Responding to Joint Attention Mediates the Relation between Early Imitation and Later Expressive Language in Infants at High and Low Risk for Autism Spectrum Disorder

Sarah R. Edmunds

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science

University of Washington

2015

Committee:

Wendy L. Stone

Kevin M. King

Program Authorized to Offer Degree:

Psychology

University of Washington

Abstract

Responding to Joint Attention Mediates the Relation between Early Imitation and Later Expressive Language in Infants at High and Low Risk for Autism Spectrum Disorder

Sarah R. Edmunds

Chair of the Supervisory Committee:
Wendy L. Stone, Ph.D.
Psychology

Infant siblings of children with autism (HR infants) are at greater risk for language delay than infants with typically developing older siblings (LR infants). This study examined the early developmental pathways that underlie language growth in HR and LR infants using a prospective longitudinal design. Two early social-communicative skills that predict expressive language in both children with autism and those with typical development are motor imitation (i.e., imitating the actions of others) and responding to joint attention (i.e., following the direction of another person's interest; RJA). We hypothesized that: (1) RJA would mediate the association between imitation and expressive language over the first two years of life, and (2) mediation would be stronger for HR infants than LR infants. Imitation, RJA, and expressive vocabulary were assessed in 84 infants (50 HR) between 12 and 18 months. Results revealed that 15-month RJA mediated the association between 12-month imitation and 18-month expressive vocabulary, even after controlling for earlier levels of RJA and language. A conditional direct effect was also found; after accounting for the mediation effect, 12-month imitation directly affected 18-month expressive vocabulary for LR, but not HR, infants. These results support a developmental sequence for language development that can inform future intervention efforts for children at risk for developmental challenges.

Infants' acquisition of language gives them a powerful tool with which to interact with and learn about the world. Infants learn language in the context of social interactions (Kuhl, 2007), using a variety of basic social-communicative skills that facilitate their attention to salient cues offered by adults (Baldwin, 1995; Gergely, Egyed, & Kiraly, 2007). Little is known about how distinct social-communicative skills interact over infants' early years to shape their language development.

Autism spectrum disorder (ASD) is highly heterogeneous. Language abilities vary greatly across children with ASD; many of these children also experience delays or impairment in their language development (Anderson et al., 2007; Dereu, Roeyers, Raymaekers, & Warreyn, 2012; Paul et al., 2011). ASD is characterized by two main features: impairment in social interaction and communication abilities; and restricted or repetitive interests or behaviors (American Psychological Association [APA], 2013). While impairments in expressive or receptive language abilities are not required for a diagnosis of ASD, children's expressive language predicts their later social and adaptive functioning; greater faculty with language facilities more meaningful social interaction and increased occupational possibilities (Anderson et al., 2007; Kasari et al., 2010; Luyster, Kadlec, Carter, & Tager-Flusberg, 2008; McDuffie et al., 2005). Determining how and when language impairments become reliably observable in early development would allow us to intervene as early as possible. Early ASD-specialized intervention is associated with dramatic improvements in functioning (Dawson et al., 2010; Rogers & Vismara, 2008). Children with ASD tend to have language impairments that become apparent in their second year (e.g., Zwaigenbaum et al., 2005), so infant skills that predict language in that time period could be powerful targets for early intervention. It is known which social-communicative skills predict language in both typically developing children and children with ASD, but if there is a temporal sequence in which these skills interact to most profoundly affect later language, this knowledge could inform more targeted, developmentally appropriate interventions.

Infant siblings of children with ASD are an ideal population in which to study when language impairments emerge because they are at elevated risk for ASD or other developmental delays, including language (Constantino, Zhang, Frazier, Abbacchi, & Law, 2010; Messinger et al., 2013; Ozonoff et al., 2011). While the prevalence rate of ASD in the U.S. population is currently 1 in 68 infants (CDC, 2014), later-born siblings of children already diagnosed with ASD (high-risk; HR infants) have a family recurrence risk of 1 in 5 (Ozonoff et al., 2011). Of the HR infants who are not diagnosed with ASD, 25% will likely be diagnosed with a language delay (Constantino et al., 2010) or display elevated ASD symptomology or reduced cognitive functioning (Messinger et al., 2013). HR infants can provide valuable information about language development in ASD because they can be studied when their expressive language grows most rapidly, prior to the age at which an ASD diagnosis is typically given.

Diagnoses of ASD tend to be most reliable after 30 months of age (Turner & Stone, 2007). However, infants' language ability grows exponentially before reliable diagnosis is currently possible; they experience a "vocabulary explosion" from 18 to 24 months of age (McMurray, 2007). At 18-months, typically developing infants can produce 50 words on average, although there are great individual differences in expressive vocabulary at this age (Fenson et al., 1994). HR infants, on the other hand, produce fewer words than typically developing (TD) infants at 18 months (Mitchell et al., 2006; Zwaigenbaum et al., 2005). Studying both HR infants and typically developing, low risk (LR) infants in the second year of life could help researchers both (1) identify risk markers for ASD and (2) understand how language development may be derailed in ASD.

Basic Social Communicative Skills Build Expressive Language

To understand the atypical language development seen in children with ASD, we must consider how language typically develops. Language learning occurs in a social context; social interactions drive the dramatic growth in expressive language that infants experience in their second year of life (Kuhl, 2007). This growth in both receptive and expressive language is thought to occur because foundational social-communicative skills develop in the first and second years; infants begin to share others' focus of attention, play together with others, and use gestures such as pointing. Social-communicative skills are thought to be early precursors of language because both these early skills and formal language occur in and reinforce social interactions; gesturing, sharing gaze, and joint play are how infants communicate before they can use language, and language is a more symbolic method of communication which is added to the existing social interaction infants have with others. In Bruner's social-pragmatic approach to language acquisition, children use basic social-communicative skills to participate in social interactions while adults scaffold infants' attention by repetitively directing infants' attention to simple, salient stimuli (Bruner, 1982; 1983). In this way, infants' use of social-communicative skills in interactions shapes their attention and the information they receive such that they learn more efficiently from the environment (Baldwin, 1995; Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; Gergely et al., 2007; McMurray, 2007). In general, typically developing (TD) infants begin to use social-communicative skills regularly between 9 and 15 months of age (Carpenter et al., 1998). Two specific social skills have been found to predict later language in TD infants: the ability to imitate others' actions (e.g., Charman et al., 2000) and the ability to follow or respond to another's focus of attention (e.g., Morales et al., 2000). Imitation and responding to joint attention (RJA) also predict later language in HR infants (e.g., Charman, Baron-Cohen, Swettenham, Drew, & Cox, 2003; Stone & Yoder, 2001; Toth, Munson, Meltzoff, & Dawson, 2006). However, these early skills have been measured at the same time point within studies conducted thus far; therefore, it is not yet known whether imitation and RJA interact to influence each other and then predict language, or at which ages these skills and their interaction contribute most to language development.

Imitation: Development and Contribution to Expressive Language

Infants imitate when they match their behavior to what they observe. Imitation is an early and basic type of reciprocal communication that infants and caregivers share through smiles, vocalizations, and actions (e.g., Ingersoll, 2008; McDuffie et al., 2007). Infants' imitation increases dramatically from 6 to 24 months of age (Jones, 2007), yet individual infants have highly variable imitation abilities (Young et al., 2011). Imitation of others' actions has been found to emerge at about 12.5 months of age in typically developing children (Carpenter et al., 1998). Infants can imitate many types of actions, including actions on objects and gross motor gestures.

The relationship between imitation and expressive language is likely based in social interaction. That is, infants' imitation increases social interaction, which provides an ideal context for learning language. Imitation is thought to be one of the earliest ways by which infants and adult partners interact reciprocally (Nadel, Guerini, Peze, & Rivet, 1999), and imitation may help infants learn about the relation between themselves and others (Meltzoff & Gopnik, 1993). Imitation is an integral part of infants' social context and is considered a basis for more complex social-communicative behavior such as language (Charman et al., 2003; Stone & Yoder, 2001; Young et al., 2011).

In early childhood, imitation has been found to predict later expressive language in both TD children and children with ASD when they are 1 to 3 years old. Two- to 3-year-old children who are diagnosed with ASD show deficits in imitation relative to both TD children and children with developmental delay (Siller & Sigman, 2008; Young et al., 2011), and their imitation ability at that age predicts their expressive language at 4 years (Charman et al., 2003; Ingersoll & Meyer, 2011; Stone et al., 1997; Stone & Yoder, 2001; Toth et al., 2006). The association between imitation and later language is also present early in life; for both TD infants and infants who went on to be diagnosed with ASD, imitation at 12 months predicted their expressive language at 24 months (Boucher, 2008; Young et al. 2011). The early predictive association between imitation and language within the second year supports the theory that imitation helps create a social context for language learning at the time when infants' vocabularies are growing most rapidly.

Responding to Joint Attention: Development and Contribution to Expressive Language

Responding to joint attention (RJA) is defined as infants' ability to follow the direction of an adult's interest or attention to an object (Mundy et al., 2003). RJA typically develops around 9-15 months for TD children and tends to increase linearly throughout the first and second years of life (Boucher, 2008; Ibanez, Messinger, & Stone, in prep; Mundy et al., 2007; Siller & Sigman, 2008). In typically developing infants, RJA was found to emerge at 13 months on average (Carpenter et al., 1998). Impairment of RJA is a central feature of ASD, and is observable early in life; for instance, 12- to 23- month-old HR infants displayed fewer RJA behaviors than TD children (Presmanes, Walden, Stone, & Yoder, 2007).

RJA has been associated with later language for both TD and ASD children; by habitually following to adults' attentional focus, infants are thought to be more likely to attend when caregivers label objects, thus facilitating language development (Baldwin, 1995). RJA may have a direct, functional connection with language; when adults attempted to elicit TD 2-year-olds' attention and label a novel object, children who displayed RJA behaviors learned more object labels than children who did not display RJA behaviors (Akhtar, Carpenter, & Tomasello, 1996). This connection between RJA and language is present in children with ASD as well. For instance, 3- to 4-year-old children with ASD who responded less frequently to adults' bids for attention were found to be at greater risk for language delay or impairment (Siller & Sigman, 2008). In addition, RJA impairment in children with ASD has been found to adversely affect their language learning. In one experiment, 3- to 6-year-old children with ASD were less likely than TD children to respond to the joint attention of an adult by following their gaze to a novel object the adult labeled. Instead, these children mapped the label they heard to an object to which they were attending, rather than the object that was the adult's focus of attention. As a result, children with ASD exhibited decreased learning of the object labels compared to TD children (Walton & Ingersoll, 2013). The deficit in RJA that children with ASD tend to display may have real implications for learning language.

Infants' ability to respond to adults' attention bids may contribute most to language acquisition in infancy and toddlerhood, rather than in early childhood. RJA measured at 6 to 18 months has been found to predict expressive language at 2 and 2 ½ years in both HR and LR infants (Boucher, 2008; Morales et al., 2000; Mundy, Block, Hecke, Van, & Parlade, 2007; Presmanes et al., 2007), and in LR infants, RJA has also been found to predict concurrent expressive language (Carpenter et al., 1998; Mundy, Kasari, Sigman, & Ruskin, 1995). Research on whether RJA measured at 2 years or later predicts language has yielded mixed results in children with ASD and has not been studied in TD children. In toddlers with ASD, joint attention at 2 years predicted receptive, but not expressive, language at 3 ½ years (Charman et al., 2003). However, Anderson and colleagues (2007) studied the trajectories of joint attention and expressive language in 2- to 9-year-old children with ASD and found that early joint attention predicted later language ability across that period. RJA before 2 years may more profoundly affect language for both HR and LR infants than RJA measured after 2 years.

Responding to Joint Attention as a Mediator in the Imitation-to-Language Pathway

Research has shown that both HR and LR infants' imitation and RJA abilities predict their later expressive language. However, it is not yet clear how imitation and RJA may be linked to each other throughout development. While RJA has been concurrently associated with imitation in older children diagnosed with ASD (Luyster et al., 2008; McDuffie et al., 2007; Rogers, Hepburn, Stackhouse, & Wehner, 2003), concurrent relations between imitation and RJA in younger HR and LR infants are largely yet to be established. Furthermore, because most studies of older TD children and children diagnosed with ASD have assessed RJA and imitation abilities concurrently and then assessed language at a later time point, the directionality of the association between imitation and RJA has not yet been empirically demonstrated.

Some sparse evidence exists to suggest that earlier imitation ability might contribute more to later RJA development than earlier RJA contributes to later imitation. Training in imitation has been found to increase RJA and spontaneous expressive language abilities in 2- to 4-year-old children with ASD (Ingersoll & Schreibman, 2006). One study found that when measured concurrently in the context of a larger model explaining conversation skill in typically developing 5-year-olds, there was a stronger relation between imitation and joint attention when imitation was treated as a predictor than when joint attention was treated as a predictor, suggesting that imitation ability might be more fundamental to joint attention than the other way around (Farrant, Maybery, & Fletcher, 2011).

Imitation and RJA may emerge at similar times in typically developing children; however, whether one skill is more of a precursor for the other is still unclear. In one study, as many as 80% of children experienced the emergence of imitation and attention following skills within 3 months of each other. When examining the number of TD infants who had achieved various social-communicative skills (e.g., joint engagement, communicative gestures, language) by 12 months, imitation and attention following were the only two skills which were not found to have a “prerequisite relationship;” that is, not all infants had achieved imitation before attention following or vice versa (Carpenter et al., 1998).

The development of imitation may more clearly precede RJA in older children who are diagnosed with ASD. Carpenter, Pennington, and Rogers (2002) characterized the order in which individual 4-year-old children with ASD had achieved the ability to follow attention and to imitate actions by observing the percentage of children in the sample that had achieved each skill in a cross-sectional design. They found that more children with ASD had developed the ability to imitate at 4 years than had developed the ability to follow others’ attention. Wu and Chiang (2014) assessed children with ASD at two time points, 2.5 and 4 years, and found that these children tended to demonstrate imitation abilities before RJA abilities. However, younger HR infants should be studied in order to determine the developmental sequence of imitation and RJA in this vulnerable population during the period when these social-communicative skills are most important for language.

It is hypothesized that imitation, as an interactive activity, increases infants’ RJA. Children who find the manipulation of objects and imitation of others reinforcing may then more often follow the visual attention of others (McDuffie et al., 2007). Because early imitative play develops infants' and caregivers' shared, joint attention to objects (Ingersoll, 2008; Toth et al., 2006), it is hypothesized that imitation ability is essential for teaching the social and learning value of following others' attention.

It is further proposed that early imitation ability affects later expressive language indirectly by facilitating RJA. Evidence for this model comes from several sources. Imitation is a fundamental behavior that contributes to later language beginning early in infancy, while RJA is viewed as a higher-level behavior comprising basic abilities or precursors such as imitation (Charman, 2004). As such, infants' imitation may functionally affect their later expressive language because imitation contributes to infants' RJA ability, which then contributes to expressive language. RJA also seems to be a stronger predictor of expressive language than is imitation. Dawson and colleagues (2004) found that joint attention, but not other behaviors such as imitation, predicted concurrent language ability at 3-4 years, suggesting that joint attention continues to have a role in later language development after imitation is no longer important for language. Other regression models find joint attention to predict language above and beyond imitation, suggesting imitation may be important earlier in development (Mundy, Sullivan, & Mastergeorge, 2009). Infants who find imitating others reinforcing may respond more often to adults' bids for attention in the hope they will be presented with more opportunities for social interaction. When infants respond to caregivers' bids for attention, it may create more opportunities for infants to learn language, as it is likely that adults are labeling objects when attempting to engage their infant (Baldwin, 1995).

Indirect Effect Conditional on Risk Group

Individual differences in imitation and RJA abilities have been found to predict variation in later expressive language for both HR and LR infants. However, this mediation model may be moderated by infants' risk group (i.e., whether they are at high or low familial risk for ASD; see Figure 1). The correlations between imitation, RJA, and expressive language may be stronger for HR infants compared to LR infants. In older toddlers, imitation is concurrently related to RJA in children with ASD but not in typically developing children (McDuffie et al., 2007; Rogers et al., 2003). In younger infants, Ibanez, Messinger, and Stone (in prep) have found that RJA and expressive language are concurrently correlated at 12 months for infant siblings of children with ASD but *not* typically developing infants. Presmanes and colleagues (2007) studied 12- to 23-months-olds, infants of the same age as those in the current study. They found that RJA predicted expressive language for HR but not LR infants. Therefore, it is hypothesized that imitation, RJA, and expressive language in the proposed mediation model may be more strongly correlated for children at risk for with ASD than for low-risk children.

It is also important to note that younger siblings at risk for ASD are a heterogeneous group. Possible outcomes for HR infants include ASD as well as language delay, broader cognitive delay, and increased but subclinical ASD symptomology (Constantino et al., 2010; Messinger et al., 2013). Differences in the strength of the proposed mediation may indeed be found in infant siblings of children with ASD compared to infant siblings of TD children if: 1) the mediation model is especially strong in the 20% of siblings who go on to develop ASD, driving the effect; or 2) the overall genetic liability associated with being a sibling of a child with ASD contributes to stronger links between imitation, RJA, and language than those seen in typically developing infants.

Hypotheses

This study examined the role of responding to joint attention (RJA) as a potential mediator in the relation between imitation ability and later expressive language ability in 12- to 18-month-old infants at high and low risk for ASD. This study is one of the first to examine the sequential contribution of infants' early skills to their later language ability in a prospective, longitudinal design. Two hypotheses are proposed:

Hypothesis 1: Responding to joint attention at 15 months will mediate the association between imitation ability at 12 months and expressive vocabulary at 18 months for both HR and LR infants.

Hypothesis 2: The indirect effect and direct effect will be conditional on risk group such that HR infants will display stronger associations than LR infants on all paths of the mediation model.

Method

Participants

The sample reported in this paper was drawn from a longitudinal study investigating the social and emotional development of HR infants and LR infants at the University of Washington and Vanderbilt University. HR infant participants were recruited through research centers, clinics, and the greater community, while LR infant participants were recruited from county and statewide databases of birth records. Inclusion criteria for both groups included: (1) the absence of severe sensory or motor impairments, (2) the absence of identified metabolic, genetic, or progressive neurological disorders, (3) gestational age > 37 weeks, (4) birth weight at least 2500 grams, and (5) older sibling > 36 months of age upon study entry. Infants were enrolled in the study at 6, 9, or 12 months of age.

A total of 84 infants (56 from VU; 28 from UW) comprised the sample that participated in the current study. Infants participated in the current study when they were 12 months, 15 months, and 18 months old. The same 84 infants participated at each age, and to be included in the sample, infants needed to provide data for all relevant variables at the 12-, 15- and 18-month time points. HR infants (*n* = 50, males = 29) had at least one older sibling who was diagnosed with ASD, verified by the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000), Autism Diagnostic Interview-Revised (ADI-R; Rutter, Le Couteur, & Lord, 2003), and clinical diagnosis based on DSM-IV (APA, 2000). LR infants (*n* = 34, males = 16) had at least one older sibling who was typically developing, verified by parental report and a cutoff score of lower than 9 on the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) and no reported history of ASD in first, second, or third degree relatives. The majority of infants had mothers with a college degree or higher and were Caucasian. Maternal level of education, infants' race/ethnicity, and infants' age at testing are reported in Table 1.

Procedure

This study was approved by the Institutional Review Boards of both the University of Washington and Vanderbilt University. Parents provided informed consent prior to participation in all research procedures. Infants participated in 1- to 2-hour assessments in the lab at 12, 15, and 18 months; see Table 2. Parents held infants or sat a short distance away while experimenters engaged infants in behavioral measures. Infants' imitation ability was measured at 12 months. Infants' RJA was measured at 12 and 15 months. Infants' expressive vocabulary size was measured at 12, 15, and 18 months. Equal time intervals of measurement (i.e., 3-month intervals) help produce unbiased mediation estimates (Cole & Maxwell, 2003).

Measures

Screening Tool for Autism in Toddlers (STAT). Imitation ability was assessed using the Imitation domain score on the STAT (Stone, Coonrod, & Ousley, 2000; Stone, Coonrod, Turner, & Pozdol, 2004; Stone, McMahon, & Henderson, 2008). The STAT is an interactive assessment with activities in four domains—Play, Requesting, Directing Attention, and Imitation—designed to identify children at risk for ASD. The four domains of the STAT can also be used separately to assess basic behaviors (Stone et al., 2004). The STAT has been validated for use with between 12 and 35 months of age (Stone, McMahon, & Henderson, 2008). The STAT has an inter-rater reliability of $\kappa = 1.00$ and a test-retest reliability of $\kappa = 0.90$ (Stone et al., 2004).

The Imitation domain score comprises four items. In each item an experimenter performs a distinct action with an object or action, simultaneously providing a sound unrelated to anything the object or action might usually make. For instance, in the item called “hopping the dog,” an experimenter hops a plastic toy dog laterally along the table while saying, “Beep! Beep! Beep!” The infant receives up to three opportunities to imitate each item, and the best response for each item is scored as a Pass (1 point) Fail (0 points). Scores on the total imitation domain range from 0 to 4, with higher scores indicating more imitation responses.

Early Social Communication Scales (ESCS). Infants’ RJA behaviors were assessed using infants’ score on the Gaze Following Task of the Early Social Communication Scales (ESCS; Mundy et al., 2003). The subscale has established validity as a measure of RJA (Mundy, Sigman, & Kasari, 1994). The Gaze Following Task consists of eight trials. During each trial, infants were seated in the laps of their caregivers at a table across from an experimenter. The experimenter says the name of the infant three times while pointing to one of eight colorful posters around the room. If the infant turns and looks at the poster to which the experimenter is pointing, RJA is coded as “pass” for that trial. Scores on the Gaze Following Task range from 0 to 8, with higher scores indicating more frequent RJA behaviors during administration. Coding of RJA during the ESCS, as indexed by intraclass correlations, was excellent at both 12 months (ICC .94) and 15 months (ICC = .98).

MacArthur-Bates Communicative Development Inventories (MCDI). Infants' expressive vocabulary was assessed using the “Words Said” subscale of the MacArthur-Bates Communicative Development Inventories (MCDI; Fenson et al., 2007). The MCDI is a parent checklist of vocabulary words. In the “Words Said” section, parents are asked to mark the words that their child “understands and says.” The MCDI has been found to have reliability of 0.97 using Cronbach's alpha and concurrent validity of 0.74 with other common language measures (Boucher, 2008). Children receive a point for each word they understand and say; there are 680 words in total on the checklist.

Analytic Plan

Preliminary analyses. Missing data analysis for the outcome variable, 18-month expressive vocabulary, will be conducted to determine whether participants with missing data at the outcome differ from those with data for that variable. Risk group differences in 12-month imitation were analyzed using an independent samples t-test. Risk group differences over time for RJA and expressive vocabulary were analyzed using mixed-design ANOVAs, with Risk group as the between-subjects factor and Time point as the within-subjects factor. Pearson correlations were used to assess initial associations between study variables.

Mediation analyses. It was hypothesized that infants' imitation at 12 months would predict their 18-month expressive vocabulary indirectly through their RJA ability at 15 months.

This indirect effect, or mediation, was calculated using two separate multiple regression models (Hayes, 2013). One model assessed the effect of the predictor (12-month imitation) on the mediator (15-month RJA; path *a*), and the second model assessed the effect of 15-month RJA on the outcome (18-month expressive vocabulary), controlling for 12-month imitation (path *b*). The indirect effect is the product of the regression coefficients *a* and *b*. The direct effect (path *c'*) is the relation between imitation and expressive vocabulary that remains after considering the indirect effect. The predictor and mediator variables were centered prior to entrance into the model.

Previous levels of the mediator and outcome—infants' RJA at 12 months and infants' expressive vocabulary at 12 and 15 months—were centered and included as covariates in the mediation model. This controlled for previous levels of RJA and vocabulary and allowed a closer analysis of how the early skills of imitation and RJA work together to affect later language, above and beyond the predictive effect language has on itself over time (Cole & Maxwell, 2003; Maxwell, Cole, & Mitchell, 2012; Selig & Preacher, 2009). This creates a model that assesses whether imitation at 12 months affects later growth in RJA from 12 to 15 months, which then affects expressive vocabulary at 18 months.

We used a resampling strategy, bootstrapping, to generate the most accurate estimate of the indirect effect and evaluate its significance. Bootstrapping can be used with small sample sizes and non-normally distributed data (Cole & Maxwell, 2003; MacKinnon, Fairchild, & Fritz, 2007; Preacher, Rucker, & Hayes, 2007). Bootstrapping is sampling with replacement from the empirical sample to create additional samples of the same size as the empirical sample. This study used 10,000 bootstrapped samples, which is the recommended sampling rate (Hayes, 2013). We calculated an indirect effect from each bootstrapped sample. Because the indirect effect is the product of two coefficients, it has a non-normal distribution; the use of any significance test that assumes normality is unwise (MacKinnon, Fairchild, & Frtiz, 2007). The significance of the indirect effect was assessed by rank-ordering the 10,000 bootstrapped-generated values to create a bias-corrected confidence interval around the final indirect effect value at the midpoint of the distribution. If the bias-corrected confidence interval does not include zero, the indirect effect is significant.

To evaluate conditional effects by risk group, risk group (HR infants versus LR infants) was tested as a potential moderator of the indirect and direct effect. Risk group was included as a predictor in the two regression equations that comprised the mediation model, such that the values for paths *a, b*, and *c'* were allowed to vary by group.

Results

Preliminary Analyses

Missing data. Children with missing data for 18-month expressive vocabulary did not differ from children with complete data based on their 12- and 15-month RJA, 12-month imitation, sex, risk group, or maternal education. Those with 18-month EV missing data also did not differ from those with complete data based on their 12- and 15-month measurements of expressive vocabulary, suggesting that the data were missing completely at random (MCAR).

Risk group differences over time. Infants' motor imitation at 12 months did not differ between LR and HR infants, $t(82) = -0.69$, p = .45.

The mixed-design ANOVA for RJA revealed no significant main effect of Risk group, $F(1, 82) = 1.48$, $p = .23$, but it did reveal a significant main effect of Time point, such that RJA increased from 12 to 15 months, $F(1, 82) = 23.84$, $p < .001$. No interactions between Risk group and Time point were found, $F(1, 82) = 1.71$, $p = .19$.

Similarly, the mixed-design ANOVA for expressive vocabulary revealed no significant main effect of Risk group, $F(1, 82) = 2.97$, $p = .10$. For tests involving the within-subjects variable of Time point, the assumption of sphericity was violated; the Greenhouse-Geisser correction was therefore used. Results revealed a main effect for Time point, with expressive vocabulary increasing significantly over time, $F(1.08, 88.32) = 62.15$, $p < .001$. Post-hoc analyses using a Bonferroni correction revealed that infants' expressive vocabulary grew significantly at each time point: from 12 to 15 months, $t(83) = -6.63$, $p < .001$, 15 to 18 months, $t(83) = -7.33$, $p < .001$, and from 12 to 18 months, $t(83) = -7.72$, $p < .001$. There was no significant interaction between Risk group and Time point in predicting expressive vocabulary, $F(1.08, 88.32) = 3.81$, $p = .05$. See Figure 2. Means and standard deviations for all variables can be found in Table 3.

Correlations between variables. Correlations for all variables can be found in Table 4 through Table 6. For both HR and LR infants, RJA at 12 months was weakly to moderately correlated with RJA at 15 months, $r = .43$, $p < .01$ (HR infants) and $r = .36$, $p < .05$ (LR infants). For HR infants, 18-month expressive vocabulary was strongly correlated with expressive vocabulary at both 12 months, $r = .52$, $p < .001$ and at 15 months, $r = .69$, $p < .001$. For LR infants, 15-month expressive vocabulary was moderately correlated with 18-month expressive vocabulary, $r = .47$, $p = .005$, but 12-month expressive vocabulary was only weakly and non-significantly correlated with 18-month EV, $r = .22$, $p > .05$. For LR infants, 12-month imitation was weakly to moderately correlated with 18-month expressive vocabulary, $r = .37$, $p = .03$. For HR infants, 12-month imitation was weakly, non-significantly correlated with 18-month expressive vocabulary, $r = -.05$, $p > .05$.

Mediation

Model 1: Indirect and direct effects across all infants. As hypothesized, 12-month imitation was related to increased RJA behaviors (path *a*) for all infants, $B = .51$, $p = .05$, which was, in turn, related to greater expressive vocabulary at 18 months (path *b*), $B = 3.95$, $p = .03$. The indirect effect, *ab*, was $B = 2.03$; for each additional item infants imitated on the STAT at 12 months, they could speak an average of 2.03 more words at 18 months as a result of 12-month imitation's influence on 15-month RJA, which in turn affected 18-month expressive vocabulary. The indirect effect was estimated to fall between 0.34 and 6.30 with 95% confidence, an interval that did not include zero. The direct effect was not significant across all infants, $B = 2.89$, $p > .05$; see Table 7.

Model 2: Conditional effects by risk group.

Model building. We assessed whether the indirect or direct effects of the model were conditional on, or varied by, risk group. Interaction terms were added to each regression model to assess whether the effect of imitation on RJA (path *a*) or the effect of RJA on expressive vocabulary (path *b*) varied by group. These interaction terms were not significant ($p > .05$), indicating that ASD risk does not moderate the indirect effect of 12-month imitation on 18-month expressive vocabulary through 15-month RJA. However, the direct effect, the effect of 12-month imitation on 18-month expressive vocabulary controlling for 15-month RJA (path *c'*), did vary by risk group; the direct effect was significant for LR infants, $B = 12.46$ with a 95% CI of [-0.10, 24.82], but not HR infants, $B = -4.43$ with a 95% CI of [-14.97, 6.11].

Final model. A more parsimonious final model was estimated which included a significant non-conditional indirect effect that included all infants and a significant direct effect that was conditional by risk group; see Table 8 and Figure 3. In this model, the indirect effect, *ab*, was *B* = 1.64 with a 95% confidence interval of [0.24, 5.31]; for each additional item infants imitated on the STAT at 12 months, they could speak an average of 1.64 more words at 18 months as a result of the indirect effect.

A conditional direct effect was present for LR infants, *B* = 12.67 with a 95% CI of [0.45, 24.89], but for not HR infants, *B* = 1.00 with a 95% CI of [-15.00, 5.89]. For each additional item that LR infants imitated at 12 months, they were estimated to speak on average 12.67 more words at 18 months, above and beyond the indirect effect. For HR infants, however, here was no significant direct effect of 12-month imitation on 18-month expressive vocabulary; the indirect effect of imitation on language through RJA comprised the only relation; see both Table 8 and Figure 3.

In the final model, the non-conditional indirect effect of *B* = 1.64 had a small completely standardized effect size of *b* = .03, while the conditional direct effect for LR infants of *B* = 12.67 had a relatively larger completely standardized effect size of *b* = .17 (Hayes, 2013).

Discussion

This study sought to identify a developmental pathway by which basic social-communicative skills affect later language ability for both typically developing infants and infants at risk for ASD during the critical second year of life. It was hypothesized that infants' RJA at 15 months would mediate the relation between their imitation at 12 months and their expressive vocabulary at 18 months. This indirect effect was hypothesized to be conditional on ASD risk group; HR infants would have stronger associations between imitation, RJA, and language than would LR infants.

There was a significant indirect effect for all infants combined. Regardless of their risk group, infants' imitation ability at 12 months predicted their expressive vocabulary at 18 months indirectly through their RJA ability at 15 months. RJA may mediate the relation between imitation and language because imitating others fosters social interest that develops into RJA, a more sophisticated social-communicative skill (Ingersoll, 2008; McDuffie et al., 2007), and infants who are following an adult's attention to an object may more easily learn the label for that object (Ahktar et al., 1996; Baldwin, 1995; Morales et al., 2000; Walton & Ingersoll, 2013). Regardless of infants' risk for ASD, early imitation ability leads to higher levels of later expressive language in part through their intermediate RJA behaviors. That this developmental pathway exists for both LR and HR infants further reinforces the theory that basic social-communicative skills interact to build more complex communicative behaviors such as language (e.g., Baldwin, 1995; Carpenter et al., 1998).

The second hypothesis, that the indirect and direct effects would be stronger for HR infants compared to LR infants, was not supported. The indirect effect had a very small effect size (b = .03). Given this and the relatively small sample size when split by risk group (HR = 50; LR = 34), the model may not have had enough power to determine relative strength of the indirect effect by risk group. Although we did not find the hypothesized conditional indirect effect to be stronger for HR compared to LR infants, we did find that there was a conditional direct effect of 12-month imitation on 18-month expressive language after controlling for the indirect effect; this direct effect was significant for LR infants only. In other words, after accounting for the relation between imitation and language that occurs through 15-month RJA, 12-month imitation remained a significant predictor of 18-month expressive language for LR, but not HR infants. This is contrary to the study's hypothesis that any associations in the model would be stronger for HR infants compared to LR infants. HR infants may gain language more exclusively through the imitation-to-RJA pathway. In LR infants, imitation may contribute to the development of expressive language both directly and indirectly, through RJA.

There are several possible explanations for this finding. Infants at risk for ASD may suffer deficits in a wide range of skills as a result of a single deficit in a specific social-communicative skill such as RJA. RJA could function as a gateway (or barrier) to more advanced skills. In contrast, typically developing infants may benefit from a widely reciprocal network of early social-communicative skills. RJA, and all forms of joint attention, have been thought to be “pivotal” skills for children with ASD, both because joint attention is so often impaired in these children and because joint attention has been longitudinally associated with occupational and social-communicative outcomes for children with ASD, including language (e.g., Anderson et al., 2007; Charman, 2004; Mundy et al., 2009). For typically developing infants, early imitation abilities may influence their language ability through several possible pathways. For example, imitation may enrich the overall interactivity of TD infants’ social interactions, leading to more engagement and more frequent interactions that foster language in addition to acting through RJA. The results of this study support the idea that RJA is a central skill for HR children because while the imitation-RJA-language indirect effect was found for all infants, the remaining association between imitation and expressive language was only significant for LR, and not HR, infants.

For LR infants, imitation at 12 months was found to predict infants’ expressive vocabulary at 18 months even after accounting for its indirect association through 15-month RJA. Also, for HR infants, 12-month imitation may still relate to 18-month expressive vocabulary through additional mediating variables if there is a small effect size or a suppression effect (Shrout & Bolger, 2002). What other basic skills could explain how infants’ imitation ability helps them learn words? One promising potential mediator is infants' use of gesture. Infants learn many gestures through imitation of adults, and imitating actions requires motor skill. Motor skill and gesture have also been found to relate to later language (e.g., LeBarton & Iverson, 2013; Parlade & Iverson, 2012). Gesture or motor skill may also be important in helping infants who are later diagnosed with ASD learn language; HR infants have been found to use gestures less frequently than LR infants (e.g., Stone, McMahon, Yoder, & Walden, 2007). Imitation routines help infants learn gestures (e.g., waving "bye-bye" with parents) that scaffold language (McDuffie et al., 2007). Infants use gestures to communicate more complex ideas that they are not yet able to verbalize (Iverson & Goldin-Meadow, 2005), so if infants at risk for ASD gesture less frequently, they have less practice in communicating. Infants' use of gesture may also help adults tailor their verbal input to be more relevant; for example, an infant that points to an object will likely receive a reply related to that object. If HR infants gesture less frequently, they may receive information that is less pertinent to their focus of attention.

Although both RJA and expressive vocabulary grew over time, it would have been reasonable given prior research to expect a significant interaction between time and risk group such that HR infants displayed fewer RJA behaviors and could produce fewer words than LR infants at the 18-month time point, but not the earlier time point(s). One- to two-year-old HR infants HR infants showed less RJA than LR infants (Ibanez, Grantz, & Messinger, 2013; Presmanes et al., 2007; Sullivan et al., 2007). The present study may have not found any difference by risk status at 12 and 15 months because it is a lower, more restricted age range than that used by Presmanes and colleagues. In addition, that study employed a more nuanced measure of RJA than that used in the current study; the adult provided a wider variety of cues designed to attract infants' attention. However, the RJA measure that this study used is a subscale of the ESCS, which is commonly used in studies of HR infants and therefore easier to compare to other research.

Researchers have found that HR infants produced fewer words than LR infants at 18 months, but not 12 months (Mitchell et al., 2006; Zwaigenbaum et al., 2005). One possible explanation for the null finding for expressive vocabulary by risk group at these ages in the current study is the great variation in vocabulary size that exists from 12 to 18 months. The rate of language development varies greatly for each infant. To illustrate, the standard deviations for expressive vocabulary at 12, 15 and 18 months in this study were in most cases larger than the value of the mean, indicating a wide distribution of individual differences. Zwaigenbaum and colleagues also used a different, standardized, performance-based measure of expressive language in order to obtain their results; parent-reported expressive vocabulary (i.e., full words infants can say) is more likely to experience a floor effect at 12 months than is a more general measure of expressive language which takes into account some pre-linguistic behaviors.

In contrast to previous studies that have studied older children (3-year-olds) with ASD (e.g., Ingersoll & Meyer, 2011; McDuffie et al., 2005; Stone & Yoder, 2001; Toth et al., 2006), this study found that for children at risk for ASD, 12-month imitation does not directly relate to 18-month expressive language. This difference in results may be because imitation may indirectly affect language early in children’s lives, while research on older children with ASD focuses on social-communicative skill deficits that have persisted and stabilized in later childhood and therefore may have a different functional relation to language ability. Also, the speed with which infants’ language develops complicates efforts to compare research studies on social-communicative skills; different skills may be most predictive of and important for language at different ages. Depending on the age that any skill is measured, that skill may be found to predict or not predict language outcome. The literature has focused on several skills across several ages; for example, the majority of research on language development in ASD has until recently studied children at 3 to 4 years of age, after diagnosis. Directly comparing these studies to new prospective studies of HR and LR infants in their first and second years of life is difficult and may lead to misperceptions about the relative importance of social-communicative skills at different ages. Although only about 20% of infants at risk for ASD will be diagnosed with the disorder, a large proportion of HR infants experience delays in language and social skills, and some infants do not experience any delays (Constantino et al., 2010; Messinger et al., 2013). HR infants as a group may therefore display wide variability in early social-communicative skills and language that still affect their early language development (Stone et al., 2007). It will be important to conduct further analyses for the current study comparing HR infants who are later diagnosed with ASD, HR infants with other language or social-communicative delays, and typically developing HR infants.

Studying early social-communicative skills as predictors of language in the second year has the potential to identify important skills upon which to focus in early intervention. Deficits in these early skills, often found to be impaired in children who are later diagnosed with ASD, may narrow infants' opportunities to learn from their environment, causing a cascade of impairments (Zwaigenbaum et al., 2005). Engaging in intervention for RJA and imitation as early as possible provides infants more time to use their new skills to interact socially with others and build on their social knowledge. Many interventions aim to improve infants' early social communication abilities to foster later language growth (e.g., Ingersoll, 2010; 2012; Whalen, Schreibman, & Ingersoll, 2006). This study suggests that targeting imitation and RJA skills together in an intervention may be an optimally effective approach for infants at risk for ASD. Furthermore, interventions designed to promote RJA development might be especially beneficial for young children at risk for ASD relative to LR children, given that imitation may only promote later language through RJA for these children. RJA, and joint attention in general, is thought to be a central deficit in ASD (e.g. Charman, 2004), and this study would add support to the idea that joint attention is prime target for intervention.

This study was one of the first to examine the sequential contribution of infants' early skills to their later language ability in a prospective, longitudinal design. The study used advanced statistical methods to study the processes of language development. This study lacked the power to investigate whether the pathways by which early social skills affect language differ by ASD diagnostic outcome in the HR sample. However, the sample is of a typical size compared to other studies of high-risk infants in the literature. Including infants at both high and low risk for ASD in the same study allows for comparison between groups and provides evidence that (1) language development occurs via some of the same developmental processes, regardless of risk for ASD, and (2) specific early skills, such as RJA, may be especially important for children with ASD.

Future research would benefit from investigating the role of early social-communicative skills such as imitation, RJA, and gesture on infants' language ability as it continues to increase after 18 months of age. Multiple early skills could be incorporated into a more comprehensive path model to predict language. Understanding how early social-communicative skills build on each other and contribute to language development could potentially improve both the language and social-communication deficits that are present in many children with ASD.

References

Akhtar, N., Carpenter, M., & Tomasello, M. (1996). The Role of Discourse Novelty in Early Word Learning. *Child Development*, *67*(2), 635. doi:10.2307/1131837

American Psychiatric Association. (2000). *Diagnostic and Statistical Manual of Mental Disorders-IV-TR.* Washington, D.C.; APA.

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders-V.* Washington, D.C.; APA.

Anderson, D. K., Lord, C., Risi, S., DiLavore, P. S., Shulman, C., Thurm, A., Welch, K., & Pickles, A. (2007). Patterns of growth in verbal abilities among children with autism spectrum disorder. *Journal of Counseling and Clinical Psychology, 75*(4), 594-604.

Baldwin, D. A. (1995). Understanding the link between joint attention and language. In C. Moore, P. J Dunham (Eds.), *Joint attention; its origins and role in development* (p. 131-158). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Boucher, S. M. (2008). *Joint attention, imitation, and repetitive behaviors as predictors of autism and expressive language ability in early childhood*. (Unpublished doctoral dissertation.) University of North Carolina- Chapel Hill, Chapel Hill, NC.

Bruner, J. (1982). The organization of action and the nature of the adult-infant transaction. In E. Z. Tronick (Ed.), *Social interchange in infancy: Affect, cognition, and communication*. Baltimore: University Park.

Bruner, J. (1983). *Child's talk: Learning to use language.* New York: Norton.

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, *63*(4), 1–174.

Carpenter, M., Pennington, B. F., & Rogers, S. J. (2002). Interrelations among social-cognitive skills in young children with autism. *J Autism Dev Disord, 32*(2), 91-106.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development, 15,* 481-498.

Charman, T., Baron-Cohen, S., Swettenham, G. B., Drew, A., & Cox. A. (2003). Predicting language outcome in infants with autism and pervasive developmental disorder. *Lang. Comm. Dis., 38*(3), 265-285.

Charman, T. (2004). Why is joint attention a pivotal skill in autism? *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *358*(1430), 315–24. doi:10.1098/rstb.2002.1199

Constantino, J. N., Zhang, Y., Frazier, T., Abbacchi, A. M., & Law, P. (2010). Sibling recurrence and the genetic epidemiology of autism. *The American Journal of Psychiatry*, *167*(11), 1349–56. doi:10.1176/appi.ajp.2010.09101470

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: social orienting, joint attention, and attention to distress. *Developmental Psychology, 40*(2), 271-283.

Farrant, B. M., Maybery, M. T., & Fletcher, J. (2011). Socio-emotional engagement, joint attention, imitation, and conversation skill: Analysis in typical development and language specific impairment. *First Language, 31*(1), 23-46.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., Pethick, S. J., … Stiles, J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, *59*(5), 1–185.

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). *MacArthur-Bates Communicative Development Inventories: User Guide and Technical Manual* (2nd ed.). Baltimore: Brookes.

Gergely, G., Egyed, K., & Király, I. (2007). On pedagogy. *Developmental Science*, *10*(1), 139–46. doi:10.1111/j.1467-7687.2007.00576.x

Ibañez, L. V, Grantz, C. J., & Messinger, D. S. (2013). The development of referential communication and autism symptomology in high-risk infants. *Infancy*, *18*(5), 1–18. doi:10.1111/j.1532-7078.2012.00142.x.The

Ibañez, L. V, Messinger, D. S., & Stone, W. L. (2015). Early gaze shifting predicts responding to joint attention and expressive language in high-risk infant siblings without ASD. Manuscript in preparation.

Ingersoll, B. (2012). Brief report: effect of a focused imitation intervention on social functioning in children with autism. *J Autism Dev Disord*, *42*(8), 1768–73. doi:10.1007/s10803-011-1423-6

Ingersoll, B., & Lalonde, K. (2010). The impact of object and gesture imitation training on language use in children with autism spectrum disorder. *Journal of Speech, Language, and Hearing Research, 53*, 1040-1051.

Ingersoll, B., & Meyer, K. (2011). Examination of correlates of different imitative functions in young children with autism spectrum disorders. *Research in Autism Spectrum Disorders*, *5*(3), 1078–1085. doi:10.1016/j.rasd.2010.12.001

Ingersoll, B., & Schreibman, L. (2006). Teaching reciprocal imitation skills to young children with autism using a naturalistic behavioral approach: effects on language, pretend play, and joint attention. *J Autism Dev Disord*, *36*(4), 487–505. doi:10.1007/s10803-006-0089-y

Iverson, J. M., & Goldin-Meadow, S. (2005). Gesture paves the way for language development. *Psychological Science*, *16*(5), 367–71. doi:10.1111/j.0956-7976.2005.01542.x

Jones, S. S. (2007). Imitation in infancy: the development of mimicry. *Psychological Science*, *18*(7), 593–9. doi:10.1111/j.1467-9280.2007.01945.x

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

Kuhl, P. K. (2007). Is speech learning "gated" by the social brain? *Developmental Science*, *10*(1), 110–20. doi:10.1111/j.1467-7687.2007.00572.x

LeBarton, E. S., & Iverson, J. M. (2013). Fine motor skill predicts expressive language in infant siblings of children with autism. *Developmental Science*, *16*(6), 815–27. doi:10.1111/desc.12069

Luyster, R. J., Kadlec, M. B., Carter, A., & Tager-Flusberg, H. (2008). Language assessment and development in toddlers with autism spectrum disorders. *J Autism Dev Disord*, *38*(8), 1426–38. doi:10.1007/s10803-007-0510-1

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., Pickles, A., & Rutter, M. (2000). The Autism Diagnostic Observation Schedule–Generic: A standard measure of social and communication deficits associated with the spectrum of autism, *J Autism Dev Disord,30*(3), 205–23.

MacKinnon, D. P., Fairchild, A. J., & Fritz, M. S. (2007). Mediation analysis. *Annual Review of Psychology*, *58*, 593–614. doi:10.1146/annurev.psych.58.110405.085542

McDuffie, A., Turner, L., Stone, W., Yoder, P., Wolery, M., & Ulman, T. (2007). Developmental correlates of different types of motor imitation in young children with autism spectrum disorders. *J Autism Dev Disord, 37,* 401-412

McDuffie A., Yoder, P., & Stone, W. (2005). Prelinguistic predictors of vocabulary in young children with autism spectrum disorders. *J Speech, Language, and Hearing Research, 48,* 1080-1097.

McMurray, B. (2007). Defusing the childhood vocabulary explosion. *Science*, *317*. doi:10.1126/science.1144073

Meltzoff, A., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 335–366). New York: Oxford University Press.

Messinger, D., Young, G. S., Ozonoff, S., Dobkins, K., Carter, A., Zwaigenbaum, L., Landa, R. J., et al. (2013). Beyond autism: a baby siblings research consortium study of high-risk children at three years of age. *Journal of the American Academy of Child and Adolescent Psychiatry*, *52*(3), 300–308.e1. doi:10.1016/j.jaac.2012.12.011

Mitchell, S., Brian, J., Zwaigenbaum, L., Roberts, W., Szatmari, P., Smith, I., & Bryson, S. (2006). Early language and communication development in infants later diagnosed with autism spectrum disorder. *Developmental and Behavioral Pediatrics, 27*(2), S69-S78. doi:0196-206X/06/2702-0069

Morales, M., Mundy, P., Delgado, C. E., Yale, M., Messinger, D., Neal, R., & Schwartz, H. K. (2000). Responding to joint attention across the 6- through 24-month age period and early language acquisition. *J Applied Dev Psych, 21*(3), 283-298.

Mullen, E. (1995). *Mullen Scales of Early Learning.* Circle Pines, MN: America Guidance Service.

Mundy, P., Sullivan, L., & Mastergeorge, A. M. (2009). A parallel and distributed-processing model of joint attention, social cognition, and autism. *Autism Research, 2,* 2-21.

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). A manual for the abridged Early Social Communication Scales (ESCS). *Univ of Miami, Miami, FL.*

Mundy, P., Sigman, M., & Kasari, C. (1994). Joint attention, developmental level, and symptom presentation in young children with autism. *Development and Psychopathology, 6*, 389-401.

Nadel, J., Guerini, C., Peze, A., & Rivet, C. (1999). The evolving nature of imitation as a format for communication. In J. Nadel, & G. Butterworth (Eds.), *Imitation in infancy* (pp. 209–233). Cambridge, UK: Cambridge University Press.

Ozonoff, S., Young, G. S., Carter, A., Messinger, D., Yirmiya, N., Zwaigenbaum, L., Bryson, S., Carver, L. J., Constantino, J. N., Dobkins, K., Hutman, T., Iverson, J. M., Landa, R., Rogers, S. J., Sigman, M., & Stone, W. L. (2011). Recurrence risk for autism spectrum disorders: a baby siblings research consortium study. *Pediatrics, 128,* e488-e495.

Parladé, M. V, & Iverson, J. M. (2011). The interplay between language, gesture, and affect during communicative transition: a dynamic systems approach. *Developmental Psychology*, *47*(3), 820–33. doi:10.1037/a0021811

Preacher, K. J., Rucker, D. D., & Hayes, A. F. (2007). Addressing moderated mediation hypotheses: theory, methods, and prescriptions. *Multivariate Behavioral Research*, *42*(1), 185–227. doi:10.1080/00273170701341316

Rogers, S. J., Hepburn, S. L., Stackhouse, T., & Wehner, E. (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *44*(5), 763–81.

Rutter, M., Bailey, A., & Lord, C. (2003). *Social communication questionnaire*. Los Angeles, CA: Western Psychological Services.

Rutter, M., Le Couteur, A., & Lord, C. (2003). *Autism diagnostic interview, revised manual*. Los Angeles, CA: Western Psychological Services.

Shrout, P. E., & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods*, *7*(4), 422–445. doi:10.1037//1082-989X.7.4.422

Siller, M., & Sigman, M. (2008). Modeling longitudinal change in the language abilities of children with autism: parent behaviors and child characteristics as predictors of change. *Developmental Psychology, 44*(6), 1691- 1704.

Stone, W. L., Coonrod, E. E., & Ousley, O. Y. (2000). Brief report: screening tool for autism in two-year-olds (STAT): development and preliminary data. *Journal of Autism and Developmental Disorders*, *30*(6), 607–12.

Stone, W. L., Coonrod, E. F., Turner, L. M., & Pozdol, S. L. (2004). Psychometric properties of the STAT for early autism screening. *J Autism Dev Disord, 34*(6), 691-701.

Stone, W. L., McMahon, C. R., Yoder, P. J., & Walden, T. A. (2007). Early social-communicative and cognitive development of younger siblings of children with autism spectrum disorders. *Archives of Pediatrics & Adolescent Medicine*, *161*(4), 384–90. doi:10.1001/archpedi.161.4.384

Stone, W. L., McMahon, C. R., & Henderson, L. M. (2008). Use of the screening tool for autism in two-year-olds (STAT) for children under 24 months: An exploratory study. *Autism, 12*(5), 557-573.

Stone, W. L., Ousley, O. Y., & Littleford, C. D. (1997). Motor imitation in young children with autism: what's the object? *Journal of Abnormal Child Psychology*, *25*(6), 475–85. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9468108

Stone, W., & Yoder, P. (2001). Predicting spoken language level in children with autism spectrum disorders. *Autism, 5(4) 341-361.*

Sullivan, M., Finelli, J., Marvin, A., Garrett-Mayer, E., Bauman, M., & Landa, R. (2007). Response to joint attention in toddlers at risk for autism spectrum disorder: a prospective study. *Journal of Autism and Developmental Disorders*, *37*(1), 37–48. doi:10.1007/s10803-006-0335-3

Toth, K., Munson, J., Meltzoff, A., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: joint attention, imitation, and toy play. *J Autism Dev Disord, 36, 993-1005.*

Turner, L. M., & Stone, W. L. (2007). Variability in outcome for children with an ASD diagnosis at age 2. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *48*(8), 793–802. doi:10.1111/j.1469-7610.2007.01744.x

Walton, K. M., & Ingersoll, B. R. (2013). Expressive and receptive fast-mapping in children with autism spectrum disorders and typical development: The influence of orienting cues. *Research in Autism Spectrum Disorders*, *7*(6), 687–698. doi:10.1016/j.rasd.2013.02.012

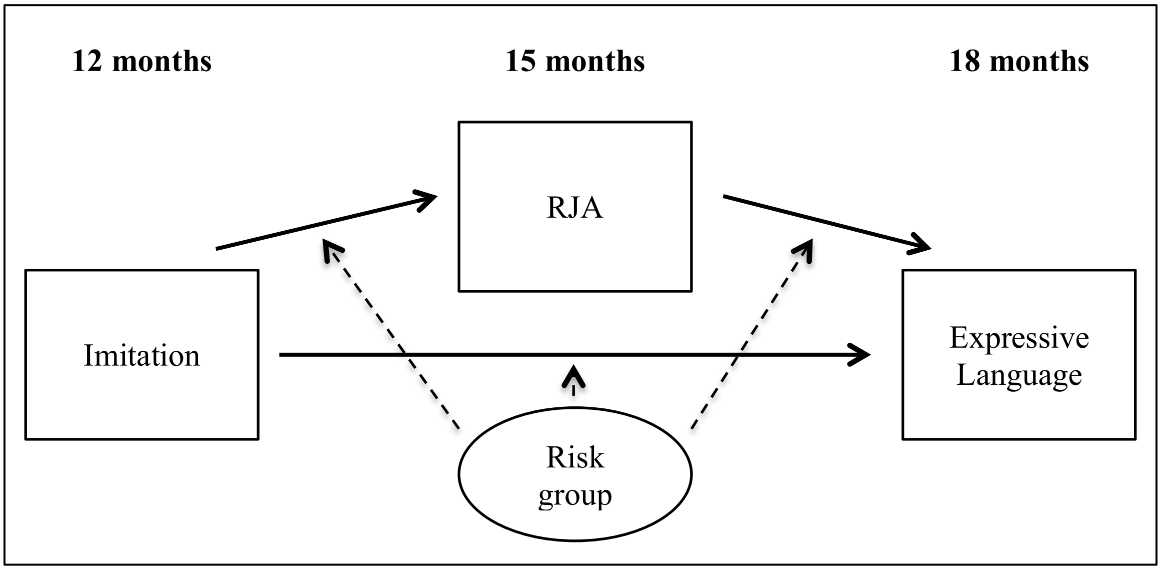
Whalen, C., Schreibman, L., & Ingersoll, B. (2006). The collateral effects of joint attention training on social initiations, positive affect, imitation, and spontaneous speech for young children with autism. *Journal of Autism and Developmental Disorders*, *36*(5), 655–64. doi:10.1007/s10803-006-0108-z

Wu, C., & Chiang, C. (2014). The developmental sequence of social communicative skills in young children with autism: A longitudinal study. *Autism*, *18*(4), 385–392. doi:10.1177/1362361313479832

Young, G. S., Rogers, S. J., Hutman, T., Rozga, A., Sigman, M., & Ozonoff, S. (2011). Imitation from 12 to 24 months in autism and typical development: a longitudinal Rasch analysis. *Developmental Psychology, 47*(6), 1565-1578.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Developmental Neuroscience* , *23*(2-3), 143–52. doi:10.1016/j.ijdevneu.2004.05.001

Figure 1. Hypothesized model. The indirect effect of 12-month imitation on 18-month expressive language through 15-month RJA is hypothesized to be conditional on risk group.



RJA = responding to joint attention

Table 1

Demographic Characteristics of the Sample

	HR Infants	**LR Infants**
Maternal Level of Education	**# (%)**	**# (%)**
HS diploma only	9 (18)	2 (6)
Associates or Bachelors degree	22 (44)	15 (44)
Masters degree or higher	13 (26)	16 (47)
No response	6 (12)	1 (3)
Participant Race/Ethnicity	**# (%)**	**# (%)**
Caucasian	36 (72)	30 (88)
Multiracial	8 (16)	3 (9)
Other	6 (12)	1 (3)
Infant age at visit (months)	*M* (*SD)*	*M* (*SD)*
12-month (Time 1)	12.27 (0.45)	12.32 (0.37)
15-month (Time 2)	15.31 (0.35)	15.22 (0.57)
18-month (Time 3)	18.21 (0.45)	18.22 (0.46)

Table 2

Measures Used for the Model

Construct	**Time Point**	**Function in Model**	**Measure**	**Variable (Measurement)**	**Score Range**
Imitation	12 months	Predictor	STAT	Imitation Domain Score	0 - 4
RJA	12 months	Covariate	ESCS	Gaze Following Task	0 - 8
	15 months	Mediator			
Expressive Vocabulary	12, 15 months	Covariate	MCDI	"Words Said" Subscale	0 - 680
	18 months	Outcome			

Table 3

Means (Standard Deviations) for Study Variables

Construct	Age (months)	HR infants	LR infants	All infants
Imitation	12	1.78 (*0.84*)	1.91 *(0.90)*	1.83 (*0.86)*
RJA	12	2.10 (1.93)	2.24 (2.00)	2.15 (1.95)
	15	3.00 (*2.13)*	3.79 *(2.20)*	3.32 *(2.18)*
Expressive	12	4.88 (6.99)	5.59 (7.50)	5.17 (7.16)
Vocabulary	15	15.34 (19.13)	18.88 (19.60)	16.77 (19.29)
	18	40.50 (43.77)	63.26 (66.65)	49.71 (54.99)

* $p < .05$. ** $p < .01$. RJA = responding to joint attention. EV = expressive vocabulary

Table 4

Correlations Among Study Variables for High Risk Infants

High Risk Infants (*n* = 50)					
	1	2	3	4	5
1. Imitation (12 months)					
2. RJA (12 months)	-.037				
3. RJA (15 months)	.114	.427**			
4. EV (12 months)	-.105	.124	.018		
5. EV (15 months)	-.003	-.006	-.150	.693**	
6. EV (18 months)	-.046	-.059	-.051	.517**	.815**

* $p < .05$. ** $p < .01$. RJA = responding to joint attention. EV = expressive vocabulary

Table 5

Correlations Among Study Variables for Low Risk Infants

Low Risk Infants (*n* = 34)					
	1	2	3	4	5
1. Imitation (12 months)					
2. RJA (12 months)	-.207				
3. RJA (15 months)	.159	.356*			
4. EV (12 months)	.026	-.078	.162		
5. EV (15 months)	.243	-.259	.088	.473**	
6. EV (18 months)	.367*	-.106	.188	.218	.821**

* $p < .05$. ** $p < .01$. RJA = responding to joint attention. EV = expressive vocabulary

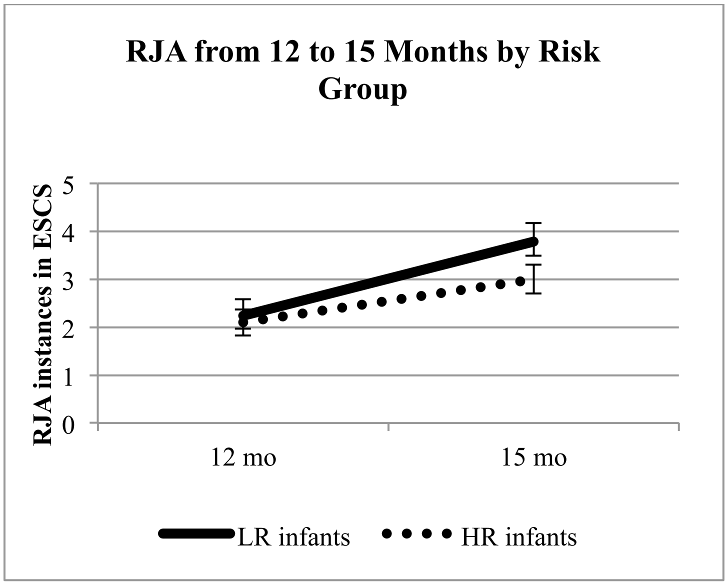
Table 6

Correlations Among Study Variables for All Infants

	All Infants (*n* = 84)				
	1	2	3	4	5
1. Imitation (12 months)					
2. RJA (12 months)	-.106				
3. RJA (15 months)	.144	.397**			
4. EV (12 months)	-.044	.039	.087		
5. EV (15 months)	.108	-.108	-.034	.601**	
6. EV (18 months)	.179	-.073	.105	.357	.800**

* $p < .05$. ** $p < .01$. RJA = responding to joint attention. EV = expressive vocabulary

Figure 2. RJA and expressive vocabulary grow significantly over time. Error bars represent +/- one standard error of the mean.



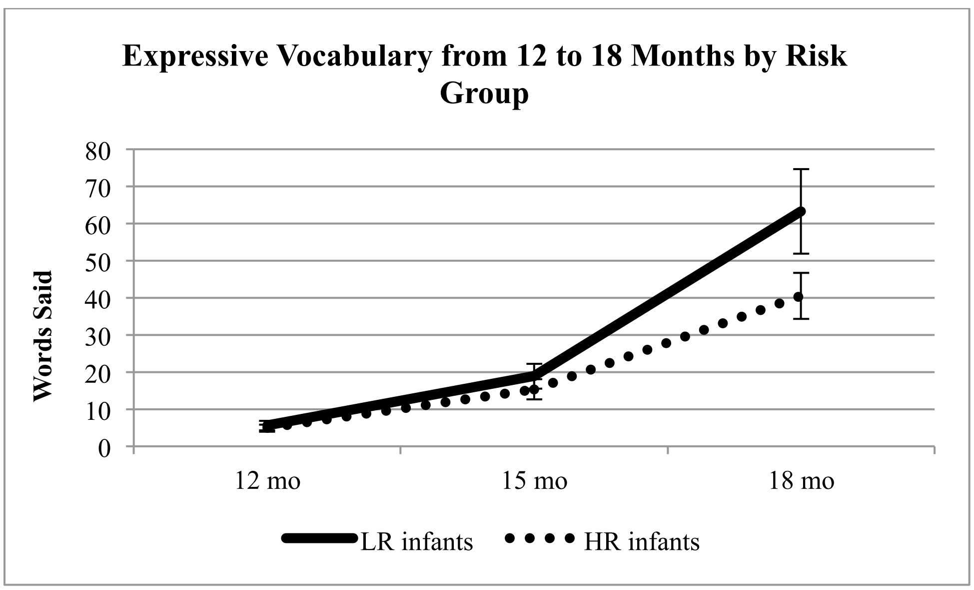


Table 7

Model 1: All Infants: A Significant Indirect Effect and a Non-significant Direct Effect

15-month RJA (mediator)				
	Model	Coeff *(B)*	*SE*	*p*
12-month imitation	*a*	0.51	0.26	0.05
Constant	-	0.50	0.40	0.22
12-month RJA	cov	0.45	0.11	0.00
12-month EV	cov	0.04	0.04	0.29
15-month EV	cov	-0.01	0.01	0.47
R^2 = .20				
F (4, 79) = 5.07, *p* <.001				

18-month expressive vocabulary (outcome)				
	Model	Coeff *(B)*	*SE*	*p*
12-month imitation	*c'*	2.89	4.19	0.49
15-month RJA	*b*	3.95	1.78	0.03
Constant	-	16.66	6.42	0.01
12-month RJA	cov	-0.63	1.98	0.75
12-month EV	cov	-1.60	0.62	0.01
15-month EV	cov	2.63	0.23	0.00
R^2 = .69				
F (6, 78) = 34.89, *p* <.001				

Mediation inferences						
	Coeff *(B)*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Indirect effect	2.03	1.28	-	-	0.34	6.30
Direct effect	2.89	4.19	0.69	0.49	-3.43	13.25

EV = expressive vocabulary. Cov = covariate. LLCI = lower limit of 95% confidence interval. ULCI = upper limit of 95% confidence interval.

Table 8

Model 2: Indirect Effect for All Infants; Direct Effect Conditional on Risk Group

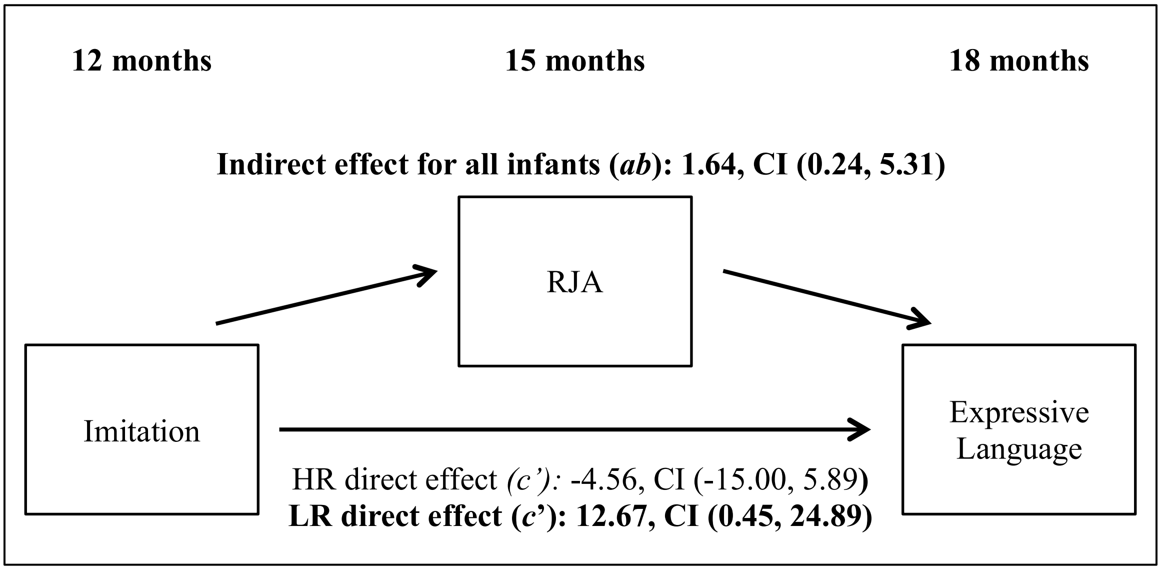
15-month RJA (mediator)				
	Model	Coeff *(B)*	*SE*	*p*
12-month imitation	*a*	0.51	0.26	0.05
Constant	-	0.50	0.40	0.22
12-month RJA	cov	0.45	0.11	0.00
12-month EV	cov	0.04	0.04	0.29
15-month EV	cov	-0.01	0.01	0.47
$R^2 = .20$				
F (4, 79) = 5.07, p <.001				

18-month expressive vocabulary (outcome)				
	Model	Coeff *(B)*	*SE*	*p*
12-month imitation	*c'* (HR)	-4.56	5.25	0.39
15-month RJA	*b*	3.20	1.75	0.07
Constant	-	5.07	7.50	0.50
12-month RJA	cov	-0.18	1.92	0.93
12-month EV	cov	-1.60	0.60	0.01
15-month EV	cov	2.55	0.23	0.00
Risk group		28.97	10.57	0.01
Risk group*imitation		17.22	7.94	0.03
$R^2 = .72$				
F (7, 76) = 27.77, p <.001				

Mediation inferences							
	Group	Coeff *(B)*	*SE*	*t*	*p*	*LLCI*	*ULCI*
Indirect effect	-	1.64	1.09	-	-	0.24	5.31
Conditional direct effect	HR	-4.56	5.26	-0.87	0.39	-15.00	5.89
	LR	12.67	6.14	2.06	0.04	0.45	24.89

EV = expressive vocabulary. LLCI = lower limit of 95% confidence interval. ULCI = upper limit of 95% confidence interval. Risk group coded as 0 = HR, 1 = LR.

Figure 3. Final mediation model. The indirect effect is significant across all infants, whereas the direct effect is significant for LR but not HR infants.



* $p < .05$. Values are unstandardized regression coefficients. Significant effects are described in bold.