detected for the rate of coordinated eye contact or coordinated smiles. Therefore, further model specification at Level 2 was not warranted.

Conditional models for the developmental trajectories of coordinated NWVs, coordinated gestures, and coordinated words were estimated with outcome group as Level 2 predictors. Results are summarized in Table 15 and depicted in Figure 10. For coordinated NWVs, no group differences in the initial rate of production of coordinated NWVs were detected. A significant increase in growth rate of coordinated NWVs was revealed for all groups except the HR-ASD group (see the top left panel of Figure 10). In fact, the HR-ASD developmental course deviated significantly from the LR group ($p < .001$), such that the estimated differential in rate of change between HR-ASD and LR infants was 0.53. Post-hoc analyses also showed that the differences in slope between the HR-ASD group and the HR-ND and HR-LD groups were also significant ($ps < .01$). The LR, HR-ND, and HR-LD groups did not differ significantly from one another. Further analyses revealed that the HR-ASD group differed significantly from the LR group by the 12 month observation ($p = .04$) and from all other HR groups by the 14 month observation ($ps < .01$).

The developmental course for rate of coordinated gestures was examined next. Results are depicted in the middle column of Table 15 and the top right panel of Figure 10. No group differences in initial value or initial rate of production were observed. The LR and HR-ND groups were not statistically different from one another. In contrast, the HR-ASD infants exhibited a different developmental trajectory, with a slight initial increase in rate of production but eventual plateauing. However, this difference in acceleration just missed conventional levels of significance (p = .066). Post-hoc analyses examining group differences at each age (via centering) indicated that by 18 months, both HR-ASD and HR-LD groups differed significantly from the LR and HR-ND groups in the overall production of coordinated gestures (ps < .05). However, only the HR-ASD group exhibited a significantly lower slope (i.e., rate of growth; p = .004). This suggests that, although the HR-LD group demonstrated a delay in the production of coordinated gestures, and their rate of production still fell far below those of the LR and HR-ND groups at 18 months, the trajectory of growth at this point is more comparable to LR and HR-ND groups.

The frequency of coordinated words was also analyzed and results are presented in the last column of Table 15. Developmental trajectories for each of the four outcome groups are depicted in the bottom left panel of Figure 10. Again, developmental patterns did not differ statistically between the LR and HR-ND groups. Relative to the LR and HR-ND groups, the HR-ASD (p = .005) and HR-LD (p = .035) groups showed slower acceleration in coordinated words over time; group differences in production became significant at 14 months (ps < .004). Not surprisingly, the HR-LD and HR-ASD groups were not distinguishable from one another in the development of coordinated words.

2.2.2.14 Between-group differences in the functions of coordinated gestures. The final set of developmental analyses focused on the communicative function of coordinated gestures. Again, no developmental change or between-child differences were observed for the rate of coordinated Social Interaction gestures; therefore, conditional models were not analyzed. Table 16 summarizes the results from the conditional models for coordinated Joint Attention gestures and coordinated Behavior Request gestures; results are also illustrated in Figure 11.

No group differences existed for initial rate of coordinated Joint Attention gestures or coordinated Behavior Request gestures at 8 months, as the values were not significantly different from zero. However, as can be observed, both LR and HR-ND groups exhibited steady growth in the frequency of coordinated Joint Attention gestures, at a similar rate (at an increase of 0.34 and 0.29 bouts per month, respectively). Both HR-LD and HR-ASD groups had significantly slower growth rates than LR and HR-ND groups (*p*s < .01); and the growth rate estimated for the HR-ASD group was also significantly slower than that for the HR-LD group (p = .035; see Figure 11). Group trajectories become more divergent over the 8- to 18-month period. Post-hoc analyses indicated that group differences between HR-ASD/HR-LD and LR/HR-ND became significant as early as 10 months (*p*s < .05) and were maintained through 18 months. The difference between the HR-ASD and HR-LD groups did not become significant until 18 months.

Findings were similar for coordinated Behavior Request gestures. The HR-ASD and HR-LD groups showed slower growth over time. Post-hoc analyses indicated that the slope (i.e., growth rate) for the HR-ASD group was significantly different from both the LR (p < .001) and HR-ND groups (p = .008) but the HR-LD group was only significantly different from the LR group (and not the HR-ND or HR-ASD group; p = .032). Trajectories for the LR and HR-ND groups were virtually indistinguishable and not statistically different.

2.2.3 Analyses Examining DST Predictions

The second overarching goal of this study was to test three predictions derived from DST having to do with the relationship between instability and the co-occurrence of communicative behaviors from four distinct modalities. Based on the available literature (e.g., Goldberg et al., 2005), it was expected that HR children who receive an ASD diagnosis will demonstrate deviation in growth trajectories for social communicative behaviors that are most discrepant from the LR comparison group. Further, it was expected that, the remaining HR groups (HR-LD, HR-ND) would also show delays in the development of these behaviors, but that those delays would be less pronounced. In other words, diagnostic outcome was expected to be significant predictor of growth trajectory parameters (e.g., intercept and slope), with expected differences between the LR group and all HR groups, as well as differences between the HR-ASD group and HR-ND groups. The following prediction-driven analyses examine assumptions about group differences in the production and frequency of Coordinated Bouts in early infancy. Table 17 contains the means, standard deviations, and ranges for each of variables examined below (see Appendix D, Tables D1-D4 for descriptive information by age for each outcome group).

2.2.3.1 Prediction 1: HR infants as a group, and particularly those later diagnosed with ASD, will produce fewer instances of communicative Coordinated Bouts. Because the total amount of communication (i.e., rate of communicative acts) differed between the four outcome groups, group differences for rate of Coordinated Bouts might reflect this disparity. Therefore, to address this prediction, Coordinated Bouts were calculated as proportion of total communicative acts (i.e., the number of Coordinated Bouts divided by the total number of communicative acts). Due to positive skew in the distribution of this variable, the natural logarithm transformation was used before running HLM analyses (Tabachnick & Fidell, 1989). In this metric, a 0.10 increase in log(Coordinated Bouts) is approximately equal to a 10% increase in the raw frequency of Coordinated Bouts. Therefore, 10% of the value of β_1 represents the increase in rate implied by a 10% increase in the raw frequency of bouts (Huttenlocher et al., 1991).

The results from the unconditional growth analyses are presented in Table 18, in the first column. Results indicated a positive and significant intercept term ($p < .001$) suggesting that the proportion of coordinated bouts is significantly different from zero at 8 months of age. The non-significant slope term suggests that there is no growth in the frequency of Coordinated Bouts over time (after controlling for growth in communicative acts overall). Importantly, significant variability in both the intercept and growth rate was detected; therefore Level 2 analyses were subsequently conducted where diagnostic outcome and gender were added a predictors.

Results of the conditional growth analysis are presented in the first column of Table 19 and illustrated in Figure 12 and indicate that diagnostic classification was significantly related to both 8-month production (intercept) and growth in relative frequency of Coordinated Bouts over time (slope). As is apparent, the LR reference group demonstrated a significant and increasing trajectory for the production of Coordinated Bouts, even after controlling for overall communicativeness (p = .001). Further, while the HR-ND group initially produced a higher proportion of communicative bouts than the LR group (p = .013), a negative slope was also detected such that the proportion of bouts decreased significantly each month (p = .005). The HR-ASD and HR-LD groups also demonstrated decreasing growth trajectories; the difference in slope from the LR group reached statistical significance for the HR-ASD group (p = .032). Post-hoc analyses indicated that by 18 months, the HR-ASD group was the only group showing a significant difference from the LR comparison group (β_{03} = -0.07, p = .022). Post-hoc analyses also showed that there were no significant differences between the HR-ND, HR-ASD, and HR-LD groups in intercept or slope.

2.2.3.2 Prediction 2a: Relative to LR infants, HR infants will exhibit restricted diversity in Coordinated Bouts. As a measure of each infant's general repertoire of communicative coordinations, the total number of different types of Coordinated Bouts produced during the 25 minute observation was calculated. For example, an infant demonstrating only word + eye contact coordinations received a diversity score of one (one type), whereas an infant producing word + eye contact, point + smile, NWV + show coordinations received a diversity score of three (three types). Descriptive data for diversity are also presented in Table 17.

Results from the unconditional growth model (see Table 18) revealed an intercept that was significantly different from zero ($p < .001$), indicating that infants produced, on average, 1.97 different types of Coordinated Bouts at the 8 month observation. There were no between-child differences in initial diversity score at 8 months. The overall diversity of coordinated behaviors increased significantly over the 8 to 18 month observation ($p < .001$); however, there was also significant between-child variability detected in growth rate ($p < .001$).

Data from the conditional models are presented in the middle column of Table 19 and illustrated in Figure 13. As is evident, all groups demonstrated a linear increase in their repertoire of communicative bouts; however, relative to the LR and HR-ND groups, the HR-ASD and HR-LD groups demonstrated significantly slower growth in diversity over time (ps < .01). The HR-ASD and HR-LD groups were not significantly different from one another in diversity growth over time. Likewise, there were no significant differences between the LR and HR-ND groups. However, post-hoc analyses indicated that the HR-ASD group differed significantly from the LR and HR-ND groups in diversity score at 12 months (ps < .001), but that the HR-LD group did not differ from the LR and HR-ND groups until 14 months (ps < .01). These results suggest that both HR-ASD and HR-LD children develop limited behavioral repertoires of Coordinated Bouts between 8 and 18 months. However, HR infants who do not receive a clinical diagnosis of ASD or exhibit language delays behave similarly to LR children in terms of the diversity (and therefore flexibility) of behaviors produced in coordination.

2.2.3.3 Prediction 2b. HR infants will produce less complex communicative coordinations compared to LR infants. Communicative complexity was evaluated by examining the degree to which communicative coordinations involved two (e.g., smile + point), three (e.g., smile + point + eye gaze), or four (e.g., smile + point + eye gaze + word) distinct behaviors. The mean number of communicative behaviors produced within coordinations was calculated and analyzed using HLM. Results from the unconditional growth model are presented in Table 18 (last column) and demonstrated that the intercept was significantly different from zero ($p < .001$) but the slope was nonsignificant. This suggests that infants initially produce Coordinated Bouts involving two behaviors and that the average number of behaviors involved in bouts remained steady over time. The variance components for intercept and slope in the unconditional model were significant (*p*s < .01), suggesting between-child differences. However, outcome group was not found to be a significant predictor of either component (see Table 18). Results suggest that infants are likely to produce two behavior combinations at any age regardless of group membership.

Further inspection of the data indicated that while all infants produced three behavior combinations at some point during the 8 to 18 month observation, four behavior combinations (involving communicative behaviors from all four modalities) were rare (see Table 17). Therefore, the proportions of infants in each group who produced four behavior combinations was computed and analyzed using a chi-square analysis with cases classified as ASD/non-ASD. Results indicated a significant difference by diagnostic outcome (ASD vs. non-ASD; $p = .039$, Fishers Exact Test, one sided). Specifically, none of the infants diagnosed with ASD produced four behavior bouts at any point during the observation period. In contrast, 23 out of 48 (32.39%) of infants not diagnosed with ASD used four behavior combinations at some point from 8 to 18 months.

2.2.3.4 Prediction 3. Relative to LR infants, when HR infants produce Coordinated Bouts, they will more likely be comprised of highly practiced, older behavioral forms (i.e., NWVs, smiles, eye contact). To address this prediction, the composition of Coordinated Bouts was examined across the 8- to 18- month period, with particular attention to coordinations comprised entirely of developmentally prior communicative expressions. Therefore, coordinations were classified into developmentally-prior or developmentally-advanced bouts based on the specific behaviors that comprised the bout.

Developmentally-prior bouts included Social Smiles and Directed Vocalizations. Social Smiles were defined as the co-occurrence of smiles and eye contact while Directed Vocalizations were defined as the co-occurrence of NWVs and eye contact (e.g., see Ozonoff et al., 2010 for similar definitions). Three types of developmentally-advanced bouts were also constructed. These included gestures combined with smiles or eye contact (Gesture + Smile/EC), words combined with smiles or eye contact (Word + Smile/EC), and gestures combined with a NWVs or words (Gesture + NWV/W). Descriptive statistics for these different types of coordinations for the overall sample are presented in Table 17 (see Appendix E, Tables E1-E2 for the number of different types of Coordinated Bouts produced by each ASD infant at each age). Data will be presented first for developmentally-prior bouts, and then for developmentally-advanced coordinations.

Developmental change in the mean rate of Social Smiles and Directed Vocalizations was analyzed first. Results from the unconditional HLM analyses are summarized in the first and second columns of Table 20. The initial rate of Social Smiles at 8 months was significantly different from zero ($p < .001$), but did not vary significantly between groups. Further, little developmental change in these types of bouts was indicated. Results suggest that, as expected, Social Smiles are a part of infants' communicative repertoires at 8 months, regardless of diagnostic outcome, and remain consistently so over time.

This pattern of results was the same for Directed Vocalizations (see Table 20). While the initial rate of Directed Vocalizations was significantly different from zero ($p < .001$), and higher than that observed for Social Smiles, no between-group differences were detected for initial rate or growth rate over time. The slope term was non-significant, indicating little change in these types of behaviors over time. Thus, it appears that Directed Vocalizations are a more prominent part of the communicative repertoire than Social Smiles, and that infants in all outcome groups produce both types of developmentally-prior coordinations at similar rates. Because between-child variation was not indicated in the unconditional analyses, Level 2 conditional models were not estimated.

Turning now to developmentally-advanced coordinations, the descriptive data presented in Table 17 indicate that infants produced Gesture + Smile/EC and Word + Smile/EC Bouts with very low frequency throughout the observation period. In fact, the mean rate of these types of bouts did not rise above 0.81 acts per 10 minutes over the entire course of 8 to 18 months. As a result, it was not possible to estimate reliable HLM models, even after data transformation methods were attempted (i.e., reliability estimates < .20).

The rate of Gesture + NWV/W coordinations was also low at 8 months but increased steadily with time (see Table 17) so that, by 18 months, infants were producing, on average, 3.84 Gesture + NWV/W Bouts per 10 minutes. Unconditional growth models (summarized in Table 20) for Gesture + NWV/W Bouts revealed that the initial value (i.e., intercept) was not significantly different from zero and variance component indicated that there were no significant between-group variation in intercept. Significant variation was detection in the growth rate at 8 months (p < .001); however, when adding diagnostic classification as a predictor in the Level 2 model, no reliable differences were found between groups in the initial (8 month) slope of Gesture + NWV/W bouts.

However, significant group disparities were found in the speed of growth (i.e., curvature) of Gesture + NWV/W combinations. Specifically, the HR-ASD group exhibited significantly slower acceleration in this type of Coordinated Bout over time than the LR group, (β_{23} = -0.04, $t(75)$ = -2.87, p = .006).[13] As is apparent in Figure 14, the trajectory for the HR-ASD group remained fairly flat throughout the 8 to 18 month period indicating little growth in this type of coordination over time. Post-hoc analyses indicated that the difference between the HR-ASD and LR groups in the trajectory of Gesture + NWV/W combinations was significant as early as 12 months (p = .002) and remained significant through 18 months (p = .002). Additional follow-up analyses indicated that there were no significant differences in slope or acceleration between the LR, HR-ND, or HR-LD groups. Further, the HR-ASD group was not significantly different from the HR-ND or HR-LD groups.

Because visual inspection of the group trajectories depicted in Figure 14 suggests that the HR-LD group begins to diverge from the HR-ASD group around 12 months of age, another post-hoc analysis was conducted where time was re-centered at 12 months and the HR-LD group was as the reference. This analysis resulted in a new set of intercept and slope parameters that reflected the mean frequency of Gesture + NWV/W Bouts at 12 (instead of 8) months of age. The new (i.e., 12-month) intercept and slope between the HR-LD and HR-ASD groups were compared. Results revealed that, as suspected, that the HR-ASD slope was significantly lower than the HR-LD group at 12 months (β_1 = -0.09, $t(75)$ = -1.94, p = .044); there was a

[13]Results were identical when assessing for group differences in Gesture + NWV combinations alone. Gesture + Word combinations were not analyzed separately due to the low frequency of this behavior (see Table 17).

nonsignificant trend for acceleration of growth (β_2 = -0.03, $t(75)$ = -1.73, , p = .087). When time was centered at 18 months, the group difference (at that specific point in time; i.e., intercept) between HR-ASD and HR-LD in the mean rate of production of Gesture + NWV/W Bouts reached statistical significance (β_0 = -1.76, $t(75)$ = -2.32, p =.023). Thus, it appears that both HR-ASD and HR-LD infants demonstrate a delay in Gesture + NWV/W Bouts, initially. However, the developmental course of these behaviors remains deviant for HR-ASD infants. In contrast, it appears that by 12 months of age, Gesture + NWV/W Bouts begin to emerge for HR-LD infants and then develop at a rate comparable to LR and HR-ND children (even though these types of bouts are still produced less frequently, overall).

2.3 DISCUSSION

This study was designed to examine the social communicative repertoire of HR infants by identifying developmental trajectories of several key communicative behaviors and their respective coordinations at multiple time points and compare them to those of LR infants. It was organized around three major goals. The first was to provide a general picture of infants' communication skills in early infancy and determine whether group differences exist in the development of specific communicative behaviors (e.g., eye contact, smiles, gestures, NWVs, words) and of coordinated communicative behaviors. The second was to gather data regarding a set of hypotheses derived from a dynamic systems model of development. These predictions had to do with the effects of instability on the patterning and coordination of different communicative behaviors, and the specific relationship between early emerging versus developmentally advanced coordinations. The last goal was to examine whether delays or deviance in the development and coordination of communicative behaviors are specific to ASD rather than an index of general communicative delay. Therefore, a small subgroup of HR infants with non-ASD language delays (HR-LD) was included in the study.

2.3.1 What is the Nature of Multimodal Communication Development in HR Infants?

2.3.1.1 The development of social communication in HR infants. A summary of significant ($p < .05$) group differences in the developmental trajectories can be found in Table 21. One primary finding was that group differences in development were not detected between the LR and HR-ND groups on rate of all communicative acts, Coordinated Bouts, gestures, words, smiles, and Joint Attention gestures, nor in the mean rate of developmentally-prior or developmentally-advanced bouts, or the diversity (i.e., repertoire) of Coordinated Bouts. While the overall frequency of NWVs and eye contact were comparable between the LR and HR-ND groups at 18 months, the pattern of development across the 8 to 18 month period differed. In both cases, the HR-ND group produced higher frequency of NWVs and eye contact at 8 months, relative to the LR group; however, the trajectory of growth either accelerated, peaked and declined (NWVs), or remained flat (eye contact). This suggests that in some aspects of communication (e.g., earlier communicative behaviors), HR-ND and TD infants may follow alternate routes of development but ultimately converge toward a common endpoint.

Overall, these results differ from previous research indicating that relative to LR peers, HR siblings are significantly lower in overall communication rate, production of single words, use of distal gestures, and use of gestures to make behavioral requests and to initiate joint attention (e.g., Cassel et al., 2007; Goldberg et al., 2005; Iverson & Wozniak, 2007; Mitchell et al., 2006; Toth et al., 2007; Yirmiya et al., 2006; Yoder et al., 2009). However, prior studies have adopted different approaches to characterizing HR infants. Some of the earlier studies did not separate HR infants later diagnosed with ASD from those with no such diagnosis in their HR sample, primarily because infants were too young at the time the study was conducted to receive a reliable diagnosis (e.g., Cassel et al., 2007). Other studies used a general subgrouping of ASD versus not (e.g., Toth et al., 2007; Mitchell et al., 2006; Yoder et al., 2009); however, it is becoming increasingly apparent that HR infants as a group are extremely heterogeneous (a point to which I will later return in the General Discussion).

As a result, more recent studies of HR infants have clustered HR children into multiple categories by the type of delay (e.g., no concerns, speech-language delay, autism/ASD). These types of studies generally have not found a significant relationship between general risk status and early social and communication behavior (e.g., Young, Merin, Rogers, & Ozonoff, 2009). The current study extends these findings and highlights the fact that a sizeable portion of HR infants (56%) appear indistinguishable in behavior from LR comparisons. Overall, this research underscores the fact that being "high risk" (i.e., having an older brother or sister with ASD) is not necessarily synonymous with later delays, concerns, or autism symptomatology. Nevertheless, a subset (26%) of HR infants was determined to have language delays (HR-LD). The extent to which HR-LD infants demonstrated additional social communicative difficulties varied depending on the specific type of behavior and age. A more thorough examination of this group follows in the General Discussion.

2.3.1.2 The development of social communication in ASD infants. The present investigation contributes to a growing body of developmental research on early social communication skills by evaluating the extent to which delayed and/or atypical patterns of communicative behaviors can be used to identify children eventually diagnosed with ASD. Findings point to the value of a comprehensive approach that examines the communicative system as a whole by measuring both preverbal and verbal aspects of communication and the importance of examining the course of developmental change over time.

Reduced gesture and word production in ASD infants was observed in this study, which is consistent with a growing body of research on HR infants (e.g., Mitchell et al., 2006; Toth et al., 2007; Wetherby et al., 2004; Yirmiya et al., 2006; Yoder et al., 2009). However, the current study extends these findings more broadly by examining a wider range of communicative behaviors, including the *coordination* of gesture, smiles, eye contact, NWVs, and words, spontaneously initiated by the child in everyday communication in the naturalistic environment of the home. Importantly, developmental trajectories modeled across the 8- to 18-month period for the HR-ASD group deviated in significant ways from the HR-ND and LR groups not only on the rate of all communicative acts, words, gestures, and Joint Attention gestures, but on the rate of Coordinated Bouts, coordinated NWVs, coordinated words, and coordinated Joint Attention and Behavior Request gestures.

This pattern of results is also consistent with previous work demonstrating that older children with ASD are often especially impaired in the coordination of communicative behaviors (Adrien et al., 1987; Buitelaar et al., 1991; Wetherby et al., 1989), and with more recent with toddlers where 18- to 24-month old children with ASD were less likely to produced joint attention acts using coordinated means than TD and developmentally delayed children (Shumway & Wetherby, 2009). The present study supplements this work by demonstrating that ASD infants' growth trajectories in the development of coordinated gestures used for joint attention deviates from LR and HR-ND infants as young as 10 months of age. Studies that have reported differences in the social communicative behaviors of ASD versus LR infants indicate that such differences are evident by 12 months and become more apparent with age (e.g., Landa & Garret-Mayer, 2006; Ozonoff et al., 2010; Yirmiya et al., 2006; Yoder et al., 2009); however, no known study has documented group differences (between ASD and TD children) before 12 months of age. The results of the present study suggest that the roots of communicative impairments in ASD may be evident earlier than previously thought, in reduced frequency of coordinated behaviors. However, an important question to ask when considering these findings is whether the developmental differences observed are specific to ASD.

2.3.1.3 Are deficits in social communication coordination specific to ASD? The current study began to determine whether deficits in communicative coordination are specific to ASD by comparing the development of these behaviors in HR infants with ASD to HR infants with language delay (HR-LD). When examining developmental trajectories over time, significant differences between the HR-ASD and HR-LD groups were found in frequency of communicative acts, single acts, and Coordinated Bouts. The most notable contribution of this study, however, was data suggesting the importance of specific types of Coordinated Bouts in distinguishing infants with ASD from HR-LD infants. Coordinations involving NWVs and/or gestures – Coordinated NWVs, Coordinated Joint Attention gestures, and Gesture + NWV/Words – were among the only communicative behaviors studied in which HR-ASD infants also differed from HR-LD in developmental course. That is, while the HR-LD group demonstrated similar starting levels of communicative behaviors at 8 months, and a slight delay at first (in comparison to LR and HR-ND groups), these infants exhibited increasing trajectories, while infants in the HR-ASD group experienced persistent delays. Therefore, one might speculate that ASD infants have a specific deficit in coordinating NWVs and gestures, particularly together.

Gesture-vocalization combinations may have important consequences for later social and linguistic development by more effectively establishing joint reference between an infant and his/her social partner (i.e., joint attention; Winder et al., in press). Thus, an infant who not only points at something of desire or interest but vocalizes while doing so produces a powerful stimulus for parent behavior, a stimulus likely to bring about a state of joint attention. For example, while a parent who is engaged in her own activities might very well fail to notice her infant silently pointing to a cat, when the infant accompanies her point with a vocalization, the parent is much less likely to miss the gesture and more likely to shift attention to the object of infant desire or interest, possibly then providing a verbal label or comment about the object (e.g., "Yes, that's a kitty, look at the kitty, what a nice kitty.").

Prior research has established the importance of NWVs for directing parental attention (Hsu & Fogel, 2001; Goldstein, King, & West, 2003; Goldstein, Schwade, & Bornstein, 2009; Gros-Louis et al., 2006). Moreover, a recent study showing that mothers increase the length of their responses selectively to certain types of gesture-speech combinations suggests the value of coordinated vocalizations for creating social learning opportunities (Goldin-Meadow et al., 2007). Thus, communicative coordinations involving vocalizations appear to establish episodes of joint attention more effectively whereby important input from a social partner may be elicited. It follows, then, that if infants later diagnosed with ASD demonstrate reduced frequency of gesture-vocalization combinations, they will also have fewer opportunities to establish shared states of attention during which linguistic and social learning occur. Indeed, we observed that ASD infants also demonstrated lower rates of coordinated gestures used for Joint Attention relative to HR-LD infants. Therefore, the absence of such experiences may negatively impact additional aspects of communication and social development and further contribute to the symptomatology of ASD (Mitchell et al., 2006; Yirmiya et al., 2006; Yirmiya et al., 2007).

2.3.2 DST as a Theoretical Model for Understanding Atypical Development.

DST posits that communicative development is a complex, integrated system where a number of behavioral configurations are possible depending on the relative influence of component behaviors along with characteristics of the child/and or environment. In typical development, the cohesiveness of the communicative system (i.e., the degree to which individual behaviors such as eye gaze, smiles, gestures, or vocalizations are tightly timed in production) may be affected by instability related to a variety of factors (e.g., onset of a new skill, task demands, biological characteristics). As previously discussed, children with ASD may be particularly susceptible to instability in the communicative system, which may lead to the delayed or atypical development of communicative coordinations. Overall, data from this study provide support for the study's three main theoretically-driven hypotheses. These are discussed in turn below.

2.3.2.1 The communicative system of ASD infants is characterized by heightened instability. DST places a strong emphasis on the dynamic interplay between a myriad of forces on the developing system and the relative stability of individual behaviors. It further suggests that there may be far-reaching effects on the organization of the broader system when one component is the least bit unstable. It is therefore possible that ASD infants demonstrate heightened instability because of a relative weakness in one (or more) component of the system. The most likely candidate based on the present findings is eye gaze. Consistent with previous research, the HR-ASD group exhibited a declining trajectory in the overall use of eye contact

(Landa et al., 2007; Ozonoff et al., 2010). It is possible, then, that a disruption in the ability to make eye contact for communicative purposes may have some degree of influence on the communicative system as a whole, specifically, the ability to coordinate behaviors from different communicative modalities.

Researchers have long proposed a developmental link between early dyadic social interaction, the temporal coordination of communicative behavior it affords, and the subsequent development of triadic joint attention behaviors in TD children (Adamson & Bakeman, 1985; Bakeman & Adamson, 1984; Striano & Rochat, 1999). The earliest form of joint attention seen in typical development involves the alternation of eye contact between an object of interest and a social partner (Carpenter et al., 1998). However, if ASD infants experience a decline in the use of eye contact during the period where TD children begin to use eye contact to coordinate social attention and establish shared engagement states with others, then opportunities to "practice" coordinating may be limited. Fewer experiences establishing joint attention using eye contact alone may impact infants' ability to initiate joint attention by coordinated eye contact with other types of communication (e.g., conventional gestures). Further research is needed to explore whether and how reduced eye contact may impact the development of more sophisticated communicative behaviors.

With the exception of coordinated Joint Attention gestures, group differences did not emerge before 12 months of age. However, over the next 6 months, the developmental trajectories for the HR-ASD infants became much more divergent from the Non-ASD groups. After 12 months, the non-diagnosed infants showed clear positive growth in the production and coordination of communicative behaviors while developmental trajectories for the HR-ASD group remained flat or decreasing. This suggests that behavioral markers of ASD may not be apparent in children prior to 12 months of age, at least not in the communication domain.

It is therefore not yet clear whether the difficulty observing ASD symptomatology in the first year of life reflects a true developmental sequence in the emergence of ASD or whether the field has not yet been able to identify the most salient behaviors. The current study suggests that difficulty with certain types of communicative coordinations (e.g., coordinated Joint Attention gestures) may distinguish ASD from TD at earlier ages. Interestingly some researchers have suggested that early motor impairments predate and have a direct influence on later social and communication deficits (cf., Iverson, 2010, for a discussion of the relationship between advances in motor skills and language acquisition; and Bhat, Landa, & Galloway for a review and discussion of the link between motor and social impairments in infants, children, and adults with ASD). Thus, because the development of more complex communication skills (e.g., emergence of gestures) draws on skills from other domains, including motor, when there are weaknesses and/or delays in all of these systems, requiring them to come together to support advances in the communicative system is problematic. Future research focused on early motor delays, for example, and the ways in which they contribute to language and communication skills HR infants may better elucidate the way in which this complex disorder unfolds in infancy.

2.3.2.2 The communicative system of ASD infants exhibits a lack of behavioral variability and flexibility. As noted in the Introduction, TD children have a number of communicative behaviors available to them and are able to coordinate these behaviors temporally such that initial coordinations can disassemble and reassemble into more effective configurations if modifications are needed (e.g., an unresponsive partner, excess background noise, onset of a developmental transition). The results of this study suggest that in the case of infants with ASD, there is a lack of behavioral variability and flexibility in communicative performance.

First, consistent with expectation, HR-ASD infants demonstrated suppressed trajectories in the repertoire (i.e., diversity) of Coordinated Bouts, indicating that these infants produced a smaller number of behavioral configurations. This finding extends prior work demonstrating that young children with ASD have a limited range of gesture types (Wetherby et al., 2007). A reliance on a restricted set of communicative behaviors versus the flexible, integrated use of a variety of types of behaviors means that the ASD infant may have limited ability to adapt to changing environmental demands. For example, when faced with an unresponsive social partner, TD children often utilize communicative repair strategies (i.e., the repetition or modification of a communicative signal when faced with failure to communicate; Alexander, Wetherby, & Prizant, 1997; Golinkoff, 1986).

Thus, the child who, after saying “juju” to request more juice, realizes that her mother is unresponsive, and is then able to again say “juju ba!” or another vocalization and perhaps also point to the cup and make eye contact with her mother, demonstrates the flexible use of multiple communicative signals. However, a disorganized system simply may not be able to meet these demands of circumstances that require the addition or substitution of communicative utterances such as these. Indeed, there is evidence that children with autism are more likely to experience communicative breakdowns than their TD peers, but may make fewer attempts to repair the breakdowns or may use less sophisticated strategies (e.g., vocal repairs; see Keen, 2003 for a review).

The current study also hypothesized that ASD infants would demonstrate less complexity in communicative behaviors. Previous research indicated that children with ASD have a lower proportion of utterances involving combination of more than two communicative behaviors (e.g., co-production of gesture, vocalization, and eye gaze) than TD children and children with other developmental delays (Stone et al., 1997; Wetherby et al., 2004). While this study did not detect differences in the average number of behaviors produced within Coordinated Bouts, ASD infants were less likely to produce the highest level of complexity involving the combination of behaviors from all four modalities. Difficulty using less complex coordinations may lead to a greater reliance on well-established, developmentally-prior behaviors.

2.3.2.3 Communicative coordinations involving earlier-emerging behaviors are more prominent in ASD infants. DST proposes that during times of systemic instability, patterns involving developmentally prior behavioral forms are likely to be stronger and therefore more frequently produced (Thelen, 2004; Thelen & Smith, 1994). If the communicative system of the ASD infant is predisposed to instability, then coordinations involving well-established, pre-existing behaviors may be more frequent. Thus, the third hypothesis suggested by DST was that the communicative systems of children with ASD may get “stuck” in developmentally prior states more frequently than other children. In other words, ASD infants were predicted to demonstrate relative ease in coordinating behaviors such as smiles and eye gaze that, from an early age, are produced within highly repetitive and well-structured caregiver-child interactions (Thelen & Smith, 1994). These patterns were hypothesized to become so entrenched in the communicative repertoire of ASD infants that they would have more difficulty transitioning into new behavioral modes when needed. Results were consistent with this prediction.

Of note, all groups, including infants with ASD, produced similar frequencies and developmental patterns of early developmental behaviors such as smiles alone, social smiles (i.e., smiles coordinated with eye contact) and directed vocalizations (i.e., NWVs coordinated with eye contact). These types of behavioral configurations typically emerge very in early infancy (between 3-6 months) within the context of caregiver-infant dyadic interactions, which are highly repetitive, scaffolded, and follow a predictable sequence (Stern, 1985). Drawing from DST, during times of systemic instability, patterns involving developmentally prior behavioral forms are likely to be stronger and therefore more frequently produced (Thelen, 2004; Thelen & Smith, 1994). Results are consistent with prior research that shows increased levels of social engagement (i.e., mutual eye gaze and smiling) in ASD children during social situations that were highly regulated by the caregiver (e.g., pat-a-cake or peek-a-boo; Sigman et al., 1986).

In contrast, the data from this study indicate that HR-ASD infants produced gestures and used gestures to initiate joint attention and make behavior requests at lower rates than other HR infants. Gestures typically emerge later in development; they are a form of triadic communication in which attention is coordinated between self, other, and some third object, event, or symbol (Adamson, 1995; Tomasello, 1995). It is possible, then, that when the transition to triadic communication occurs (around 8 to 12 months), ASD infants' communicative system may not adapt to produce new behavioral configurations and may instead continue to fall back on pre-existing patterns (see also Thelen, 2005). That is, patterns that are initially adaptive and relatively "intact" may become so habitual that ASD children have greater difficulty transitioning into a new behavioral mode (e.g., triadic communication). Thus, data from the present investigation do not support the notion that HR-ASD infants show deviance in all social behavior; rather there appears to be specific difficulty transitioning to more developmentally advanced communicative forms and behaviors (e.g., gestures, words, gesture-vocalization coordinations).

Overall, the findings from Study 1 lead to three major conclusions. First, the behavioral symptoms of ASD within the social communication domain appear to emerge over time, beginning just after the first year of life and becoming more pronounced by 18 months. Second, ASD infants do not appear to have widespread difficulties in the production and coordination of all social communication behaviors; rather, they demonstrate a pronounced deficit in the coordination of more developmentally advanced behaviors. In particular, gestures coordinated with pre-speech vocalizations emerged as a unique predictor. Finally, while a subset of non-ASD HR infants also experienced delays in social communication and language (HR-LD), the majority of HR infants demonstrated communication skills more comparable to typical development. The implications of these findings for developmental research and clinical applications will be considered in the General Discussion.

3.0 STUDY 2

Study 2 takes a more descriptive approach and assesses: a) the extent to which production and coordination of social communicative behaviors varies as a function of interactional context (naturalistic observation, semi-structured observation, and parent report) in HR infants; b) whether repeated prospective assessments of communicative ability in HR infants may differentiate true risk for communicative difficulties versus more transient delays; and c) whether diagnostic classification can be improved by the use of multiple measures of communication, specifically multimodal social communication in a naturalistic setting.

As previously discussed, some studies suggest that communicative competence is best captured in contexts that offer a greater degree of support (e.g., Sigman et al., 1986), while others report that skills are more evident in familiar settings with familiar social partners (e.g., McHale et al., 1980). These findings leave open the question of what the best approach is for evaluators to take when assessing children at risk for communication delays. At present, the screening process assumes that early delay predicts later delay; and referral decisions are often based on a single assessment at a single timepoint (Darrah et al., 2003). Although authors are encouraging the addition of multiple assessment points and the inclusion of natural communication samples and parent report into current evaluation practices (e.g., Adolph et al., 2008; Crais et al., 2009; Darrah et al., 2003; Tager-Flusberg et al., 2009), very little research has addressed this issue. Further, the results of Study 1 suggest that assessment of *multimodal* (i.e., coordinated) communication in naturalistic contexts may contribute unique and valuable information to the diagnostic picture, one that is not yet fully integrated in early developmental screening procedures. Three primary questions will be addressed in Study 2.

1. To what extent do HR children demonstrate variability across measures of social communication, and is this variability apparent over time?

2. Will HR infants demonstrate persistent or transient delays within the communicative domain over time?

3. To what degree will the inclusion of multiple measures of HR infants' social communication skills improve prediction of diagnostic outcome at 36 months?

3.1 METHOD

3.1.1 Participants

Participants for Study 2 included the 50 HR infants from Study 1.

3.1.2 Procedure

Three measures designed to assess communicative development were collected in infants' homes monthly from 8 to 18 months as part of the larger research protocol.

3.1.2.1 Naturalistic and play segments. This study utilized the data obtained at monthly video- and audio-recorded sessions from 8 to 18 months during the 25-minute caregiver-child play segment described above in Study 1.

3.1.2.2 Early Social Communication Scales (ESCS). At each session beginning at 8 months, the abridged ESCS was administered to infants (Mundy et al., 2003). The ESCS is a 15-20 minute semi-structured interaction that is designed to examine children's tendency to initiate coordinated shared attention with a tester in children between the ages of 8 and 30 months. High interrater agreement for the ESCS has been well documented (Mundy et al., 2003), as well as test-retest stability across 14 to 17 months (Mundy & Gomes, 1998) and predictive validity in relation to language and social competence outcomes in a variety of typical and atypical populations (Morales et al., 2000; Mundy & Gomes, 1998; Mundy et al., 1995; Mundy et al., 1990; Sigman & Ruskin, 1999).

Multiple trained examiners administered the ESCS in accordance with procedures outlined in the abridged ESCS manual (Mundy et al., 2003). For this assessment, an examiner and the infant were seated facing one another at a small table, with the infant seated on a caregiver's lap. A set of toys, visible but out of reach to the infant, was placed to the side of the examiner. Caregivers were instructed not to initiate interaction with their infant as the examiner presented the toys to the infant one at a time as a means of eliciting JA behaviors. The examiner then systematically presented the infant with an array of novel toys (five active wind-up toys and three hand-operated toys) following guidelines outlined in the abridged ESCS manual (Mundy et al., 2003).

In each presentation, the examiner activated the toy on the table in front of, but out of reach of the child. The toy was wound up so that it remained active for approximately 6–10 seconds. After the toy ceased moving, the examiner placed the toy within reach of the child. The child was then allowed to play with the toy for approximately 10 seconds. Each toy was presented for a minimum of three trials and a maximum of five trials. Throughout the testing session, only one toy was present on the table at a time. While an attempt was made to follow a specific task administration order, variation in presentation was acceptable provided that the experimenter presented all specified toys during the course of an administration.

Each toy presentation occurred with natural but minimized verbal interaction with the child. The examiner was encouraged to speak to the child only during transitions in the testing procedure (e.g., while activating a toy or selecting a new toy), but otherwise remain silent but attentive during actual task presentation. However, if a child initiated a bid for shared attention, the examiner was instructed to provide a natural but brief response (e.g., by smiling and nodding, or by saying “mmm hmmm,” or “Yes, I see!”).

Videotaped data from the ESCS was coded continuously using the Observer (Video-Pro version XT, Noldus Information Technologies) to identify episodes of joint attention. Coding was completed using standard procedures (Mundy et al., 2003). Two infant-initiated joint attention variables were analyzed in this study: Initiating Joint Attention (IJA) and Initiating Behavior Requests (IBR). IJA reflects behaviors employed to communicate interest in an object or event, includes two subscale scores reflecting either the frequency of two eye contact behaviors (Low-IJA) or two conventional gestures (e.g., High-IJA). Low-IJA items include: 1) making eye contact with the examiner while manipulating a toy; and 2) alternating eye contact between an active mechanical toy and the examiner. High-IJA items are: 1) pointing to an active mechanical toy within reach or unattainable distal objects in the room (e.g., pictures on the wall) with or without eye contact; and 2) showing by raising objects toward the examiner's face with eye contact.

IBR variables, which reflect behaviors used to obtain or get rid of an object, include the two subscale scores reflecting the frequency with which the child reaches and/or makes eye contact with the experimenter (Low-IBR), or uses gestures and/or eye contact (e.g., High-IBR). Low-IBR items are: 1) making eye contact after an object has been moved out of reach, 2) reaching for a toy that is out of reach; 3) making eye contact while reaching for a toy; High-IBR items include: 1) pointing to a toy that is out of reach but attainable; and 2) giving a toy to the tester.

Coding was completed by three primary observers blind to infants' HR status, outcome classification, and study hypotheses. Coders were trained on a series of standard reliability videotapes and achieved intra-class correlation coefficients of .80 or higher on all scoring categories for a total of 10 videotapes before study coding commenced. In addition, intraclass correlations between one primary coder and one reliability coder were computed on 10% of the ESCS segments randomly chosen from sessions of different infants at different ages. The inter-rater reliabilities were: Low IJA = .965, High IJA = .942, Low IBR = .944, High IBR = .865. All correlation coefficients were significant (*p*s < .01).

3.1.2.3 MacArthur-Bates CDI. CDI data collected from 8 to 18 months as described above in Study 1 were utilized in this study.

3.1.2.4 Diagnostic classification. Outcome classifications at 36 months were determined in the same manner as in Study 1.

3.2 RESULTS

Study 2 was designed to assess the extent to which production and coordination of social communicative behaviors in HR infants varies as a function of interactional context, social partner, and informant. To this end, three sets of analyses addressed the three main study questions outlined above. The first was designed to examine patterns of production of social communication skills across sampling techniques and over time. The second examined relative stability in individual children's CDI scores across time; and the final set examined the extent to which diagnostic outcome can be correctly predicted using direct assessments (i.e., ESCS) and parent report (i.e., CDI) as well as a more elaborated measurement system that incorporates the coding of multimodal communication in natural communication samples (i.e., Naturalistic Observation).

3.2.1 Question 1: Are There Differences in Communicative Performance Across Contexts and Over Time?

The primary aim of this research question was to examine whether HR infants demonstrate variability in communication skills across the structured (ESCS) and unstructured (naturalistic and toy play) contexts. This is important because most research examining social communication skills in HR infants has generally take place in a laboratory or clinic setting where communication is elicited and assessed within structured interactions. Little is known about spontaneous patterns of communication in familiar, everyday environments. Therefore, it is unclear to what extent infant behavior under standardized conditions is characteristic of the child in the everyday environment. If such differences exist, it will be important to include careful surveillance of communicative behavior under natural conditions in developmental screening procedures when assessing infants at risk for ASD.

Two steps were taken in an effort to make data gathered in the ESCS and naturalistic observation directly comparable. First, only communicative behaviors that were coded in both contexts were included for analysis. Since IJA and IBR were only coded for gestures in the naturalistic home setting, only those ESCS codes involving gestures (i.e., High-IJA and High-IBR) were included for analysis (see Study 1 Method for a more detailed coding description). Second, frequencies were converted into rate (per 10 minutes) to correct for variations in observation length.

To examine concurrent relations among the social communication measures, Pearson product-moment correlation coefficients were computed separately for rates of Joint Attention and Behavior Request in the ESCS and Naturalistic contexts at each assessment age for the full HR sample. These are presented in Tables 22 and 23. Of the 50 correlations computed, only four were significant. Of these four, only one was between concurrent measures: ESCS IJA at 18 months and Naturalistic IJA at 18 months (r = 0.43, p < .01). This suggests that prior to 18 months children’s production of joint attention behaviors in one context is not necessarily related to production in the other context.

Looking at relationships across observations, the rate of gestures used to initiate IJA in the naturalistic setting (Naturalistic IJA) at 10 months was positively and significantly related to gestures used to initiate IJA in the ESCS context (ESCS IJA) at 14 months (r = 0.37, p < .05). In addition, there was a positive correlation between ESCS IJA at 14 months and Naturalistic IJA at 18 months (r = 0.37, p < .05). For IBR, only the association between ESCS IBR at 14 months and Naturalistic IBR at 18 months was significant.

To explore potential context differences further, data were subjected to a two-way repeated measures analysis of variance (ANOVA) with Age and Context as within subjects factors and Outcome Group (HR-ND, HR-LD, and HR-ASD) as the between subjects factor.[14] Simple effects analyses and follow-up *t*-tests were conducted when appropriate. Results will be presented for separately IJA and IBR. A final set of analyses was conducted to compare the proportions of joint attention episodes in each context that were IJA or IBR.

3.2.1.1 IJA. The top panel of Figure 15 presents the mean rate of IJA in the ESCS context by age and outcome group, and the bottom panel of Figure 15 presents the mean rate of IJA in the Naturalistic Observation context by age and outcome group. As is evident in the figures, there was a significant increase in rate of IJA with age, regardless of context, for the majority of HR infants. However, children in the HR-ASD group produced IJA at lower rates at all ages in both contexts. The repeated measures ANOVA confirmed significant main effects of Age (F(1.79, 56.50) = 3.75, p = .034, η^2 = .11) and Outcome Group (F(2, 31) = 4.11, p = .026, η^2 = .21), and a nonsignificant main effect of Context (F(1.00, 31.00) = 2.97, *ns*). No interaction effects were detected.

Follow-up post-hoc tests (Sidak) examining the source of the main effect of Outcome Group indicated that the mean rate of IJA for HR-ASD group was significantly lower than the HR-ND group (p = .03); the difference between the HR-ASD group and the HR-LD group trended towards significance for the HR-LD group (p = .078). No significant pairwise

[14]Repeated measures ANOVAs were chosen so that both age and context could be examined as within-subjects factors in the same analysis; this type of nonparametric analysis is not possible. However, it is acknowledged that basic assumptions were violated due to unequal variances in some of the dependent variables and the small and uneven number of infants in each of the three outcome groups (IJA: HR-ND n = 23, HR-LD n = 5, HR-ASD n = 6; IBR: HR-ND n = 21, HR-LD n = 8, HR-ASD n = 7). Therefore, an adjusted F test (Greenhouse-Geisser) was used for the repeated measures ANOVA, resulting in more conservative estimations of effects. Further, nonparametric Kruskal-Wallis Tests were conducted with follow-up nonparametric independent samples t tests (Mann-Whitney U). In both cases, results were unchanged.

comparisons were revealed for age suggesting that infants demonstrate slow and steady growth in IJA over the 8 to 18 month period (versus a significant jump in production from one time point to the next). Overall, context differences were not found to be significant when measuring IJA in HR infants; however, it is possible that the lack of context differences may be due to the fact that IJA is a low frequency behavior in this population (especially in HR-ASD children).

3.2.1.2 IBR. The next set of analyses focused on rate of production of IBR in the ESCS and Naturalistic contexts. As can be observed in Figure 16 (top panel), the mean rate of IBR increased steadily with age in the ESCS context; however the mean rate of IBR produced in the naturalistic context was lower than that in the ESCS context and remained so over time (see bottom panel of Figure 16). This difference is evident for all infants regardless of group, and contexts effects appear to become larger with age. The repeated measures ANOVA carried out on this data revealed a significant main effect of Age ($F(2.79, 91.97) = 16.02$, $p < .001$, $\eta^2 = .33$) and Context ($F(1.00, 33.00) = 83.61$, $p < .001$, $\eta^2 = .72$). However, these main effects were qualified by a significant Age x Context interaction ($F(3.01, 99.39) = 13.09$ $p < .001$, $\eta^2 = .28$). The main effect of Outcome Group was not significant ($F(2, 33) = 1.59$, *ns*), suggesting that there were no statistically significant differences in rate of IBR between the HR-ND, HR-LD and HR-ASD infants (in either context; see Figure 16).

Post-hoc paired samples *t* tests indicated that the context differences were statistically significant at 8 ($t(43) = 2.67$, $p = .011$), 10 ($t(46) = 6.32$, $p < .001$), 12 ($t(41) = 6.10$, $p < .001$), 14 ($t(45) = 8.21$, $p < .001$), and 18 months, with all HR infants producing IBR at higher rates in ESCS relative to Naturalistic. In sum, contextual differences appear to be prominent when measuring IBR (versus IJA) and become more pronounced with time.

3.2.1.3 ESCS vs. Naturalistic Observation. To control for observed differences in rates of occurrence, IJA and IBR were calculated as proportions of total joint attention episodes produced in each context. These proportions were calculated for the full HR sample ($n = 50$) and examined separately for ESCS and Naturalistic. Figure 17 illustrates the mean proportions of joint attention episodes that were IJA or IBR for the ESCS (top panel) and Naturalistic Observation (bottom panel) separately.

Paired samples *t* tests revealed significant differences between the proportion of IJA and IBR in the ESCS context at 8 ($t(29) = 39.13$, $p < .001$), 10 ($t(40) = 14.70$, $p <$ 001), 12 ($t(41) = 29.98$, $p < .001$, 14 ($t(45) = 19.85$, $p <.001$), and 18 ($t(48) = 20.32$, $p < .001$) months, suggesting that the ESCS is very well designed to elicit IBR whereas IJA is much less observable (see top panel of Figure 17). However, as is evident in the bottom panel of Figure 17, the relative frequencies of IJA and IBR were more comparable in the Naturalistic Observation. Indeed, in the Naturalistic context, the proportion of IJA differed significantly from the proportion of IBR only at the 8 month observation ($t(21) = 2.66$, $p = .015$), when higher level IJA is just emerging.

Thus, while HR infants produced predominantly IBR in the ESCS, they made comparable use of gestures for initiating joint attention and for initiating behavior requests in the Naturalistic Observation. Interestingly, examination of data from only the HR-ASD infants indicated that results were almost identical to those for the larger HR sample as a whole.[15] Thus, it is important to evaluate joint attention (IJA and IBR) in more than one context to ensure an accurate picture of social communication abilities in HR infants. A naturalistic context may be more likely to offer opportunities to observe both IJA and IBR communicative attempts, whereas structured assessments like the ESCS may not be as well-suited for eliciting IJA.

[15]Paired samples *t* tests revealed significant differences between the proportion of IJA and IBR at all ages in the ESCS context, ps < .001. However, the only differences detected in the Naturalistic context was at 18 months, where the proportion of IJA was marginally lower than the proportion of IBR ($t(6) = 2.23$, $p = .067$).

3.2.2 Question 2: Are Communicative Delays in HR Infants Persistent or Transient Over Time?

Currently, programs for early screening for infants with developmental delays assume that early delay predicts later delay, and therefore referral decisions are often based on assessments at one point in time. However, theories such as DST maintain that development is nonlinear (Thelen, 1995; Thelen & Smith, 1994). Indeed, studies of TD children support these assumptions and demonstrate that the rate of emergence of communication skills is not constant (e.g., Darrah et al., 2003; Fenson et al., 1994). As suggested previously, the development of communication skills in HR infants also possesses some degree of variability. While many HR children will exhibit some delays in the communication domain (Mitchell et al., 2006; Yirmiya et al., 2006; Yirmiya et al., 2007), it not yet known whether these delays are present from early infancy and, if so, whether they are consistently observed or more variable over time. Increasing emphasis on the early diagnosis of ASD means that clinicians and researchers are beginning to suggest that standardized screenings for ASD take place at earlier points in development (e.g., 12 month well-visits; Pierce et al., 2011). If HR infants do not demonstrate stability in assessment of communication skills over time, then developmental surveillance may be preferred over one-point screening. The question of interest here therefore is whether communicative delays in HR infants are persistent or transient over time.

This research question was addressed using three primary measures of communicative and language development obtained from the CDI: Total Gestures, Words Understood, and Words Produced. The first two measures are assessed on the CDI-WG, which all primary caregivers completed at 8, 10, 12, and 14 months. Words Produced was assessed on both versions of the CDI and thus was analyzed across the 8 to 18 month timeframe.

Scores for Total Gestures were obtained by totaling the number of gestures/actions endorsed in the Early Gestures (First Communicative Gestures and Games and Routines) and Later Gestures (Actions with Objects, Pretending to Be a Parent, and Imitating Other Adult Actions) subscales. Scores for the Words Understood was the sum of total words indicated by parents as being *only understood* by their infant. For ages at which caregivers completed the Words and Gestures form of the CDI, the Words Produced score was created by totaling the number of words endorsed as being understood and said by the infant.[16] For visits at which the Words and Sentences form was administered, the Words Produced score represents the number of words endorsed by parents; comprehension is not assessed on this version of the CDI. Final data were available for 240 of the 250 (50 infants x 5 sessions) measures (96%): The CDI was not completed for five infants at 8 months (2 HR-ASD, 2 HR-LD, 1 HR-ND); two infants at 10 months (1 HR-LD and 1 HR-ND); and one infant at 12 (HR-LD), 14 (HR- LD) and 18 months (HR-ASD). For descriptive purposes, the mean raw scores for Total Gestures, Words Understood, and Words Produced for HR infants by outcome group are presented in Figure 18.

To evaluate the consistency with which HR infants demonstrate delays within the communicative domain over time, three separate analyses were performed on the CDI data. First, correlational analyses were conducted to examine stability of raw scores for each of the three communicative skills/domains assessed with the CDI (i.e., Total Gestures, Words Understood, and Words Produced). Associations between consecutive assessments of these skills were examined for the HR infants as a group. Next, visual analyses of graphs of individual infants' data were used to examine stability in measurement at the individual level, and to evaluate the

[16]Nine caregivers of HR infants completed the CDI-WG at 18 months (HR-ND n = 2; HR-ASD n = 3; HR-LD n = 4). A Mann-Whitney *U* test indicated that although the mean number of words produced at 18 months was lower for infants using the CDI-WG than for those using the CDI-WS ($M_{CDI\text{-}WG}$ = 23.78, *SD* = 26.65; $M_{CDI\text{-}WS}$ = 63.49, *SD* = 83.80), this different was not statistically reliable (U = 120.00, p = .11). Further, while all 9 HR infants demonstrated a decrease in percentile scores from 14 to 18 months, the number of words increased or stayed the same.

proportions of infants demonstrating stable and unstable raw scores over time. It was expected that examination of variability in individual trajectories over time would provide richer information about patterns of development. Finally, CDI scores falling at or below the 10th percentile are often used to indicate communicative delay in older infants (e.g., Ellis et al., 2002; Gershkoff-Stowe et al., 1997; Heilmann et al., 2005; Robertson & Ellis, 1999). However, it is not yet known how frequently HR infants score in this range, and how consistent low scores are at such young ages (e.g., 12 months). Therefore, the proportion of infants scoring at or below 10th percentile at each age was examined.

3.2.2.1 Within-domain stability. Table 24 presents correlations between ages for raw scores at 8, 10, 12, 14, and 18 months for Total Gestures, Words Understood, and Words Produced. In general, adjacent ages were highly correlated with one another, regardless of domain. Additionally, for both Total Gestures and Words Understood, 8 month scores were highly correlated with scores at 12 (and 14 months for Words Understood). However, Word Produced raw scores at 8 months had little relationship to scores at later time points. This was not surprising considering that most children do not produce single words until closer to 12 months, so raw scores at 8 months (Words Produced ≈ 0) is not expected to correlate to later ages. The strongest relationships detected were within the Words Understood domain, where scores were correlated at all age points. This pattern of results held when HR-ASD infants were removed from the analyses.

3.2.2.2 Intra-individual stability. In a manner consistent with previous studies (Darrah et al., 2003), individual raw score plots for each infant were generated with a 95% confidence interval (CI) plotted around each score. The CI was used to account for measurement error and was calculated using the formula provided in the CDI manual (Fenson et al., 2007, p. 102). Separate plots were created for each domain (i.e., Total Gestures, Words Understood, and Words Produced). If an individual infant's profile of scores obtained across the various observation points had at least one score with a CI that did not overlap with those from any of the other assessment points, the profile was considered to be unstable. Figure 19 illustrates examples of stable (top panel) and unstable (bottom panel) developmental profiles within the Total Gestures domain.

No common pattern of change could be identified across individual infants. Some infants had low scores initially and attained higher scores steadily as they got older, while others had scores that were more variable (see Figure 19). [17] The proportions of HR infants demonstrating stable and unstable communication profiles were compared for each domain using Binomial tests; all results were significant, suggesting that for most children, scores were generally stable over time (*p*s $< .001$). However, instability in scores was apparent over the five assessments in 30% of HR infants for Total Gestures, in 8% for Words Understood, and in 14% for Words Produced. Thus, there was a small subset of infants who exhibited substantial interindividual variability in CDI raw scores over time.

To determine whether this variability was characteristic of infants in a particular outcome group, the proportions of HR-ASD, HR-LD, and HR-ND infants showing stable versus unstable profiles was examined. All but one HR-ASD infant (88.9%) showed stable scores over time in the Total Gestures domain and 100% of HR-ASD infants demonstrated stability in Words Understood and Words Produced. Similarly, 75% of HR-LD infants exhibited stable profiles for Total Gestures and 100% of HR-LD infants showed stability in the Words Understood and

[17]This interindividual variability suggests that the variability observed is not due solely to test structure or the change in forms from 14 to 18 months.

Words Produced domains. In contrast, 75%, 85.7%, and 60.7% of HR-ND infants showed stable scores for Total Gestures, Words Understood, and Words Produced, respectively. A Kruskal-Wallis Test revealed indicated a trend toward significance for group differences in stability of Words Produced (χ^2 (2, N =49) = 6.00, p = .05), with a higher proportion of HR-ND infants demonstrating unstable raw scores than HR-ASD and HR-LD infants. This pattern of results indicate that HR-ASD and HR-LD infants were more likely to exhibit stable developmental profiles, particularly in language measures (Words Understood and Words Produced).

Frequency of low scores.

The findings just presented suggest that the HR children who go on to exhibit developmental concerns (i.e., ASD, Language Delay) are more likely to have stable CDI scores in early infancy. However, the nature of infants' scores is not yet clear. For example, one might assume that the 'at-risk' profile is one of consistently below average scores but we do not know yet whether HR-ASD and HR-LD infants repeatedly receive low scores on language assessments in early infancy. Therefore, this final analysis examined the frequency with which HR infants received low scores on the CDI.

For this analysis, all raw scores were first converted to percentile scores using gender-specific norms in the CDI manuals. The proportions of HR infants who received scores falling at or below the 10th percentile at each age were calculated. Table 25 shows the numbers (and percentages) of HR infants scoring at or below the 10th percentile at each age separately for each domain; some infants scored below the cutoff in more than one domain. In the Total Gestures domain, more infants scored below the 10th percentile at the early assessments, while the numbers of infants scoring below cutoff was fairly consistent across assessment ages in the

Words Understood domain. For Words Produced, more infants received scores below the cutoff at older ages.

Table 26 shows the number of times individual infants scored at or below the 10^{th} percentile in each domain on the CDI. With the exception of Words Produced, most infants falling below the 10^{th} percentile did so more than once. Further, there were a substantial number of infants who scored at or below the 10^{th} percentile at all assessment ages (i.e., four times). Thus, for example, 8 infants for Total Gestures and 12 infants for Words Understood had scores at or below the 10^{th} percentile at the 8, 10, 12, and 14 month assessments. However, for Words Produced, many HR infants did not fall under the cut-off. This is likely due to the fact that percentile scores before 12 months account for the fact that word production at this age is rare. For example, the percentile score equivalent for a raw score of zero words at 12 months is 25^{th} percentile, whereas at 14 months, a raw score of zero words is equivalent to the 10^{th} percentile. To examine potential outcome group differences in the frequency with which infants scored below cutoff in each domain, the number of times infants in each group received a score $\leq 10^{th}$ percentile was calculated and analyzed using a Kruskal-Wallis Tests with Outcome Group (HR-ND, HR-LD, and HR-ASD) as the between subjects factor. Results will be presented for each domain separately.

In regards to Total Gestures, there was a significant difference among outcome groups in the number of times infants scored at or below the 10^{th} percentile across the 8 to 18 month period ($\chi^2(2, N = 50) = 8.56$, $p = .014$). Mann-Whitney U post-hoc analyses indicated that infants in the HR-ND group scored below cut-off significantly fewer times than infants in the HR-ASD ($U = 57.00$, $p = .041$) and HR-LD groups ($U = 109.00$, $p = .041$). The percentage of infants scoring at or below the 10^{th} percentile zero, one, two, three, or four times is presented by outcome group in

Figure 20. As can be observed, among those infants falling below the cut-off, most in the HR-ND group did so only once. Only two HR-ND infants had scores below the 10^{th} percentile on all four occasions, while greater proportions of HR-ASD and HR-LD infants scored in the at-risk category at all four assessment points.

For Words Understood, the HR-ASD and HR-LD groups scored below cut-off slightly more frequently than the HR-ND group; the Kruskal-Wallis Test just missed conventional levels of significance, however, ($\chi^2(2, N = 50) = 5.36, p = .069$). The percentage of infants in each group who received low scores for Words Understood is illustrated in Figure 21. As is evident, most of the infants in the HR-ND group did not score below cut off at all (i.e., zero times), and the majority of infants who did score at or below the 10^{th} percentile did so only once or twice across the 8 to 14 month period. Interestingly, however, there was still a subset of HR-ND infants who scored in the low range at every time point. Most of the HR-LD infants scored below cut-off at all four assessments. This was also the case for the HR-ASD; however, a higher proportion of HR-LD infants received low scores only once.

Finally, the Kruskal-Wallis Test revealed a highly significant group difference in the frequency of times infants scored below the cut-off for Words Produced (χ^2 (2, $N = 50$) = 17.52, $p < .001$). Follow-up Mann-Whitney tests conducted to evaluate pairwise differences among the three groups indicated that HR-ND infants were less likely to score at or below the 10^{th} percentile than HR-LD infants ($U = 85.00$, $p = .006$) and HR-ASD infants ($U = 34.50$, $p = .001$). Figure 22 illustrates the number of times low scores were received on Words Produced and the percentage of infants from each group. A high percentage of infants in the HR-ND group never scored below cut-off on Words Produced. Further, HR infants who scored below cutoff did so only once or twice (and typically at the later age points, i.e., 14 and 18 months). Again, this is likely due to the fact that word production prior to 12 months is rare. Further examination of low scores in word production beyond 18 months may be helpful in elucidating differences among clinical outcome groups in developmental profiles for this communicative domain. In sum, although delays in gesture and language development were apparent among some HR-ND infants, HR-ASD and HR-LD infants were more likely to receive low scores on multiple occasions, while HR-ND infants scored at or below the 10^{th} percentile less frequently.

3.2.3 Question 3: To what degree does the inclusion of multiple measures of HR infants' social communication skills improve prediction of diagnostic outcome at 36 months?

Here, I examine the contribution of social communication measures collected from multiple sources in discriminating HR children later diagnosed with ASD from HR children with a language delay and HR children not diagnosed with ASD or a language delay. Assessment of social communication skills in HR infants generally utilizes standardized assessments, such as the ESCS and CDI, and often takes place in a laboratory or clinic setting. Although researchers have suggested that HR assessment include natural communication samples (e.g.,Tager-Flusberg et al., 2009), very little work has followed this recommendation. At issue is whether communicative behavior samples collected in HR infants' natural environments, in combination with commonly utilized standardized assessments, can better inform prediction of diagnostic outcome.

This issue was explored using data from the ESCS, parent-report CDI, and naturalistic observation (collected for both studies). First, a series of Kruskal-Wallis Tests (due to the uneven numbers of infants in each diagnostic group) was conducted to determine whether, on average, variables from each measure differed significantly between the three outcome groups (HR-ND, HR-ASD, HR-LD). Significant findings were followed up with Mann-Whitney *U* tests.

To reduce the number of comparisons, variables were eliminated based on the lack of significant group differences detected in previous analyses. First, only those behaviors from the naturalistic observation for which the HR-ASD group was significantly lower in model parameters than the HR-ND group were considered. Additionally, data from the 8 and 10 month assessments were not included due to the fact that behaviors were infrequently produced at these ages (and thus group differences were unlikely). Using these criteria, mean rate of IJA[18] from the ESCS, and raw scores for Total Gestures, Words Understood, and Words Produced from the CDI were selected. In addition, the following variables from the naturalistic observation were included for analysis: the rate of all communicative acts (including all single acts and all Coordinated Bouts; Communicative Acts); the rate of all single communicative behaviors (Single Acts), the rate of communicative behaviors produced in coordination (Coordinated Bouts); the rate of gestures (Gestures); the rate of gestures used to initiate joint attention gestures (Joint Attention Gestures); the rate of Coordinated Bouts including NWVs (Coordinated NWV); the rate of coordinated gestures used to initiate joint attention (Coordinated Joint Attention Gestures), the rate of coordinated gestures used to initiate behavior requests (Coordinated Behavior Request Gestures); and the number of different types of Coordinated Bouts (Diversity).

The means and standard deviations for social communicative behaviors derived from the ESCS, CDI, and naturalistic observation are presented in Table 27. A series of nonparametric Kruskal-Wallis one-way ANOVAs revealed significant group differences (i.e., $ps < .05$) for 20 variables and nonsignificant trends (i.e., $ps < .10$) for an additional six variables. Post-hoc

[18]High-IBR was not included in this analysis due to the absence of significant group differences reported above (see Study 2, Question 1).

comparisons were conducted to further evaluate significant and marginally significant group differences using Mann-Whitney *U* tests. Significant differences (i.e., *ps* < .05) were found between the HR-ASD groups and *both* the HR-ND and HR-LD groups on the following 6 variables: ESCS IJA (18 months); Naturalistic Communicative Acts (14 and 18 months), Naturalistic Single Acts (14 months and 18 months), and Naturalistic Coordinated NWVs (18 months). There were also significant differences (*p*s < .05) between the HR-ASD and HR-ND groups but not the HR-ASD and HR-LD groups on an additional 19 variables: ESCS IJA (14 months), CDI Total Gestures (12, and 14 months), CDI Words Understood (12 and 14 months), CDI Words Produced (12, 14, and 18 months), Naturalistic Gestures (14 and 18 months), Naturalistic Joint Attention Gestures (14 and 18 months), Naturalistic Coordinated Bouts (14 and 18 months), Naturalistic Coordinated NWVs (14 months), Naturalistic Coordinated Joint Attention Gestures (14 and 18 months), and Diversity (14 and 18 months).

To address the question of whether or not group membership (HR-ND, HR-ASD, and HR-LD) could be correctly predicted from the social communication measures, a discriminant analysis was conducted using the variables for which the HR-ASD group was significantly different from the HR-ND or HR-LD groups. Of particular interest was to what extent prediction of diagnostic outcome at 36 months is improved by knowledge of infant communicative behavior during a naturalistic play setting at home. Therefore, a discriminant analysis was first run using only data gathered from the standardized and semi-structured measures (i.e., ESCS, CDI) at 14 and 18 months.

The discriminant analysis revealed significant results. Two functions emerged;[19] the first accounted for 90.8% of the variance and the second function accounted for the remaining 9.2%

[19]With more than two groups, it is possible to obtain more than one discriminant function (DF). The first DF is that which maximally separates the groups. The second DF, independent to the first (i.e., their contributions to the

of the variance. The overall Wilks' lambda was significant, $\Lambda = 0.50$, χ^2 (18, N = 46) = 29.61, p = .041), indicating that overall the predictors differentiated among the three groups. The residual Wilks' lambda was not significant, however ($\Lambda = 0.91$, χ^2 (8, N = 46) = 3.59, p = .892), indicating that the predictors did not differentiate significantly among the three groups after partialling out the effects of the first discriminant function (i.e., the first function was sufficient in predicting group membership). As shown in Table 28, 73.9% of the cases were correctly classified based on the ESCS and CDI scores. All nine infants later diagnosed with ASD were correctly identified, yielding a sensitivity of 100% (*true positives*). Specificity (i.e., the proportion of HR-No ASD infants for whom critical indicators were absent in infancy, or *true negatives*), however, was substantially lower (67.6%). Eighteen HR-ND infants were correctly classified into the HR-ND group whereas 3 HR-ND infants were misidentified as ASD and 6 were misidentified as HR-LD. Seven HR-LD infants were correctly classified as LD; however, 3 HR-LD infants were mistakenly predicted to be in the HR-ASD group.

Next, to determine whether or not group membership prediction is improved by adding data gathered through behavior coding from the home observation, another discriminant analysis was carried out, adding the variables with significant group differences from the Naturalistic Observation (indicated in Table 27). As before, two functions were calculated by the model; the first accounted for 70.5% of the variance and the second function accounted for the remaining 29.5% of the variance. The overall Wilks' lambda was significant, $\Lambda = 0.07$, χ^2 (48, N = 46) = 81.33, p = .002; however, the residual Wilks' lambda was not significant ($\Lambda = 0.36$, χ^2 (23, N = 46) = 31.01, p = .123), indicating that the second function did not contribute any additional value

discrimination between groups does not overlap), maximally separates the groups on variance not yet explained by the first DF (Tabachnick & Fidell, 1996).

to the model. Importantly, the number of correctly classified cases increased to 93.3% (see Table 28).

Again, 100% of the HR children diagnosed with ASD at 36 months were correctly identified by the predictors in the model, yielding 100% sensitivity. Importantly, specificity (91.7%) was much improved over the previous model. As can be seen in Table 28, all HR-LD infants were correctly identified as LD. In addition, of the 27 HR-ND infants, 24 were correctly identified as without ASD or LD whereas 3 infants were incorrectly predicted to be in the ASD group. Both the sensitivity and specificity for this model were above 80%, which is the recommended cutoff for screening tools (Meisels, 1989). Although discriminant analysis on samples this small should be interpreted with caution, the high percentage of agreement in classification suggests that these groups differed substantially on measures of early social communication behaviors, particularly at 14 and 18 months, and that behavior samples gathered from a naturalistic play setting improved the ability to predict whether HR infants were later classified as ASD or LD.

3.3 DISCUSSION

Study 2 adopted a more descriptive approach by examining how factors such as setting (structured vs. naturalistic), assessment type (standardized, parent-report, behavior sample), and frequency (repeated assessments) affect the measurement of these skills in HR infants in the first two years of life. This type of information may prove useful in informing screening and clinical practice as the field continues to move towards identifying and diagnosing ASD at younger ages.

In general, findings from this study support the need to “widen the lens” when assessing ASD risk in early infancy. Information on communication abilities varies in relation to the context in which skills are assessed, the source of measurement, and the point in time at which they are assessed. Further, wide variability was found both within and across children. A clinical appreciation of this variability should lead to the examination of developmental profiles, in addition to absolute scores, which may improve the accuracy of screening for ASD in infancy.

3.3.1 Question 1: Do HR Infants Demonstrate Variability in Communication Skills Across Contexts?

One striking finding from this study was that there was very little relationship between joint attention behaviors observed in the ESCS (structured) and Naturalistic (unstructured) contexts. The lack of significant correlations between behaviors in the two contexts leads to the conclusion that children who do little in one context do not necessarily do little in the other context. Contextual differences were more apparent for behavior requests and became more prominent with time. In contrast, joint attention behaviors were equally represented in the naturalistic context.

These results have important clinical implications. For example, naturalistic interactions with a familiar adult) may provide more opportunities for the child to engage in episodes of joint attention. Indeed, prior research shows that joint attention is enhanced when young children with autism interact with their caregivers compared to peers (Rice, 2001). This information may be especially useful for intervention research targeted to improve joint attention skills in children with ASD. For example, treatment procedures that explicitly involve caregivers may be better suited for eliciting and developing these types of skills. Research examining the efficacy of parent-implemented interventions for young children with ASD, such as the Early Start Denver Model and the Early Social Interaction Project, is promising (e.g., Dawson et al., 2010; Woods & Wetherby, 2003; Wetherby & Woods, 2006). However, further investigations that specifically examine the impact of contextual differences on treatment outcome are needed to make any firm conclusions on this point.

Research has long demonstrated that behavior requests, or behaviors produced for the purpose of getting others to do something, are often the main mode of responding in younger children with ASD (Mundy et al., 1994; Wetherby, 1986; Wetherby et al., 2004). However, much of this research has utilized the ESCS or other similar standardized assessments (e.g., CSBS-DP; Wetherby & Prizant, 2002) to evaluate performance. However, findings from the current study suggest that the conditions under which communicative utterances are elicited may differentially impact the production of requesting and commenting behaviors.

For example, a common object used in many social-communication experimental paradigms is the mechanical wind-up toy (or some other object spectacle, e.g., bubbles). Children with ASD have been described as having more difficulty disengaging their attention from highly interesting stimuli (i.e., "sticky attention;" Landry & Bryson, 2004) and an affinity for repetitive movements (O'Neil & Jones, 1997; Ornitz et al., 1977; Wetherby et al., 2004). Therefore, they may be too "caught" by the presentation of a wind-up toy to initiate a communicative bid to share interest *during* the interesting event (i.e., Joint Attention), and may be more likely to request that the toy be activated again (i.e., Behavior Request). Therefore, one would expect to observe a higher frequency of Behavior Requests in the ESCS context, which was the pattern observed in the current study.

Nevertheless, semi-structured assessments are beneficial for a number of reasons. As mentioned above, assessments such as these that utilize a series of specific interactive situations with built-in social prompts are thought to maximize participants' opportunity for social communication. However, there are also limitations to this approach. Given that the communication abilities of children with ASD have been shown to be more context-bound than those of other children, the communicative behaviors captured during a novel social situation in an unfamiliar setting with an unknown adult may not be entirely representative (Wetherby, 1986). Overall, the results of the present study offer a different perspective on young HR infants' joint attention abilities by examining these skills in naturalistic contexts in addition to structured assessments.

3.3.2 Question 2: Do HR Infants Demonstrate Persistent or Transient Delays in Communication?

This study also examined the relative utility of repeated assessments of communication skills in HR infants over time. With increasing emphasis on moving the age of ASD diagnosis downward (e.g., CDC, 2012, Autism Speaks, Inc., 2012a), this study focused on an earlier point in development than that typically employed for screening. Currently, the *American Academy of Pediatrics* (AAP) recommends screening for ASD at 18 and 24 months of age (Johnson & Myers, 2007); this study focused on the 8 to 18 month period. The results of this study indicate that, as a group, HR infants show a great deal of instability in communication scores in early infancy. While Scores on the CDI at adjacent assessment points were found to be highly correlated with one another (particularly for gestures and words understood), inspection of individual infants' scores over time revealed a high degree of instability. Variability among profiles did not follow predictable patterns, with some infants showing steadily increasing scores and many others showing abrupt shifts in performance at certain points in time. This nonlinear pattern of development is often observed in typically developing children (e.g., Darrah et al., 2003) and is consistent with DST and the concept of a discontinuous rate of emergence of developmental skills (Smith & Thelen, 2003).

The greatest degree of instability was found in the HR-ND group; HR-ASD and HR-LD infants exhibited consistently low scores in all domains of the CDI. There are at least two important implications of this finding. First, HR infants who receive consistently low scores in the communication domain over time may be at greater risk for long-term developmental problems (e.g., ASD or language delay). Second, and perhaps more importantly, many HR-ND infants also received low scores on at least one occasion over the course of the 8 to 18 month observation period. Therefore, many non-diagnosed HR children would be identified as 'at-risk' for communication difficulties if assessment were to occur at a single point in time (e.g., 12 months). Thus, the false positive rate for identifying developmental delay in younger infants may be attenuated if surveillance of HR infants occurs at relatively frequent and repeated intervals throughout infancy.

The importance of repeated assessments over time for understanding developmental change has been argued in the developmental literature for years (Vygotsky, 1978; Wohlwill, 1970, 1973; Thelen & Ulrich, 1991). A recent study demonstrated the consequences of infrequent sampling in drawing inaccurate or incomplete developmental conclusions (Adolph et al., 2008). For example, longer intervals in the frequency of observations of infant motor behavior reduced the accuracy in estimating the onset of motor milestones and the ability to detect individual variability. Because many previous studies have assessed communication and language development in ASD infants at few time points, there is a need to better characterize the course of development including understanding the shape of change over time. Inadequate sampling can have serious implications in documenting developmental delays in clinical populations such as ASD.

Study 2 also examined communication skills across different domains of the CDI, and included assessment of gestures, receptive language and expressive language. Parent-report measures of expressive language (i.e., CDI Words Produced) were not sufficient in identifying which HR infants later received an ASD diagnosis; not surprisingly, many HR-LD infants also received low scores. In addition, scores did not typically fall below the 10^{th} percentile cut off until later ages (e.g., 14 and 18 months) because words are not expected to emerge until after 12 months. Information gathered from additional domains in the CDI – Total Gestures and Words Understood – offered more insight into the nature of communication delays in HR infants. For example, of those infants scoring below the 10^{th} percentile on Total Gestures, HR-ASD infants were more likely than HR-ND and HR-LD infants to receive low scores at all four assessment points. This is consistent with new research that found that gesture raw scores on the CDI was the only measure that differentiated children with ASD from other clinical groups (e.g., specific language impairment, developmental delay) at 12 months (Veness et al., 2012).

Therefore, examination of developmental profiles over time and across different communication domains, including gestures and receptive language, is needed to determine risk of later ASD diagnosis with greater precision. As language and communication delays are one of the first concerns raised by parents of children with ASD (De Giacomo & Fombonne, 1998), more evaluation of developmental patterns using additional well-validated instruments is necessary. For now, an awareness of the value of repeated assessments in creating a profile of communication serves as a reminder to clinicians that there is more to consider in assessing risk for ASD. If the goal is to move the age of diagnosis of ASD downward, clinicians should be prepared to invest more time and resources into screening HR infants in multiple areas of development and at multiple time points in infancy.

3.3.3 Question 3: To What Degree Does the Inclusion of Multiple Measures of Communication Skills Improve Prediction of an ASD Diagnosis?

Perhaps one of the most exciting findings from the current study was that information gathered during observation of behavior in the everyday setting of the home improved prediction of diagnostic outcome when combined with standardized assessments and parent report. When variables derived from behavioral observation was added to data collected from the ESCS and CDI, the percentage of children correctly classified as HR-ND, HR-ASD, or HR-LD increased from 73.9% to 93.3%. Importantly all HR-ASD and HR-LD infants were correctly predicted by the combination of these measures. Specificity (91.7%) was comparable to other well-utilized ASD screeners like the CSBS-DP (Wetherby et al., 2008) and the Screening Tool for Autism in Toddlers (STAT; Stone, McMahon & Henderson, 2008). Sensitivity (100%) matched that of the current gold standard screening instrument, the Modified Checklist for Autism in Toddlers (MCHAT; e.g., Robins, Fein, Barton, & Green, 2001).

Overall, the findings from this study support the notion that multimethod sampling procedures that incorporate structured evaluation, parent report, and measures derived from naturalistic interactions provide a more complete picture of infants' communicative repertoires (Tager-Flusberg et al., 2009; Crais et al., 2009). Although this study was descriptive and exploratory in nature, findings nevertheless indicate that an understanding of the nature of communication difficulties in HR infants requires a more comprehensive profile of communication skills that includes *repeated assessments over time* and the collection of information from multiple sources, including *naturalistic observation*.

4.0 SUMMARY AND GENERAL DISCUSSION

The primary objective of this research was to examine developmental trajectories of the production and multimodal coordination of social communication behaviors from 8 to 18 months in HR and LR infants. Of particular interest was the nature of social communication impairments in HR infants who later received an ASD diagnosis, specifically whether the earliest manifestations of communication delays include difficulty integrating communicative signals across modalities during social situations in a familiar setting.

This work was guided by the principles of DST and asked whether specific patterns of behavior can be identified in early infancy to create a profile of risk that can be used to predict a later ASD or related clinical diagnosis. From a dynamic systems point of view, communicative development involves a complex, collective system with dynamic interplay among multiple components that self-organize to produce a potentially very large set of behavioral combinations. For the most part, communicative abilities generally emerge and develop in a similar fashion across children, with temporary deviations as new skills emerge and are consolidated with old skills. However, for some children, variability in the course of communicative development may deviate from the norm due to characteristics of the child and/or the environment.

Study 1 revealed that, while all infants demonstrated similar levels of communicative behavior at 8 months, the ASD infants exhibited significantly slower growth not only in the overall rate of communicative acts and individual behaviors (i.e., words, gestures, gestures used to initiate joint attention) but also in *coordinated* behaviors (i.e., Coordinated Bouts, coordinated NWVs, coordinated words, and coordinated Joint Attention and Behavior Request gestures). However, the only specific coordinations that effectively distinguished ASD infants from those exhibiting language delays were those that involved NWVs (coordinated NWVs and Gesture + NWV/W) as well as those involving gestures used to initiate joint attention (Coordinated Joint Attention gestures). Study 2 demonstrated that information gathered on social communication skills during observation in a natural setting improved prediction of diagnostic outcome when combined with standardized assessments and parent report; and the setting, method of measurement, and frequency of assessment were found to be important factors in determining risk. Across the two studies, variability was apparent both between and within infants, suggesting that HR infants are an extremely heterogeneous and unique group. Findings are discussed below in terms of the contribution they make to our understanding of HR infants as a group and to continued efforts in early screening and diagnosis of ASD in infancy.

4.1 CHARACTERIZING HR INFANT SIBLINGS

The overwhelming lack of significant group differences between LR and HR-ND groups is important because many previous infant sibling studies have detected such group differences in social communication behaviors (Cassel et al., 2007; Goldberg et al., 2005; Mitchell et al., 2006; Toth et al., 2007; Yirmiya et al., 2006). In the current study, developmental growth in social communication behaviors followed a typical trajectory for many of the HR non-diagnosed infants. Nevertheless, variability in the expression and development of social communication behaviors was also detected among HR infants in the current study, not only between subgroups of infants but within infants as well.

At the individual level, many of the HR infants demonstrated significant changes in communication skills as indicated by change in raw scores (i.e., beyond a 95% confidence interval) and some infants received below average scores at some assessment points but not others. HR-ASD and HR-LD infants were more likely to show stable (and low) scores over time. While this distinction between a resolution versus persistence of delay may help distinguish between children later diagnosed with ASD and other HR infants, it does not address the fact that many HR children not meeting criteria for ASD or LD may be identified as "at-risk" in screening efforts, particularly if they occur at young ages. This is important to keep in mind because even TD children exhibit variability in repeated measures of communication (e.g., Darrah et al., 2003).

It is possible that there is something unique about those HR (and TD) children who show stable versus unstable patterns of development. Characteristics such as temperament and affect regulation have been investigated in HR infants and were shown to correlate with ASD symptomatology (Clifford et al., 2012; Garon et al., 2009). It is not hard to see how a temperament profile characterized by low positive affect, high negative affect, and difficulty controlling attention and behavior may not only influence the ability to obtain a valid assessment during screening, but also directly affect the ability to engage in meaningful social interactions with others. Further investigation of temperament and attention along with other potential "third variables" may help explain additional aspects of the variability observed in this sample of HR infants. Overall, the HR-ND infants observed in the current study look very "typical," even in terms of the variability expressed in the development course of behaviors, observational context, and the specific point in time at which behaviors were observed.

4.1.1 Language delay in HR infants

One important and unique aspect of the design of the current study was that it identified a subset of infants from the original HR group that met criteria for language delays but did not receive an ASD diagnosis (i.e., HR-LD). That is, with the inclusion of a HR-LD comparison group, it was possible to separate HR infants who follow a more typical developmental pathway (HR-ND) from those who experience delays in communication.

Even in the absence of ASD symptomatology, a subset of HR infants (26%) exhibited patterns of delay in early communication and language development. The proportion of HR children with language delays is consistent with recent data that suggest that approximately 15-30% of HR siblings will exhibit milder social and communicative difficulties (Gamliel et al., 2007; Sullivan et al., 2007). The question of whether broader expression of ASD symptomatology exists in the HR sibling group, as well as whether potential early markers are associated with longstanding clinically significant difficulties (e.g., language disorder) is still a controversial topic and cannot be answered with the current study. Future research that involves additional (non-HR) clinical comparison groups (e.g., global developmental delay, specific language impairment), family studies, and long-term outcomes (e.g., preschool and beyond) is necessary to fully understand the nature of BAP in infancy.

Because delays in gesture use and gesture-vocalization combinations seem to resolve (or follow a trajectory towards resolution) in the HR-LD group, it is reasonable to ask whether delays in language production may also resolve over time. If this is the case, then what do the initial delays documented in this subgroup really mean? Could at least some HR-LD infants merely be considered "late talkers," children who are a little slow to develop language but not necessarily delayed or impaired in language? Research on "late talkers" shows that the majority of children move into the normal range for expressive language typically by 3 years of age and for grammar and conversation skills by school age (Dale, Price, Bishop, & Plomin, 2003; Ellis Weismer, 2007; Rescorla 2002; Rice et al., 2008). However, previous work also show that late talkers who demonstrate delays in both receptive and expressive language have poorer outcomes and are more likely to receive a formal diagnosis of specific language impairment (Thal et al., 1991; Ellis & Thal, 2008). Following HR infants beyond the third birthday and incorporating a specific evaluation of language is necessary to address these questions. Examining individual differences in HR-LD infants in, for example, receptive language and use of gestures (two skills demonstrated to predictive of continued delay in late talkers; Thal, 2000) may also help determine the significance of non-ASD communication difficulties in HR infants.

4.1.2 ASD in HR infants

Specific comparison of infants and toddlers having LD versus ASD is important since language delay is often the first developmental disruption suspected by parents of children with autism (Filipek et al., 1999). Further, communication delays are present among many HR infants, including infants who do not eventually receive an ASD diagnosis (e.g., Gamliel et al., 2007; Landa & Garrett-Mayer, 2006; Sullivan et al., 2007; Yirmiya et al., 2006; Zwaigenbaum et al., 2005). This present investigation was one of the very few HR infant sibling studies to include a comparison HR group. The inclusion of the HR-LD group allowed the identification of early behavioral markers that are *specific* and *unique* to ASD. As was observed, there were many social communication behaviors for which both HR-LD and ASD were delayed, including, gestures (particularly those used to initiate joint attention), words, coordinated words, and diversity in repertoire of coordinated bouts. However, only a few variables behaviors effectively distinguished HR-ASD from HR-LD.

Differences in developmental trajectories between HR-LD and HR-ASD infants were detected for the broader categories of total communicative acts, single acts, and Coordinate Bouts. More global ratings of the frequency of social communication behavior may be useful to use in initial evaluations to create a "snapshot" of an infant's current social repertoire. Indeed, these variables were sensitive enough to specifically capture infants with ASD (and not language delay). More global measures of social communication skills are incorporated in current diagnostic tools (e.g., ADOS-G; Lord et al., 2000), and have been shown to correlate highly with coded rates of the same behaviors (Ozonoff et al., 2010). However, in this study, it was also found that relative to HR-LD infants, HR-ASD infants demonstrated slower growth over time in the rate of coordinated NWVs, higher level joint attention (i.e., coordinated Joint Attention gestures, High IJA), and Gesture + NWV/Word coordinations, as well as declining growth in the rate of eye contact. By identifying individual behaviors within these more global categories that also seem specific to ASD (e.g., NWV coordinations), we can begin to isolate early markers of the disorder; this not only contributes to our understanding of how ASD unfolds in early infancy but may also be useful in refining and guiding more effective treatment interventions.

This current study offered another important contribution to the goal of determining specificity by examining developmental trajectories of early communication at frequent and repeated intervals over 8 to 18 months. By tracking development over time, it was possible to identify with more accuracy the point in development where behavioral symptoms of ASD began to emerge. While ASD growth trajectories diverged from the LR and HR-ND groups as early as 10 months of age for some communicative behaviors (i.e., coordinated Joint Attention gestures) and by12 months for the majority of behaviors, findings indicated that ASD specificity emerges closer to 14 months. In other words, differences between HR-ASD and HR-LD groups in developmental patterns of social communication behaviors were not found until 14 months of age; trajectories continued to become more discrepant through 18 months. While more research with larger sample sizes, longer sampling of behavior, and additional clinical comparison groups is needed to replicate the findings documented here, these results have clear implications for early autism screening, diagnosis, and intervention.

4.2 CLINICAL IMPLICATIONS FOR EARLY SCREENING AND DIAGNOSIS

4.2.1 Frequent monitoring of HR infants

Findings from this research suggest that assessment should be more intensive and more frequent for with high-risk groups. It is understood that there are a number of practical issues that might prohibit the repeated and complete surveillance of HR infants, including time, money, and clinical resources. Nevertheless, the effects of undiagnosed or misdiagnosed infants are great, both on the cost for society (Jarbrink & Knapp, 2001; Ganz, 2007), as well as the emotional and economic well-being of families. For example, the Autism Society estimates that the lifetime cost of caring for an individual with autism ranges from $3.5-5 million, and that these costs can be reduced by two-thirds or more with early diagnosis and intervention (Autism Society, 2007).

It is also important to recognize that HR infants exhibit highly variable developmental trajectories when making evaluation and referral decisions. In the present study, many of the group differences in developmental trajectories identified between ASD and other groups in our observational data were found at 12 months of age. These group differences grew over time and were most striking at 18 months of age. However, there was also a fair amount of *instability* from 8 to 18 months in parent-report measures of communication skills. Therefore, if it is only feasible to evaluate an HR infant at one time point, 18 months may be preferred as it would most likely offer the most reliable information. However, because of the instability inherent in this population, additional assessments at 12 and 14 months would be beneficial in creating an individual developmental profile for the child, and this information may allow clinicians to be more confident in conclusions drawn at 18 months. More research is needed in this area to determine how best to integrate information from assessments at young ages into evaluation of a child at 18 and 24 months (the ages that are currently recommended for screening by the AAP; Johnson & Myers, 2007).

4.2.2 Communicating the meaning of delay to HR families

The process of noticing, discussing, and acting on ASD concerns in very young children is an extremely challenging and sensitive issue (Warren & Stone, in press). Given the high recurrence rate for HR siblings (18% in the current study; see Ozonoff et al., 2011 for comparable rates), families who already have a child diagnosed with ASD are routinely faced with the challenge of attempting to make sense of early differences, and what action to take as a result. Many of the parents of HR infants in this study expressed concerns to research staff at some point during the course of the study, including parents of infants in the HR-ND group. Parental concern or stress may have an impact (positive or negative) on the development of HR infants' social communication development.

It is therefore important to exhibit caution when communicating to families about risk and the meaning of delays. First, as noted above, it is important to describe the nature of variability in social communication skills that is observed throughout this period of development in HR as well as TD children. Further, some research indicates that some delays in HR infants may eventually resolve in infancy or early childhood (Gamliel et al., 2007). Nevertheless, identification of concerns should lead to further assessment of the child's social, communication, and play development with an experienced clinician (Zwaigenbaum et al., 2009).

However, with the growing trend toward identifying ASD at increasingly early ages, we must also consider important ethical and clinical issues with regard to early assessment and diagnosis (Warren & Stone, in press; Zwaigenbaum et al., 2009). While the data thus far suggests that "earlier is better" (Mandell et al., 2005), there is little evidence of what therapies and what intervention strategies are most effective in populations this young. Therefore, the need for research on the efficacy of very early intervention approaches is critical. Although a variety of evidence-based interventions exist for preschool-aged children with ASD (Rogers, 1998), it is not clear that such interventions would be equally beneficial, or even appropriate, for children younger than two.

Early research in this area, however, is promising. The Early Start Denver Model, (Rogers & Dawson, 2010) offers a comprehensive developmental behavioral intervention to toddlers with suspected ASD. The first report to be published on the efficacy of this intervention indicated that children diagnosed with ASD between 18 and 30 months who received this type of intensive (home-based) intervention demonstrated large improvements in cognition, language, and adaptive behavior, compared to those receiving treatment as usual (Dawson et al., 2010). Currently, as part of the Toddler Treatment Network (Autism Speaks, Inc., 2012b), the authors are evaluating the extension of this program to children as young as 12-15 months old (Estes & Rogers, 2012). Nevertheless, one type of intervention strategy is not necessarily going to be effective for all children and all families. Much more research is needed before clinicians can be confident in about making recommendations for treatment of ASD-related behaviors in infancy.

4.2.3 Integrating spontaneous communication samples into screening and assessment of HR infants

The present findings indicate the importance of considering communicative behavior as it occurs naturally in a familiar environment. Although it is not yet practical to code behavior frequencies during medical office visits, these results suggest that it may be possible to develop measures that can be rated by physicians or nursing staff during well-child visits that capture additional information about an infant's current social communicative repertoire. More research is necessary to refine the process by which behavior is coded.

For example, is it possible to capture enough information about infants' communicative initiations in a 10 minute observation versus 25 minutes? What differences in communication styles might we see if parents were to interact with their children in a lab or medical office as opposed to their homes? Finally, are there significant differences in communication frequency or style during toy play setting versus everyday activities? This information could be particularly useful in light of the fact that some research is beginning to examine the usefulness of integrating home videos into the diagnostic process for ASD (*The Harvard Autworks Video Project*, Wall et al., 2012). This research is examining the use of machine learning algorithms to facilitate faster and less clinically intensive diagnosis of ASD. Researchers are developing and analyzing the effectiveness of a mobile tool in which short home video clips can be uploaded and used for diagnosis.

The current investigation also points to the potential usefulness of NWVs, and in particular, gesture-vocalization combinations, in identifying infants at risk for developing ASD. The integration of vocalization with other subtle changes in facial expression, eye contact, and gesture is currently included in gold standard assessment of older individuals suspected of ASD (ADOS, Modules 3 and 4; Lord et al., 2000). Further, the coordination of facial expression, eye contact, gesture, and sound has been identified as a red flag for ASD in toddlers (Wetherby et al., 2004). As many HR children exhibit delayed language, this work highlights the potential for early preverbal communicative behavior to be used in screening for later developmental outcomes. It is at least possible that careful surveillance of preverbal communicative behavior, especially as it occurs in the familiar conditions of the home environment, and observation of the timetable for the emergence of critical milestones (e.g., combining non-word vocalizations with eye gaze to caregiver, combining non-word vocalizations with gesture, first use of showing and pointing) might be useful in differentiating among these potential outcomes and in doing so well before the end of the first year.

4.2.4 Implications for the treatment of HR infants

Finally, the extent to which researchers can better understand the strengths and deficits in the social communicative profile in children with ASD will have important implications for how treatment programs are designed and implemented. How we understand atypical development has large implications for how we intervene to change or modify it. Therefore, if we continue to think about communication skills as discrete isolated behaviors and likewise implement interventions that focus on improving children's joint attention skills or speech production alone without consideration for how the development of these skills might be integrated with other communicative skills, we may be missing out on key aspects of social communicative development.

Accordingly, it might be very useful to develop an intervention approach designed to enhance the preverbal communicative environment of the home. Such a program might focus on sensitizing parents to the potential developmental importance of preverbal behaviors such as vocalizations, eye contact, and gestures (particularly the coordination of these behaviors), and to the need to respond to these communicative attempts contingently. The Early Start Denver Model closely approaches this type of intervention by coaching parents and emphasizing skills that promote affective engagement and social reciprocity by focusing on nonverbal as well as verbal behaviors (Dawson et al., 2010; Rogers & Dawson, 2010). In addition, without an appreciation for the bi-directional influence of the social environment, treatment efforts are bound to fall short.

4.3 GENERAL CONCLUSIONS

Very rarely have social communication skills in children with ASD been studied as multimodal processes in the context of the rich, multimodal environment in which they develop. A dynamic systems approach (Thelen & Smith, 1994) offers a unique and ecologically valid perspective on communicative functioning in children with ASD. Communication cannot be fully understood by dissecting the dynamic system into its constituent parts because the individual components and their associated functions are embedded within the context of the whole system. Accordingly, understanding the phenomenon of atypical communication requires investigations in multiple modalities, the use of multiple methods and contexts, including the comparison of specific clinical groups, and assessments of interactions as they unfold over time (Iarocci & McDonald, 2006).

Sampling procedures that incorporate structured evaluation, parent report, and measures derived from naturalistic interactions may provide a more complete picture of infants' communicative repertoires (Tager-Flusberg et al., 2009; Crais et al., 2009). While recent research suggests that there is not likely to be a single model to describe this strikingly complex disorder (e,g., Pickels et al., 1995; Risch et al., 1999), it is hoped that future models may build on the principles described here to provide further accounts for how multiple components combine to affect social and communication development in children with ASD.

In conclusion, the findings from the current investigation suggest that some infants with ASD do have difficulties with social communication including the integration of multimodal communicative signals. However, this is not an absolute deficit; rather it varies as function of individual characteristics, sampling techniques, and the point in development in which behavior is assessed. Overall the present findings underscore the fruitfulness of an integrated, systems approach to understanding the social communicative profile of children with ASD. The DST model outlined above provides a novel theoretical framework for considering the interrelationship among developmental processes, individual differences, developmental trajectories, and the influences of the broader social environment. Future research that is theoretically driven and developmentally sensitive will allow us to gain deeper insight into the underlying processes and complexities of the communication disturbance in ASD.

5.0 TABLES

Table 1: Demographic Information for High Risk and Low Risk Groups

	HR (n = 50)		LR (n = 30)	
Gender				
Female (%)	28	(56%)	16	(53%)
Male (%)	22	(44%)	14	(47%)
Racial or ethnic minority (%)	7	(14%)	2	(7%)
Birth Order				
First Born (%)	0	(0%)	12	(40%)
Second Born (%)	24	(48%)	14	(47%)
Later than Second Born (%)	26	(52%)	4	(13%)
Multiplex Family (%)	5	(10%)	n/a	n/a
Mean age for Mothers (SD)	34.10	(4.43)	31.77	(4.58)
Mean age for Fathers (SD)	35.70	(4.30)	32.83	(4.21)
Maternal Education				
Graduate or Professional School (%)	15	(30%)	16	(53%)
Some College or College Degree (%)	33	(66%)	13	(43%)
High School (%)	2	(4%)	1	(3%)
Paternal Education				
Graduate or Professional School (%)	18	(36%)	12	(40%)
Some College or College Degree (%)	27	(54%)	15	(50%)
High School (%)	3	(6%)	3	(10%)
Mean Paternal Occupational Prestige (SD)[a]	60.40	(14.96)	57.79	(12%)

Note. HR = High Risk; LR = Low Risk.
[a]Nakao-Teas occupational prestige score; not able to be calculated for 5 fathers in HR group and 4 fathers in LR group.

Table 2: Mean (SD) Standardized Scores at 18, 24, and 36 months for the HR Outcome Groups

	HR-ND (*N* = 28)			HR-LD (*N* = 13)			HR-ASD (*N* = 9)		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
18m CDI Words Produced Percentile Score	38.33	(26.24)	27	7.69	(8.07)	13	3.33	(5.00)	9
24m CDI Words Produced Percentile Score	47.92	(23.31)	24	18.85	(19.06)	13	6.11	(8.58)	9
36m CDI Words Produced Percentile Score	32.00	(27.42)	25	3.85	(4.63)	13	5.71	(9.76)	7
36m MSEL Visual Reception T Score	57.89	(14.06)	28	51.85	(15.5)	13	34.2	(17.21)	5
36m MSEL Fine Motor T Score	51.14	(14.38)	28	40.38	(13.51)	13	24.25	(7.61)	8
36m MSEL Receptive Language T Score	54.14	(9.08)	28	44.23	(8.80)	13	24.00	(9.80)	6
36m MSEL Expressive Language T Score	58.35	(9.05)	26	48.54	(8.89)	13	31.5	(11.90)	6
36m MSEL Early Learning Composite	110.11	(17.52)	27	93.00	(14.94)	13	64.4	(19.39)	5
36m ADOS Communication + Social Algorithm Score	3.13	(3.58)	24	2.70	(1.42)	10	14.13	(6.38)	8

Note. HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; CDI = MacArthur-Bates Communicative Development Inventory; MSEL = Mullen Scales of Early Learning; ADOS = Autism Diagnostic Observation Schedule.

Table 3: Summary and Description of Referrals, Evaluations, and Early Intervention for HR Infants

SN	Referral	Evaluation	Results	EI Services
HR-ASD				
12417	Contacted by research staff due to low scores on study measures	Yes – 22m	Diagnosed with PDD-NOS at 22m; referred for services	SLT, OT, and CD from 23m^{+}
19521	Contacted by research staff due to low scores on study measures	Yes – 36m by study	Diagnosed with PDD-NOS by study but parent did not agree with diagnosis	N/A
19576	Contacted by research staff due to low scores on study measures	Yes – 36m by study	Diagnosed with PDD-NOS by study; parent scheduled a hearing evaluation	N/A
17438	Contacted by research staff due to failed MCHAT at 24m	Yes – 26 and 30m	Diagnosed with Autism at 30m; referred for EI services	SLT, PT, and OT from 24m^{+}
36575	Self-referred	Yes – 11m	Referred for EI services	PT and OT from 11m^{+}
36578	Self-referred	Yes – 10m	Referred for EI services	OT, SLT, PT, and CD from 11m^{+}
36579	Self-referred	Yes – 10m	Referred for EI services	OT and CD from 12m^{+}
24909	Self-referred (also failed MCHAT at 24m)	Yes – 16m	Diagnosed with Expressive/ Receptive Language Disorder; referred for EI services	CD, EI preschool, play group from 24m^{+}
16694	Self-referred (also failed MCHAT at 24m)	Yes- 18, 24, and 36m	Diagnosed with PDD-NOS at 24m and Autism at 36m; referred for EI services	OT, SLT, and CD from 18m^{+}
HR-LD				
24843	Initiated by study due to poor articulation at 36m	Unknown	Unknown	SLT (for articulation) from 18-36m^{+}
16640	Initiated by study due to high (invalid) ADOS and language difficulties at 36m	Unknown	Unknown	N/A
26375	Initiated by study due to low CDI and/or MSEL scores at 24m	No – parent reported language improvement	N/A	N/A
23494	Initiated by study due to low CDI and/or MSEL scores at 24m	No	N/A	PT from 20m

Table 3 continued

SN	Referral	Evaluation	Results	EI Services
15000	Self-referred	Yes – S/L evaluation at 20m	Diagnosed with Expressive/ Receptive Language Disorder; referred for services	SLT and CD from 20-36m
59423	Self-referred	Yes – 16m	Diagnosed with speech apraxia; referred for EI services	SLT from 16-33m
17811	Self-referred	Yes – 9m	Referred for EI services	SLT from 9-18m
25042	Self-referred	Yes – 18m	Referred for EI services	SLT, OT, PT, and CD from 18-24m
21717	Self-referred	Yes – 18m	Referred for EI services	SLT and CD from 18-24m
61218	Self-referred	Yes – 30m	Results within normal limits	N/A
12665	No	N/A	N/A	N/A
13856	No	N/A	N/A	N/A
14578	No	N/A	N/A	N/A
HR-ND				
15495	Self-referred	Yes – 13m	Gross motor delays	PT from 13-36m
18445	Self-referred	Yes – 13m	Gross motor delays	PT from 13-14m
23958	Self-referred	Yes – 10m	Feeding difficulties	CD and feeding from 10m
34056	Self-referred	Yes – 10m	Global delays	OT, PT, and SLT from 11m
38940	Self-referred	Yes – 30m for tantrums	Results within normal limits	N/A
35548	Self-referred	Yes – 30m for stuttering	Results within normal limits	N/A

Note. EI = Early Intervention; HR-ASD = High Risk-Autism Spectrum Disorder; PDD-NOS = Pervasive Developmental Disorder-Not Otherwise Specified; SLT = Speech and Language Therapy; OT= Occupational Therapy; CD = Child Development Therapy; MCHAT = Modified Checklist for Autism in Toddlers; PT = Physical Therapy; HR-LD = High Risk-Language Delay; ADOS = Autism Diagnostic Observation Schedule; CDI = MacArthur-Bates Communicative Development Inventory; MSEL = Mullen Scales of Early Learning; S/L = Speech and Language; HR-ND = High Risk-No Diagnosis.

Table 4: Inter-rater Reliability Analysis of Communicative Acts

Intraclass correlation coefficient (ICC)	
Summary Behaviors	
Total number of communicative acts	0.80
Total number of coordinated bouts	0.82
Total number of non-word vocalizations	0.78
Total number of words	0.99
Total number of gestures	0.75
Total number of deictic gestures	0.72
Total number of representational gestures	0.32
Total number of point gestures	0.91
Total number of eye contact	0.69
Form of Communicative Acts	
Smiles	0.74
Eye Gaze: Eye contact	0.64
Eye Gaze: Gaze switch	0.00
Gesture: Reach	0.51
Gesture: Index finger point	0.61
Gesture: Index finger touch	0.75
Gesture: Give	0.83
Gesture: Show	0.64
Gesture: Representational Conventional	0.47
Gesture: Representational Descriptive	0.00
Vocal Utterance: Word sequence	0.82
Vocal Utterance: Word	0.98
Vocal Utterance: Syllabic NWV	0.78
Vocal Utterance: Non-syllabic NWV	0.44
Function of Communicative Acts	
Joint Attention	0.89
Behavior Regulation	0.86
Social Interaction	0.69
Complexity of Communicative Acts	
Complexity: Simultaneous	0.91
Complexity: Single	0.61
Complexity: 2 Behavior Bout	0.83
Complexity: 3 Behavior Bout	0.75
Complexity: 4 Behavior Bout	0.46

Note. NWV = non-word vocalization.
Key: ICC = Excellent (>.80); Good (>.60); Moderate (>.40); Poor (<.40).

Table 5: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Communicative Behaviors by Form and Function for the Full Sample

	Age														
	8 (n = 74)			10 (n = 78)			12 (n = 77)			14 (n = 79)			18 (n = 79)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Overall Frequency															
Communicative Acts	13.35	10.32	68.87	21.49	11.74	52.37	25.64	12.57	61.60	30.64	18.71	100.66	38.59	23.22	155.21
Single Behaviors	10.31	7.51	46.35	14.88	8.34	37.57	21.57	10.49	49.60	21.87	13.49	63.51	28.84	17.94	128.08
Form															
Eye Contact	5.41	5.86	38.37	9.91	7.27	34.26	5.26	4.77	19.78	10.63	7.09	34.35	9.40	8.26	38.43
Smiles	1.48	2.62	16.45	2.78	3.80	22.31	1.47	2.28	9.98	3.06	3.78	19.57	3.41	4.59	23.51
NWVs	9.41	7.31	40.37	14.56	10.03	43.17	19.67	11.65	54.40	22.92	15.43	65.21	24.59	16.29	99.74
Gestures	0.29	0.54	2.40	1.37	1.79	8.00	1.66	1.86	9.20	4.11	4.74	25.97	6.92	7.38	37.22
Words	0.00	0.00	0.00	0.06	0.28	2.00	0.23	0.84	5.20	0.82	2.45	18.38	5.20	8.85	52.66
Function of Gestures															
Joint Attention	0.09	0.31	2.00	0.76	1.38	6.00	1.00	1.26	5.60	2.17	2.88	12.80	3.62	4.56	20.01
Behavior Request	0.13	0.33	2.00	0.21	0.36	1.60	0.44	0.90	5.20	1.06	1.39	6.00	1.94	2.31	12.81
Social Interaction	0.01	0.05	0.41	0.11	0.43	2.40	0.06	0.25	1.60	0.27	0.69	3.60	0.32	0.81	4.78

Note. NWV = Non-word Vocalizations.

Table 6: Unconditional Growth Models for Rate (per 10 minutes) of Communicative Acts, Single Acts, and Coordinated Bouts

	Communicative Acts			Single Behaviors			Coordinated Bouts		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})	12.92	***	1.06	9.48	***	0.67	3.46	***	0.47
Growth Rate									
Intercept (β_{10})	2.47	***	0.27	1.83	***	0.19	0.64	***	0.10
Acceleration									
Intercept (β_{20})									
Variance Components									
Var. in Growth Rate (r_{1i})	1.72	***		1.37	***		0.42	***	
Var. in Acceleration (r_{2i})									
Level 1 Error (e_{ti})	12.68			9.38			5.61		
No. of Parameters (FIML)	4			4			4		
Deviance (FIML)	3169.75			2945.05			2476.37		

Note. FIML = Full Information Maximum Likelihood.
***p < .001.

Table 7: Unconditional Growth Models for Rate (per 10 minute) of Eye Contact, Smiles, NWVs, Gestures, and Words

	Eye Contact			Smiles			NWVs			Gestures			Words		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept															
Intercept (β_{00})	6.69	***	0.62	1.60	***	0.29	9.13	***	0.99						
Growth Rate															
Intercept (β_{10})	0.33	**	0.12	0.18	**	0.06	3.30	***	0.59	0.66	**	0.06			
Acceleration															
Intercept (β_{20})							-0.18	**	0.06				0.05	***	0.01
Variance Components															
Var. in Intercept (r_{0i})	2.29														
Var. in Growth Rate (r_{1i})	0.51	*		0.21	**		3.09	***		0.52	***				
Var. in Acceleration (r_{2i})							0.31	*					0.08	***	
Level 1 Error (e_{ti})	6.78			3.33			9.37			2.89			1.87		
No. of Parameters (FIML)	6			4			7			3			3		
Deviance (FIML)	2602.40			2065.20			2990.17			2061.62			1820.31		

Note. NWVs = Non-word vocalizations; FIML = Full Information Maximum Likelihood.
**p* < .05. ***p* < .01. ****p* < .001.

Table 8: Unconditional Growth Models for Rate (per 10 minutes) of Functions of Gestures

	Joint Attention			Behavior Request			Social Interaction		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})									
Growth Rate									
Intercept (β_{10})	0.35	***	0.04	0.09	*	0.04	0.04		0.01
Acceleration									
Intercept (β_{20})				0.01	†	0.01			
Variance Components									
Var. in Growth Rate (r_{1i})	0.32	***		0.28	***		0.05	***	
Var. in Acceleration (r_{2i})				0.04	***				
Level 1 Error (e_{ti})	1.81			0.78			0.47		
No. of Parameters (FIML)	3			6			3		
Deviance (FIML)	1698.16			1134.87			574.98		

Note. Rate per 10 minutes. FIML = Full Information Maximum Likelihood.
†$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

Table 9: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Coordinated Communicative Behaviors by Form and Function for Overall Sample

	Age														
	8 (n = 74)			10 (n = 78)			12 (n = 77)			14 (n = 79)			18 (n = 79)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Overall Frequency															
Coordinated Bouts	2.96	3.75	22.92	6.35	5.95	23.11	3.65	3.71	15.51	8.77	7.11	40.35	9.62	7.81	37.22
Form															
Eye Contact	2.83	3.47	20.43	6.00	5.64	23.11	3.10	3.43	15.13	7.29	5.67	28.36	6.32	5.90	29.22
Smiles	1.14	2.30	14.95	2.27	3.38	21.51	1.03	1.89	8.92	2.58	3.17	15.98	2.47	3.26	14.74
NWVs	2.03	2.31	9.97	4.20	4.15	18.40	2.52	2.57	11.60	5.99	5.09	29.60	5.70	4.80	20.80
Gestures	0.11	0.25	1.20	1.02	1.53	7.60	0.94	1.26	6.40	2.79	3.26	17.20	4.64	5.08	25.62
Words	0.00	0.00	0.00	0.02	0.10	0.80	0.06	0.20	1.20	0.33	1.14	9.19	1.36	2.34	11.97
Function of Gestures															
Joint Attention	0.05	0.15	0.80	0.59	1.12	5.60	0.61	0.87	4.00	1.64	2.30	11.60	2.65	3.37	17.20
Behavior Request	0.06	0.19	1.20	0.16	0.30	1.50	0.28	0.60	3.60	0.77	1.11	5.60	1.37	1.93	10.37
Social Interaction	0.01	0.05	0.41	0.11	0.42	2.40	0.04	0.17	1.20	0.22	0.60	3.60	0.29	0.75	4.43

Note. EC = Eye Contact; NWV = Non-word Vocalizations.

Table 10: Unconditional Growth Models for Rate (per 10 minutes) of Coordinated Eye Contact, Smiles, NWVs, Gestures, and Words

	Eye Contact			Smiles			NWVs			Gestures			Words		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept															
Intercept (β_{00})	4.02	***	0.44	1.39	***	0.27	2.52	***	0.31						
Growth Rate															
Intercept (β_{10})	0.32	**	0.08	0.15	**	0.05	0.36	***	0.06	0.32	**	0.09			
Acceleration															
Intercept (β_{20})										0.02		0.01	0.01	***	0.00
Variance Components															
Var. in Intercept (r_{0i})															
Var. in Growth Rate (r_{1i})	0.14			0.17			0.26	***		0.64	***				
Var. in Acceleration (r_{2i})										0.09	***		0.02	***	
Level 1 Error (e_{ti})	5.23			3.06			3.82			1.62			0.60		
No. of Parameters (FIML)	4			4			4			6			3		
Deviance (FIML)	2384.99			1994.44			2174.49			1729.74			917.98		

Note. NWV = Non-word Vocalizations; FIML = Full Information Maximum Likelihood.
**p < .01. ***p < .001.

Table 11: Unconditional Growth Models for Rate (per 10 minutes) of Function of Coordinated Gestures

	Joint Attention			Behavior Request			Social Interaction		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Growth Rate									
Intercept (β_{10})	0.26	***	0.03	0.13	***	0.02	0.03	***	0.01
Variance Components									
Var. in Growth Rate (r_{1i})	0.23	***		0.11	***		0.04		
Level 1 Error (e_{ti})	1.45			0.85			0.42		
No. of Parameters (FIML)	3			3			3		
Deviance (FIML)	1509.86			1072.97			493.98		

Note. FIML = Full Information Maximum Likelihood.
***p < .001.

Table 12: Conditional Growth Models of Gender and Outcome Group Predicting Growth Trajectories for Rate (per 10 minutes) of Communicative Acts, Single Acts, and Coordinated Bouts

	Communicative Acts[a]			Single Behaviors[b]			Coordinated Bouts[c]		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})	12.90	***	0.96	9.47	***	0.82	3.46	***	0.47
Male									
HR-ND									
HR-ASD									
HR-LD									
Growth Rate									
Intercept (β_{10})	2.87	***	0.31	2.05	***	0.28	0.83	***	0.12
Male	-0.60	†	0.36	-0.52		0.27	-0.08		0.13
HR-ND	0.02		0.52	0.16		0.42	-0.14		0.16
HR-LD	-0.81	†	0.42	-0.53		0.29	-0.32		0.18
HR-ASD	-2.46	***	0.35	-1.73	***	0.26	-0.74	***	0.13
Variance Components									
Var. in Intercept (r_{0i})									
Var. in Growth Rate (r_{1i})	1.47	***		1.19	***		0.35	***	
Level 1 Error (e_{ti})	12.68			9.38			5.61		
No. of Parameters (FIML)	8			8			8		
Deviance (FIML)	3151.69			2928.20			2463.70		

Note. NWVs = Non-word vocalizations; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; FIML = Full Information Maximum Likelihood.
[a]Contained two outliers. [b]Contained one outlier. [c]Contained one outlier.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 13: Conditional Growth Models of Gender and Outcome Group Predicting Growth Trajectories for Rate (per 10 minutes) of Smiles, Eye Contact, NWVs, Gestures, and Words

	Smiles[a]			Eye Contact[b]			NWVs[c]			Gestures[d]			Words[e]		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept															
Intercept (β_{00})	1.60	***	0.29	6.69	***	0.62	9.15	***	0.76						
Male															
HR-ND															
HR-LD															
HR-ASD															
Growth Rate															
Intercept (β_{10})	0.17	*	0.08	0.43	**	0.15	2.03	*	0.80	0.87	***	0.11			
Male	0.04		0.08	0.10		0.13	-2.20	**	0.80	-0.11		0.12			
HR-ND	-0.02		0.08	-0.05		0.14	3.10	**	1.05	-0.19		0.16			
HR-LD	0.10		0.14	-0.11		0.22	1.35		1.04	-0.51	***	0.13			
HR-ASD	-0.07		0.08	-0.56	**	0.16	-0.52		1.02	-0.57	***	0.13			
Acceleration															
Intercept (β_{20})							0.02		0.08				0.05	**	0.01
Male							0.22	*	0.09				-0.04		0.01
HR-ND							-0.39	**	0.11				0.03		0.02
HR-LD							-0.22		0.11				-0.03	*	0.01
HR-ASD							-0.17		0.11				-0.04	*	0.01

Variance Components

Table 13 continued

	Smiles[a]			Eye Contact[b]			NWVs[c]			Gestures[d]			Words[e]		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Var. in Intercept (r_{0i})															
Var. in Growth Rate (r_{1i})	0.20	**		0.01			2.40	***		0.47	***				
Var. in Acceleration (r_{2i})							0.24	**					0.07	***	
Level 1 Error (e_{ti})	3.33			48.25			9.36			2.89			1.87		
No. of Parameters (FIML)	8			8			15			7			7		
Deviance (FIML)	2063.27			2597.84			2953.41			2047.63			1802.87		

Note. NWVs = Non-word vocalizations; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; FIML = Full Information Maximum Likelihood.
[a]Contained three outliers. [b]Contained two outliers. [c]Contained two outliers. [d]Contained four outliers. [e]Contained two outliers.
*p < .05. **p < .01. ***p < .001.
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Table 14: Conditional Growth Models of Gender and Outcome Group Predicting Growth Trajectories for Rate (per 10 minutes) of Function of Communicative Gestures

	Joint Attention[a]			Behavior Request[b]		
	Coefficient		*SE*	Coefficient		*SE*
Growth Rate						
Intercept (β_{10})	0.47	***	0.06	0.11		0.07
Male	-0.06		0.07	0.01		0.08
HR-ND	-0.07		0.10	0.04		0.10
HR-LD	-0.30	***	0.08	-0.13		0.09
HR-ASD	-0.38	***	0.07	-0.07		0.09
Acceleration						
Intercept (β_{20})				0.01		0.01
Male				-0.01		0.01
HR-ND				-0.01		0.02
HR-LD				0.00		0.01
HR-ASD				-0.01		0.02
Variance Components						
Var. in Growth Rate (r_{1i})	0.29	***		0.28	***	
Var. in Acceleration (r_{2i})				0.04	***	
Level 1 Error (e_{ti})	1.81			0.78		
No. of Parameters (FIML)	7			14		
Deviance (FIML)	1683.50			1123.79		

Note. NWVs = Non-word vocalizations; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; FIML = Full Information Maximum Likelihood.
[a]Contained two outliers; [b]Contained three outliers.
[†]p < .10. *p < .05. **p < .01. ***p < .001.

Table 15: Conditional Growth Models of Gender and Outcome Group Predicting Growth Trajectories for Rate (per 10 minutes) of Coordinated Communicative Behaviors

	NWVs[a]			Gestures[b]			Words[c]		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})	2.51	***	0.31						
Male									
HR-ND									
HR-LD									
HR-ASD									
Growth Rate									
Intercept (β_{10})	0.49	***	0.08	0.27	†	0.14			
Male	0.05		0.08	-0.28		0.17			
HR-ND	-0.09		0.10	0.24		0.23			
HR-LD	-0.20		0.11	-0.20		0.19			
HR-ASD	-0.53	***	0.09	-0.01		0.19			
Acceleration									
Intercept (β_{20})				0.04	†	0.02	0.02	**	0.00
Male				0.02		0.03	-0.01	*	0.00
HR-ND				-0.04		0.03	0.00		0.00
HR-LD				-0.02		0.03	-0.01	*	0.00
HR-ASD				-0.05	†	0.02	-0.01	**	0.00
Variance Components									
Var. in Intercept (r_{0i})									
Var. in Growth Rate (r_{1i})	0.19	**		0.60	***				
Var. in Acceleration (r_{2i})				0.09	***		0.02	***	
Level-1 Error (e_{ti})	3.81			1.62			0.60		
No. of Parameters (FIML)	8			14			7		
Deviance (FIML)	2159.29			1703.87			906.52		

Note. NWVs = Non-word vocalizations; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; FIML = Full Information Maximum Likelihood.
[a]Contained one outlier; [b]Contained five outliers; [c]Contained four outliers.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 16: Conditional Growth Models of Gender and Outcome Group Predicting Growth Trajectories for Rate (per 10 minutes) of Function of Coordinated Gestures

	Joint Attention[a]			Behavior Request[b]		
	Coefficient		*SE*	Coefficient		*SE*
Growth Rate						
Intercept (β_{10})	0.34	***	0.5	0.15	***	0.02
Male	-0.04		0.06	-0.03		0.03
HR- ND	-0.05		0.07	-0.01		0.04
HR-LD	-0.22	***	0.06	-0.07	*	0.03
HR-ASD	-0.29	***	0.05	-0.11	***	0.02
Variance Components						
Var. in Growth Rate (r_{1i})	0.20	***		0.10	***	
Level-1 Error (e_{ti})	1.45			0.85		
No. of Parameters (FIML)	7			7		
Deviance (FIML)	1493.87			1063.51		

Note. NWVs = Non-word vocalizations; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; FIML = Full Information Maximum Likelihood.
[a]Contained two outliers. [b]Contained three outliers.
[†]$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 17: Descriptive Information for Coordinated Bouts for Overall Sample – Prediction-Driven Analyses

	Age														
	8 (n = 74)			10 (n = 78)			12 (n = 77)			14 (n = 79)			18 (n = 79)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Frequency															
P. of Bouts	0.21	0.19	1.00	0.28	0.18	0.74	0.14	0.11	0.45	0.27	0.14	0.65	0.23	0.12	0.55
Mean No. of Behaviors	2.09	0.19	1.33	2.10	0.13	0.75	2.07	0.16	1.00	2.16	0.14	0.64	2.07	0.30	2.88
2 Behavior Bouts[a]	2.72	3.32	20.93	5.69	4.99	21.51	3.53	3.10	12.41	7.14	5.76	33.16	8.20	6.51	30.82
3 Behavior Bouts[a]	0.31	0.58	2.62	0.85	1.26	5.20	0.45	0.69	2.81	1.53	1.69	8.40	1.37	1.48	6.78
4 Behavior Bouts[a]	0.01	0.07	0.41	0.04	0.16	0.80	0.02	0.08	0.40	0.07	0.21	1.20	0.06	0.21	1.20
Diversity	1.92	1.27	6.00	3.67	2.52	13.00	3.25	2.44	12.00	6.47	4.24	25.00	7.90	4.89	23.00
***Bout Types**[a]*															
Social Smiles	0.77	1.55	10.47	1.62	2.68	19.92	0.73	1.39	6.21	1.50	2.06	10.40	1.53	2.37	10.36
Directed Vocalization	1.96	2.26	9.97	3.60	3.63	14.80	1.86	2.04	8.03	4.09	3.30	12.82	2.70	2.54	11.88
Gesture + EC/S	0.03	0.13	0.80	0.41	0.66	3.61	0.25	0.51	3.20	0.74	1.00	4.38	0.81	1.77	13.21
Word + EC/S	0.00	0.00	0.00	0.01	0.09	0.80	0.03	0.16	1.20	0.19	0.65	4.39	0.52	0.95	4.00
Gesture + NWV/W	0.08	0.21	0.80	0.61	1.23	6.80	0.69	1.02	4.80	2.05	2.85	17.20	3.84	4.06	19.60

Note. P. = Proportion; No. = Number; Diversity = Number of different types of Coordinated Bouts; EC = Eye Contact; S = Smile; NWV = Non-word vocalization; W = Word.
[a]Calculated as rate per 10 minutes.

Table 18: Unconditional Growth Models for the Proportion, Diversity, and Average Number of Coordinated Bouts

	Proportion of Bouts			Diversity of Bouts			Average No. Behaviors in Bouts		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})	0.19	***	0.11	1.97	***	0.20	2.08	***	0.00
Growth Rate									
Intercept (β_{10})	0.00		0.00	0.61	***	0.06	0.00		0.00
Variance Components									
Var. in Intercept (r_{0i})	0.00	*					0.02	**	
Var. in Growth Rate (r_{1i})	0.00	*		0.12	***		0.00	***	
Level 1 Error (e_{ti})	0.01			7.77			0.04		
No. of Parameters (FIML)	6			4			6		
Deviance (FIML)	-514.41			1987.52			-71.65		

Note. Diversity = Number of different types of Coordinated Bouts; No. = Number; FIML = Full Information Maximum Likelihood.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 19: Conditional Growth Models of Gender and Outcome Group Predicting Growth Trajectories for the Proportion, Diversity, and Average Number of Coordinated Bouts

	Proportion of Bouts[a]			Diversity of Bouts[b]			Average No. Behaviors in Bouts[c]		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})	0.15	***	0.06	1.97	***	0.20	2.06	***	0.02
Male	-0.02		0.02				0.01		0.04
HR-ND	0.07	**	0.03				0.03		0.05
HR-LD	0.05		0.03				0.03		0.06
HR-ASD	0.05		0.05				0.08		0.06
Growth Rate									
Intercept (β_{10})	0.01	**	0.00	0.78	***	0.08	0.00		0.00
Male	0.00		0.00	-0.10		0.08	-0.01		0.01
HR-ND	-0.01	**	0.00	-0.14		0.10	-0.00		0.00
HR-LD	-0.01	†	0.01	-0.37	**	0.10	-0.01		0.01
HR-ASD	-0.01	*	0.01	-0.54	***	0.10	-0.01		0.02
Variance Components									
Var. in Intercept (r_{0i})	0.05	*					0.12		
Var. in Growth Rate (r_{1i})	0.01			0.29	***		0.03		
Level 1 Error (e_{ti})	0.12			2.79			0.20		
No. of Parameters (FIML)	14			8			14		
Deviance (FIML)	-524.47			1967.46			-75.69		

Note. Diversity = Number of different types of Coordinated Bouts; No. = Number; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; FIML = Full Information Maximum Likelihood.
[a]Contained two ouliers; [b]Contained one outlier; [c]Contained two outliers.
†p < .10. *p < .05. **p < .01. ***p < .001.

Table 20: Unconditional Growth Models for Rate (per 10 minutes) of Social Smiles, Directed Vocalization, and Gesture + NWV/W Coordinated Bouts

	Social Smiles			Directed Vocalizations			Gesture + NWV/W		
	Coefficient		*SE*	Coefficient		*SE*	Coefficient		*SE*
Intercept									
Intercept (β_{00})	0.98	***	0.18	2.59	***	0.26	0.08		0.07
Growth Rate									
Intercept (β_{10})	0.06	†	0.03	0.06		0.04	0.14		0.09
Acceleration									
Intercept (β_{20})							0.02	*	0.01
Variance Components									
Var. in Intercept (r_{0i})	0.29			0.71					
Var. in Growth Rate (r_{1i})	0.02			0.01			0.25	***	
Var. in Acceleration (r_{2i})							0.01	***	
Level 1 Error (e_{ti})	3.99			8.36			1.80		
No. of Parameters (FIML)	6			6			7		
Deviance (FIML)	1663.97			1929.90			1578.20		

Note. NWV = Non-word vocalization; W = Word; FIML = Full Information Maximum Likelihood.
†p < .10. *p < .05. **p < .01. ***p < .001.

Table 21: Summary of Significant Between-Group Differences in the Development of Communicative Behaviors from 8 to 18 months

	Significant post hoc ($p < .05$)		
	Intercept (β_{00})	Growth Rate (β_{10})	Acceleration (β_{20})
Overall Frequency			
Communicative Acts	-	HR-ASD < LR HR-ASD < HR-ND HR-ASD < HR-LD	-
Single Acts	-	HR-ASD < LR HR-ASD < HR-ND HR-ASD < HR-LD	-
Form of Behaviors Overall			
Smiles	-	none	-
Eye Contact	-	HR-ASD < LR	-
NWVs	-	HR-ND > LR	HR-ND < LR
Gestures	-	HR-ASD < LR HR-LD < LR HR-ASD < HR-ND HR-LD < HR-ND	-
Words	-	-	HR-ASD < LR HR-LD <LR HR-ASD < HR-ND HR-LD < HR-ND
Function of All Gestures			
Joint Attention	-	HR-ASD < LR HR-LD < LR HR-ASD < HR-ND HR-LD < HR-ND	-
Behavior Request	-	none	none
Social Interaction	-	none	-
Overall Frequency of Bouts			
Coordinated Bouts	-	HR-ASD < LR HR-ASD < HR-ND HR-ASD < HR-LD	-
Form of Coordinated Behaviors			
Coordinated Eye Contact	-	-	-
Coordinated Smiles	-	-	-
Coordinated NWVs	-	HR-ASD < LR HR-ASD < HR-ND HR-ASD < HR-LD	-
Coordinated Gestures	-	none	none

Table 21 continued

	Significant post hoc ($p < .05$)		
	Intercept (β_{00})	Growth Rate (β_{10})	Acceleration (β_{20})
Coordinated Words	-	-	HR-ASD < LR HR-LD < LR HR-ASD < HR-ND HR-LD < HR-ND
Function of Coordinated Gestures			
Coordinated Joint Attention Gestures	-	HR-ASD < LR HR-LD < LR HR-ASD < ND HR-ASD < LD	-
Coordinated Behavior Request Gestures	-	HR-ASD < LR HR-LD < LR HR-ASD < HR-ND	-
Coordinated Social Interaction Gestures	-	none	-
Coordinated Bouts			
P. of Coordinated Bouts	HR-ND > LR	HR-ND < LR HR-ASD < LR	-
No. of Behaviors in Bouts	none	none	-
Diversity of Bouts	-	HR-ASD < LR HR-LD < LR HR-ASD < HR-ND HR-LD < HR-ND	-
Specific Types of Bouts			
Social Smiles	-	-	-
Directed Vocalization	-	-	-
Gesture + EC/S	-	-	-
Word + EC/S	-	-	-
Gesture + NWV/W	-	none	ASD < LR

Note. Frequency measured as rate per 10 minutes; HR-ASD = High Risk-Autism Spectrum Disorder; LR = Low Risk; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; NWV = Non-word vocalization; P. = Proportion; No. = Number; Diversity = Number of different types of Coordinated Bouts; EC = Eye Contact; S = Smile; W = Word.

Table 22: Pearson Product-Moment Correlations between Rates of Joint Attention during the ESCS and Naturalistic Observation

	ESCS				
Naturalistic Observation	8 months	10 months	12 months	14 months	18 months
8 months	-0.05	0.01	0.08	-0.08	-0.04
10 months	-0.02	0.17	0.21	0.37*	0.13
12 months	0.08	-0.03	-0.09	0.01	-0.09
14 months	-0.14	-0.11	-0.07	0.09	0.00
18 months	-0.08	-0.01	0.08	0.37*	0.43**

Note. ESCS = Early Social Communication Scales.
*p < .05. **p < .01.

Table 23: Pearson Product-Moment Correlations between Rates of Behavior Requests during the ESCS and Naturalistic Observation

	ESCS				
Naturalistic Observation	8 months	10 months	12 months	14 months	18 months
8 months	-0.09	-0.02	0.03	-0.17	0.11
10 months	0.10	0.25	0.20	0.28	-0.08
12 months	0.28	-0.03	-0.11	0.00	-0.08
14 months	0.06	-0.01	0.08	0.21	0.04
18 months	-0.03	0.06	0.22	0.44**	0.21

Note. ESCS = Early Social Communication Scales.
**p < .01.

Table 24: Pearson Product-Moment Correlations for Raw Scores within the MacArthur-Bates CDI Domains at 8, 10, 12, 14, and 18 months

CDI Domain	Assessment age (months)				
	8	10	12	14	18
8 months					
Total Gestures		.555**	.341*	.207	
Words Understood		.756**	.655**	.545**	
Words Produced		.560**	.235	-.001	.151
10 months					
Total Gestures			.636**	.612**	
Words Understood			.940**	.757**	
Words Produced			.696**	.385**	.543**
12 months					
Total Gestures				.807**	
Words Understood				.882**	
Words Produced				.607**	.634**
14 months					
Total Gestures					
Words Understood					
Words Produced					.648**

Note. CDI = Communicative Development Inventories.
*p < .05. **p < .01.

Table 25: Numbers (and percentages) of Infants with a Score of ≤ 10th Percentile at Each Age in Each MacArthur-Bates CDI Domain

CDI Domain	Age of assessment (months)				
	8 (n = 45)	10 (n = 48)	12 (n = 49)	14 (n = 49)	18 (n = 49)
Total Gestures	31 (69%)	21 (44%)	14 (29%)	14 (29%)	n/a
Words Understood	18 (40%)	20 (42%)	17 (35%)	14 (29%)	n/a
Words Produced	0 (0%)	0 (0%)	0 (0%)	11 (22%)	22 (45%)

Note. CDI = Communicative Development Inventories.

Table 26: Number of Times HR Infants Scored ≤ 10th Percentile on the MacArthur-Bates CDI in each Domain

CDI Domain	Frequency of scores ≤ 10th percentile					
	Zero times	One time	Two times	Three times	Four times	Five times
Total Gestures	12	16	10	4	8	n/a
Words Understood	14	11	6	7	12	n/a
Words Produced	28	11	11	0	0	0

Note. Children may score below the 10th percentile in more than one domain. CDI = Communicative Development Inventories.

Table 27: Means, Standard Deviations, and Ranges for Key Variables from the ESCS, MacArthur-Bates CDI, and Naturalistic Observation for HR-ND, HR-LD, and HR-ASD Infants at 12, 14, and 18 months

	HR-ND (n = 28)			HR-LD (n = 13)			HR-ASD (n = 9)			
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*p* value
12 months										
ESCS[a]										
IJA	0.47	0.94	3.63	0.73	2.06	6.55	0.32	0.84	2.22	
CDI[b]										
Total Gestures	21.50	6.24	25.00	16.75	8.78	29.00	14.67	8.06	25.00	*
Words Understood	67.64	64.56	301.00	26.92	30.94	103.00	24.56	22.56	75.00	***
Words Produced	5.79	5.38	19.00	1.25	1.54	5.00	0.78	1.39	4.00	***
Naturalistic Observation[a]										
Communicative Acts	25.28	11.20	44.99	26.88	14.35	43.34	18.02	12.55	34.28	
Single Acts	20.92	9.13	34.95	22.52	11.35	34.11	14.49	10.29	31.09	
Gestures	1.65	2.14	9.20	0.83	0.87	2.40	1.02	1.34	4.40	
Joint Attention Gestures	1.06	1.46	5.20	0.33	0.53	1.60	0.31	0.66	2.00	†
Coordinated Bouts	3.01	2.68	8.43	2.16	2.48	8.14	2.17	2.25	7.20	
Coordinated NWVs	3.01	2.68	8.43	2.16	2.48	8.14	2.17	2.25	7.20	
Coordinated Joint Attention Gestures	0.76	1.21	4.00	0.18	0.27	0.80	0.27	0.66	2.00	
Coordinated Behavior Request Gestures	0.39	0.75	3.60	0.07	0.16	0.40	0.13	0.28	0.80	
Diversity Bouts	3.57	2.79	12.00	3.09	2.77	9.00	2.78	2.49	7.00	
14 months										
ESCS[a]										
IJA	1.68	2.18	9.84	1.82	2.88	9.19	0.41	0.93	2.74	†
CDI[b]										
Total Gestures	33.39	9.41	35.00	25.17	10.77	31.00	39.22	36.13	113.00	***
Words Understood	127.64	82.77	330.00	58.08	54.21	159.00	2.89	4.70	14.00	****
Words Produced	22.54	31.41	124.00	4.33	5.48	16.00	8.78	8.04	21.00	****
Naturalistic[a]										
Communicative Acts	36.94	23.44	98.67	22.90	14.78	58.77	13.04	7.10	17.92	**
Single Acts	25.97	16.40	58.72	16.49	10.93	42.49	8.54	4.18	12.00	**
Gestures	5.21	6.35	25.57	1.26	0.99	2.78	1.59	1.37	3.59	**

Table 27 continued

	HR-ND (n = 28)			HR-LD (n = 13)			HR-ASD (n = 9)			
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*p* value
Joint Attention Gestures	2.88	3.54	12.40	0.63	0.62	1.59	0.31	0.52	1.20	**
Coordinated Bouts	7.87	6.45	29.20	4.86	4.09	14.30	2.85	3.00	9.97	*
Coordinated NWVs	7.87	6.45	29.20	4.86	4.09	14.30	2.85	3.00	9.97	*
Coordinated Joint Attention Gestures	2.28	2.93	11.60	0.50	0.63	1.59	0.13	0.40	1.20	****
Coordinated Behavior Request Gestures	1.01	1.47	5.60	0.36	0.49	1.59	0.22	0.21	0.40	
Diversity Bouts	7.57	5.21	25.00	4.00	2.22	8.00	3.67	2.06	6.00	**
18 months										
ESCS[a]										
High-IJA	2.32	3.54	14.40	1.63	1.92	7.06	0.56	1.36	4.08	†
CDI[b]										
Words Produced	90.96	92.68	344.00	17.08	11.41	31.00	8.78	8.04	21.00	****
Naturalistic[a]										
Communicative Acts	37.61	29.01	158.77	31.65	16.35	53.75	14.96	7.81	20.14	**
Single Acts	29.22	24.11	130.44	22.97	9.56	31.60	11.43	5.24	14.44	**
Gestures	6.84	7.42	29.62	4.10	3.79	12.38	2.78	3.86	12.26	†
Joint Attention Gestures	3.93	5.03	20.00	1.86	2.24	7.99	0.80	1.12	3.16	*
Coordinated Bouts	8.39	7.49	28.32	8.68	7.62	24.15	3.53	4.11	12.26	†
Coordinated NWVs	4.74	4.80	20.80	5.24	5.06	15.05	1.41	1.78	5.14	*
Coordinated Joint Attention Gestures	2.84	3.77	17.20	1.35	2.03	7.59	0.44	0.89	2.77	**
Coordinated Behavior Request Gestures	1.54	2.34	10.37	0.98	1.43	4.75	0.44	0.42	1.19	
Diversity Bouts	7.57	4.52	19.00	6.23	4.09	12.00	4.00	3.64	11.00	†

Note. ESCS = Early Social Communication Scales; CDI = MacArthur-Bates Communicative Development; HR-ND = High Risk-No Diagnosis, HR-LD = High Risk, Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder; IJA = Initiating Joint Attention; Inventories; NWV = Non-word Vocalization; IBR = Initiating Behavior Request; Diversity = Number of different types of Coordinated Bouts.
[a]Measured as rate per 10 minutes. [b]Calculated as raw scores. †*p* < .10, **p* < .05, ***p* < .01, ****p* < .005, *****p* < .001.

Table 28: Numbers and Percentages of Participants Classified Correctly from Discriminant Analysis of the ESCS, CDI, and Naturalistic Observation

	Predicted Group Membership					
	HR-ND		HR-LD		HR-ASD	
Actual Group Membership	*n*	*%*	*n*	*%*	*n*	*%*
ESCS and CDI[a]						
HR-ND (n = 27)	18	66.7	6	22.2	3	11.1
HR-ASD (n = 9)	0	0.0	0	0.0	9	100.0
HR-LD (n = 10)	0	0.0	7	70.0	3	30.0
ESCS, CDI, and Naturalistic[b]						
HR-ND (n = 27)	24	88.9	0	0.0	3	11.1
HR-ASD (n = 9)	0	0.0	0	0.0	9	100.0
HR-LD (n = 10)	0	0.0	9	100.0	0	0.0

Note. ESCS = Early Social Communication Scales; CDI = MacArthur-Bates Communicative Development Inventories; HR-ND = High Risk-No Diagnosis; HR-LD = High Risk-Language Delay; HR-ASD = High Risk-Autism Spectrum Disorder.
[a]73.9% of original grouped cases correctly classified based on ESCS and CDI alone.
[b]93.3% of original grouped cases correctly classified based on ESCS, CDI, and Naturalistic Observation.

6.0 FIGURES

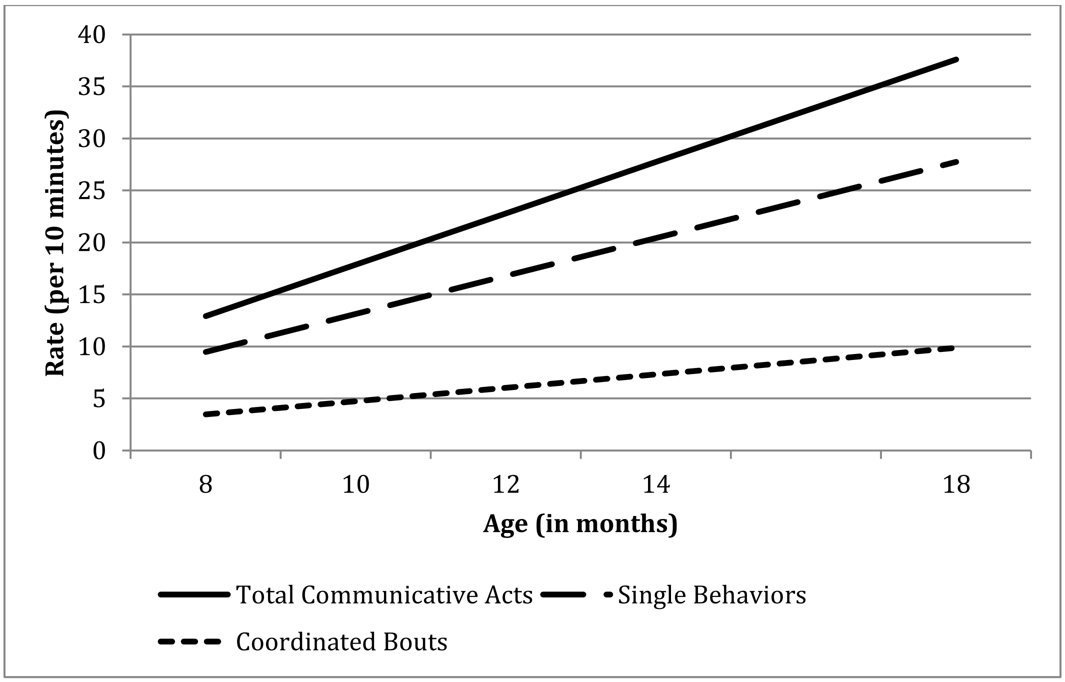


Figure 1: Developmental trajectories of overall communication from 8 to 18 months of age

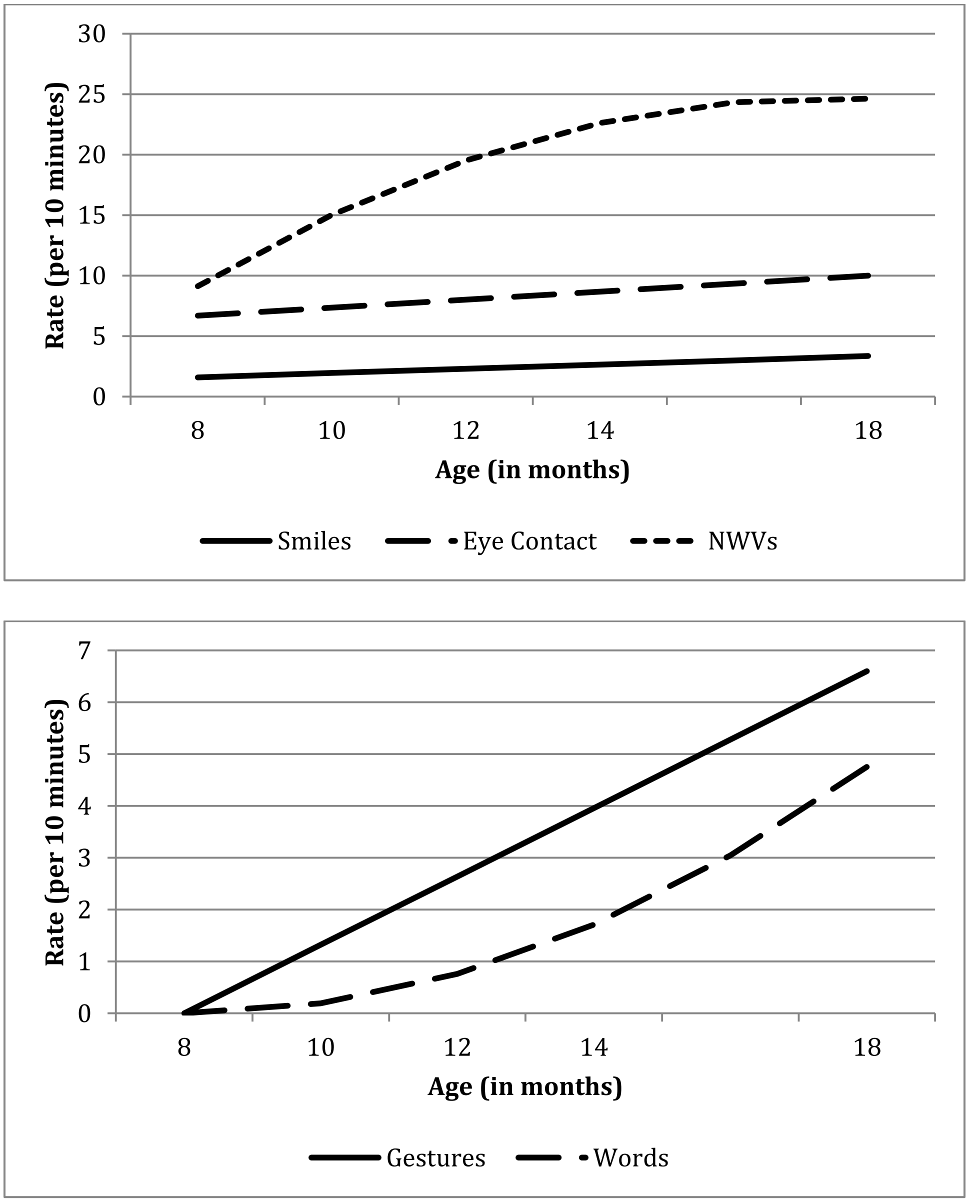


Figure 2: Developmental trajectories for early-emerging (top) and developmentally-advanced (bottom) communicative behavior forms from 8 to 18 months of age

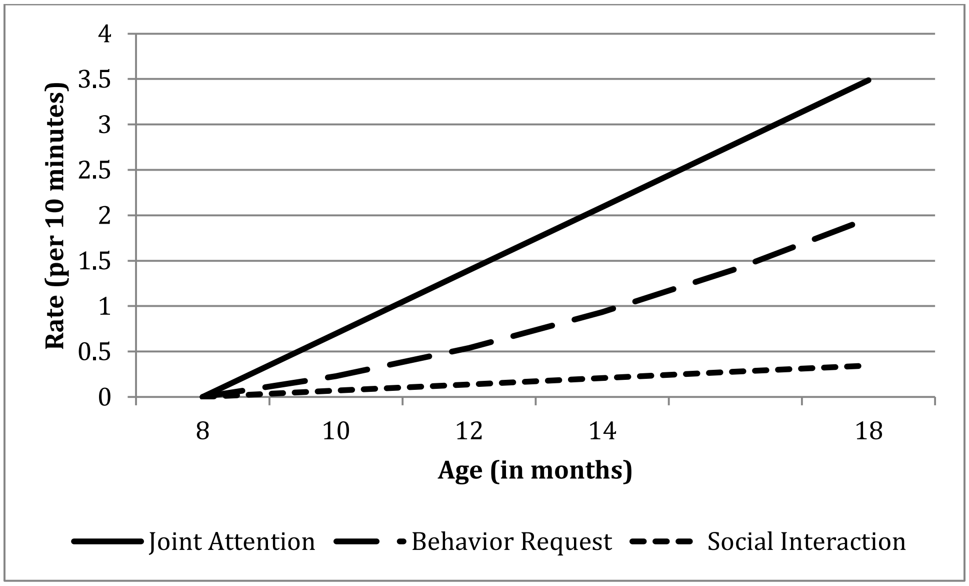
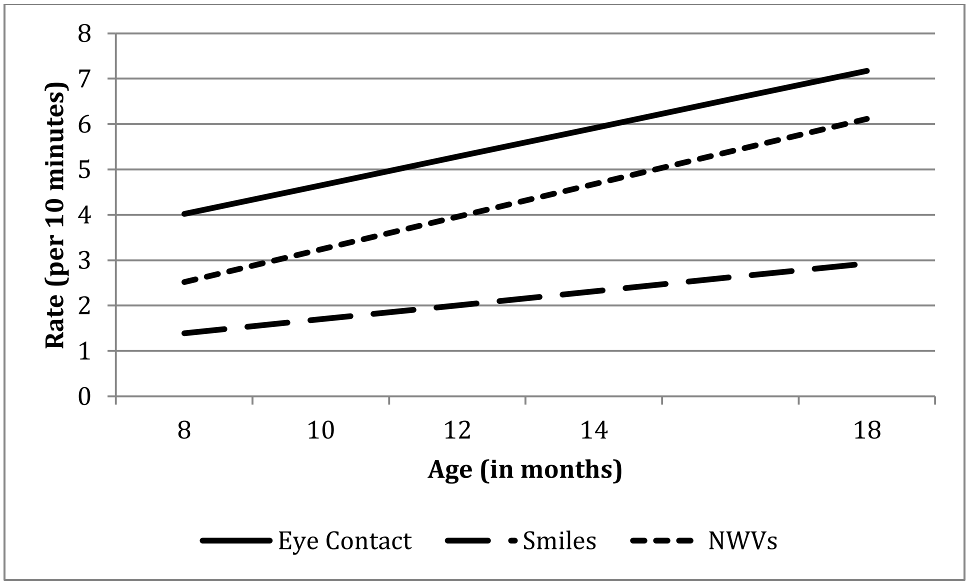


Figure 3: Developmental trajectories of Joint Attention, Behavior Request, and Social Interaction gestures from 8 to 18 months of age



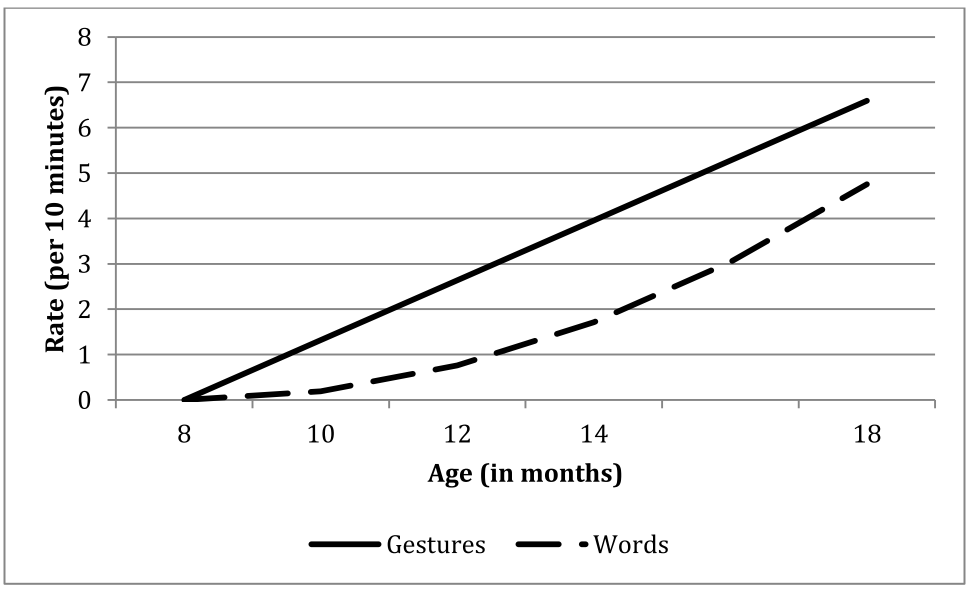


Figure 4: Developmental trajectories for coordinated early emerging (top) and developmentally-advanced (bottom) communicative behavior forms from 8 to 18 months of age

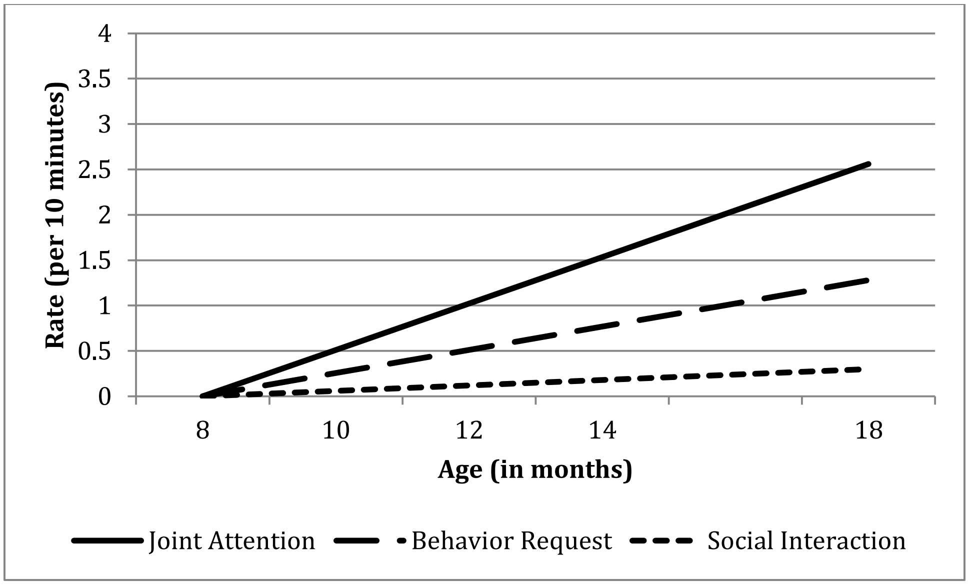


Figure 5: Developmental trajectories of coordinated Joint Attention, Behavior Request, and Social Interaction gestures from 8 to 18 months of age

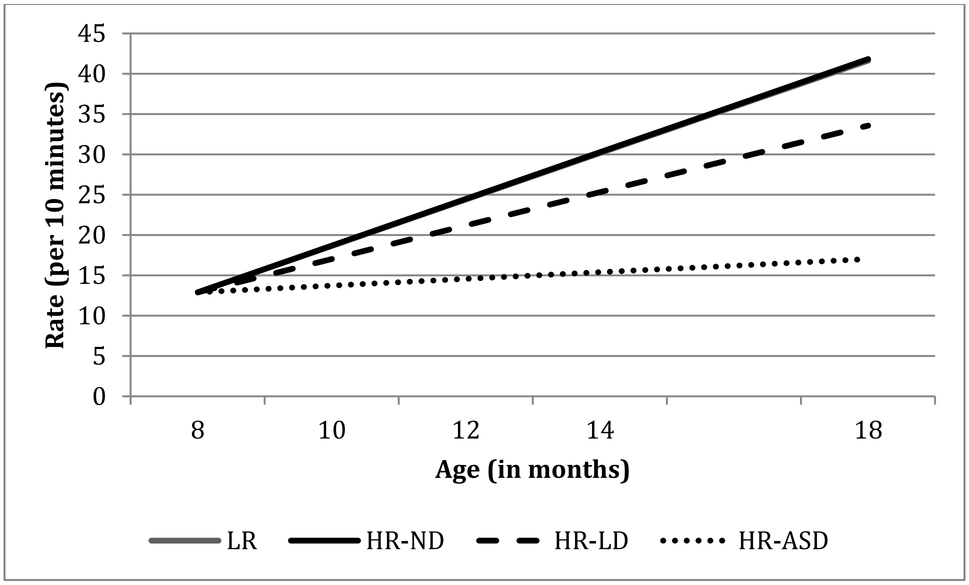


Figure 6: Developmental trajectories of total communicative acts by outcome group from 8 to 18 months of age

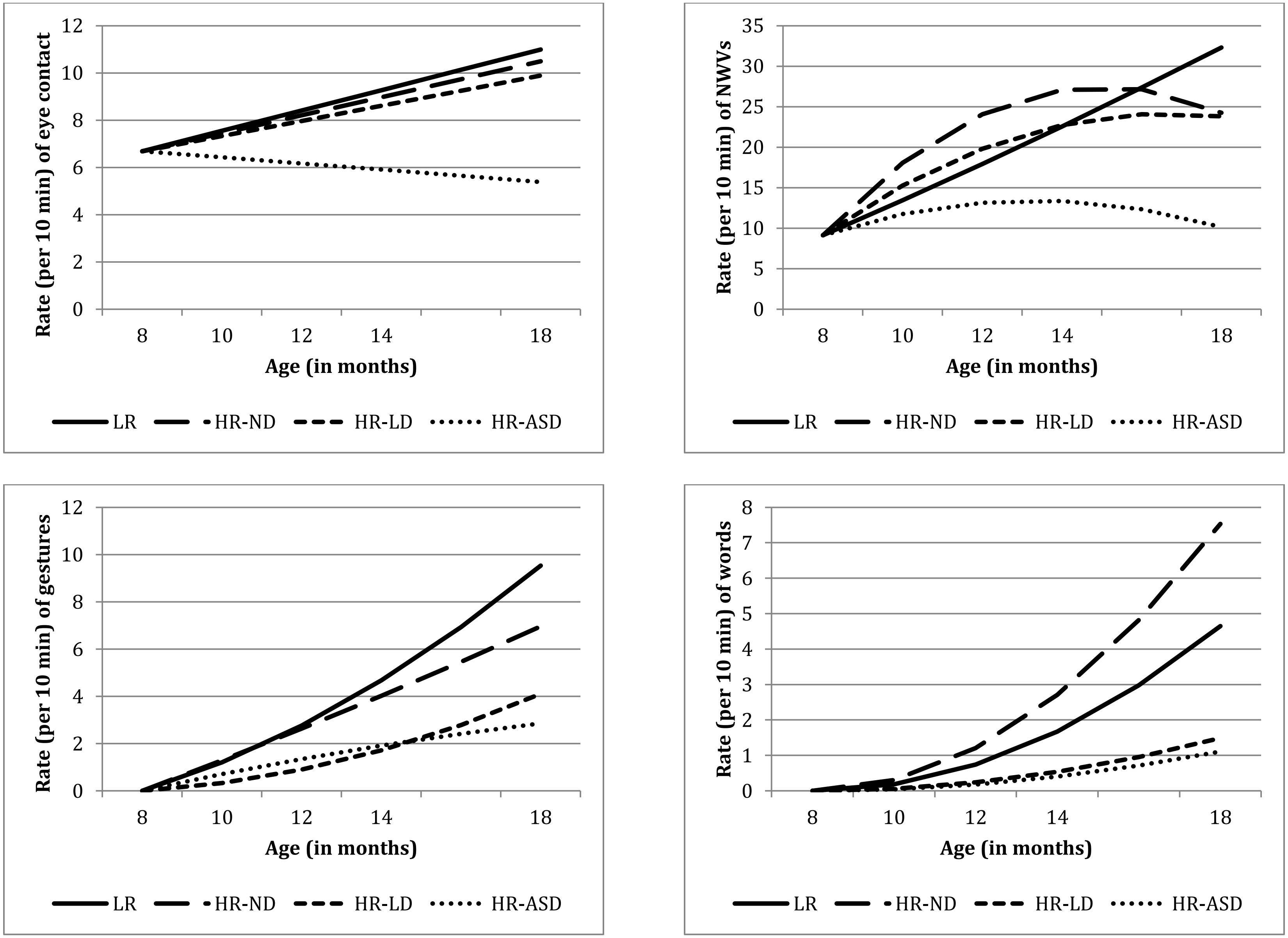


Figure 7: Developmental trajectories for communicative behavior forms by outcome group from 8 to 18 months of age

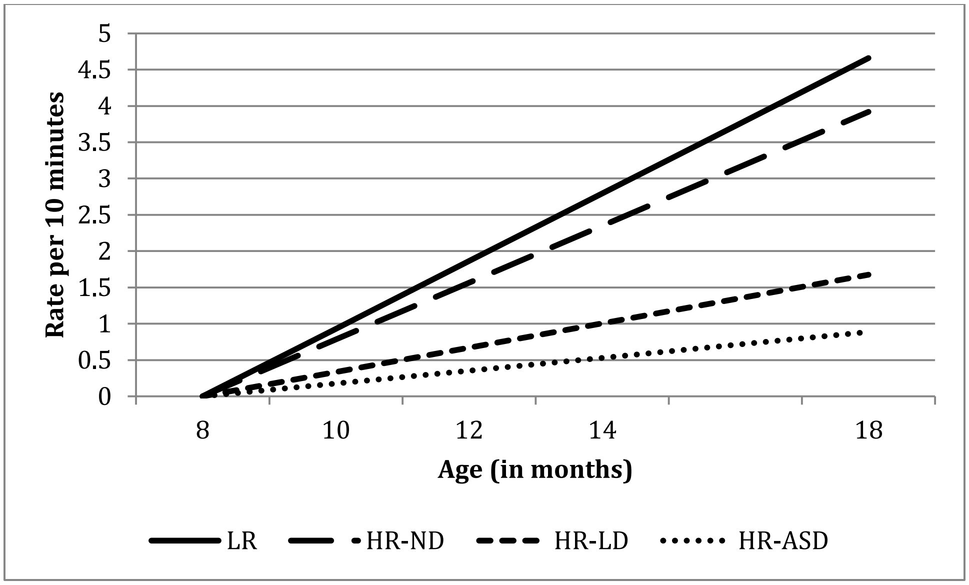


Figure 8: Developmental trajectories of Joint Attention gestures by outcome group from 8 to 18 months of age

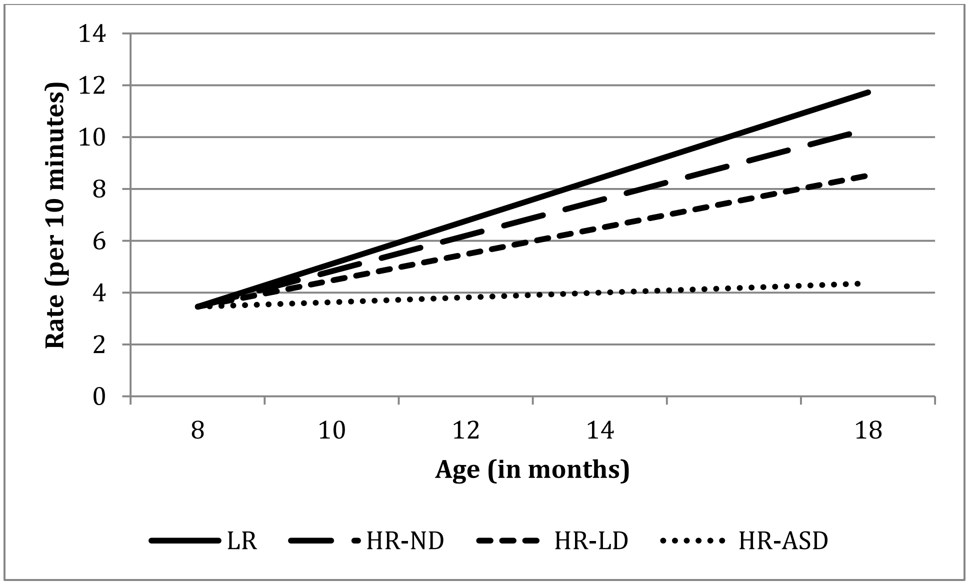


Figure 9: Developmental trajectories of Coordinated Bouts by outcome group from 8 to 18 months of age

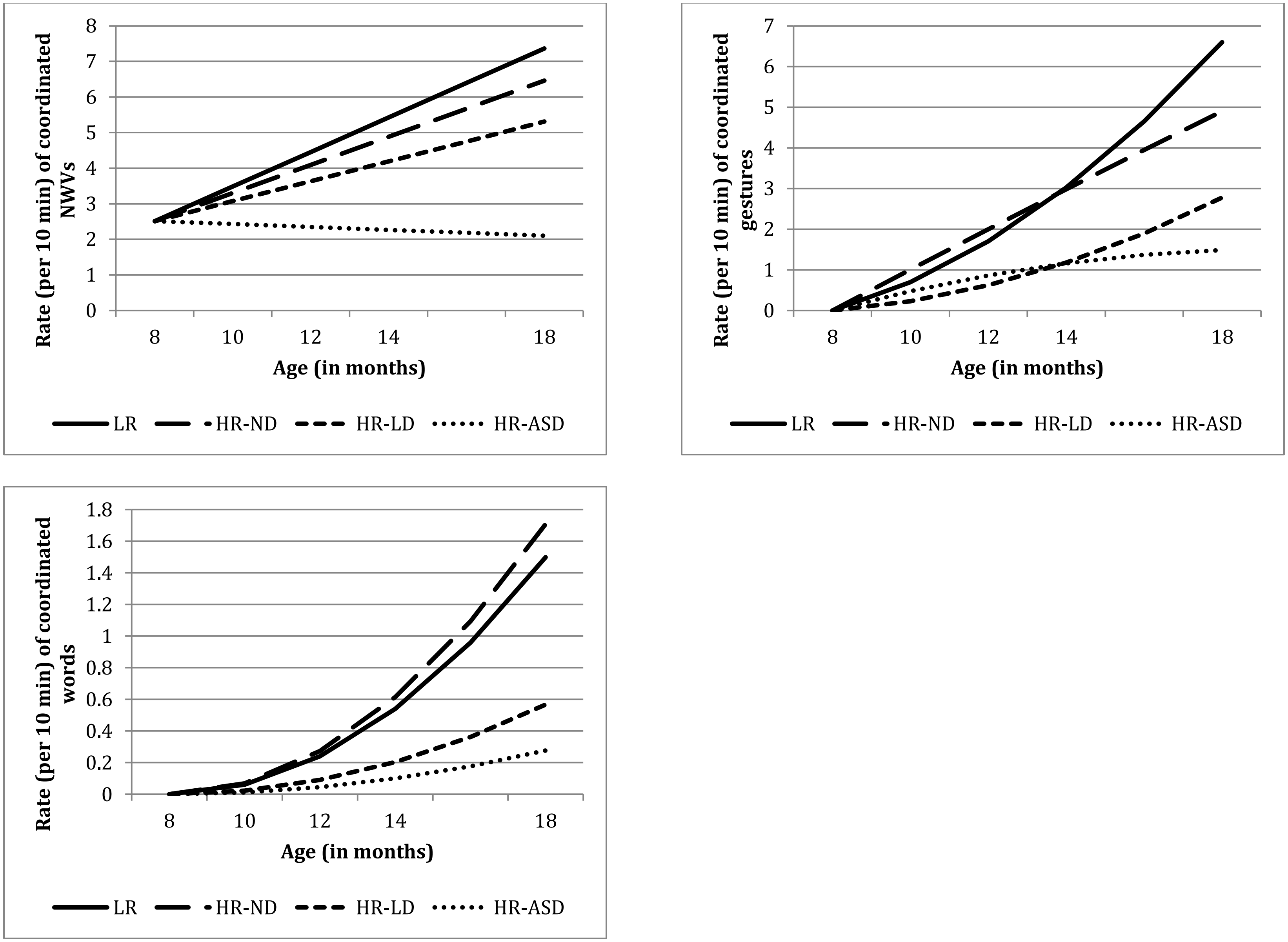


Figure 10: Developmental trajectories of communicative behavior forms produced in Coordinated Bouts by outcome group from 8 to 18 months of age

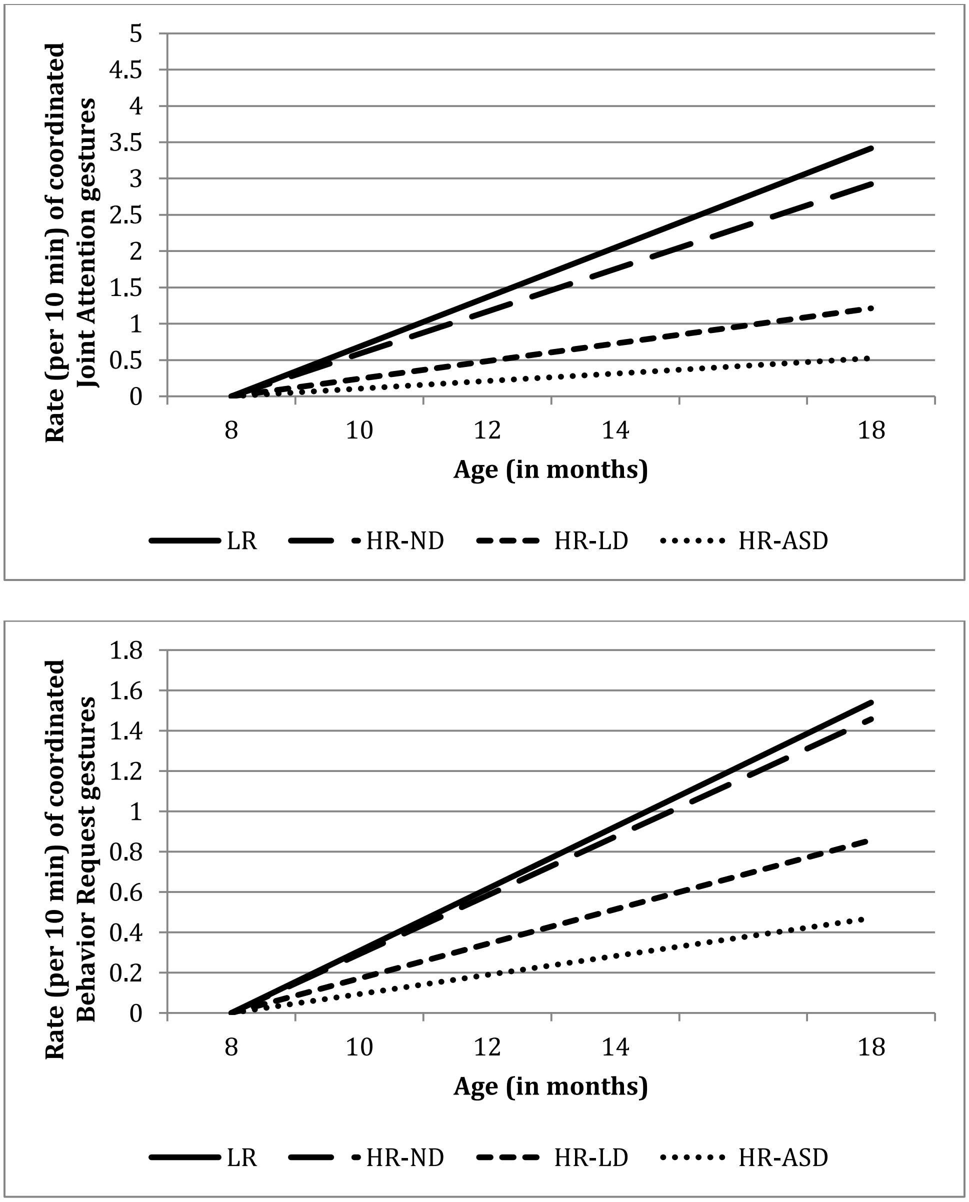


Figure 11: Developmental trajectories for coordinated Joint Attention and Behavior Request gestures by outcome group from 8 to 18 months of age

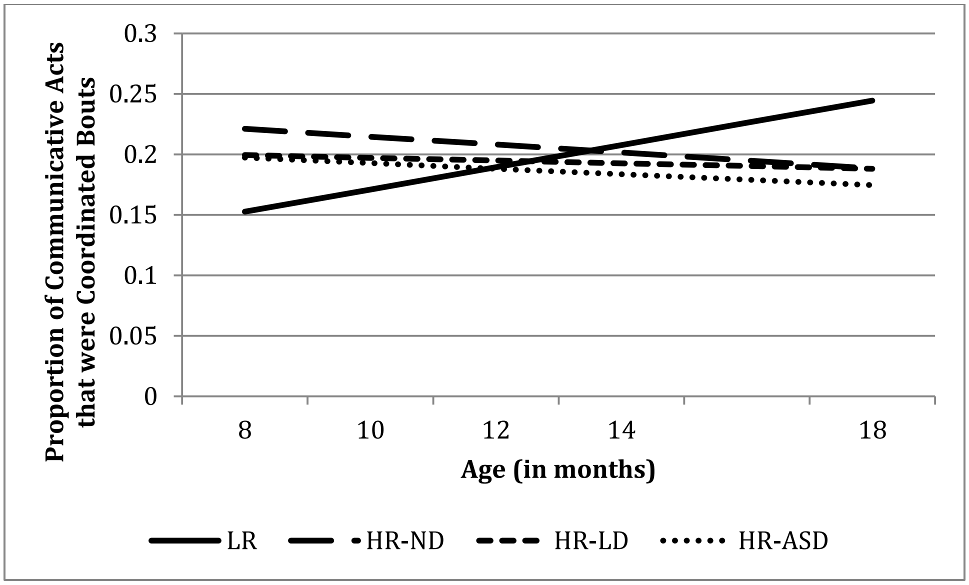


Figure 12: Developmental trajectories for proportion of communicative acts that were Coordinated Bouts by Outcome Group from 8 to 18 months of age

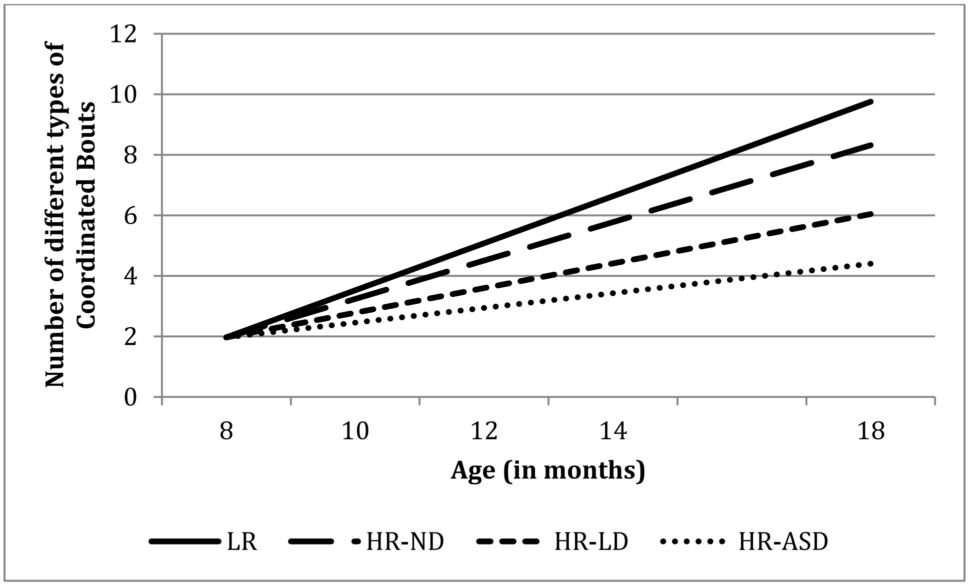


Figure 13: Developmental trajectories for diversity of Coordinated Bouts by outcome group from 8 to 18 months of age

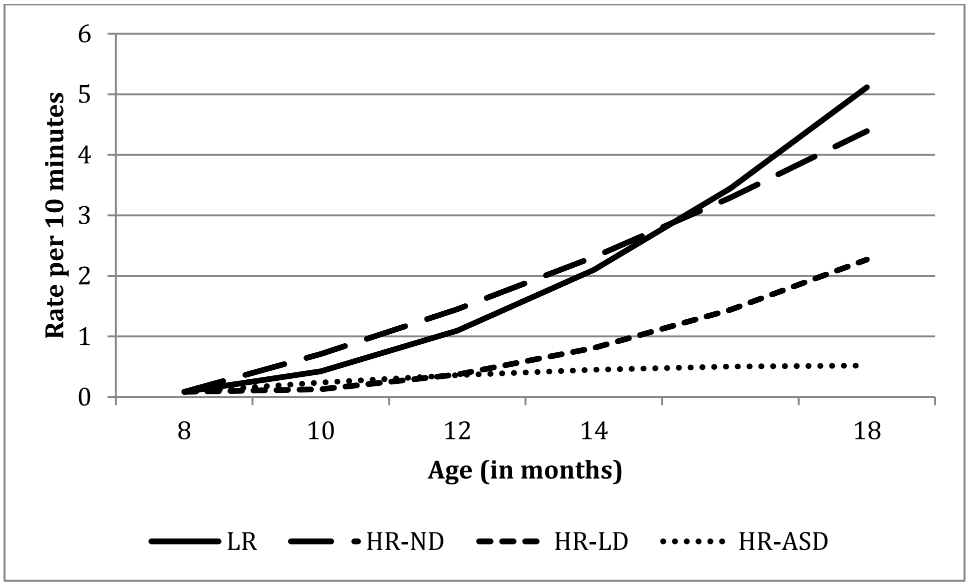


Figure 14: Developmental trajectories of Gesture + NWV/W Bouts by outcome group from 8 to 18 months of age

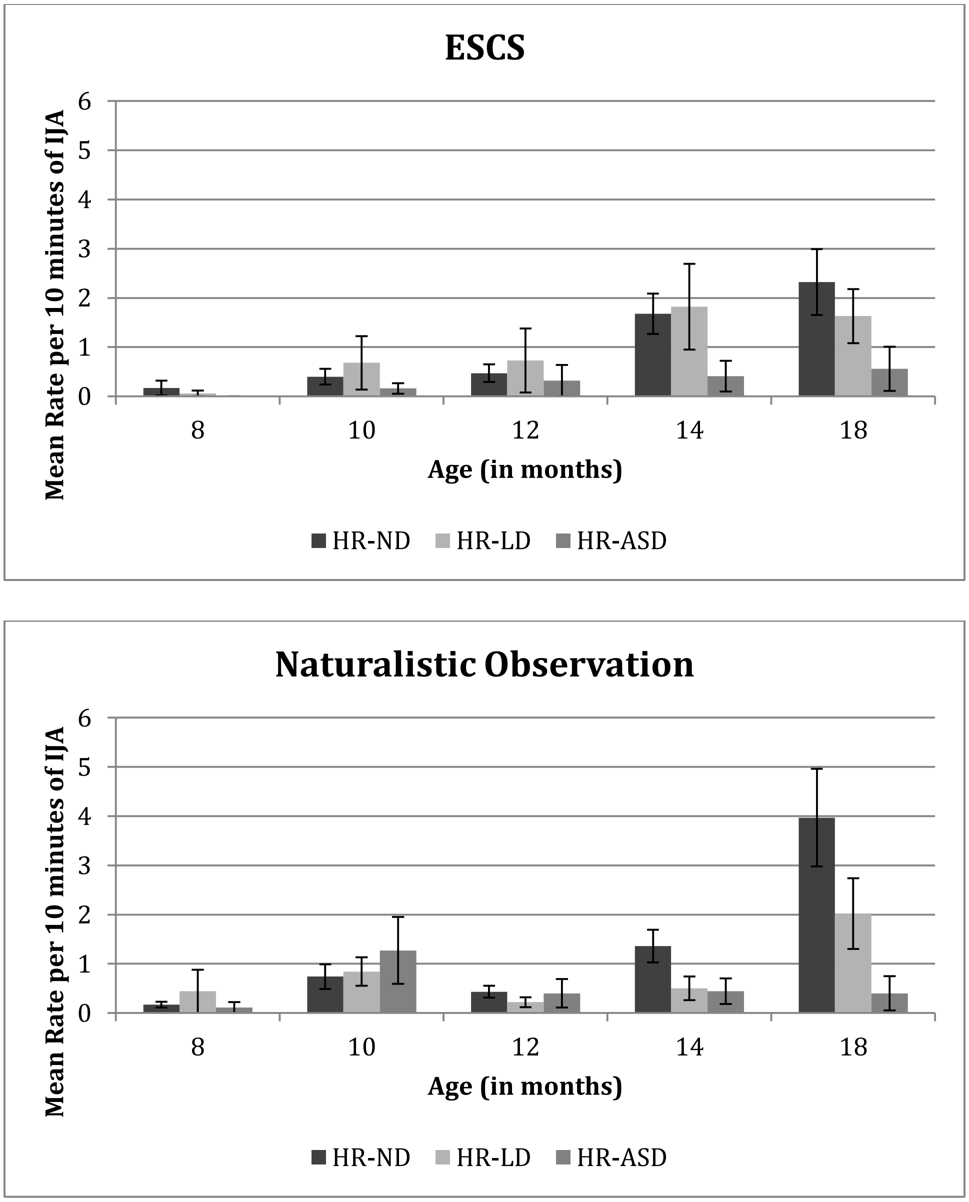
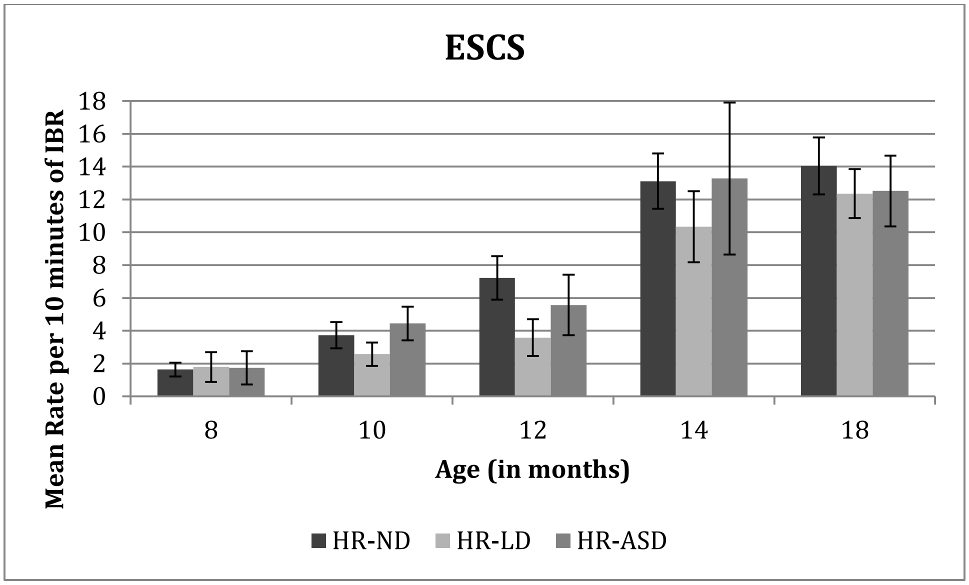


Figure 15: Mean rate of Initiating Joint Attention (IJA) in the ESCS (top) and Naturalistic Observation (bottom) for High Risk infants by outcome group. Error bars indicate standard errors



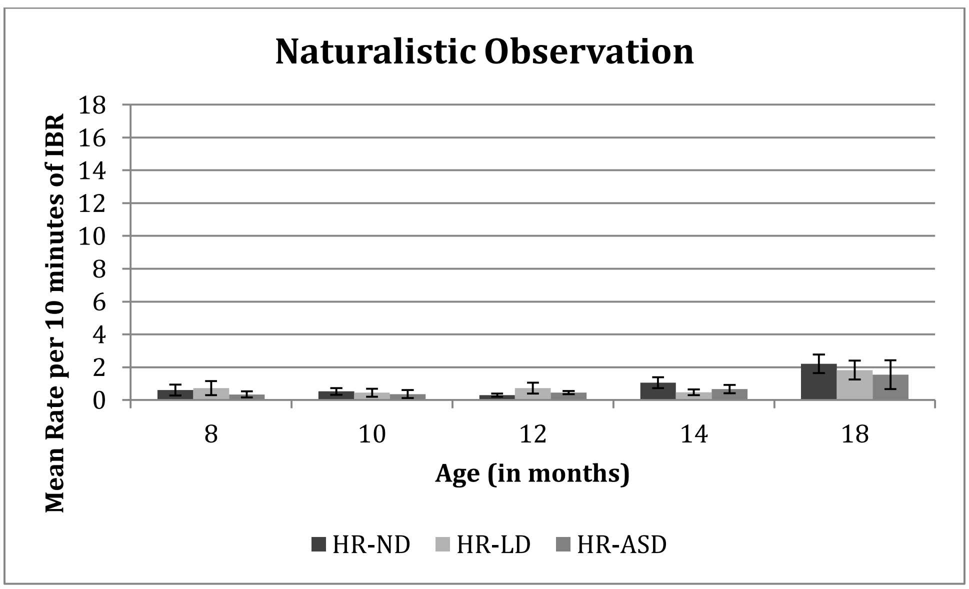


Figure 16: Mean rate of Initiating Behavior Request (IBR) in the ESCS (top) and Naturalistic Observation (bottom) for High Risk infants by outcome group. Error bars indicate standard errors

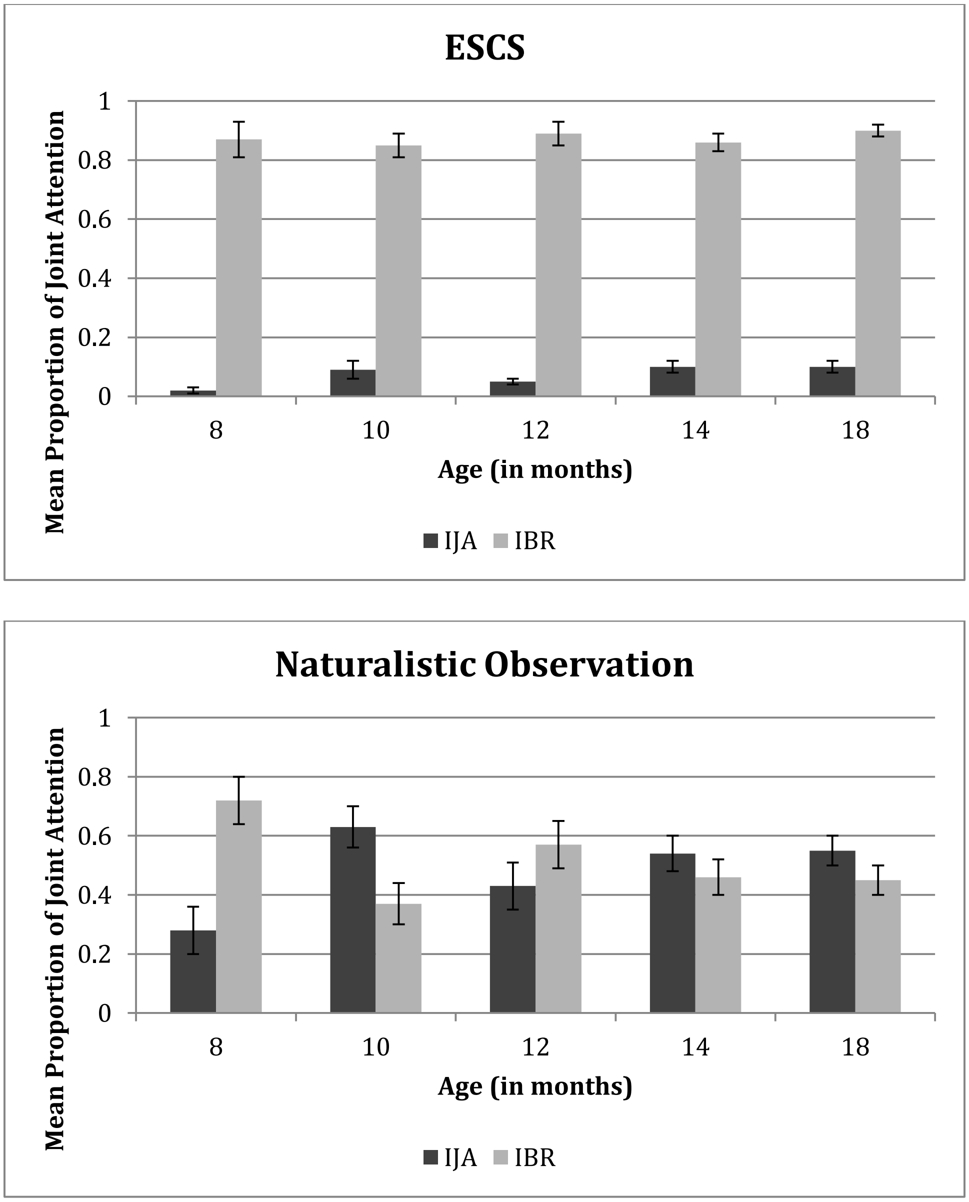


Figure 17: Mean proportions of Joint Attention and Behavioral Requests in the ESCS (top) Naturalistic Observation (bottom). Error bars indicate standard errors

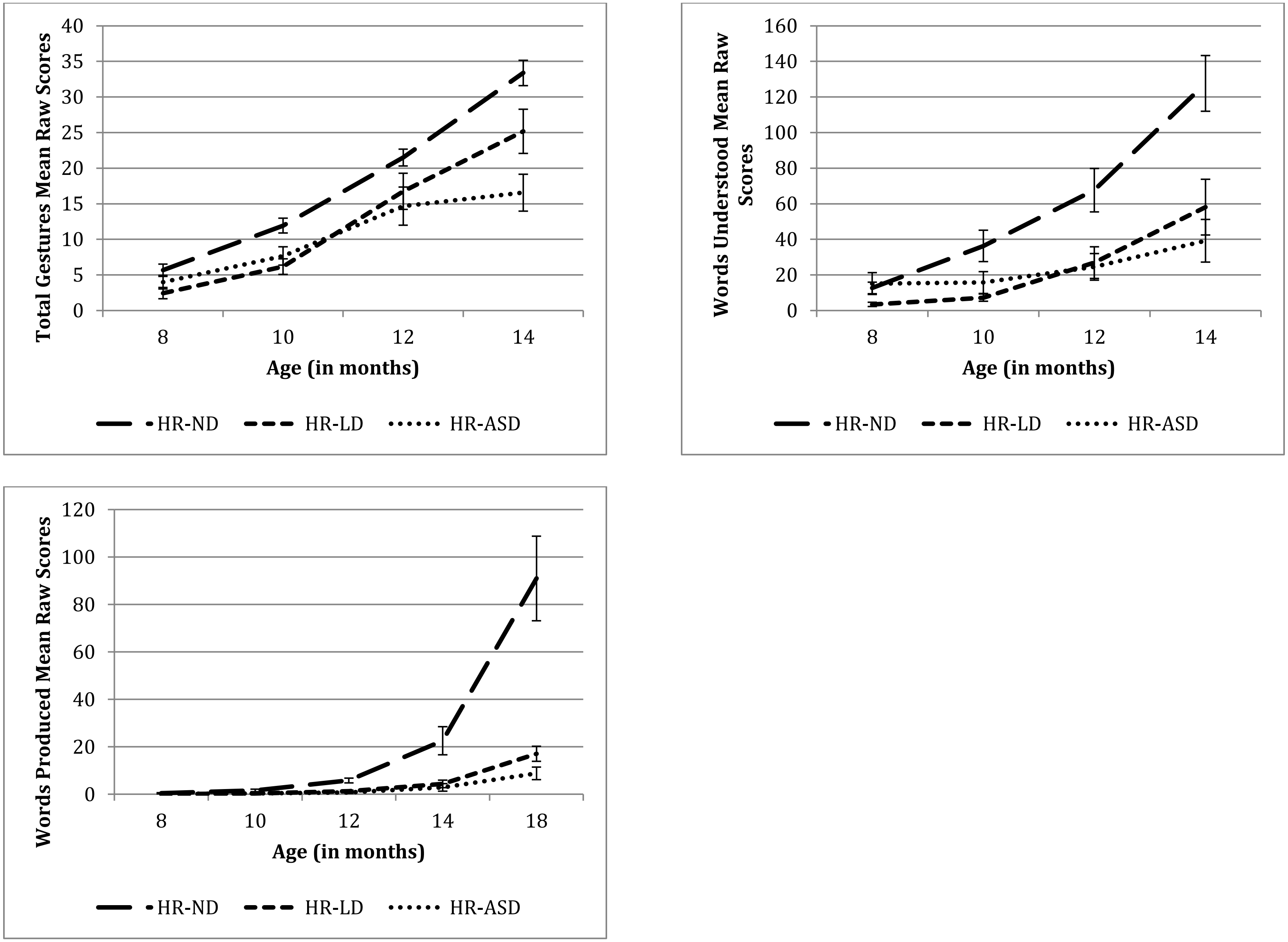
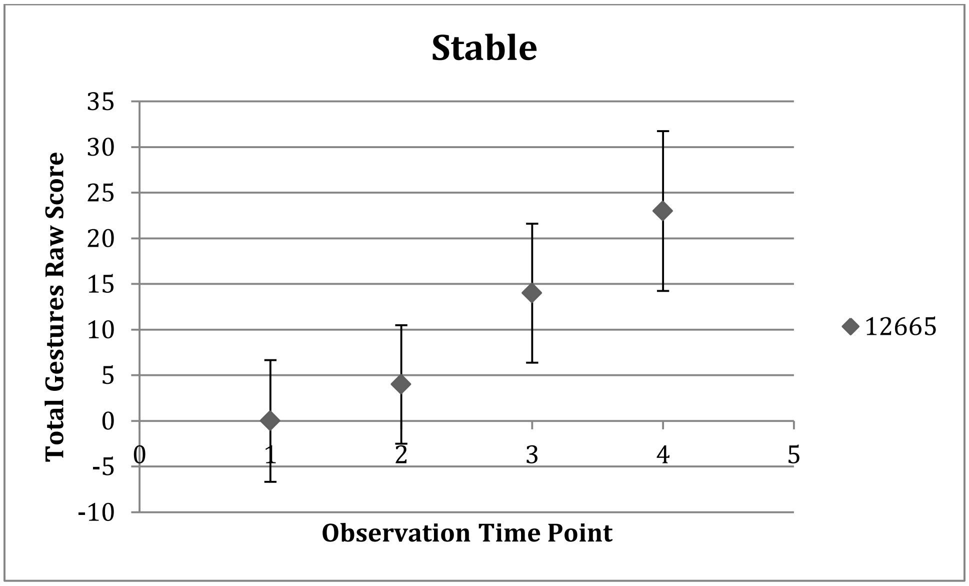


Figure 18: CDI Total Gestures, Words Understood, and Words Produced mean raw scores for High Risk infants by outcome group. Error bars indicate standard errors



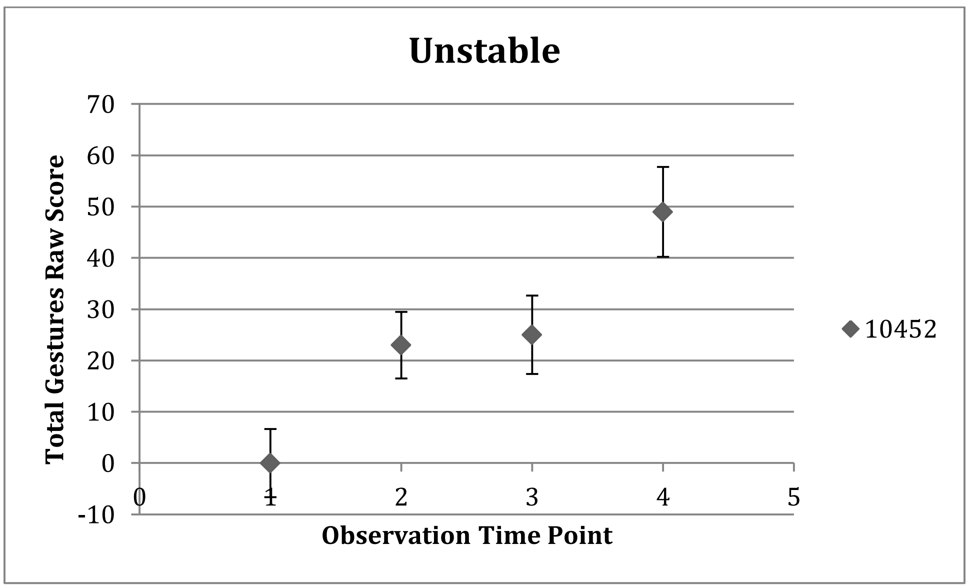


Figure 19: Examples of stable (top) and unstable (bottom) developmental profiles for Total Gestures raw scores with confidence intervals

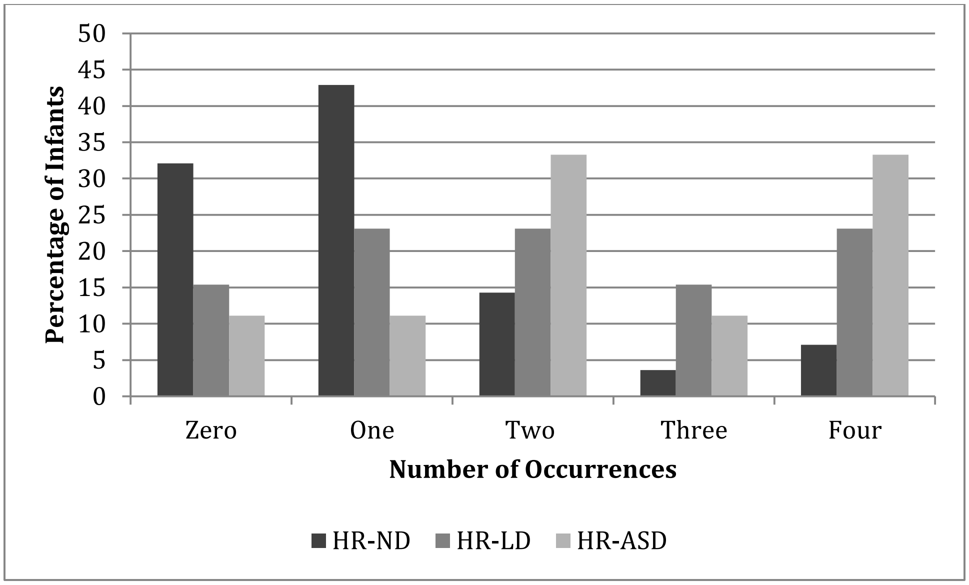


Figure 20: Percentages of infants in each outcome group with scores ≤ 10th percentile on CDI Total Gestures: Number of occurrences

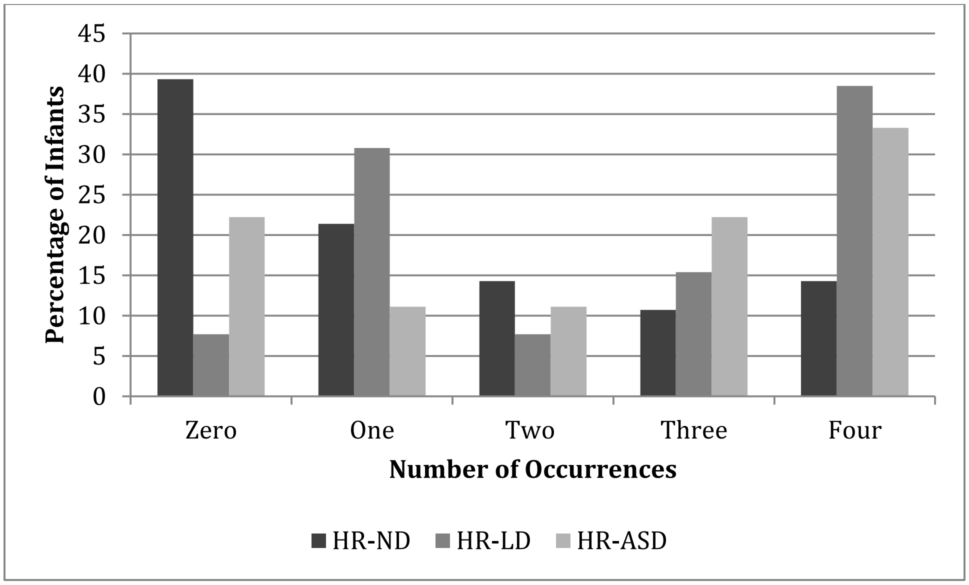


Figure 21: Percentages of infants in each outcome group with scores ≤ 10th percentile on CDI Words Understood: Number of occurrences.

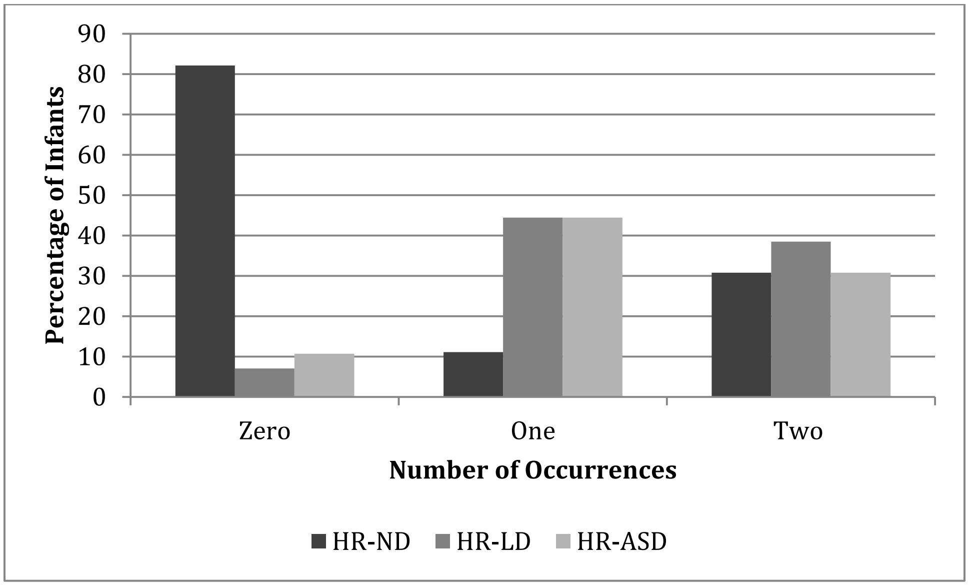


Figure 22: Percentages of infants in each outcome group with scores ≤ 10th percentile on CDI Words Produced: Number of occurrences

APPENDIX A

DESCRIPTION OF CODING CONVENTIONS

Table A1: Coding Descriptions for Communicative Behavior Forms

Communicative Behaviors	**Definition/Description**
Vocal Utterances	Code the highest form observed. For example, if a string of babble contains one recognizable word then code as "Word" only. Do not code affective vocal utterances (e.g., laughing, squealing, crying, and whining). Criteria based loosely on TD literature on infant vocal development (Stoel-Gammon, 1992).
Word Sequence	Sequential combination of meaningful words – at least 2 meaningful words (like "momma car").
Word	Words involve use of the same sound pattern to refer to a specific referent on multiple occasions or in different contexts. They are either actual English words (e.g., "dog," "cat," "duck," "hot"), verbal markers such as "uh huh" (yes), "nuh uh" (no), or "uh oh," or sound patterns that are consistently used by a particular child to refer to a specific object or event (e.g., using "bah" to refer to a bottle in a variety of different contexts). Non-word vocalizations may also be present, but there must be one interpretable word.
Syllabic NWV	This type of NWV includes one consonant AND one clearly discriminable vowel (in either order; e.g., 'da,' 'la,' 'bbbbbbaaaa'); canonical or reduplicated babbling, which is the reproduction of the same consonant-vowel (CV) unit two or more times (e.g., 'bababa,' 'adad'); variegated babbling, or two or more different CV units that occur within one breath (e.g., 'babadada,' 'la de,' 'gugudada,' 'babe'). This category also includes long strings of jibberish sounding utterances that involve multiple vowels and consonants (e.g., 'la da la la eeaa').
Non-syllabic NWV	Any vowel OR consonant sound without a syllable (e.g., 'aa,' 'mm'). Vocalizations also including more than 1 consonant OR vowel sound (but not both) at a time are also included in this category (e.g., 'aaaoooeee,' 'mmmnnnp'). 'Aaammpp' is NOT a vowel because the utterance includes both a consonant AND a vowel sound. **Raspberries, sounds in which infants use their lips (or a combination of tongue and lips) to produce noisy friction sounds, sometimes with voicing or trilling of the lips, should be coded as Non-syllabic NWVs.
Affective NWV	Any vocal sound directly expressing an affective or bodily state (e.g., laughing, squealing, fussing, whining, crying, grunting). These are distinguished from NWVs on the basis of situational context (e.g., "aaaaah" as a non-word

	vocalization was distinguished from "aaaaah" as a whine based on the vocalization's occurrence during an episode on infant noncompliance).
Deictic Gestures	
Index Finger Point	A well-formed index finger point to a distal or proximal object
Index Finger Touch-Point	A well-formed index finger point that touches the target object, picture or person. Be careful not just tracing or exploring the object with finger. In other words, touches are only counted as Points when the child is using the pointing finger touch to call the adult's attention to the object touched.
Reach	The child extends her arm with an open palm or repeated opening/closing of the hand to *indicate desire for an object*. Arms may be up but hands also need to be articulated to be considered a reach. *Do not score if the child actually obtains the object by him/herself without assistance from the adult.* A reach bid ends when the child retracts his/her arm or the arm relaxes.
Give	The extension of the arm with object in hand *with the intention for the other person to take the object.* The child hands the object to the person in order to request an action ("do it again") or to get rid of the object, or to offer the object in an act of "sharing". Gives require arm extension and *hand to hand exchange*.
Show	The child presents the object in the general direction of the caregiver and makes eye contact with the person. The object should be presented relatively still for a second or two and should be raised up toward the caregiver's face.
Representational Gestures	
Rep Conventional	Culturally defined signs or social markers, e.g., nodding, shaking head, thumbs up, clapping for "yay" etc.
Rep Descriptive	Gestures describing qualities or characteristics of an object or situation (e.g., waving hands for hot, raising the arms high for tall). Representational gestures can also provide a label for a specific object. They can act as labels by either (a) replicating the action performed by an agent involving the object (e.g., making the hand like a cup and pretending to drink for "cup") or (b) copying the movement that would be performed by the object itself (e.g., flapping arms for bird, wiggling nose for rabbit, rocking side to side for penguin).

Eye Gaze	
Gaze Switch	Triadic gaze switch of object-person-object or person-object-person; must make eye contact rather than just looking to person's face, and the whole sequence must take place within 3 seconds to be sure it is a gaze switch rather than just repeated attention shifts. Because of this, the whole sequence must be initiated by the child; for example, if the child is looking at an object, makes eye contact because the caregiver calls his name then looks back at the object, this is credited as Eye Contact but not as a Gaze Switch.
Eye Contact	Instances in which the infant looks to person's *face/eyes*. Beware of <u>fleeting</u> eye contact. Do not code "Eye Contact" if the infant does not pause while looking at the face or eyes.
Facial Expressions	
Smile	An upward turning of the corners of the lips *often* accompanied by narrowed/crinkled eyes (i.e., eye constriction) and a widened mouth, or displayed with mouth closed and without eye constriction/cheek raising.
Coordinations	
Coordinated Bout	When more than one form occurs at the same time, they are coded as simultaneous. Simultaneous combinations *always* overlap in time. For example, child points at a car and holds the point while saying "car." If there is a clearly discriminable period of time between the end of a gesture and the beginning of a vocalization or vice versa, code as a Sequential Coordination.

Table A2: Coding Descriptions of Gesture Functions, and Complexity and Composition of Coordinated Bouts

Modifiers	**Definition/Description**
Function	The purpose of the child's act, what the child is attempting to communicate. Only code a single function for each act. If an act's function seems ambiguous, then code what seems to be the primary function. It may help to watch more of the videotape to see if the communication is repeated and what the outcomes are.
Joint Attention	Remark about an object or event etc., which has no obvious instrumental function (e.g., trying to get or activate an object or event) but seems to be more to SHARE experiences or objects or events with others or to declare ("*look at that*!"). A "Show" gesture is prototypical of this type of behavior.
Behavior Request	The function of these behaviors is to elicit supportive action or aid from the partner in obtaining objects or events. They differ from joint attention behaviors in that they serve to communicate a want or desire (e.g., nodding head "yes" when a game is suggested) rather than a comment (e.g., saying "uh-oh" when a toy is knocked over). Giving in order to obtain aid in opening or activating an object is a prototypical behavior. The Request bid are most often seen when the child directs his or her attention to toys that are out of reach, upon the removal of a toy, or after an active toy has ceased moving. Look for leaning towards the desired toy with pointing and reaching ("*give me that*!").
Social Interaction	<u>The focus is on face-to-face interaction</u>, e.g., a smile directed to the caregiver while playing a social game such as peek-a-boo. Also includes the use of a gesture to elicit and maintain turn-taking with objects such as offering objects back and forth with a social partner.
Coordinations Only	
Complexity	Specify the number of different single forms that are involved in the coordination (i.e., 2, 3, or 4).
Composition	Note which single forms occurred within a given coordination.

APPENDIX B

DESCRIPTIVE STATISTICS FOR ALL COMMUNICATIVE BEHAVIORS

Table B1:Mean Rate (per 10 minutes), Standard Deviations, and Ranges for Specific Breakdowns of Communicative Behaviors by Form and Function for the Full Sample

	Age														
	8 (n = 74)			10 (n = 78)			12 (n = 77)			14 (n = 79)			18 (n = 79)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Form															
Eye Contact	2.65	3.07	17.70	3.99	3.21	15.10	2.27	1.86	9.20	3.30	2.53	9.61	3.10	3.11	15.14
Smiles	0.29	0.54	2.40	0.42	0.76	4.80	0.32	0.59	2.80	0.48	0.89	4.81	0.90	1.66	8.76
Vocal Utterances	9.41	7.31	40.37	14.62	10.14	45.17	19.91	11.76	54.40	23.74	16.38	71.51	29.79	21.51	152.40
Non-syllabic NWV	5.67	4.50	20.93	6.35	4.60	23.63	10.53	7.11	33.20	8.50	5.92	28.00	8.65	6.15	29.92
Syllabic NWV	1.62	2.37	14.40	3.91	4.60	26.78	6.54	5.56	24.38	8.24	8.59	37.20	10.04	9.23	58.64
Word	0.00	0.00	0.00	0.05	0.20	1.20	0.18	0.70	4.80	0.48	1.46	9.19	3.63	6.65	40.69
Word Sequence	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.74	4.00
Gestures	0.29	0.54	2.40	1.37	1.79	8.00	1.66	1.86	9.20	4.11	4.74	25.97	6.92	7.38	37.22
Deictic Gestures	0.13	0.37	2.40	0.22	0.46	2.39	0.54	0.78	4.80	1.05	2.00	10.42	2.00	2.93	15.90
Point	0.02	0.11	0.80	0.05	0.17	1.20	0.08	0.23	1.60	0.37	0.90	4.39	0.74	1.56	7.61
Touch-Point	0.02	0.10	0.80	0.03	0.15	1.20	0.02	0.09	0.40	0.24	0.78	4.39	0.41	1.11	7.16
Reach	0.10	0.32	2.40	0.06	0.17	0.80	0.11	0.30	2.00	0.12	0.27	1.57	0.17	0.39	2.00
Give	0.00	0.00	0.00	0.06	0.19	1.20	0.27	0.51	2.40	0.36	0.92	6.77	0.72	1.25	6.40
Show	0.01	0.05	0.40	0.04	0.19	1.20	0.09	0.22	1.20	0.02	0.08	0.40	0.04	0.11	0.40
Rep Conventional	0.04	0.24	2.00	0.10	0.37	2.80	0.14	0.31	1.60	0.19	0.48	3.60	0.19	0.43	2.40
Function of Gestures															
Joint Attention	0.09	0.31	2.00	0.76	1.38	6.00	1.00	1.26	5.60	2.17	2.88	12.80	3.62	4.56	20.01
Behavior Request	0.13	0.33	2.00	0.21	0.36	1.60	0.44	0.90	5.20	1.06	1.39	6.00	1.94	2.31	12.81
Social Interaction	0.01	0.05	0.41	0.11	0.43	2.40	0.06	0.25	1.60	0.27	0.69	3.60	0.32	0.81	4.78

Note. Rate per 10 minute. NWV = Non-word vocalization; Rep Conventional = Representational Conventional

APPENDIX C

DESCRIPTIVE STATISTICS FOR COMMUNICATIVE BEHAVIORS BY OUTCOME GROUP

Table C1: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Communicative Behaviors by Form and Function for the Low Risk (LR) Group

	Age														
	8 (n = 30)			10 (n = 30)			12 (n = 29)			14 (n = 30)			18 (n = 29)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Overall Frequency															
Communicative Acts	11.13	7.86	33.20	15.58	9.98	35.60	20.32	13.52	56.40	29.19	14.18	59.20	44.93	17.97	61.75
Single Behaviors	11.13	6.08	27.20	10.65	6.88	30.00	17.60	11.46	45.20	20.24	11.20	48.00	31.82	13.55	47.53
Form															
Eye Contact	3.89	3.40	15.18	8.28	6.72	24.08	3.31	3.50	14.80	10.11	5.72	23.63	12.38	8.66	35.63
Smiles	1.19	2.34	11.98	1.56	2.45	9.52	0.41	0.77	3.20	3.49	4.18	16.83	3.69	4.81	23.51
NWVs	9.53	7.04	32.00	12.34	8.50	32.40	18.24	12.90	51.20	22.01	12.16	58.80	31.48	14.02	54.80
Gestures	0.29	0.57	2.40	1.64	2.13	7.60	2.18	1.88	8.80	4.98	3.84	12.02	9.56	8.47	36.83
Words	0.00	0.00	0.00	0.01	0.07	0.40	0.15	0.60	3.20	0.88	1.66	7.58	5.15	8.48	39.62
Function of Gestures															
Joint Attention	0.04	0.12	0.40	0.99	1.64	6.00	1.42	1.24	5.60	2.69	2.74	8.41	4.98	5.00	20.01
Behavior Request	0.16	0.43	2.00	0.26	0.36	1.50	0.51	1.02	4.80	1.30	1.31	4.33	2.45	2.43	12.81
Social Interaction	0.00	0.00	0.00	0.08	0.30	1.57	0.07	0.24	1.20	0.21	0.44	1.60	0.55	1.18	4.78

Note. NWV = Non-word vocalization.

Table C2: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Communicative Behaviors by Form and Function for the High Risk – No Diagnosis (HR-ND) Group

	Age														
	8 (n = 27)			10 (n = 27)			12 (n = 28)			14 (n = 28)			18 (n = 28)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Overall Frequency															
Communicative Acts	12.66	10.52	53.32	24.97	13.73	49.17	25.28	11.20	44.99	36.94	23.44	98.67	37.61	29.01	158.77
Single Behaviors	9.08	6.80	30.40	16.10	10.33	39.57	20.92	9.13	34.95	25.97	16.40	58.72	29.22	24.11	130.44
Form															
Eye Contact	7.28	8.27	38.37	12.36	8.57	33.07	6.29	5.12	17.60	13.01	8.28	34.35	7.66	7.07	27.09
Smiles	1.93	3.37	16.45	4.48	4.99	22.31	1.61	2.62	9.98	3.09	4.07	19.57	2.59	3.62	13.55
NWVs	10.02	8.32	40.37	19.09	12.52	41.97	21.75	10.02	43.38	29.67	18.58	65.21	22.92	19.17	99.33
Gestures	0.26	0.44	2.00	1.54	1.73	8.00	1.65	2.14	9.20	5.21	6.35	25.57	6.84	7.42	29.62
Words	0.00	0.00	0.00	0.16	0.46	2.00	0.49	1.22	5.20	1.34	3.69	18.38	8.78	11.01	52.66
Function of Gestures															
Joint Attention	0.11	0.29	1.20	0.78	1.42	6.00	1.06	1.46	5.20	2.88	3.54	12.40	3.93	5.03	20.00
Behavior Request	0.07	0.16	0.40	0.24	0.43	1.60	0.50	1.04	5.20	1.26	1.78	6.00	1.87	2.53	10.37
Social Interaction	0.02	0.08	0.41	0.13	0.48	2.40	0.03	0.15	0.80	0.41	0.89	3.60	0.11	0.28	1.20

Note. NWV = Non-word vocalization.

Table C3: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Communicative Behaviors by Form and Function for the High Risk – Language Delay (HR-LD) Group

	Age														
	8 (n = 10)			10 (n = 12)			12 (n = 11)			14 (n = 12)			18 (n = 13)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Overall Frequency															
Communicative Acts	10.63	8.43	27.15	16.86	5.11	18.71	26.88	14.35	43.34	22.90	14.78	58.77	31.65	16.35	53.75
Single Behaviors	7.59	5.83	19.27	11.94	3.91	15.56	22.52	11.35	34.11	16.49	10.93	42.49	22.97	9.56	31.60
Form															
Eye Contact	5.41	4.35	14.44	8.65	4.67	13.21	7.29	5.72	19.78	8.77	6.66	24.23	10.07	9.59	30.10
Smiles	0.71	0.85	2.50	1.83	2.38	7.07	2.48	3.07	9.31	2.61	2.98	9.82	4.91	5.85	15.84
NWVs	9.17	7.75	24.77	13.06	4.30	14.88	22.65	11.99	34.51	19.46	12.36	50.05	23.18	11.28	36.38
Gestures	0.26	0.44	1.20	0.65	1.18	3.48	0.83	0.87	2.40	1.26	0.99	2.78	4.10	3.79	12.38
Words	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.16	0.40	0.95	0.87	2.40
Function of Gestures															
Joint Attention	0.08	0.25	0.80	0.41	0.80	2.48	0.33	0.53	1.60	0.63	0.62	1.59	1.86	2.24	7.99
Behavior Request	0.18	0.41	1.20	0.12	0.30	0.99	0.15	0.27	0.80	0.46	0.53	1.59	1.50	1.86	5.20
Social Interaction	0.00	0.00	0.00	0.03	0.12	0.40	0.00	0.00	0.00	0.03	0.11	0.39	0.24	0.47	1.60

Note. NWV = Non-word vocalization.

Table C4: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Communicative Behaviors by Form and Function for the High Risk – Autism Spectrum Disorder (HR-ASD) Group

	Age														
	8 (n = 7)			10 (n = 9)			12 (n = 9)			14 (n = 9)			18 (n = 9)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Overall Frequency															
Communicative Acts	9.26	4.84	14.00	14.58	8.12	24.80	18.02	12.55	34.28	13.04	7.10	17.92	14.96	7.81	20.14
Single Behaviors	7.03	4.42	12.80	9.15	6.83	21.60	14.49	10.29	31.09	8.54	4.18	12.00	11.43	5.24	14.44
Form															
Eye Contact	4.75	2.96	8.41	9.72	6.58	16.80	5.88	4.54	14.80	7.43	6.40	18.73	4.24	4.70	14.63
Smiles	1.49	1.53	4.41	2.28	2.93	7.99	2.14	1.83	5.57	2.17	2.43	5.98	2.78	4.58	13.54
NWVs	6.92	3.29	8.80	10.37	7.85	24.80	14.18	10.93	30.40	9.60	5.60	13.21	9.66	5.68	16.42
Gestures	0.46	0.88	2.40	0.93	1.15	3.20	1.02	1.34	4.40	1.59	1.37	3.59	2.78	3.86	12.26
Words	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.55	1.60
Function of Gestures															
Joint Attention	0.29	0.76	2.00	0.44	0.90	2.80	0.31	0.66	2.00	0.31	0.52	1.20	0.80	1.12	3.16
Behavior Request	0.11	0.20	0.40	0.09	0.18	0.40	0.40	0.35	0.80	0.40	0.49	1.20	1.15	1.66	4.75
Social Interaction	0.00	0.00	0.00	0.27	0.80	2.39	0.22	0.53	1.60	0.35	1.06	3.19	0.35	0.73	1.99

Note. NWV = Non-word vocalization.

APPENDIX D

DESCRIPTIVE STATISTICS FOR COORDINATED BOUTS

Table D1: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Coordinated Communicative Behaviors for the Low Risk (LR) Group

	Age														
	8 (n = 30)			10 (n = 30)			12 (n = 29)			14 (n = 30)			18 (n = 29)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Frequency															
Coordinated Bouts	2.45	3.23	14.78	4.93	5.26	22.80	2.72	2.81	12.40	8.95	5.73	22.83	13.12	7.73	34.03
P. of Bouts	0.17	0.16	0.65	0.24	0.13	0.55	0.13	0.09	0.31	0.29	0.15	0.62	0.28	0.11	0.44
No. of Behaviors	2.04	0.08	0.25	2.08	0.12	0.54	2.03	0.17	0.83	2.18	0.14	0.47	2.06	0.39	2.23
2 Behavior Bouts	5.60	7.00	32.00	10.87	11.62	46.00	5.90	6.07	26.00	18.03	11.91	45.00	27.21	16.30	72.00
3 Behavior Bouts	0.50	1.20	5.00	1.30	2.25	11.00	0.62	0.94	4.00	4.00	3.38	12.00	5.21	3.77	14.00
4 Behavior Bouts	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.19	1.00	0.30	0.60	2.00	0.31	0.81	3.00
Diversity	1.80	1.40	6.00	3.70	2.76	13.00	3.14	1.98	8.00	7.27	3.63	12.00	10.17	4.93	19.00
Form															
Eye Contact	2.25	2.92	11.98	4.55	4.74	19.60	1.99	2.42	8.80	7.40	5.04	22.03	9.11	6.48	27.22
Smiles	0.87	1.91	9.59	1.28	1.99	7.53	0.30	0.72	3.20	3.06	3.55	14.40	2.93	3.47	14.74
NWVs	1.76	2.04	7.20	3.23	3.58	15.20	2.30	2.65	11.60	5.63	3.88	16.82	8.17	4.10	14.81
Gestures	0.11	0.30	1.20	1.22	1.67	7.20	1.02	0.90	4.80	3.10	2.44	7.61	6.53	5.39	25.21
Words	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.18	0.80	0.36	0.65	2.80	1.63	2.73	11.43
Function of Gestures															
Joint Attention	0.04	0.12	0.40	0.72	1.15	4.82	0.74	0.57	2.00	1.95	2.07	6.41	3.78	3.46	13.21
Behavior Request	0.07	0.24	1.20	0.20	0.31	1.50	0.30	0.59	2.80	0.88	0.99	3.93	1.72	1.91	10.01
Social Interaction	0.00	0.00	0.00	0.07	0.23	1.18	0.01	0.07	0.40	0.15	0.31	1.20	0.48	1.08	4.43
Bout Types															
Social Smiles	0.54	1.10	5.19	1.04	1.61	5.95	0.18	0.42	1.60	1.85	2.53	10.40	1.78	2.65	10.36
Directed Voc	1.69	2.02	7.20	2.57	2.79	10.03	1.48	2.07	7.60	3.58	2.57	12.82	3.87	2.58	8.73
Gesture + EC/S	0.04	0.16	0.80	0.56	0.85	3.61	0.14	0.25	0.80	0.95	1.10	3.60	1.39	2.57	13.21
Word + EC/S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.60	2.80	0.79	1.23	4.00
Gesture + NWV/W	0.07	0.21	0.80	0.66	1.20	6.00	0.88	0.89	4.40	2.16	1.83	6.00	5.15	3.64	12.55

Note. P. = Proportion; No. = Mean Number; Diversity = Number of different types of Coordinated Bouts; Voc = Vocalization; EC = Eye Contact; S = Smile; NWV = Non-word vocalization; W = Word.

Table D2: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Coordinated Communicative Behaviors for the High Risk-No Diagnosis (HR-ND) Group

	Age														
	8 (n = 27)			10 (n = 27)			12 (n = 28)			14 (n = 28)			18 (n = 28)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Frequency															
Coordinated Bouts	3.58	4.72	22.92	8.87	7.05	22.71	4.37	4.05	13.17	10.97	8.94	39.95	8.39	7.49	28.32
P. of Bouts	0.25	0.23	1.00	0.33	0.21	0.72	0.15	0.12	0.45	0.28	0.13	0.51	0.21	0.12	0.49
No. of Behaviors	2.01	0.46	2.67	2.15	0.15	0.50	2.11	0.15	0.62	2.17	0.15	0.64	2.08	0.11	0.50
2 Behavior Bouts	6.93	8.57	42.00	18.52	14.79	53.00	9.25	8.42	29.00	22.18	17.88	82.00	18.32	16.29	67.00
3 Behavior Bouts	0.93	1.54	5.00	3.44	3.93	12.00	1.46	2.03	7.00	5.11	5.40	21.00	2.46	3.25	13.00
4 Behavior Bouts	0.07	0.27	1.00	0.30	0.61	2.00	0.04	0.19	1.00	0.14	0.59	3.00	0.07	0.26	1.00
Diversity	2.00	1.30	5.00	4.59	2.65	9.00	3.57	2.79	12.00	7.57	5.21	25.00	7.57	4.52	19.00
Form															
Eye Contact	3.47	4.34	20.43	8.43	6.73	22.71	3.81	3.69	12.38	8.84	6.62	27.96	4.49	4.42	15.16
Smiles	1.64	3.10	14.95	3.78	4.65	21.51	1.20	2.11	7.98	2.59	3.40	15.98	1.74	2.44	8.37
NWVs	2.32	2.65	9.97	5.77	4.94	18.00	3.01	2.68	8.43	7.87	6.45	29.20	4.74	4.80	20.80
Gestures	0.12	0.22	0.80	1.17	1.72	7.60	1.17	1.70	6.40	3.89	4.40	17.20	4.78	5.43	23.60
Words	0.00	0.00	0.00	0.04	0.17	0.80	0.10	0.28	1.20	0.55	1.78	9.19	1.91	2.58	11.97
Function of Gestures															
Joint Attention	0.06	0.15	0.45	0.68	1.37	5.60	0.76	1.21	4.00	2.28	2.93	11.60	2.84	3.77	17.20
Behavior Request	0.06	0.14	0.40	0.18	0.32	1.20	0.39	0.75	3.60	1.01	1.47	5.60	1.54	2.34	10.37
Social Interaction	0.02	0.08	0.41	0.13	0.48	2.40	0.03	0.15	0.80	0.34	0.79	3.60	0.10	0.28	1.20
Bout Types															
Social Smiles	1.14	2.18	10.47	2.57	3.87	19.92	0.83	1.53	5.99	1.48	2.06	8.79	1.11	1.74	6.38
Directed Voc	2.23	2.56	9.97	4.95	4.33	14.40	2.22	2.11	8.03	5.06	3.83	12.40	1.74	1.68	6.40
Gesture + EC/S	0.03	0.11	0.45	0.33	0.50	1.60	0.37	0.73	3.20	0.80	1.07	4.38	0.47	0.98	4.00
Word + EC/S	0.00	0.00	0.00	0.03	0.15	0.80	0.09	0.25	1.20	0.27	0.89	4.39	0.60	0.87	3.99
Gesture + NWV/W	0.09	0.20	0.80	0.84	1.54	6.80	0.80	1.31	4.80	3.09	4.05	17.20	4.31	4.79	19.60

Note. P. = Proportion; No. = Mean Number; Diversity = Number of different types of Coordinated Bouts; Voc = Vocalization; EC = Eye Contact; S = Smile; NWV = Non-word vocalization; W = Word.

Table D3: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Coordinated Communicative Behaviors for the High Risk-Language Delay (HR-LD) Group

	Age														
	8 (n = 10)			10 (n = 12)			12 (n = 11)			14 (n = 12)			18 (n = 13)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Frequency															
Coordinated Bouts	3.04	2.87	8.99	4.93	3.06	9.64	4.36	4.80	15.51	6.42	5.09	17.88	8.68	7.62	24.15
P. of Bouts	0.24	0.13	0.37	0.26	0.14	0.51	0.12	0.12	0.42	0.26	0.12	0.36	0.22	0.14	0.40
No. of Behaviors	2.13	0.31	1.00	2.04	0.12	0.50	2.02	0.09	0.34	2.12	0.15	0.39	2.02	0.32	1.21
2 Behavior Bouts	6.20	5.35	15.00	11.33	6.92	21.00	10.09	10.31	32.00	13.67	11.28	41.00	18.15	15.52	48.00
3 Behavior Bouts	0.50	0.71	2.00	0.83	1.75	7.00	0.73	2.10	7.00	2.50	3.55	11.00	3.38	3.80	13.00
4 Behavior Bouts	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.30	1.00	0.00	0.00	0.00	0.08	0.28	1.00
Diversity	2.00	1.05	3.00	2.42	1.31	4.00	3.09	2.77	9.00	4.00	2.22	8.00	6.23	4.09	12.00
Form															
Eye Contact	2.96	2.83	8.99	4.69	3.10	9.64	3.96	4.54	15.13	5.72	4.48	15.89	6.54	6.29	19.41
Smiles	0.61	0.82	2.50	1.59	2.00	5.10	2.27	2.99	8.92	2.05	2.37	8.25	3.69	4.49	12.67
NWVs	2.57	2.46	7.11	3.50	2.49	7.98	2.16	2.48	8.14	4.86	4.09	14.30	5.24	5.06	15.05
Gestures	0.12	0.27	0.80	0.41	0.83	2.98	0.39	0.60	1.94	0.92	1.03	3.18	2.51	2.94	10.79
Words	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.47	1.20
Function of Gestures															
Joint Attention	0.08	0.25	0.80	0.26	0.57	1.99	0.18	0.27	0.80	0.50	0.63	1.59	1.35	2.03	7.59
Behavior Request	0.08	0.25	0.80	0.12	0.30	0.99	0.07	0.16	0.40	0.36	0.49	1.59	0.98	1.43	4.75
Social Interaction	0.00	0.00	0.00	0.03	0.12	0.40	0.00	0.00	0.00	0.03	0.11	0.39	0.24	0.47	1.60
Bout Types															
Social Smiles	0.43	0.63	1.88	1.29	1.67	4.39	1.73	2.20	6.21	0.99	0.86	2.36	2.38	3.29	7.96
Directed Voc	2.45	2.48	7.51	3.22	2.49	7.98	1.94	2.11	6.98	4.24	3.61	12.32	3.31	3.32	11.88
Gesture + EC/S	0.00	0.00	0.00	0.13	0.20	0.40	0.18	0.27	0.78	0.30	0.49	1.20	0.27	0.46	1.56
Word + EC/S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.19	0.40
Gesture + NWV/W	0.12	0.27	0.80	0.28	0.86	2.98	0.21	0.41	1.16	0.63	0.86	2.73	2.24	2.90	10.79

Note. P. = Proportion; No. = Mean Number; Diversity = Number of different types of Coordinated Bouts; Voc = Vocalization; EC = Eye Contact; S = Smile; NWV = Non-word vocalization; W = Word.

Table D4: Mean Rate (per 10 minutes), Standard Deviations, and Ranges of Coordinated Communicative Behaviors for the High Risk-Autism Spectrum Disorder (HR-ASD) Group

	Age														
	8 (n = 7)			10 (n = 9)			12 (n = 9)			14 (n = 9)			18 (n = 9)		
	M	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*	*M*	*SD*	*Range*
Frequency															
Coordinated Bouts	2.23	2.67	8.01	5.43	5.74	15.99	3.54	3.62	10.80	4.50	4.82	15.15	3.53	4.11	12.26
P. of Bouts	0.19	0.20	0.63	0.31	0.27	0.67	0.15	0.13	0.37	0.26	0.20	0.53	0.19	0.14	0.37
No. of Behaviors	2.17	0.26	0.67	2.11	0.12	0.25	2.15	0.17	0.50	2.08	0.07	0.18	2.14	0.33	1.00
2 Behavior Bouts	4.71	5.77	17.00	11.56	11.47	32.00	7.67	7.57	22.00	10.11	10.39	32.00	8.00	9.06	28.00
3 Behavior Bouts	0.86	1.21	3.00	2.00	3.20	8.00	1.22	1.72	5.00	1.22	1.64	5.00	0.89	1.54	4.00
4 Behavior Bouts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.33	1.00	0.00	0.00	0.00
Diversity	2.00	1.00	3.00	2.44	1.24	4.00	2.78	2.49	7.00	3.67	2.06	6.00	4.00	3.64	11.00
Form															
Eye Contact	2.23	2.67	8.01	5.30	5.73	15.99	3.45	3.49	10.40	4.19	4.84	14.75	2.74	3.60	11.47
Smiles	1.14	1.34	4.01	1.92	2.79	7.59	1.33	1.38	3.58	1.65	1.89	5.18	1.50	2.32	6.77
NWVs	1.37	1.80	5.21	3.65	4.24	11.59	2.17	2.25	7.20	2.85	3.00	9.97	1.41	1.78	5.14
Gestures	0.06	0.15	0.40	0.67	0.91	2.39	0.58	1.12	3.20	0.79	1.01	3.19	1.19	1.95	6.33
Words	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.18	0.40
Function of Gestures															
Joint Attention	0.06	0.15	0.40	0.31	0.66	2.00	0.27	0.66	2.00	0.13	0.40	1.20	0.44	0.89	2.77
Behavior Request	0.00	0.00	0.00	0.04	0.13	0.40	0.13	0.28	0.80	0.22	0.21	0.40	0.44	0.42	1.19
Social Interaction	0.00	0.00	0.00	0.27	0.80	2.39	0.18	0.41	1.20	0.31	0.93	2.79	0.35	0.73	1.99
Bout Types															
Social Smiles	0.80	0.98	2.80	1.12	1.56	4.40	1.02	1.17	3.18	1.08	1.32	3.34	0.79	1.14	2.77
Directed Voc	1.37	1.80	5.21	3.51	4.33	11.59	1.90	1.70	5.20	2.54	2.84	9.17	1.06	1.27	3.20
Gesture + EC/S	0.06	0.15	0.40	0.53	0.75	2.00	0.31	0.52	1.20	0.48	0.79	2.39	0.75	1.39	4.35
Word + EC/S	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gesture + NWV/W	0.00	0.00	0.00	0.13	0.28	0.80	0.27	0.66	2.00	0.31	0.33	0.80	0.44	0.64	1.98

Note. P. = Proportion; No. = Mean Number; Diversity = Number of different types of Coordinated Bouts; Voc = Vocalization; EC = Eye Contact; S = Smile; NWV = Non-word vocalization; W = Word.

APPENDIX E

COORDINATED BOUT TYPES PRODUCED BY THE ASD SAMPLE

Table E1: Number of Each of the Various Developmentally Prior Coordinated Bout Types Produced by Each of the ASD Infants

	Social Smiles	Directed Vocalizations	
SN	EC + S	NWV + EC	NWV + EC + S
8 months			
19521	1	1	0
19576	1	1	0
17438	0	4	1
36575	0	4	1
36578	2	1	0
36579	7	10	3
24909	1	0	2
16694	0	0	0
10 months			
12417	3	2	0
19521	0	2	0
19576	0	2	0
17438	6	7	0
36575	6	7	0
36578	5	18	7
36579	11	21	8
24909	0	2	0
16694	0	0	0
12 months			
12417	4	5	2
19521	1	6	1
19576	1	6	1
17438	1	0	1
36575	1	0	1
36578	0	0	0
36579	0	3	0
24909	0	0	0
16694	8	6	1
14 months			
12417	5	5	2
19521	0	2	0
19576	0	2	0
17438	0	1	0
36575	0	1	0
36578	3	8	1
36579	0	2	0

Table E1 continued

	Social Smiles	Directed Vocalizations	
SN	EC + S	NWV + EC	NWV + EC + S
24909	0	0	0
16694	9	9	1
18 months			
12417	0	0	0
19521	0	0	0
19576	0	0	0
17438	6	1	2
36575	6	1	2
36578	0	0	0
36579	0	2	0
24909	1	8	0
16694	4	1	0

Note. S = Smile; EC = Eye Contact; NWV = Non-word Vocalization

Table E2: Number of Each of the Various Developmentally Advanced Coordinated Bout Types for Each of the ASD Infants

	Gesture + EC/S							Gesture + VOC					
	RC + S	RC + EC	RC + S + EC	REACH + S	REACH + EC	GIVE + EC	SHOW + EC	RC + W + EC	RC + NWV + EC	REACH + NWV	REACH + NWV + EC	GIVE + NWV	GIVE + NWV + EC
8 months													
19521	0	0	0	0	0	0	0	0	0	0	0	0	0
19576	0	0	0	0	0	0	0	0	0	0	0	0	0
17438	0	0	0	0	0	0	0	0	0	0	0	0	0
36575	0	0	0	0	0	0	0	0	0	0	0	0	0
36578	0	0	0	0	0	0	0	0	0	0	0	0	0
36579	0	0	0	0	0	0	0	0	0	0	0	0	0
24909	0	0	0	0	0	0	0	0	0	0	0	0	0
16694	0	0	0	0	0	0	0	0	0	0	0	0	0
10 months													
12417	0	1	0	0	0	0	0	0	0	0	0	0	0
19521	0	0	0	0	0	0	1	0	0	0	1	0	0
19576	0	0	0	0	0	0	1	0	0	0	1	0	0
17438	0	0	0	0	0	0	0	0	0	0	0	0	0
36575	0	0	0	0	0	0	0	0	0	0	0	0	0
36578	0	0	0	0	0	0	5	0	0	0	0	0	0
36579	0	0	0	0	0	0	0	0	0	0	0	0	0
24909	0	4	0	0	0	0	0	0	2	0	0	0	0
16694	0	0	0	0	0	0	0	0	0	0	0	0	0
12 months													
12417	0	1	0	0	0	2	0	0	0	0	0	0	1
19521	0	0	0	0	1	0	0	0	0	0	0	0	0
19576	0	0	0	0	1	0	0	0	0	0	0	0	0
17438	0	0	0	0	0	0	0	0	0	0	0	0	0
36575	0	0	0	0	0	0	0	0	0	0	0	0	0

Table E2 continued

	Gesture + EC/S							Gesture + VOC					
	RC + S	RC + EC	RC + S + EC	REACH + S	REACH + EC	GIVE + EC	SHOW + EC	RC + W + EC	RC + NWV + EC	REACH + NWV	REACH + NWV + EC	GIVE + NWV	GIVE + NWV + EC
36578	0	0	0	0	0	0	0	0	0	0	0	0	0
36579	0	0	0	0	0	0	0	0	0	0	0	0	0
24909	0	0	0	0	0	0	0	0	0	0	0	0	0
16694	0	0	0	0	0	0	0	0	0	0	0	0	0
14 months													
12417	0	0	0	0	0	2	0	0	0	0	0	0	0
19521	0	0	0	0	0	0	0	0	0	0	0	0	0
19576	0	0	0	0	0	0	0	0	0	0	0	0	0
17438	0	0	0	0	0	0	0	0	0	0	0	1	0
36575	0	0	0	0	0	0	0	0	0	0	0	1	0
36578	0	0	0	0	0	0	0	0	0	0	0	0	0
36579	0	0	0	0	0	0	0	0	0	1	0	0	0
24909	0	0	0	0	0	0	0	0	0	0	0	1	0
16694	0	1	0	0	1	0	0	0	1	0	0	0	0
18 months													
12417	0	0	0	0	0	0	0	0	0	0	0	1	0
19521	0	0	0	0	2	0	0	0	0	0	0	0	0
19576	0	0	0	0	2	0	0	0	0	0	0	0	0
17438	4	0	1	1	0	0	0	0	0	0	0	0	0
36575	4	0	1	1	0	0	0	0	0	0	0	0	0
36578	0	0	0	0	0	0	0	1	0	0	0	0	0
36579	0	0	0	0	0	0	0	0	0	0	0	0	0
24909	0	0	0	0	0	1	0	0	0	1	0	0	0
16694	0	0	0	0	1	0	0	0	0	0	0	0	0

Note. RC = Representational Conventional; S = Smile; EC = Eye Contact; VOC = Vocal Utterance (NWV and Words); NWV = Non-word Vocalization

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