Gesture as a Predictor of Language Development in Infants at High Risk for Autism Spectrum Disorders

by

Rachel K. Sandercock

Submitted to the Faculty of

the Kenneth P. Dietrich School of Arts and Sciences in partial fulfillment

of the requirements for the degree of

Bachelor of Philosophy

University of Pittsburgh

2013

UNIVERSITY OF PITTSBURGH

The Kenneth P. Dietrich School of Arts and Sciences

This thesis was presented

by

Rachel K. Sandercock

It was defended on

April 10, 2013

and approved by

Celia A. Brownell, Ph.D., Professor, Department of Psychology

Jennifer Ganger, Ph.D., Visiting Faculty, Department of Psychology

Robert H. Wozniak, Ph.D., Professor, Department of Psychology, Bryn Mawr College

Thesis Director: Jana M. Iverson, Ph.D., Professor, Department of Psychology

Gesture as a Predictor of Language Development in Infants at High Risk for Autism Spectrum Disorders

Rachel K. Sandercock

University of Pittsburgh, 2013

In typically developing children, gesture use predates and predicts changes in language. Because language development is often delayed in later-born siblings of children with autism spectrum disorders (ASD) (who are at heightened biological risk for the disorder; heightened risk infants: HR), even those who are not eventually diagnosed with ASD, gesture may be one of the earliest indicators of later delays. To examine the pattern of gesture use and language development in HR infants, gesture referents for HR infants and low risk (LR) comparison infants were coded at 14 and 18 month home visits. HR infants who went on to receive either a language delay (LD) or ASD diagnosis exhibited less frequent gesture use and used gesture to indicate a smaller variety of referents than their typically developing peers at both 14 and 18 months. In comparison to LR infants, HR infants who went on to receive LD or ASD diagnoses also exhibited smaller increases in gesture use from 14 to 18 months. While there was a significant positive correlation between gesture frequency at 14 months and vocabulary size at 18 months for the HR group, HR infants that received eventual LD or ASD diagnoses converted a smaller proportion of gesture referents to words in later vocabulary than did LR infants. Taken together, these results suggest that early gesture use and its relationship to later language development differentiates HR infants who receive later LD or ASD diagnoses from typically developing infants, indicating that gesture may have the potential to be used as marker of language delays prior to the onset of speech.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

This thesis project was supported in part by the University of Pittsburgh Honors College through a 2012 Brackenridge Summer Research Fellowship awarded to the author. This research was also supported by grants from the National Institute of Health (R01 HD41607 and R01 HD054979) to Jana M. Iverson.

This project would not have been possible without a number of people. First and foremost, I would like to express my deepest gratitude to my thesis director, Dr. Jana Iverson, for her constant support over the past two years. Your unwavering belief in me and my ability to complete this project, even when my own was severely lacking, means so much to me. You have contributed immeasurably to my personal and intellectual growth, and I am eternally grateful for the opportunities your mentorship has provided.

Additionally, I would like to thank the members of my committee—Drs. Celia Brownell, Jennifer Ganger, and Robert Wozniak—for their dedication to this project. Your invaluable feedback and thought-provoking questions challenged me to take my work to a higher level.

I owe huge thanks to all the members of the Infant Communication Lab for their assistance and encouragement, and for being the best cheering section I could possibly ask for. Special thanks to Dr. Eve Sauer LeBarton for playing a vital role in developing and implementing this project, and for making time to do all of the reliability coding with me.

Thanks also to Kaitlin Schuessler for her help in accessing and organizing all of the needed video data, and to Nina Leezenbaum for generously offering guidance throughout my research.

I would also like to extend a sincere thank you to all the infants and their families without whose enthusiastic participation this research could not have been completed.

Finally, to my family and friends, thank you for your unequivocal love and support, and for always being there to remind me that there is life outside of the lab.

1.0 INTRODUCTION

Before they are able to speak, children often rely on gestures as their primary means of communication. Gestures can be categorized as either deictic or representational/conventional. Deictic gestures, which make up approximately 88% of the gestural repertoire in infants and young toddlers (Crais, Watson, & Baranek, 2009), indicate objects or events in the immediate environment. These include giving (e.g., the child hands a toy to his mother), requesting (e.g., the child extends his arm and hand, opening and closing the palm, to indicate that he wants the toy his mother is holding), showing (e.g., the child holds up a toy in his mother's potential line of sight), and pointing (e.g., the child extends his index finger toward a toy). Representational/conventional gestures, which typically emerge later, have a form and meaning that is either culturally defined (e.g., shaking one's head to mean "no") or defined in the context of particular caregiver-child interactions (e.g., holding a fist to one's ear to mean "telephone," e.g., Iverson & Goldin-Meadow, 2005).

In typically developing (TD) infants, patterns of early gesture use predict subsequent changes in language development (Iverson & Goldin-Meadow, 2005). The question to be addressed in this research is whether a similar pattern of development is apparent in infants at heightened genetic risk for Autism Spectrum Disorders (ASD). Because gesture is so tightly linked to language development, its use is also a potential index of language delay, indicating that it may be valuable as a diagnostic marker before other delays are visible. For example, gesture delay in children with pre- or perinatal brain lesions predicts later delays in language (Sauer, Levine, & Goldin-Meadow, 2010). Similarly, gesture in children at risk for ASD may provide a very early index of a child's communicative development, allowing for equally early intervention to improve language and communication outcomes. By examining pre-linguistic communication and the emergence of language in high risk children, we may be able to better predict language delay, and, in turn, help to identify ASD earlier in development.

1.1 GESTURE AND LANGUAGE DEVELOPMENT IN TD INFANTS

Gesture, speech, and language are closely related, both neurologically and developmentally (Iverson & Thelen, 1999). In TD infants, gesture generally emerges in predictable ways, with showing, giving, and pointing beginning at approximately 10 months of age (Bates, 1976). Before language emerges, gestures serve as a child's primary means to communicate intentionality and desire, and to represent objects and people in the environment. This stage of communication provides a foundation for the emergence of language development. Because gestures typically develop spontaneously and in tandem with early words, the use of early gestures is strongly associated with vocabulary comprehension and production after the first year of life (Mitchell et al., 2006).

Gesture also plays a major role in the emergence of syntax and the acquisition of lexical items. Iverson and Goldin-Meadow (2005) proposed that changes in gesture should not only predate but also predict changes in language. They tested this hypothesis by closely examining how gesture production corresponds to lexical and syntactic development in the early stages of language development. Focusing on gestures and speech observed at monthly intervals in typically developing children between the ages of 10 and 24 months, they found that referents observed initially in children's gestural repertoire subsequently appeared in their spoken word vocabularies soon after. For example, if a child pointed to a ball at 14 months, the word "ball" was highly likely to appear in his vocabulary at 18 months. This finding indicates that gesture does, in fact, play a role in early language development and can be used to predict development. Gesture may help new meanings enter children's communicative repertoires by allowing them to be practiced, thus laying the foundation for the eventual appearance of these meanings in speech.

There is also a significant relationship between single-gesture and gesture-word (i.e., crossmodal) utterances and vocal production in infants observed at 16 and 20 months old. Using both gestures and gesture-word combinations is an important facet of the transition to two-word speech, and the number of gesture-word and two-word combinations increased significantly from one age point to the next (Capirci et al., 1996). Moreover, there is a strong correlation (Spearman r_s = .94) between the age at which children produce their first supplementary gesture-speech combinations (pointing at a dog while saying "run") and the age at which they start producing two-word utterances ("dog run"; Iverson & Goldin-Meadow, 2005). There is also a strong relationship between changes in the types of gesture-word combinations children produce and the changes in their speech patterns that follow (Özçalişkan & Goldin-Meadow, 2005). For example, children produced gesture-speech combinations with two arguments ("mommy" + pointing at a chair) and combinations with an argument and a predicate ("touch" + pointing at a dog) before beginning to produce the same constructions in speech ("mommy chair;" "touch doggie").

1.2 GESTURE AND DELAYS IN LANGUAGE DEVELOPMENT

Gesture use is decreased and generally much less communicative in children with developmental disabilities and delays, and amount of pre-linguistic communication is highly predictive of their later communication abilities (Crais, Watson, & Baranek, 2009). This pattern is especially evident among children with ASD, which is defined in part by impairments in communication (American Psychiatric Association, 2000). In many cases, individuals with ASD never develop sufficient speech abilities for day-to-day communication (Landa, 2007). Early indicators of language delay and impairment often appear during the first year of life and can include diminished responsiveness, delayed onset of babbling, and lack of or unusual gesture use (Landa, 2007). Continuing into the second and third years of life, children with ASD also exhibit less frequent and less diverse use of babbling, words, word combinations, and integration of gesture and speech than TD children (Landa, 2007). They are less likely to use gesture to request or indicate objects in their environment, or to initiate joint attention (Johnson & Myers, 2007). Furthermore, children with ASD may also have difficulty developing symbols into language (Tager-Flusberg & Caronna, 2007).

One of the most pressing needs in ASD research is further exploration of early identification, not only of ASD itself, but of related developmental delays as well. Though many parents of children with ASD report symptoms as early as 16 months, most children do not receive a definitive diagnosis until the age of four years or older (Siegel et al., 1988). The goal is not to diagnose ASD as early as possible, but rather to accurately and reliably predict a later diagnosis. Early identification opens the window for early intervention, which has been shown to improve outcomes for those with ASD (Mundy & Crowson, 1997).

Focusing on later-born infant siblings of children with ASD offers the greatest opportunity to study early indicators of ASD and other developmental delays, specifically language delay. These infants are at heightened biological risk for the disorder (heightened risk infants: HR), with a recurrence rate of approximately 18.7% (Ozonoff et al., 2011). However, recent research indicates that HR infants are also at risk for other developmental delays (see Rogers, 2009, for a review). Thus, for example, a large proportion of HR infants exhibit delayed onset of early developmental milestones and delayed language development at 18 months; these delays were even apparent among infants who did not receive an ASD diagnosis (Iverson & Wozniak, 2007). Yirmiya et al. (2006) found that the average developmental language age of HR infants was significantly lower than that of their low risk counterparts (i.e., infants with no known genetic risk of ASD: LR). HR infants also tend to score lower in receptive and expressive language abilities (Ozonoff, Rogers, & Sigman, 2005), and parents report significantly fewer words and phrases understood (Stone et al., 2007). More recently, Winder et al. (in press) found that HR infants produced lower rates of spontaneous communicative non-word vocalizations, showing and pointing gestures, and combinations of vocalizations and gestures.

While early delays in communicative development are evident among many HR infants, they appear to be most severe in infants who ultimately receive a diagnosis of ASD. Mitchell et al. (2006) reported that HR infants who went on to receive an ASD diagnosis understood fewer phrases at both 12 and 18 months, and understood and produced significantly fewer words at 18 months than low risk infants or HR infants who did not go on to receive a diagnosis. They observe that, because understanding and production of words did not differentiate the ASD group until 18 months, gesture may be a better indicator of later diagnosis for HR infants before 18 months. Examining gesture as a precursor to language development in later-born siblings of children with ASD is therefore one way to increase the likelihood of predicting language delay prior to the emergence of language.

Focusing on this area of communication will also help to elucidate the relationship between language and gesture in early vocabulary development in HR infants. As indicated by Iverson and Goldin-Meadow (2005), gesture predates and predicts changes in language in TD children because it provides an opportunity for children to communicate meanings that they are not yet able to express verbally; referring to these meanings through gesture may facilitate language learning. By expanding on this research to focus on HR infants, it is possible to explore whether or not the process of language development in these children mirrors that of TD children. Furthermore, understanding how gesture not only predicts but also shapes language as a whole has implications for treatment, where encouraging gesture usage may have the potential to increase and improve language development.

1.3 PRESENT STUDY

The evidence reviewed above suggests that gesture may be one of the earliest means of insight into later language abilities for TD infants and infants at risk for language and communication delays and difficulties. The present study expands upon Iverson and Goldin-Meadow's (2005) research, examining gesture as a predictor of language development in infants at heightened risk for ASD. Two primary questions will be addressed. First, how does gesture use by HR infants compare to that of infants with no family history of ASD (Low Risk; LR infants)? I predict that HR infants will produce significantly fewer gestures and gesture to a significantly smaller variety of referents than their LR counterparts. Second, will the gesture referents produced by HR infants relate to words that appear in their vocabularies soon after, in line with the pattern of development identified by Iverson and Goldin-Meadow (2005) amongst TD infants? Based on the patterns evidenced by typically developing children, I expect to see an equally strong relationship between gesture and vocabulary development in HR infants.

2.0 METHOD

2.1 PARTICIPANTS

Two groups of infants participated in this research. The first group consisted of 46 infants at heightened genetic risk for ASD (HR infants) based on having at least one older sibling with a diagnosis (e.g., Ozonoff et al., 2011). This group was subsequently divided into three subgroups based on diagnostic outcome status at 36 months (see below): those that received no diagnosis (HR-ND), those that received a language delay diagnosis (HR-LD), and those that received an autism spectrum disorder diagnosis (HR-ASD). The HR sample as a whole was 88% European-American, 10% Hispanic-American, and 2% Asian-American. Thirty-five percent of the mothers had some graduate or professional school experience, 61% had some college or a college degree, and 4% completed high school only. Parental occupations were identified to provide a general index of social class. Because 46% of the mothers were stay-at-home moms, Nakao-Treas occupational prestige scores (Nakao & Treas, 1994) were calculated only for the fathers' occupations. The mean prestige score was 60.10 (*SD* = 14.99), and generally fell within the managerial/professional range.

The second group consisted of 28 infants (13 males) with no family history of ASD. Ninety-three percent of the infants were European-American, and 7% were Asian-American. Fifty-three percent of the mothers had some graduate or professional school experience, 43% had some college or a college degree, and 3% completed high school only. The mean Nakao-Treas occupational prestige score for fathers was 57.79 (*SD* = 12), again generally falling in the managerial/professional range (33% of the mothers were stay-at-home moms).

2.2 MEASURES

2.2.1 MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 2002)

Parents of HR and LR infants were asked to complete the CDI at each visit, beginning at 8 months. The CDI is a highly reliable and well-validated measure, designed to inventory parent-reported information on the course of language and communication development in infants and toddlers.

From 8 to 14 months, parents completed the Words and Gestures form of the CDI (CDI-WG; Fenson et al., 2007). This form consists of a 396-item vocabulary checklist, in which parents are asked to indicate words that their child a) only understands and b) words that their child both says and understands, and a checklist of early gestures and actions performed by the child.

At 18 months, parents of LR infants completed the Words and Sentences form of the CDI (CDI-WS; Fenson et al., 2007). The CDI-WS consists of a 680-word vocabulary checklist, in which parents indicate what words their child says, as well as a section on children's use of English morphology and syntax. Parents of HR infants completed the CDI-WG if the child was producing relatively few words and had no two-word combinations at 18 months. They completed the CDI-WS only if the child had a significant productive vocabulary and some word combinations.

At 36 months, parents completed the CDI-III, which is designed for children aged 30-37 months (Fenson et al., 2007). This form 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.

2.2.2 Autism Diagnostic Schedule-Generic (ADOS-G; Lord et al., 2000)

The ADOS-G was administered to all HR infants at 36 months as part of a formal diagnostic assessment. The ADOS is a structured play schedule designed to elicit behaviors indicative of ASD, and includes systematic probes for symptoms in social interaction, communication, play, and repetitive behavior (Lord et al., 2000). Using standardized administration and scoring, it reliably distinguishes children with ASD from TD children and children with other non-ASD developmental disorders (Lord et al., 2000).

2.2.3 Mullen Scales of Early Learning (MSEL; Mullen, 1995)

The MSEL was administered to all HR infants at the 18, 24, and 36 month outcome visits. It provides a comprehensive measure of general cognitive functioning across five subscales: Visual Reception, Receptive Language, Expressive Language, Fine Motor, and Gross Motor (Mullen, 1995).

2.3 DIAGNOSTIC OUTCOME GROUPS

Final diagnostic outcome was assessed for HR infants at the 36-month follow-up visit using the Autism Diagnostic Outcome Schedule-Generic (Lord, et al., 2000) and data from the Mullen Scales of Early Learning Mullen, 1995) the CDI (Fenson et al., 2002).

HR infants were classified into one of three diagnostic outcome categories: a) *ASD (HR-ASD),* b) *Language Delay without ASD (HR-LD),* and c) *No Diagnosis (HR-ND).* Though LR infants did not undergo a formal evaluation process to confirm typical development, no developmental concerns were noted by parents or research staff.

2.3.1 ASD

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

Seven HR infants received a diagnosis of ASD; of these infants, 3 received AD diagnoses (2 males) and 4 received Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS; 2 males).

2.3.2 Language Delay without ASD

HR infants were assigned to the HR-LD subgroup if they met one of the following criteria and *did not* receive a diagnosis of ASD (many of the children classified with ASD also exhibited language delay):

1) Standardized scores on the CDI-WS 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, and 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 deviations below the mean at 36 months (e.g., Landa & Garrett-Mayer, 2006; Ozonoff et al., 2010).

Using these criteria, 7 infants (3 males) were classified as HR-LD.

2.3.3 No Diagnosis

The remaining 32 HR infants (13 males) did not meet any of the above criteria for ASD or LD (HR-ND).

2.4 PROCEDURE

HR and LR infants were videotaped at home with a primary caregiver as part of larger longitudinal studies carried out by the University of Pittsburgh Infant Communication Lab. Home visits for HR infants occurred monthly from 5 to 14 months of age, with follow-up visits at 18, 24, and 36 months. Home visits for LR infants occurred bimonthly from 2 to 19 months of age. The present study focuses on data from the home visits at 14 and 18 months. These ages were selected because children's gesture use typically begins between 9 and 12 months (Bates, 1976).

The entire home visit lasted approximately 30-45 minutes. While they were being filmed, infants wore a cloth vest holding a wireless microphone at shoulder level for enhanced audio recording. The present study coded only the video data collected during the naturalistic and play sections of home visits, which lasted 25 minutes in total for each infant at all age points. The naturalistic section of filming consisted of 15 minutes of unstructured observation. Caregivers were asked to go about their normal routine, and infants were observed in contexts and activities typical to the time of day in which the visit occurred. The second section of filming consisted of 10 minutes of free play and social interaction between the infant and caregiver. The same fixed order of observational contexts was employed for all infants at all sessions.

2.5 CODING

2.5.1 Gestures

Communicative gestures were coded throughout the entire home visit. Gestures were coded if 1) the infant made a clear effort to direct the caregiver's attention, 2) the gesture was not a direct manipulation of a person or object, and 3) the gesture was not part of a ritual (e.g., blowing a kiss) or a game (e.g., patty cake).

Gestures were categorized as either deictic or representational/conventional. Deictic gestures include giving, requesting, showing, and pointing. Because they often have meanings and forms that are culturally defined, representational/conventional gestures consistently indicate specific referents, though in some cases these meanings may be defined by a particular context (Iverson & Goldin-Meadow, 2005; Parladé, 2012).

2.5.2 Gesture Referents

Gesture referents were coded by a primary coder (the author) who was blind to both infant group membership and diagnostic outcome status (see Appendix A for the full coding manual). For deictic gestures, the referent was coded as the object indicated or held up by the hand. For example, if a child pointed to a ball on the floor or holds up a ball to show his mother, the referent would be "ball." The referents of representational/conventional gestures are the related culturally defined meanings, such as a nod to mean "yes," or representative of another meaning in context, such flapping one's arms to mean "bird" (Iverson & Goldin-Meadow, 2005). The counts of total gesture types and tokens of each kind (deictic vs. representational/conventional) were calculated for each child at both age points. *Gesture types* refers to the number of unique gesture referents a child produced, whereas *gesture tokens* refers to the total number of communicative gestures produced. For example, if a child pointed to a dog three times, "dog" was counted as three tokens, but as only one type.

The referents of all identified deictic and representational/conventional gestures were coded at both 14 and 18 months. One difficulty in this type of coding stems from the potential ambiguity of some gestures. For example, if a child points to a picture of a cat in a book, is the intended meaning the cat, the book, or even the color of the cat? Confounds were avoided by adhering to a strict coding scheme, consistently glossing meaning at the most basic level (for instance, "car") and noting sub- and superordinate ("vehicle" vs. "Honda") information as needed (see Appendix A).

2.5.3 Reliability

In order to assess reliability, 27 of the observation videos were chosen at random (18%) and independently coded by the author and another trained coder, blind to one another's codes. I was blind to both infant group membership and outcome classification; the second coder had some knowledge of both factors. Prior to commencing data coding for the current study, I was trained to at least 80% agreement on all criteria. Reliability meetings were held regularly to prevent drift and to allow for estimation of reliabilities. Disagreements were resolved by joint viewing of the clips and discussion. Reliability analyses reflect the original codes. Agreement between coders was 90.30% for identifying gesture referents (n = 412).

3.0 RESULTS

The primary purpose of this research was to investigate the relationship between gesture production and language development in HR infants. Data analyses focused on two main questions: First, how does gesture use differ between HR-ND, HR-LD, and HR-ASD infants and compare to that of LR infants at 14 and 18 months of age? Second, how do the number and referents of infants' gestures at 14 months relate to their overall and specific vocabulary development at 18 months, and does this relationship vary in relation to outcome status? I begin by examining *between-group* differences in variety and frequency of gesture production at 14 and 18 months respectively. This is followed by *within-group* analyses of developmental change in gesture variety and frequency from 14 to 18 months. Finally, I present data on relationships between measures of gesture production at 14 months and CDI word vocabulary at 18 months.

All of the analyses reported below were conducted using IBM Statistical Package for Social Sciences (IBM SPSS, version 21.0). Inspection of the distributions indicated significant skewing and substantial individual variability, especially among the HR infants. Therefore, I utilized nonparametric statistics (Siegel & Castellan, 1988) and present medians and average deviations as measures of central tendency and variability. Nine infants (2 LR, 1 HR-ND, 4 HR-LD, and 2 HR-ASD) were administered the CDI-WG in place of the CDI-WS at 18 months Three infants (1 LR and 1 HR-ND) were excluded from analyses involving the 18 month CDI because the measure was not administered for them at that age point.

3.1 GESTURE AT 14 MONTHS

Table 1 presents the median numbers of gesture types and tokens for each of the four outcome groups at 14 months. These data indicate that infants in all 3 of the HR subgroups gestured to a smaller variety of referents than their LR counterparts. A Kruskal-Wallis one-way analysis of variance confirmed this difference (χ^2 (3, N = 74) = 10.90, p = .012). Follow-up Mann-Whitney U tests showed that both the HR-LD group (U = 44.50, p = .026) and the HR-ASD group (U = 32.50, p = .007) produced significantly fewer gesture types than the LR group. The HR-ND group did not differ significantly from either the HR-LD or HR-ASD group, or from the LR group. The HR-LD and HR-ASD groups also did not differ significantly from one another.

With regard to gesture tokens, the data in Table 1 show that infants across the HR groups produced fewer gesture tokens than did LR infants. A Kruskal-Wallis test revealed that this difference was significant (χ^2 (3, N = 74) = 9.50, p = .023), and subsequent Mann-Whitney U tests revealed that the HR-LD group (U = 39.5, p = .016) and the HR-ASD group (U = 41.00, p = .018) both produced significantly fewer gesture tokens overall than the LR group. None of the other comparisons were statistically significant.

3.1.1 Deictic Gestures

Table 1 also presents data on deictic gesture type and token production at 14 months. Production of deictic gesture types (Points, Shows, Reaches, Gives, and Index Touches) differed significantly between outcome groups at 14 months (Kruskal-Wallace test, χ^2 (3, N = 74) = 12.59, p = .006). Follow-up Mann-Whitney U tests indicated that the HR-ASD group produced significantly fewer deictic gesture types than both the LR (U = 26.50, p = .003) and the HR-ND groups (U = 46.00, p = .014). There were no significant differences between any other groups.

As is evident in Table 1, groups also differed significantly on deictic gesture token production, with LR infants producing the most and HR-ASD infants producing the least (χ^2 (3, N = 74) = 9.50, p = .023). Both the HR-LD (U = 50.00, p = .047) and the HR-ASD groups (U = 28.50, p = .007) produced significantly fewer deictic gesture tokens than the LR group. The HR-ASD group also produced significantly fewer deictic gesture tokens at 14 months than the HR-ND group (U = 43.00, p = .011). No other comparisons were statistically significant.

3.1.2 Representational/Conventional Gestures

As can be seen in Table 1, the median numbers of representational/conventional gestures produced by each outcome group at 14 months were very similar and did not differ statistically.

3.2 GESTURE AT 18 MONTHS

Table 2 presents the median numbers of gesture types and tokens for each outcome group at 18 months. With regard to overall gesture types, the data in Table 2 show a pattern similar to that seen at 14 months, with the LR group producing the most and HR-ASD producing the least. A Kruskal-Wallis test indicated that the median number of total gesture types differed significantly between outcome groups (χ^2 (3, N = 74) = 17.22, p = .001). Examining the data in the table, it is evident that the groups that received diagnoses (HR-LD and HR-ASD) produced fewer gesture types than those that did not. These differences were confirmed by Mann-Whitney U tests: both the HR-LD group (U = 30.50, p = .005) and the HR-ASD group (U = 19.50, p = .001) produced significantly fewer gesture types than the LR group, and the HR-ASD group produced significantly fewer gesture types than the HR-ND group (U = 40.50, p = .009). The LR group did not differ significantly from the HR-ND group, nor did the HR-LD group differ significantly from the HR-ASD group. There was also not a significant difference between the HR-ND and HR-LD groups.

In line with the patterns seen at 14 months, there were also significant differences between the numbers of gesture tokens produced by each group (χ^2 (3, N = 74) = 13.62, p = .003), as can be seen in Table 2. Both the HR-LD group (U = 38.50, p = .014) and the HR-ASD group (U = 23.00, p = .002) continued to produce significantly fewer gesture tokens overall than the LR group. The HR-ASD group also produced significantly fewer gesture tokens at 18 months than the HR-ND group (U = 53.00, p = .030). As at 14 months, there were no other significant differences between groups.

3.2.1 Deictic Gestures

Table 2 displays the median number of deictic gesture types produced by each group, once again indicating that the groups without diagnoses produced more than those with either LD or ASD outcomes. A Kruskal-Wallis test confirmed the existence of these differences (χ^2 (3, N = 74) = 19.32, p = .000). The HR-LD group (U = 29.00, p = .004) and the HR-ASD group (U = 16.00, p = .001) produced significantly fewer deictic gesture types at 18 months than the LR group. The HR-LD group (U = 57.00, p = .042) and the HR-ASD group (U = 27.00, p = .002) also produced significantly fewer deictic gesture types at 18 months than the HR-ND group. There were no significant differences between the HR-LD and HR-ASD groups, or between the LR and HR-ND groups.

There were also significant differences in the number of deictic gesture tokens produced by each outcome group (χ^2 (3, N = 74) = 13.62, p = .003), as seen in Table 2. As at 14 months, the HR-LD (U = 43.50, p = .024) and HR-ASD (U = 23.00, p = .000) groups both produced significantly fewer gesture tokens than the LR group. The HR-ASD group also produced significantly fewer deictic gesture tokens than the HR-ND group (U = 26.00, p = .002). No other comparisons indicated significant differences.

3.2.2 Representational/Conventional Gestures

The data in Table 2 indicate that, as at 14 months, there were no significant differences between any groups in production of representational/conventional gesture types. Unlike at 14 months, however, there were differences in the median number of representational/conventional gesture tokens produced by the 4 groups, and these were statistically significant (χ^2 (3, N = 74) = 8.15, p = .043). Follow-up Mann-Whitney U tests indicated that the HR-LD group produced significantly fewer representational/conventional gesture tokens at 18 months than the LR group (U = 48.00, p = .031). There were no other significant differences between groups.

3.3 CHANGE IN GESTURE FROM 14 TO 18 MONTHS

Comparison of the data presented in Tables 1 and 2 suggests that only the LR group showed a developmental increase in gesture production from 14 to 18 months. To examine within-group changes from 14 months to 18 months on production of gesture types and tokens, I used the Wilcoxon Rank Sum test. These analyses revealed that for only the LR group, total gesture types, deictic gesture tokens, and total gesture tokens increased significantly from 14 to 18 months (T = 290.50, p = .015; T = 249.50, p = .019; T = 273.00, p = .043). Across all other groups, medians for gesture types and tokens either increased slightly, though not significantly, or were very similar.

3.4 RELATIONS BETWEEN GESTURE AT 14 MONTHS AND WORD VOCABULARY AT 18 MONTHS

Data on the median number of words produced by infants in each outcome group as reported by parents on the CDI at 18 months are presented in Table 3. As is evident in the table, the HR-LD and HR-ASD groups were very similar, with smaller median numbers of words than either the LR or HR-ND group. A Kruskal-Wallis test indicated that this difference was, in fact, significant (χ^2 (3, N = 74) = 21.17, p = .000). Follow-up Mann-Whitney U tests revealed that both the HR-LD (U = 9.50, p = .000) and HR-ASD (U = 10.5, p = .000) groups had significantly fewer words reported than the LR group. In addition, the word vocabularies of both the HR-LD group (U = 35.50, p = .004) and the HR-ASD group (U = 40.50, p = .010) were significantly smaller than that of the HR-ND group. Neither the LR and HR-ND groups nor the HR-LD and HR-ASD groups, respectively, differed significantly from one another.

In light of these differences in word vocabulary size at 18 months, I next explored whether they were related to overall measures of gesture at 14 months. First, I calculated Spearman correlations to examine the relationship between the numbers of gesture types and tokens produced at 14 months with the number of words produced as reported on the 18 month CDI. The correlations for the full sample as well as for the LR and overall HR group are presented in Table 4. Table 5 displays correlations computed separately for each of the three subgroups of HR infants. Scatterplots of these data are presented in Appendix B.

As can be seen in Table 4, there were significant weak positive correlations for both the number of gesture types and tokens produced by the sample as a whole at 14 months with the number of words appearing in vocabulary at 18 months. There were also slightly weaker but still significant positive correlations between the number of gesture types and tokens produced by the HR group as a whole at 14 months with the number of words appearing in vocabulary at 18 months. The LR group showed essentially no correlation between either gesture types or tokens at 14 months and 18 month vocabulary.

As is evident in Table 5, there were no significant correlations between either the number of gesture types or tokens produced at 14 months and the number of words appearing in vocabulary at 18 months among the HR subgroups. For the HR-ND group, both correlations were weak but positive. The HR-ASD group showed relatively strong, though still not significant, positive correlations on gesture types and tokens with 18 month vocabulary size. Though not statistically significant, it should also be noted that for the HR-LD group, both of these correlations were negative, distinguishing it from the remaining two HR subgroups.

Next, I focused on the developmental relationship between gestures and word vocabulary at the level of specific meanings. Do gesture referents produced at 14 months appear as words in infants' vocabularies at 18 months, and does this relationship vary in relation to outcome status? To address this question, for each gesture referent produced by each individual child at 14 months, I located the corresponding word on the 18 month CDI. In some cases, a given gesture referent did not have a corresponding word on the CDI. Overall, 64.97% of 14 month gesture referents were represented on the 18 month CDI (range = 0% - 100% across individual children). For each child, I then calculated the percentage of gesture referents at 14 months that were converted to words on the CDI at 18 months ("Gesture-Word Conversion") by dividing the number of 14 month gesture types that became words by the total number of 14 month gesture referents available as words on the 18 month CDI. These data are presented in Table 3.

As is apparent in the table, there was a clear difference between the LR and HR-ND groups versus the HR-LD and HR-ASD groups. A Kruskal-Wallis test confirmed this difference (χ^2 (3, N = 7) = 12.26, *p* = .007), and follow-up Mann-Whitney *U* tests demonstrated that both the HR-LD group (*U* = 42.50, *p* = .028) and the HR-ASD group (*U* = 21.00, *p* = .001) achieved significantly lower gesture-word conversion percentages than the LR group. The HR-ASD group also converted proportionately fewer gesture referents to words than the HR-ND group (*U* = 45.5, *p* = .010).

Results of these analyses suggest that for the two HR subgroups with language and communication delays (HR-LD and HR-ASD), relatively fewer 14 month gesture referents later appeared in children's word vocabularies. It is unclear, however, whether this difference may be related to the previously reported finding that infants in both of these groups had significantly fewer gesture types and produced fewer gestures than both of the LR and HR-ND groups. To examine this possibility, I created two subgroups of LR and HR children (irrespective of diagnostic outcome): one in which LR and HR children were individually matched on number of total gesture types (within 2 types) produced at 14 months (LR n = 17; HR n = 17 (HR-ND n = 15; HR-LD n = 1; HR-ASD n = 1)), and the other (LR n = 15; HR n = 15 (HR-ND n = 12; HR-LD n = 0; HR-ASD n = 3)) matched on number of total gesture tokens (within 2 tokens) produced at 14 months. I then compared LR and HR subgroups on the total number of words produced on the 18 month CDI and percentage of gesture-word conversion using Mann-Whitney *U* tests. These data are presented in Tables 6 and 7.

Though the data in Table 6 indicate that the HR group converted proportionately fewer gestures to words and produced a smaller median number of words on the 18 month CDI than LR infants matched on number of numbers of gesture types, these differences were not statistically significant. Due to high variability in production of gesture tokens in the sample as a whole, the LR and HR subgroups were not identical on median number of gesture tokens produced, as shown in Table 7, because fewer exact matches could be found than for the subgroups matched on gesture types, thus requiring more infants to be matched within 2 tokens. Despite this difference, there were once again no significant differences on either variable between the LR and HR groups matched on gesture tokens.

4.0 DISCUSSION

The primary purpose of this research was to explore the role of gesture in language development for infants at heightened genetic risk for autism spectrum disorders. For this purpose, infants were observed during everyday activities in their homes at 14 and 18 months. The present study had major findings in three primary areas. First, there were significant differences in the variety and frequency of gesture use between the outcome groups. Second, the pattern of developmental change for the LR group from 14 to 18 months was markedly different than that of HR infants, regardless of diagnostic outcome. Finally, the relationship between gesture production and general language development, as well as the relationship between gesture referents and the specific words that appeared in vocabulary varied noticeably between groups. Each of these findings will be discussed in turn.

4.1 GESTURE PRODUCTION

As expected, infants who received a later LD or ASD diagnosis used gesture to indicate a smaller variety of referents at both 14 and 18 months than their typically developing peers (LR and HR-ND). In line with past research revealing that gesture use is generally less diverse in children who go on to receive diagnoses of developmental delays (Landa, 2007), infants in the HR-LD and HR-ASD groups produced significantly fewer gesture types at 14 months than infants in the LR group, and significantly fewer gesture types than both the LR and HR-ND groups at 18 months.

A large body of research has also indicated that gesture use overall is markedly decreased in infants who go on to have developmental delays and disabilities (e.g. Crais, Watson, & Baranek, 2009; Johnson & Myers, 2007). As with gesture type, HR-LD and HR-ASD infants produced significantly fewer gesture tokens at 14 months than did LR infants, and the HR-ASD group produced significantly fewer gesture tokens than both typically developing groups at 18 months.

While the aforementioned differences were also apparent among deictic gestures specifically, there were no differences in production of representational/conventional gestures between groups until 18 months. This lack of difference is largely due to the fact that there were very few representational/conventional gestures produced by any of the groups at 14 months, supporting the observation that these types of gestures tend to emerge later (Iverson & Goldin-Meadow, 2005). At 18 months, the only significant difference was between the HR-LD and LR groups, with the HR-LD group producing significantly fewer representational/conventional gesture tokens than the latter. This suggests that, like children with ASD, children with language delays have difficulty converting symbols into language (Tager-Flausberg & Caronna, 2007).

4.2 CHANGE IN GESTURE FROM 14 TO 18 MONTHS

Consistent with a large body of research indicating that HR infants as a whole tend to show slowed and less robust developmental gains than LR infants (e.g. Landa et al., 2007; Landa & Garrett-Mayer, 2006; Lord, Luyster, Guthrie, & Pickles, 2012), only the LR group showed significant increases in gesture production from 14 to 18 months. The LR group increased in production of total gesture types, deictic gesture tokens, and total gesture tokens between the two age points. Though some preliminary findings indicate a possible regression in gesture use after 14 months in infants who later receive ASD diagnoses, the present study did not identify any such pattern; though none of the HR groups increased significantly in gesture type or token production, there were no declines, supporting instead the possibility of a developmental plateau in HR infants' communicative abilities.

4.3 RELATIONS BETWEEN GESTURE AT 14 MONTHS AND WORD VOCABULARY AT 18 MONTHS

The present study found that both the HR-LD and HR-ASD groups produced significantly fewer words on the 18 month CDI than did either group with typically developing outcomes. This difference is consistent with previous work demonstrating that HR infants exhibit delayed language development, even those who do not receive ASD diagnoses (Iverson & Wozniak, 2007). These delays include fewer words and phrases understood (Stone et al., 2007), lower receptive and expressive language abilities (Ozonoff, Rogers, & Sigman, 2005), and a lower average developmental language age than their LR peers (Yirmiya et al., 2006).

Unlike these findings, however, the present study did not identify significant differences between the LR and HR-ND groups. While the HR-LD group displayed less advanced language development than the LR group even without an ASD diagnosis, simply being at heightened genetic risk for ASD did not distinguish infants from the LR group in this facet, as the HR-ND group achieved language outcomes comparable to the LR group. The fact that the HR-ASD group was producing fewer words at 18 months than both the LR and HR-ND groups is consistent with Mitchell et al.'s (2006) report that early communicative delays are most severe among HR infants who go on to receive an ASD diagnosis, with these infants producing and understanding fewer words and phrases at 18 months than HR infants who do not receive later ASD diagnoses. Paralleling the between-group differences seen in gesture production, the findings presented on vocabulary size also support past research showing that gesture is closely linked to later language outcomes (e.g. Iverson & Thelen, 1999; Capirci et al., 1996; Mitchell et al., 2006; Özçalişkan & Goldin-Meadow, 2005).

To look more specifically at how gesture production predicts general language development, I also focused on the relationship between the number of gesture types and tokens produced by each group at 14 months and the number of words produced according to the 18 month CDI. Though there was a significant positive correlation between the number of both gesture types and tokens produced and the number of words produced for the sample as a whole and for the overall HR group, there was essentially no relationship for the LR group. Additionally, in looking at the individual HR outcome groups, while gesture production and vocabulary size were positively correlated for both the HR-ND and HR-ASD groups, the relationship was negative for the HR-LD group. Despite the lack of statistical significance, the clear negative correlation for the HR-LD group is a notable finding.

An interesting question, then, is why this group appears to demonstrate a different relationship between gesture and later word production than the LR and other HR groups. According to Iverson and Braddock (2011), children with language impairments may utilize gestures more frequently than TD peers in order to compensate for lack of expressive language abilities. Though HR-LD infants in the present study did not exhibit more gesture use than the

LR or HR-ND infants, use of gesture as compensatory tool in lieu of spoken language may account for the negative correlation of the two measures. Additionally, Thal and Tobial (1992) observed that truly delayed late talkers used neither symbolic/conventionalized nor non-symbolic gestures in a compensatory manner. Instead, use of communicative gestures paralleled delayed language production and comprehension, lending further support to the current study in which HR-LD infants produced significantly fewer gesture types and tokens, and fewer words than TD peers.

The present study also found that the HR-LD and HR-ASD groups both converted proportionately fewer 14 month gestures referents to words at 18 months than the LR group, and that the HR-ASD group converted significantly fewer gestures to words than either the LR group or the HR-ND group. One primary aim of this research was to compare the relationship found by Iverson and Goldin-Meadow (2005) between gesture and the specific words that appear in later vocabulary for typically developing children to that of HR infants. They found that an average of 50% (*SD* = .12) of words that first appeared in gesture transferred or spread to speech soon after. In the present study, for both the LR and HR-ND groups the median proportions of gesture-word conversion was 33.33%, indicating that gesture referents at 14 months may have predictive power for words that appear in vocabulary 18 months, though predictive power in the current sample was not as strong as that identified by Iverson and Goldin-Meadow (2005). However, this difference may be due in part to variations in methods: while the present study utilized the CDI at a single age point as a measure of language, Iverson and Goldin-Meadow (2005) used words produced during home visits, collapsed across many sessions. In contrast to the TD groups, the median proportions of gesture-word conversion for both the HR-LD and HR-ASD groups was 0.00%. Though it was predicted that HR infants would exhibit an equally strong relationship between gesture referents and words, this was not the case for those that received later diagnoses.

One factor that may help to explain HR-LD and HR-ASD infants' lack of gesture-word conversion is their decreased use of gesture overall in comparison to the groups that achieved typical development. As Iverson & Goldin-Meadow (2005) note, gesture plays a facilitating role in early language development and may serve as a means of practicing new meanings in order to provide a foundation for their appearance in speech. Without producing sufficient gestures to facilitate typical language development later on, these infants who go on to receive diagnoses may then be facing cascading failures in their communicative development. Additionally, infant gesturing allows opportunities for parents to provide verbal translations of the referent. Moments in which infants are focused on a referent for which a parent is providing the corresponding word are crucial to language learning (Tomasello & Farrar, 1986). Fewer gestures mean fewer of these opportunities, and, as a result, fewer words may then appear in infants' vocabulary.

Although comparisons of vocabulary outcomes for LR and HR subgroups matched on numbers of gesture types and tokens yielded no statistically significant results, they still indicated that there is an underlying difference between LR and HR infants. If gesture production is interpreted as a measure of development, then infants matched on these variables should be comparable in vocabulary size and in gesture-word conversation. However, despite the lack of statistical significance, there were stark contrasts between the two groups. The median proportion of gesture-word conversions for the HR subgroup matched on types was 13.33% lower than that of the LR subgroup. This difference was even more apparent among the groups matched on gesture tokens: while the median proportion of gesture-word conversions was

33.33% for the LR subgroup, it was 0.00% for the HR subgroup, indicating that at least half of the infants in the group converted no gesture referents at 14 months to words at 18 months.

In looking at the median numbers of words produced by each of these groups on the 18 month CDI, distinct differences are once again apparent. For the subgroups matched on number of gesture types, the median number of words produced on the CDI by the HR group was 57.57% of the median number produced by the LR group. For the subgroups matched on tokens, the median number of words produced by the HR group was only 46.38% of the LR median. The differences between these subgroups are even more striking in light of the fact that the HR subgroup was largely comprised of infants from the HR-ND group. These findings lend further support to previously mentioned research showing that HR infants are more likely to exhibit delays in development than their LR counterparts, regardless of later diagnostic outcome. Because the infants in these subgroups were matched on levels of communicative development at 14 months, the clear differences in vocabulary at 18 months provide additional evidence for a developmental plateau among HR infants.

4.4 CLINICAL IMPLICATIONS

Taken together, the results reported here, though preliminary in nature, may have implications for developmental screening and may be relevant to identifying early factors associated with ASD. As the TD groups (LR and HR-ND) were significantly distinct across variables from those that went on to receive diagnoses, the results imply that differences in gesture use may provide considerable insight into predicting developmental outcomes. It is important to note, however, that although the LR and HR-ND groups did not differ significantly from one another on any variable, there was a striking amount of variability at the individual level for infants in the HR-ND group, as mirrored in a large body of past research (e.g. Iverson & Wozniak, 2007). In a clinical setting then, an individual HR infant may display patterns of gesture use comparable to that of infants who go on to receive diagnoses, but still go on to achieve typical development. Consequently, more research is needed in order to better distinguish low-gesturing HR-ND infants from those who will go on to receive LD or ASD diagnoses.

There were also no significant differences between the HR-LD and HR-ASD groups across any variable. This indicates that decreased gesture production and variety may not be specific to ASD, at least at the ages studied here, once again necessitating further research to distinguish these HR subgroups from one another. However, these factors can still be indicative of general risk status, thus allowing for early intervention, particularly since gestures may be one of the earliest means of observing atypical development prior to the emergence of speech (Mitchell et al., 2006). Keeping in mind that HR infant siblings are at heightened risk not only for ASD, but for language delay and other developmental disorders as well (Yirmiya et al,. 2006), tracking abnormalities in infant gesture can be a useful way to screen for these disorders in addition to ASD before other indicators become evident. As gestures are frequently occurring and can be easily recognized by observers, they are an ideal candidate for inclusion in screening for language delays and, with further research, for ASD as well.

Table 1. Descriptive statistics for gesture types and gesture tokens at 14 months

	14 Months							
	LR (n = 28)		HR-ND (n = 32)		HR-LD (n = 7)		HR-ASD (n = 7)	
	Median (AD)	Range	Median (AD)	Range	Median (AD)	Range	Median (AD)	Range
Total Types	5.5 (3.00)	0:11	4 (4.47)	0:27	2 (1.31)	1:7	1 (1.10)	0:4
Deictic Types	4.5 (2.79)	0:11	2 (3.15)	0:19	2 (1.31)	1:7	0 (1.14)	0:4
Representational Types	.5 (.79)	0:3	0 (.82)	0:3	0 (0.00)	0:0	0 (.82)	0:3
Total Tokens	11 (7.64)	0:24	5.5 (9.5)	0:52	2 (1.43)	1:8	2 (2.90)	1:11
Deictic Tokens	8.5 (6.95)	0:22	4.5 (8.36)	0:42	2 (1.43)	1:8	1 (1.39)	0:6
Representational Tokens	.5 (1.78)	0:12	0 (1.75)	0:12	0 (0.00)	0:0	0 (2.61)	0:11

Table 2. Descriptive statistics for gesture types and gesture tokens at 18 months

	18 Months							
	LR (n = 28)		HR-ND (n = 32)		HR-LD (n = 7)		HR-ASD (n = 7)	
	Median (AD)	Range	Median (AD)	Range	Median (AD)	Range	Median (AD)	Range
Total Types	7.5 (4.94)	0:29	5 (3.50)	0:19	3 (1.59)	0:6	2 (1.18)	1:4
Deictic Types	7 (4.72)	0:27	5 (3.23)	0:16	2 (1.35)	0:6	1 (.98)	0:4
Representational Types	1 (.81)	0:3	0 (.81)	0:3	0 (1.02)	0:4	1 (.86)	0:3
Total Tokens	16 (13.5)	70:91	9 (11.12)	0:63	5 (4.82)	0:16	4 (2.29)	1:8
Deictic Tokens	14.5 (11.90)	0:87	8.5 (10.58)	0:63	4 (4.78)	0:16	1 (1.80)	0:8
Representational Tokens	2 (2.61)	0:12	0 (1.41)	0:9	0 (.41)	0:4	2 (1.63)	0:5

Table 3. Descriptive statistics for number of words produced on the 18 months CDI and gesture-word conversion from 14 to 18 months

	LR (n = 28)		HR-ND (n = 32)		HR-LD (n = 7)		HR-ASD (n = 7)	
	Median (AD)	Range	Median (AD)	Range	Median (AD)	Range	Median (AD)	Range
CDI Words Produced	63 (70.51)	17:354	42 (64.39)	0:347	16 (8.08)	2:24	17 (5.63)	3:21
Gesture-Word Conversion (%)	33.33 (28.67)	0:100	33.33 (34.12)	0:100	0.00 (24.49)	0:100	0.00 (0.00)	0:0

Table 4. Spearman correlations between the number of gesture types/tokens produced at 14 months and the total number of words produced on the 18 month CDI

	Number of Words Produced on 18 Month CDI		
	Overall (n = 71)	LR (n = 26)	HR (n = 45)
Total Types	.399**	-.003	.371*
Total Tokens	.384**	.081	.372*

*p < .05; **p < .01

Table 5. Spearman correlations between the number of gesture types/tokens produced at 14 months and the total number of words produced on the 18 month CDI for HR subgroups

	Number of Words Produced on 18 Month CDI		
	HR-ND (n = 31)	HR-LD (n = 7)	HR-ASD (n = 7)
Total Types	.325	-.319	.692
Total Tokens	.284	-.318	.510

Table 6. Descriptive statistics for the LR and HR subgroups matched on number of gesture types at 14 months

	LR (n = 17)		HR (n = 17)	
	Median (AD)	Range	Median (AD)	Range
Total Types	4.00 (2.14)	0:10	4.00 (2.14)	0:10
Gesture-Word Conversions (%)	33.33 (29.14)	0:100	20.00 (30.55)	0:100
CDI Words Produced	69.00 (69.88)	17:354	40.00 (75.10)	0:347

Table 7. Descriptive statistics for LR and HR subgroups matched on number of gesture tokens at 14 months

	LR (n = 15)		HR (n = 15)	
	Median (AD)	Range	Median (AD)	Range
Total Tokens	6.00 (1.77)	0:7	5.00 (1.62)	0:7
Gesture-Word Conversions (%)	33.33 (30.54)	0:100	00.00 (28.17)	0:100
CDI Words Produced	69.00 (53.73)	17:354	32.00 (57.51)	0:328

APPENDIX A

GESTURE MEANINGS: CODING CRITERIA

CG =Child Gesture

Gesture Meanings below are represented in all CAPS for clarity. Meanings should be entered normally when actually coding.

General Rule: Be **conservative**; attribute as little as possible to glosses.

A. Gestures Meanings for Particular Gestures:

1. Deictic Gestures: C**oncrete noun** meanings. The meaning is the referent of the gesture

For **Give** and **Show** gestures the referent is the object in the child's hand. For **Point** and **Reach** gestures, the referent is the object that the child is pointing/reaching to.

a) Gloss the noun

-The gloss should be one word (see exceptions below) and should not contain modifiers.

Examples, point to a [blue ball] = BALL

point to [child's ear] = EAR

point to [toy fork] = FORK

-If a modifier is meaningful given the context, include it in parentheses after the noun.

Example, point to a [blue ball] = BALL (BLUE)

-In general we gloss at the basic level. However, it is possible that in a given context a superordinate or subordinate level gloss is more appropriate—this happens infrequently, though. In general, avoid using superordinate level categories.

Examples, point to [a car] = CAR (*not* VEHICLE)

point to [a train] = TRAIN (*not* VEHICLE)

point to [a circle] = CIRCLE (*not* SHAPE)

-In general, objects are coded as a whole. BUT, is a specific part of an object is being clearly identified, code that part with the whole as a modifier.

Examples, point to [the nose of a teddy bear] = NOSE (BEAR)

point to [the door of the barn] = DOOR (BARN)

-For shape sorter blocks, code the name of the shape with "block" as the modifier.

Example, point to a [diamond-shaped block] = DIAMOND (BLOCK)

-For pictures on paper, photographs and books, the referent is the pictured object (*not* the object on which the picture appears).

Example, point to [butterfly drawing on a page] = BUTTERFLY

-Sometimes a referent is a picture that appears on another object that could also be the referent. In this case, gloss the pictured object, but note in parentheses the object on which it appears.

Examples, point to [apple on a puzzle] = APPLE (ON PUZZLE)

point to [bird sticker on side of barn] = BIRD (ON BARN)

NOTE: If the picture is on a puzzle piece that the child is manipulating or referring to individually (i.e. separate from the puzzle), code just the picture

Example, point to a giraffe-shaped puzzle piece with a picture of a giraffe on it = GIRAFFE

b) Proper Nouns (PN):

-People: Avoid coding a person's proper name as the meaning. Instead use a general term.

Examples, point to [mom whose name is Jane] = MOM
point to [brother whose name is John] = BROTHER
point to [researcher, recording tech, etc.] = EXPERIMENTER
point to [child you are coding] = CHILD

-Characters: Code a well-known cartoon or popular toy character as the proper name for that character.

Example, point to [Elmo] = ELMO

-Unknown characters: Sometimes children will be playing with a toy doll or toy man without a conventionalized popular character name. In this case, gloss the meaning as the object.

Example, point to [toy girl who is in barn set] = GIRL

-If there is a specific name that the family has assigned to that character it can be placed in parentheses after the name of the object.

Example, point to [doll family has been calling Missy] = DOLL (MISSY)

-Conventionalized Food & Toys: Gloss a brand name of a food as the name of that food if it is conventionalized.

Examples, point to a [cheerio] = CHEERIO
point to a [lego building block] = LEGO

-Unconventionalized Food & Toys: If you do not know the exact kind of a food or toy or it is not conventionalized, gloss as the noun label for that food or toy.

Examples, point to a [nonspecific square block] = BLOCK
point to a [Pepperidge Farm cookie] = COOKIE

-If you think the proper name for a toy or food may be meaningful in the context, you can gloss that proper name in parentheses after the name of the object.

Examples, point to a [Pepperidge Farm cookie] = COOKIE (Pepperidge Farm)

c) <u>Special Cases:</u>

- When the referent is a picture in a *book*, enter "in book" after the referent

Example, point to apple in a book = APPLE IN BOOK

point to picture in book that is unclear on video = UNCLEAR IN BOOK

-When a referent is an object inside another object, enter "in *object name*" after the referent.

Example, point to cheerios in a bowl = CHEERIOS IN BOWL

-When a referent is visible through something transparent, code the object inside, not the transparent object

Examples, point to an elephant inside a clear block = ELEPHANT
point through window = OUTSIDE

-Because the meaning of a **deictic gesture** is the noun that is the referent of the gesture, locations are not glossed. Even if the context suggests that the child intends to convey a direction, still enter the meaning as the object to which the point is directed.

Examples, point [*up* toward ceiling] = CEILING
point [to a location on rug where toys should be placed] = RUG

- Each gesture gets only one meaning gloss (see above). However, for compound words or words produced as one lexical item, both words can be entered as the meaning.

Examples, “teddy bear”, “video camera”, “napkin holder”

2. Representational Gestures:

-For **Conventional** gestures, this is the culturally agreed upon definition of the word (see Conventional Cheat Sheet). If a conventional gesture does not appear on the sheet, use the family’s conventionalized meaning—there should be a 1:1 mapping between the family meaning and the form.

-For **Representational Other**, the meaning is the thing, movement, attribute, etc. conveyed by that gesture. Context will help determine the meaning of the gesture. Avoid lengthy descriptions (e.g. THE BLUE BIRD THAT WAS ALREADY FLYING IN THE AIR WHEN THEY LOOKED OUTSIDE). However, include all information that you think the child is conveying.

Example, Child flaps arms up and down like a bird = BIRD

-If the context suggests that the child is meaning to convey “flying”, include this with the gloss

Example, Child flaps arms up and down like a bird = BIRD FLYING

B. Unclear Meanings. Use *context* (e.g. conversational, objects in environment, etc.) to determine meaning. However, avoid relying entirely on parent or child speech—you should have some evidence independent of the speech as well. If the meaning of the gesture is unclear, sometimes it can be inferred from the overall context of the video or from watching earlier or later portions of the video. For instance, the referent may be obscured from view on the video, but one minute later the camera angle may change and you can now see the referent. In this case, use the new information on the identity of the referent as the meaning. In addition, we have the toys for structured parent-child toy play segments (e.g. bag of toys, teddy bear set, barn set). If a referent is unclear, you can look at the toys (in the bag packing room) to help determine the referent's identity.

-However, sometimes despite our best efforts we can't determine the meaning of the gesture. In these cases:

1. When the referent is *not* on the video, enter "OFF CAMERA" as meaning.
2. When the referent is on the video, but it is difficult to determine the specific referent from multiple possibilities, enter "UNCLEAR" at meaning.

Example, Child points to a corner of the room that contains books, a chair, and a coat, but it is not clear from context which of these items is the referent = UNCLEAR

-Exception to rule 2: If there is a superordinate term that describes all of the objects and it is possible the child means the objects as a group, then enter the superordinate term as the meaning.

Example, Child points to a pile of toys = TOYS

Child points to a pile of puzzle pieces = PUZZLE PIECES

Child points to a group of animals = ANIMALS

Conventional (C) Gestures Cheat Sheet		
Form	**Meaning**	Coding Hints & FAQ
Flip	Exclamation Question	Examples of ways to interpret "Question" meaning include "whatever", "All gone", "All done", "Don't know"
Shrug	Don't know	"Don't know" & "doesn't matter" both = "don't know"
Come	Come here Go ahead	
Pick up	Lift C	
Dismiss	Negation	"negation" includes "no" and "go away"
Wave	Greeting	We do not distinguish between "hi" and "bye" waves OR between "greeting" waves and waving for attention
Wait	Slow down Relax	
Naughties	Warning Gotcha	
Shh	Be quiet	
Number	"1", "2", "3", etc	produced with index fingers
Nod	yes	
Shake	No Emphasis	
Sweep	All gone/done	
Tada	Exclamation	Hand up (can be 1 or 2 hands); palm out; may look like a flip
Oh my	Surprise/Exclamation	Hand up; palm out; may look like a flip
Back off	Back off Don't move	
Thumbs up	Good job	
Oh man	Oh man	
Darn it	Darn it	
Pray you	Please	Hand folded in prayer position
Tastes good	Tastes good	Palm in circles on belly
Pick me	Pick me	Hand raise above head, may be waved; "I know" same
Thinking	Thinking	Single finger taps head, cheek, chin, or mouth or is pressed to head and held
Listing	List formation (e.g. listing toys or friends)	Fingers move through sequence of #s during verbal list with or without hand touching each finger
Idea	I know	Finger points upward in sign space or near head; may be accompanied by head tilt. "I know"/ "I Got it"/ "I have an idea"/ "oh" all same

Got it	Ok?	Both hands spread in front of body; palms down or facing inwards; hands press down, often repeatedly; “You Got it?”/ “Get it?”/ “Ok?”/ “You know?” all same
Clapping (pre-24months)	Exclamation	All possible meanings (e.g. “good job”, “yay!”, ”fun”) are entered as “exclamation” as the meaning.
Arms up	So big!	Form similar to “pick up”

<u>Conventional Object Referents</u>

Teddy Bear Set

Object	**Referent Coded**
Towel/cloth	Cloth (blanket)
Teddy Bear	Teddy Bear
Green Teddy Bear Set bag	Bag (TB)

Barn Set

Object	**Referent Coded**
Trough, water-side-up	Trough (water)
Trough, food-side-up	Trough (food)
Fence/wall	Fence
Barn Set bag	Bag (Barn)
Toy man who is a farmer	Farmer
Roof of barn (an immovable piece)	Barn (roof)
Door (a movable piece)	Door (barn)
Silo (separates from barn)	Silo

APPENDIX B

FIGURES

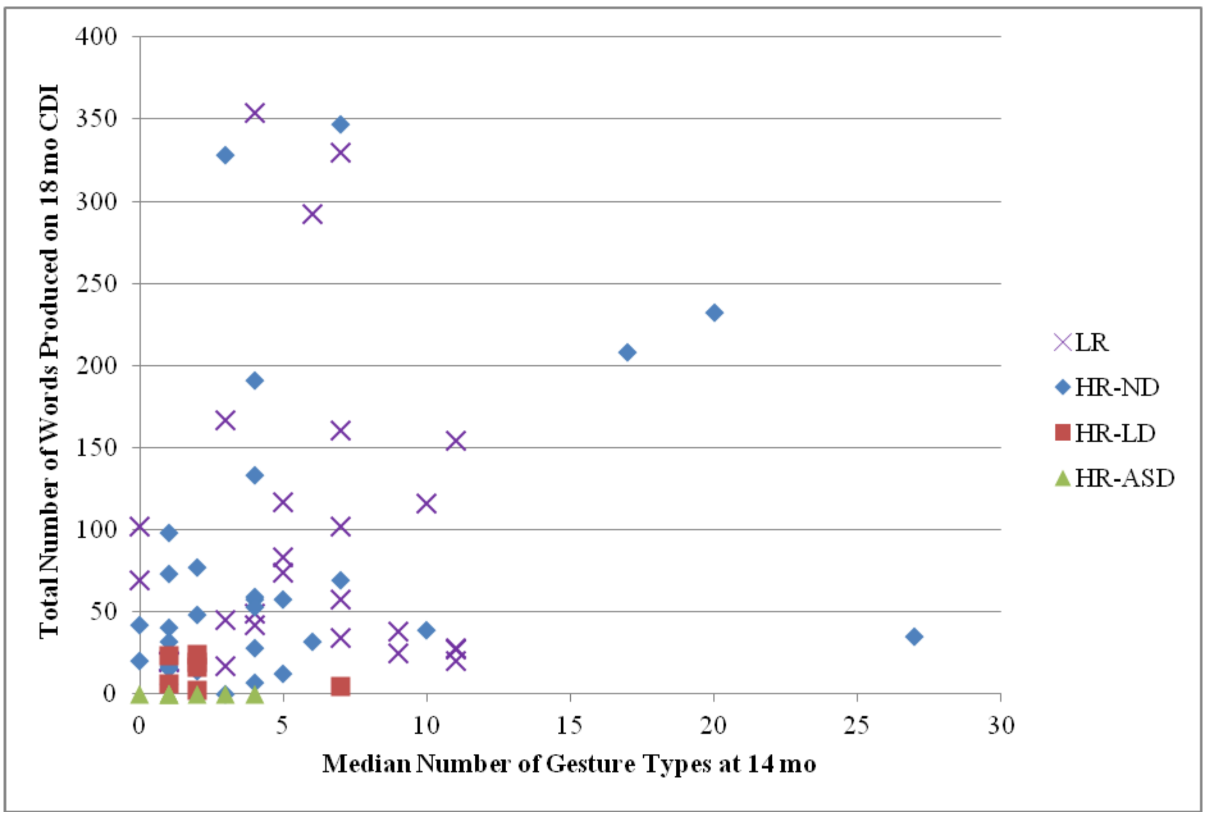

Figure 1. Relationship between the numbers of gesture referent types infants produced at 14 months and the number of words infants produced at 18 months, as reported by parents on the 18 month CDI

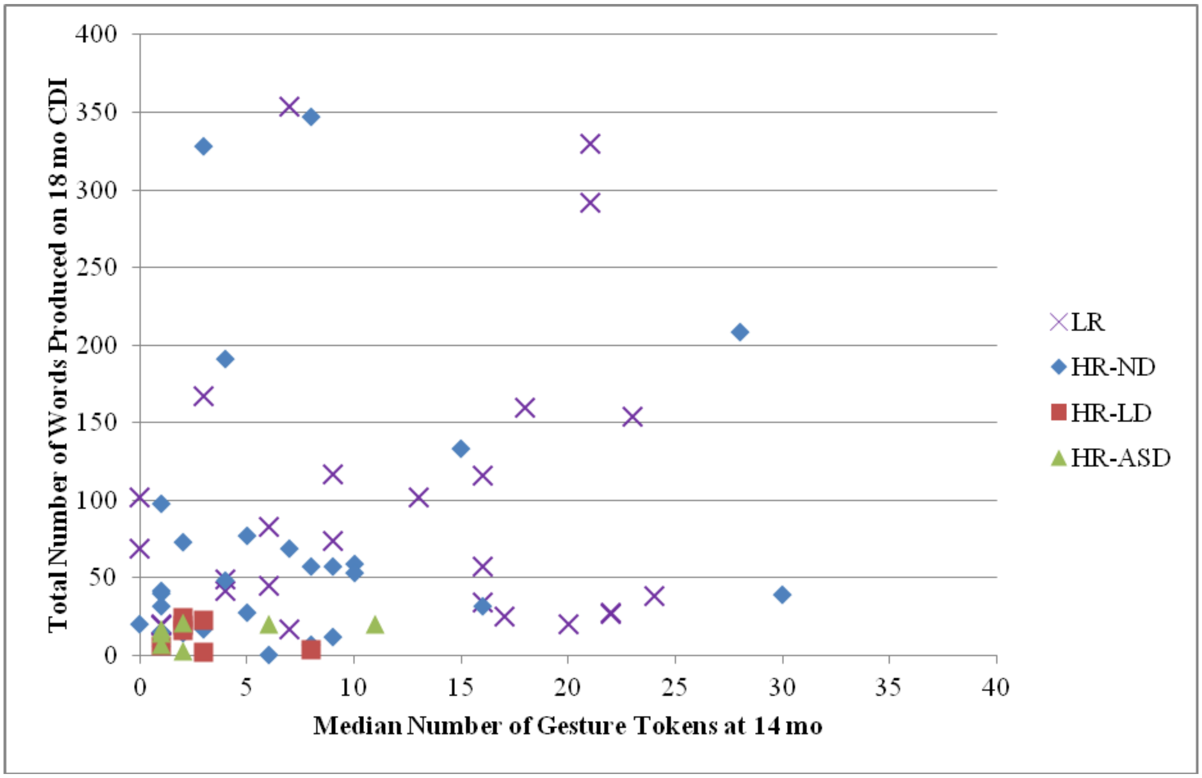

Figure 2. Relationship between the number of gesture referent tokens infants produced at 14 months and the number of words infants produced at 18 months, as reported by parents on the 18 month CDI

BIBLIOGRAPHY

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC.

Bates, E. (1976). *Language and context*. New York: Academic Press.

Braddock, B. A., Farmer, J. E., Deidrick, K. M., Iverson, J. M., & Maria, B. L. (2006). Oromotor and communication findings in joubert syndrome: Further evidence of multisystem apraxia. *Journal of Child Neurology, 21*(2), 160-163. doi:10.1177/08830738060210020501

Capirci, O., Iverson, J. M., Pizzuto, E., & Volterra, V. (1996). Gestures and words during the transition to two-word speech. *Journal of Child Language, 23*(3), 645-673.

Crais, E. R., Watson, L. R., & Baranek, G. T. (2009). Use of gesture development in profiling children's prelinguistic communication skills. *American Journal of Speech-Language Pathology, 18*(1), 95-108. doi:10.1044/1058-0360(2008/07-0041)

Fenson, L., Dale, P., Reznick, J.S., Thal, D., Bates, E., Hartung, J., Pethick, S., & Reilly, J. (2002). *MacArthur-Bates Communicative Development Inventories*. Baltimore: Paul Brookes Publishing Co.

Fenson, L., Marchman, V.A., Thal, D.J., Dale, P.S., Reznick, J.S., & Bates, E. (2007). *The MacArthur-Bates Communicative Development Inventories: User's guide and technical manual* (2nd ed.). Baltimore: Paul Brookes Publishing Co.

Heilmann, J., Weismer, S. E., Evans, J., & Hollar, C. (2005). Utility of the MacArthur-bates communicative development inventory in identifying language abilities of late-talking and typically developing toddlers. *American Journal of Speech-Language Pathology, 14*(1), 40-51. doi:10.1044/1058-0360(2005/006

Gershkoff-Stowe, L., Thal, D., Smith, L, Namy, L. (1997). Categorization and its developmental relation to early language. *Child Development, 68*, 843-859.

Iverson, J. M., & Braddock, B. A. (2011). Gesture and motor skill in relation to language in children with language impairment. *Journal of Speech, Language, and Hearing Research, 54*(1), 72-86. doi:10.1044/1092-4388(2010/08-0197

Iverson, J. M., & Goldin-Meadow, S. (2005). Gesture paves the way for language development. *Psychological Science, 16*(5), 367-371. doi:10.1111/j.0956-7976.2005.01542.x

Iverson, J. M., & Thelen, E. (1999). Hand, mouth and brain: The dynamic emergence of speech and gesture. *Journal of Consciousness Studies, 6*(11-12), 19-40.

Iverson, J.M., & Wozniak, R.H. (2006). Variation in vocal-motor development in infant siblings of children with Autism. *Journal of Autism and Developmental Disorders, 37*, 158-170. doi: 10.1007/s10803-006-0339-z

Johnson, C. P., & Myers, S. M. (2007). Identification and evaluation of children with autism spectrum disorders. *Pediatrics,120*(5), 1183-1215. doi:10.1542/peds.2007-2361

Landa, R. (2007). Early communication development and intervention for children with autism. *Mental Retardation and Developmental Disabilities Research Reviews, 13*(1), 16-25. doi:10.1002/mrdd.20134

Landa, R. J., Holman, K. C., & Garrett-Mayer, E. (2007). Social and communication development in toddlers with early and later diagnosis of autism spectrum disorders. *Archives of General Psychiatry, 64*(7), 853-864. doi:10.1001/archpsyc.64.7.853

Landa, R., & Garrett-Mayer, E. (2006). Development in infants with autism spectrum disorders: A prospective study. *Journal of Child Psychology and Psychiatry, 47*(6), 629-638. doi:10.1111/j.1469-7610.2006.01531.x

Lord, C., Luyster, R., Guthrie, W., & Pickles, A. (2012). Patterns of developmental trajectories in toddlers with autism spectrum disorder. *Journal of Consulting and Clinical Psychology, 80*(3), 477-489. doi:10.1037/a0027214

Lord, C., Risi, S., Lambrecht, L., Cook, E.H., Leventhal, B.L., DiLavore, P.C., et al. (2000). The autism diagnostic observation schedule-generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3), 205-223.

Mitchell, S., Brian, J., Zwaigenbaum, L., Roberts, W., Szatmari, P., Smith, I., & Bryson, S. (2006). Early language and communication development of infants later diagnosed with autism spectrum disorder. *Journal of Developmental and Behavioral Pediatrics, 27*(S2), S69-S78. doi:10.1097/00004703-200604002-00004

Mullen, E.M., (1995). *Mullen Scales of Early Learning* (AGS edn.) Circle Pines, MN: American Guideline Service, Inc.

Mundy, P., & Crowson, M. (1997). Joint attention and early social communication: Implications for research on intervention with autism. *Journal of Autism and Developmental Disorders. Special Issue: Preschool Issues in Autism, 27*(6), 653-676. doi:10.1023/A:1025802832021

Nakao, K., & Treas, J. (1994). Updating occupational prestige and socioeconomic scores: How the new measures measure up. *Sociological Methodology, 24,* 1–72.

Özçalişkan, Ş., & Goldin-Meadow, S. (2005). Gesture is at the cutting edge of early language development. *Cognition,96*(3), B101-B113. doi:10.1016/j.cognition.2005.01.001

Ozonoff, S., Iosif, A., Baguio, F., Cook, I. C., Hill, M. M., Hutman, T., . . . Young, G. S. (2010). A prospective study of the emergence of early behavioral signs of autism. *Journal of the American Academy of Child & Adolescent Psychiatry,49*(3), 256-266. doi:10.1097/00004583-201003000-00009

Ozonoff, S., Rogers, S., & Sigman, M. (2005, April). *Infants at risk of autism: A longitudinal study*. Paper presented at the Biennial Meeting of the Society for Research in Child Development, Atlanta, GA.

Ozonoff, S., Young, G.S., Carter, A., Messinger, D., Yirmiya, N., Zwaigenbaum, L.,…Stone, W.L. (2011). Recurrence risk for Autism spectrum disorders: A baby siblings research consortium study. *Pediatrics, 128 (3)*. doi: 10.1542/peds.2010-2825

Parladé, M.V. (2012). *The development of multimodal social communication in infants at high risk for autism spectrum disorders*. Unpublished doctoral dissertation, University of Pittsburgh.

Robertson, S. B., & Weismer, S. E. (1999). Effects of treatment on linguistic and social skills in toddlers with delayed language development. *Journal of Speech, Language, and Hearing Research, 42*(5), 1234-1248.

Rogers, S. J. (2009). What are infant siblings teaching us about autism in infancy? *Autism Research, 2*(3), 125-137. doi:10.1002/aur.81

Sauer, E., Levine, S. C., & Goldin-Meadow, S. (2010). Early gesture predicts language delay in children with pre- or perinatal brain lesions. *Child Development, 81*(2), 528-539. doi:10.1111/j.1467-8624.2009.01413.x

Siegel, S. & Castellan, N. (1988). *Nonparametric Statistics for the Behavioral Sciences*. New York: Wiley, pp. 237-294.

Siegel, B., Pliner, C., Eschler, J., & Elliott, G. R. (1988). How children with autism are diagnosed: Difficulties in identification of children with multiple developmental delays. *Journal of Developmental and Behavioral Pediatrics, 9*(4), 199-204. doi:10.1097/00004703-198808000-00004

Stone, W. L., McMahon, C. R., Yoder, P. L., & Walden, T. A. (2007). Early social communicative and cognitive development of younger siblings of children with Autism Spectrum Disorders. *Archives of Pediatrics and Adolescent Medicine, 161(4),* 384-390. doi:10.1001/archpedi.161.4.384

Tager-Flusberg, H., Caronna, E. (2007). Language disorders: Autism and other pervasive developmental disorders. *Pediatric Clinics of North America, 54* (3), 469-481.

Thal, D. J., & Tobias, S. (1992). Communicative gestures in children with delayed onset of oral expressive vocabulary. *Journal of Speech & Hearing Research, 35*(6), 1281-1289.

Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Development*, *57*(6), 1454-1463.

Weismer, S. E., & Evans, J. L. (2002). The role of processing limitations in early identification of specific language impairment. *Topics in Language Disorders*, *22*(3), 15-29. doi:10.1097/00011363-200205000-00004

Winder, B.M., Wozniak, R.H., Parladé, M.V., & Iverson, J.M. (in press). Spontaneous initiation of communication in infants at low and heightened risk for autism spectrum disorders. *Developmental Psychology*

Yirmiya, N., Gamliel, I., Pilowsky, T., Feldman, R., Baron-Cohen, S., & Sigman, M. (2006). The development of siblings of children with autism at 4 and 14 months: Social engagement, communication, and cognition. *Journal of Child Psychology and Psychiatry, 47*(5), 511-523. doi:10.1111/j.1469-7610.2005.01528.x