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Longitudinal Prediction of Language Emergence in Infants at High and Low Risk for ASD

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Abstract

This study used a prospective longitudinal design to examine the early developmental pathways that underlie language growth in infants at high risk (HR; $n = 50$) and low risk (LR; $n = 34$) for autism spectrum disorder (ASD) in the first 18 months of life. While motor imitation and responding to joint attention (RJA) have both been found to predict expressive language in children with ASD and those with typical development, the longitudinal relation between these capacities has not yet been identified. As hypothesized, results revealed that 15-month RJA mediated the association between 12-month motor imitation and 18-month expressive vocabulary, even after controlling for earlier levels of RJA and vocabulary. These results provide new information about the developmental sequencing of skills relevant to language growth that may inform future intervention efforts for children at risk for language delay or other developmental challenges.

The acquisition of language gives infants a powerful, uniquely human tool with which to interact and learn about the world. Infants learn language in the context of social interactions with adults (Kuhl, 2007), who scaffold language development through shared activities such as imitation and joint attention, that serve to facilitate infants' attention to socially salient objects and activities in the environment (Baldwin, 1995; Bruner, 1983; Gergely, Egyed, & Kiraly, 2007). Growth in both receptive and expressive language is thought to stem from foundational social-communicative skills that develop in the first and second years of life, as infants increase the extent to which they engage in turn-taking play, share others' focus of attention, and use gestures to express their needs and desires (Baldwin, 1995; Carpenter, Nagell, Tomasello, Butterworth, & Moore, 1998; McMurray, 2007).

Understanding the temporal relations between early-emerging social-communicative skills such as imitation and joint attention can inform our understanding of both typical and atypical development. Early behaviors and systems interact with, and build upon, one another in a developmental cascade that results in increasingly complex and sophisticated

behavior patterns (e.g., Masten & Cicchetti, 2010; Rogers & Pennington, 1991). While several studies have examined the longitudinal development of social-communicative and language skills in infants with typical development (TD infants) (e.g., Bates, 1977; Carpenter et al., 1998), few have examined the temporal relation of different social-communicative behaviors over time to investigate how this sequencing might influence language development in both TD children and children with – or at risk for – autism spectrum disorder (ASD; Carpenter, Pennington & Rogers, 2002; Wu & Chiang, 2014). Identifying the developmental sequences that underlie language emergence has the potential to inform prevention and intervention approaches for the 1.5% of children in the U.S. who are diagnosed with ASD (CDC, 2014) and the 6–7% of children in the US who experience other communication disorders (Pinborough-Zimmerman et al., 2007).

Children with ASD represent an ideal sample from which to learn about the development of language, as impairments in social communication represent a core diagnostic feature of ASD (American Psychological Association [APA], 2013), and their language outcomes are diverse, with some children remaining nonverbal throughout their lives and others achieving verbal fluency (Hus, Pickles, Cook, Risi, & Lord, 2007; Lord, Risi, & Pickles, 2004). However, ASD is not typically diagnosed before 24 months (Turner & Stone, 2007), whereas the “language burst” that occurs in typically developing infants occurs earlier, in the second year of life (Goldfield & Reznick, 1990; McMurray, 2007). As a result, attempts to examine the early developmental trajectories of social-communication and language have focused on infants at elevated risk for ASD by virtue of having an older sibling with an ASD diagnosis (i.e., high-risk [HR] infants). Recent large-scale prospective research has revealed that 7–19% of HR infants receive an ASD diagnosis themselves (Grønberg et al., 2013; Ozonoff et al., 2011), and an additional 20% demonstrate language or cognitive delays by 3 years of age (Messinger et al., 2013). The purpose of this longitudinal study is to identify the *developmental pathway* and temporal sequence in which social-communicative skills build on each other in the second year of life to support language emergence for HR infants compared with infants at average or low risk (LR) for ASD.

Imitating the actions of others (i.e., motor imitation) and responding to joint attention (RJA) are two important social-communicative behaviors that emerge from infants’ developing understanding that others are intentional agents (Tomasello, 1995). Impairments in both areas have been found in young children with ASD relative to those with typical development or developmental delays (e.g., Stone, Ousley, & Littleford, 1997; Mundy, Sullivan & Mastergeorge, 2009). Infants begin to imitate simple, familiar actions with objects by 7–10 months (Carpenter et al., 1998) and reliably by 8–12 months (Jones, 2007). Imitation is one of the earliest ways in which infants and adult partners interact reciprocally (Nadel, Guerini, Peze, & Rivet, 1999), through back-and-forth bouts of smiles and actions (Ingersoll, 2008; McDuffie et al., 2007). The predictability of these early imitative interactions provides a platform for infants to learn about the relation between themselves and others (Meltzoff & Gopnik, 1993), as well as an opportunity to engage in early social interactions, which provide an ideal context for language learning. Motor imitation impairments have been found for groups of young children with ASD relative to both TD children and those with developmental delay (Siller & Sigman, 2008; Stone, Ousley &

Littleford, 1997; Young et al., 2011); however, little is known about imitation abilities in HR infants as a group, despite their genetic liability for a range of developmental challenges.

RJA occurs when infants visually follow the direction of an adult's attention to an object or event (Mundy et al., 2003); examples include tracking an adult's eye gaze, point, or vocalization to locate the target of the adult's attention. RJA typically begins to emerge around 9 months (Carpenter et al., 1998; Mundy, Block, Hecke, Van, & Parlade, 2007), but does not become robust until 12–15 months of age (e.g., Ibañez, Grantz & Messinger, 2013; Mundy et al., 2007; Tomasello, 1995). Therefore, entering their second year of life, infants' imitation abilities may be more well-established than their RJA abilities. Impairment in RJA is a central feature of ASD, and group differences in RJA have been found for young children with ASD in comparison to TD children (Mundy, Sullivan & Mastergeorge, 2009) as well as those with developmental delay (Dawson et al., 2004). In addition, studies have found lower levels of RJA in HR infants compared to their LR counterparts in the second year (Presmanes, Walden, Stone, & Yoder, 2007; Sullivan et al., 2007), even after removing the children with a later ASD diagnosis from the HR group (Ibañez et al., 2013).

Both motor imitation and RJA have been found to predict later expressive language in TD children, children with ASD, and HR infants. In children with ASD, motor imitation at age 2 was found to predict expressive language ability at age 4 (Stone & Yoder, 2001). In both HR and LR 12- to 24-month-old infants, growth in motor imitation predicted concurrent growth in expressive language (Young et al., 2011). These findings support the hypothesis that imitation helps create a social context for language learning at the time when infants' vocabularies are growing most rapidly. With respect to RJA, individual differences from 6–18 months were associated with later expressive language development at 2–3 years of age in TD children (Delgado et al., 2002; Morales et al., 2000; Mundy et al., 2007). Individual differences in RJA in 2- to 4-year-old children with ASD also predicted language 2–4 years later (Sigman & Ruskin, 1999; Siller & Sigman, 2008). In addition, RJA at 15 months was found to predict expressive language concurrently for HR infants (Presmanes et al., 2007), and, importantly, to age 5 for both HR and LR infants (Malesa et al., 2012). These findings support the idea that by following adults' attentional focus, infants are more likely to attend to the objects that caregivers are labeling, thus facilitating language development (Baldwin, 1995).

While motor imitation and RJA both predict later expressive language in HR and LR infants, it is not yet clear how imitation and RJA may be linked to each other throughout early development and how they may interact longitudinally to predict language. Studies have found concurrent relations between motor imitation and RJA in young children with ASD, but not for TD children (McDuffie et al., 2007; Rogers, Hepburn, Stackhouse, & Wehner, 2003). Given some theoretical and empirical findings, a mediation model of development is proposed in which motor imitation development sets the stage for growth in RJA, which mediates the relation between motor imitation and expressive vocabulary. Early imitative play involves infants' and caregivers' shared attention to objects (Ingersoll, 2008; Toth, Munson, Meltzoff, & Dawson, 2006), which may be essential for conveying the social and learning value of following others' attentional cues. It is possible that infants' imitation of adults may facilitate and reinforce the development of RJA (McDuffie et al., 2007); imitation

is likely to provide experiences that facilitate increased understanding of what others are attending to, which may scaffold the development of RJA (Tomasello, 1995). Supporting this directionality are findings that imitation develops before RJA (Mundy et al., 2007; Nadel et al., 1999) and that training in motor imitation can increase RJA and spontaneous expressive language abilities in 2–4-year-old children with ASD (Ingersoll & Schreibman, 2006). In addition, a combined measure of initiating and responding to joint attention was found to mediate the relation between imitation and conversational skill when all abilities were measured concurrently in 5-year-old, TD children (Farrant, Maybery, & Fletcher, 2011).

Given that studies have found associations that differ by ASD diagnosis and risk status when measuring imitation, RJA, and language concurrently (Carpenter et al., 2002; Wu & Chiang, 2014), infants' risk for ASD will be examined as a moderator in this mediation model. Empirical findings are mixed as to whether associations between imitation, RJA, and expressive language will be stronger or weaker for HR infants. While some studies have found that imitation and later language were associated for children with ASD (Charman, Baron-Cohen, Swettenham, Drew, & Cox, 2003; Stone et al., 1997; Stone & Yoder, 2001) and for both HR and LR children (Young et al., 2011), another study found that imitation was related to concurrent language for TD children but not children with ASD (Rogers et al., 2003). In the second year, one study found that 15-month RJA and 5-year expressive language were associated for both HR and LR children (Malesa et al., 2012), while another study found that 12- to 23-month RJA and language were concurrently associated for HR children but not LR children (Presmanes et al., 2007).

In summary, this study examines the role of RJA as a potential mediator of the relation between motor imitation ability and later expressive language ability in 12- to 18-month-old infants at high and low risk for ASD. It is hypothesized that RJA at 15 months will mediate the association between motor imitation ability at 12 months and expressive vocabulary at 18 months for both HR and LR infants. It is further hypothesized that the indirect effect and direct effect of mediation will be conditional on risk group (i.e., moderation), but the direction of this moderation (e.g., stronger associations in HR or LR infants) is exploratory due to mixed previous findings. This study is the first to examine the sequential contribution of early skills to later language ability in HR and LR infants using a prospective, longitudinal design.

Method

Participants

The initial sample comprised 112 infants recruited into a longitudinal, prospective multisite study investigating the social and emotional development of HR infants and LR infants at the University of Washington, Vanderbilt University, and the University of Miami. HR and LR participants were recruited through research centers, clinics, local pediatric offices, and the greater community. Inclusion criteria for both groups included: (1) enrollment age between 6 and 12 months; (2) an older sibling > 36 months of age, (3) gestational age ≥ 37 weeks, (4) birth weight at least 2500 grams, (5) the absence of severe sensory or motor impairments, and (6) the absence of identified metabolic, genetic, or progressive

neurological disorders. For the HR group, the diagnosis of ASD in the older sibling was verified using 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). For the LR group, additional requirements were (1) no reported family history of ASD in first, second, or third degree relatives, and (2) a score below 9 on the Social Communication Questionnaire for all older siblings in the family (SCQ; Rutter, Bailey, & Lord, 2003).

For the present study, an additional inclusion criterion was the availability of data on imitation, RJA, and expressive vocabulary at 12, 15 and 18 months. This criterion reduced the group size to 50 HR and 34 LR infants. Demographic characteristics of the sample are presented in Table 1. No risk group differences were found for maternal education level or for infants' race/ethnicity, sex, or age at study visits. Most infants had mothers who were Caucasian (72%) and college-educated (70%).

Procedure

Institutional Review Board approval was obtained from both sites, and all parents provided informed consent prior to participation in research procedures. Infants participated in 1- to 2-hour assessments in the lab at 12, 15, and 18 months. Parents held infants in their laps or sat a short distance away while experimenters administered behavioral measures. Motor imitation was measured at 12 months, RJA at 12 and 15 months, and expressive vocabulary at 12, 15, and 18 months.

Measures

Screening Tool for Autism in Toddlers (STAT).—Motor imitation ability was assessed at 12 months using the Motor Imitation domain score on the STAT. The STAT is a 20-minute play-based assessment with activities in four domains—Play, Requesting, Directing Attention, and Motor Imitation—designed to identify 2 year-olds at risk for ASD (Stone, Coonrod, & Ousley, 2000; Stone, Coonrod, Turner, & Pozdol, 2004). The STAT is administered by trained examiners with established fidelity, and is scored “live.” Strong psychometric properties have been reported (Stone et al., 2004), and a preliminary screening cutoff score has also been identified for children as young as 14 months (Stone, McMahon, & Henderson, 2008). In addition to its use as an ASD screener, individual domain scores from the STAT have been used to assess specific social-communicative behaviors, including motor imitation (e.g., Presmanes et al., 2007; Stone, McMahon, Yoder, & Walden, 2007; Wu & Chiang, 2014).

The Motor Imitation domain comprises four items: shaking a rattle, rolling a car back and forth, banging hands alternately on the table, and hopping a small toy animal across the table. For each item an examiner performs a distinct action and encourages the child to imitate by saying, “You do it” or “Your turn.” The infant receives up to three opportunities to imitate each item, and the best response for each item is scored live as a Pass (1 point) or Fail (0 points). Motor Imitation scores range from 0 to 4, with higher scores indicating more successful imitation responses.

Early Social Communication Scales (ESCS).—RJA was assessed at 12 and 15 months 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 said the name of the infant three times while pointing to one of four colorful posters around the room; 4 trials (one to each poster) were administered during two blocks that occurred at different times during the ESCS administration. If the infant turned and looked at the poster to which the experimenter was pointing, RJA was coded as a "pass" for that trial. Scores on the Gaze Following Task range from 0 to 8, with higher scores indicating more frequent RJA. RJA was coded from videotapes by two independent trained coders. Interobserver reliability, as indexed by absolute intraclass correlations, was excellent at both 12 months ($ICC = .94$) and 15 months ($ICC = .98$).

MacArthur-Bates Communicative Development Inventories (MCDI).—Expressive vocabulary was assessed at 12, 15, and 18 months using the "Words Said" subscale of the MacArthur-Bates Communicative Development Inventories: Words and Gestures Edition for 8- to 18-month-olds (MCDI; Fenson et al., 2007). The MCDI is a well-validated parent checklist consisting of 396 vocabulary words. Parents endorsed words that their child could both understand and say. The number of words endorsed was the variable of interest.

Analytic Plan

Preliminary analyses.—Variables were measured at equal time intervals (i.e., 3-month intervals), which helps produce unbiased mediation estimates (Cole & Maxwell, 2003). Analyses were conducted in order to ascertain that participants excluded because of missing data did not differ from included participants on any of the variables of interest; that is, the analyses assessed whether data were missing completely at random (MCAR; Schafer & Graham, 2002). Risk group differences in 12-month motor imitation were analyzed using an independent samples *t*-test. Risk group differences over time for RJA between 12 and 15 months and expressive vocabulary at 12, 15, and 18 months were analyzed using mixed-design ANOVAs, with risk group as the between-subjects factor and time point as the within-subjects factor. Maternal education, race/ethnicity, and gender were not significantly associated with the 18-month expressive vocabulary outcome, and no risk-group differences were found; therefore, these variables were not included as covariates in the models.

Infants' 12-month Early Learning Composite score ($M = 105.53$; $SD = 11.49$) on the Mullen Scales of Early Learning (Mullen, 1995) was examined to determine whether the risk groups differed in cognitive ability and whether cognitive ability was associated with the developmental skills assessed. Infants' cognitive ability did not differ for HR compared to LR infants, $t(81) = -1.61$, $p > .05$. Cognitive ability was not associated with 12-month motor imitation or 15-month RJA for HR or LR infants, but it was associated with 18-month EV for HR infants, $r(82) = .36$, $p < .01$ (See Table 3). Based on this finding, 12-month cognitive ability was included in the mediation analyses. However, within the initial models, cognitive ability did not predict 15-month RJA, or 18-month EV, and it did not affect the mediation results. Therefore, it was not included in the final models, presented below.

Mediation analyses.—It was hypothesized that infants' motor imitation at 12 months would predict their 18-month expressive vocabulary indirectly through their RJA ability at 15 months. This indirect effect was calculated using two separate multiple regression models using the PROCESS macro (Hayes, 2013). One model was conducted to assess the effect of the predictor (12-month motor 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 motor 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 motor imitation and expressive vocabulary that remains after calculating the indirect effect. The predictor and mediator variables were centered prior to inclusion in the model.

Levels of the mediator and outcome at earlier ages—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 step 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 of language on itself over time (Cole & Maxwell, 2003; Maxwell, Cole, & Mitchell, 2011; Selig & Preacher, 2009). The final model assessed whether motor imitation at 12 months affected later growth in RJA from 12–15 months, which then affected expressive vocabulary at 18 months. Risk group (HR versus LR infants) was tested as a potential moderator of the indirect and direct effect.

Bootstrapping with bias-corrected confidence intervals (10,000 samples) was used to generate the most accurate estimate of the indirect effect and evaluate its significance (Cole & Maxwell, 2003; Hayes, 2013; MacKinnon, Fairchild, & Fritz, 2007; Preacher, Rucker, & Hayes, 2007).

Results

Preliminary Analyses

Missing data.—The following percentages of data were missing for each variable of interest in the original 112-participant sample: 12-month motor imitation: 4.5%; 12-month RJA: 15.2%; 12-month EV: 3.6%; 15-month RJA: 17.0%; 15-month EV: 6.3%; 18-month EV: 6.3%. Analyses were conducted to determine whether data from the full sample were missing completely at random (MCAR). Missing values for 18-month expressive vocabulary were not associated with infants' 12- and 15-month RJA, 12-month motor imitation, sex, risk group, or maternal education, $ps > .05$. Infants' 12- and 15-month expressive vocabulary also did not predict the presence of a missing value for 18-month expressive vocabulary $ps > .05$. Infants included in the final sample of 84 did not differ from the original 112-participant sample on any of the model variables, $ps > .05$. These analyses suggested that data in the original 112-infant sample were MCAR. Therefore, all subsequent analyses were conducted on the final sample, which comprised 84 infants with data on all model variables.

Risk group differences.—Means and standard deviations for study variables at each time point are presented in Table 2. Pearson product-moment zero-order correlations between study variables by ASD risk group are presented in Table 3. T-tests revealed no group

differences between HR and LR infants for motor imitation at 12 months, $t(82) = -0.69$, $p > .05$. A mixed-design ANOVA (age X risk group) for RJA revealed no significant main effect of risk group, $F(1, 82) = 1.48$, $p > .05$ and a significant main effect of time; RJA increased between 12 and 15 months, $F(1, 82) = 23.84$, $p < .001$. No interaction between risk group and time was found for RJA, $F(1, 82) = 1.71$, $p > .05$. A second mixed-design ANOVA (age X risk group) for expressive vocabulary revealed no significant main effect of risk group, $F(1, 82) = 2.97$, $p > .05$ and a significant main effect of time; expressive vocabulary increased between 12 and 18 months, $F(1.08, 88.32) = 62.15$, $p < .001$. Post-hoc analyses using a Bonferroni correction revealed that infants' expressive vocabulary grew significantly at each time point: from 12 to 15 months, $t(83) = -6.63$, $p < .001$, from 15 to 18 months, $t(83) = -7.33$, $p < .001$, and from 12 to 18 months, $t(83) = -7.72$, $p < .001$. Results for both ANOVAs were reported using the Greenhouse-Geisser correction for violation of sphericity. The interaction between risk group and time for expressive vocabulary approached significance, $F(1.08, 88.32) = 3.81$, $p = .05$ (see Figure 1).

Mediation

Model 1: Indirect and direct effects across all infants.—As hypothesized, 12-month motor imitation positively predicted 12–15 month RJA growth (path *a*) for all infants, $B = .51$, $p = .05$, and 15-month RJA positively predicted subsequent growth in expressive vocabulary from 15–18 months (path *b*), $B = 3.95$, $p = .03$. The indirect effect, $ab = 2.03$, indicated that for each additional item infants imitated on the STAT at 12 months, parents reported they could say 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, 95% confidence interval (CI) [0.34, 6.30]. The direct effect was not significant, $B = 2.89$, 95% CI of [−5.46, 11.23]. The total effect was also not significant, $B = 4.91$, 95% CI of [−3.43, 13.25].

Model 2: Conditional effects by risk group.—To assess whether the indirect or direct effects of the model were conditional on risk group, risk group*RJA and risk group*imitation interaction terms were estimated. Neither interaction term was significant ($ps > .05$), indicating that ASD risk did not moderate the indirect effect of 12-month motor imitation on 18-month expressive vocabulary through 15-month RJA. However, the direct effect of 12-month motor 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, $B = 12.46$, 95% CI of [0.45, 24.82], but not HR infants, $B = -4.43$, 95% CI of [−14.97, 6.11].

Final model.—A parsimonious final model was estimated incorporating the significant effects of previous modeling. The final model included a significant non-conditional indirect effect (that did not vary by risk group) and a significant direct effect that was conditional by risk group; see Table 4 and Figure 2. In this model, the indirect effect (*ab*) equaled 1.64 with a 95% confidence interval of [0.24, 5.31], and for each additional item infants imitated at 12 months, parents reported they could say an average of 1.64 more words at 18 months.

The direct effect was moderated by risk group; a conditional direct effect was present such that there was a significant direct effect for LR infants, $B = 12.67$ with a 95% CI of [0.45, 24.89], but not for HR infants, $B = 1.00$ with a 95% CI of [-15.00, 5.89]. Further, the 12-month imitation by risk group interaction term significantly predicted 18-month EV, $B = 17.22$, $p < .05$, indicating that the strength of these effects were significantly different. For each additional item that LR infants imitated at 12 months, parents reported they could say 12.67 more words on average at 18 months, above and beyond the indirect effect. For HR infants, however, there was no significant direct effect of 12-month motor imitation on 18-month expressive vocabulary; the indirect effect of motor imitation on expressive vocabulary through RJA comprised the only relation. In addition, the second regression model with 18-month expressive vocabulary as the outcome variable and 12-month imitation, 12- and 15-month RJA, 12- and 15-month expressive vocabulary, and risk group as predictors had an R^2 of .72; see Table 4 and Figure 2.

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

Discussion

This study examined a potential developmental pathway through which basic social-communicative skills impact later language ability for infants at low and high risk for ASD during the first 18 months of life. Specifically, it was hypothesized that infants' 12-month motor imitation affected their 18-month expressive vocabulary indirectly through 15-month RJA. This indirect effect was hypothesized to be conditional on ASD risk, with different patterns of relations observed between HR and LR infants. Zero-order correlations between scores of motor imitation, RJA, and expressive vocabulary at 12–18 months were largely non-significant. However, mediation analyses examining the effect of 12-month motor imitation on 12- to 15-month *growth* in RJA and 15–18 month *growth* in expressive vocabulary yielded significant results.

As hypothesized, motor imitation ability at 12 months predicted growth in expressive vocabulary from 15 to 18 months indirectly through growth in RJA ability from 12 to 15 months, as indicated by the significant indirect effect for all infants. Imitation may be indirectly related to expressive language through RJA because (1) imitating others reflects and/or fosters social interest that facilitates the development of RJA, a more sophisticated social-communicative skill (Ingersoll, 2008; McDuffie et al., 2007), and (2) infants who are following an adult's attention to an object may more readily learn the label for that object (Ahktar, Carpenter & Tomasello, 1996; Baldwin, 1995; Morales et al., 2000; Walton & Ingersoll, 2013). Regardless of infants' risk for ASD, early imitation led to higher levels of later expressive language in part through their intermediate RJA behaviors. The fact that this developmental pathway exists across LR and HR infants further supports the hypothesis that basic social-communicative skills interact to build more complex communicative behaviors such as language (e.g., Baldwin, 1995; Carpenter et al., 1998).

There are several implications of the similar developmental pathway observed across all infants in the form of the indirect effect. First, it suggests that motor imitation and RJA would both be appropriate targets for intervention. Second, it suggests the importance of offering intervention for RJA and imitation as early as possible for HR infants, even before a potential ASD diagnosis. Early ASD-specialized intervention is associated with improvements in social, cognitive, and adaptive functioning (Dawson et al., 2012; Rogers & Vismara, 2008). Early deficits in social-communicative skills are often found in children who are later diagnosed with ASD, and they may narrow infants' opportunities to learn from their environment, causing a cascade of impairments (Zwaigenbaum et al., 2005). Interventions for imitation (RIT; Ingersoll, 2012) and joint attention (JASPER; Goods, Ishijima, Chang, & Kasari, 2013) have already been developed for older children with ASD, but may need to be adapted for use with infants who are at risk, even before they show signs of ASD. Interventions designed to promote RJA development might be especially beneficial for young children at risk for ASD, given that motor imitation may promote later expressive language only indirectly, through RJA, for these children. Interventions that target skills that are building blocks of imitation and RJA even earlier in development, such as infants' understanding of others as intentional, gaze shifting, and motor development may also be effective. It is important to consider that, because motor imitation and RJA develop within a similar time window and both are expressions of infants' understanding of others' actions (Tomasello, 1995), motor imitation and RJA may affect each other in a transactional manner across development as they contribute to later expressive language.

The second hypothesis, that there would be moderation of the indirect and direct effects by ASD risk group, was partially supported. The direct effect of 12-month motor imitation on growth in 18-month expressive vocabulary was moderated by risk group, such that the direct effect was significant for LR infants but was non-significant for HR infants. This finding did not support the study's hypothesis that both indirect and direct effects would be moderated by ASD risk. There are several possible explanations for this result. The sample size is relatively small when split by risk group (HR = 50; LR = 34), and this small sample size decreases the likelihood that moderation of any effect (direct or indirect) will be found. In particular, there may not have been sufficient power for the model to identify an indirect effect by risk group. The indirect effect had a very small effect size ($\beta = .03$), while the direct effect had a slightly larger effect size ($\beta = .17$), making it less likely that we would find moderation of the indirect effect compared to the direct effect.

In addition, for HR infants, RJA may function as a gateway (or barrier) between early imitation and later language. For HR infants, imitation may be most useful for language precisely because it increases infants' responding to joint attention (e.g., Ingersoll, 2008). Joint attention is often impaired in children with ASD, and joint attention has been longitudinally associated with social-communicative outcomes for children with ASD, including language (e.g., Anderson et al., 2007; Charman, 2004; Mundy et al., 2009). RJA is thought to be a "pivotal" skill for children with ASD, and it may also be pivotal for HR infants. In contrast, typically developing infants' language may benefit from imitation more directly or through skills other than RJA.

It is also possible that other variables, not measured in this study, account for the relation between motor imitation and language learning. One potential mediator is infants' use of gesture. Imitation routines help infants learn gestures (e.g., waving "bye-bye" with parents) that scaffold language (McDuffie et al., 2007). Gesture has been found to relate to later language for both LR infants and HR infants in the second year of life (e.g., Paradé & Iverson, 2011), and HR infants have been found to use gestures less frequently than LR infants (Stone et al., 2007). As a consequence, HR infants may receive less information related to their focus of attention. Infants' use of gesture may also help adults tailor their verbal input to be more relevant; for example, an infant who points to an object will likely receive a reply related to that object (e.g., Golinkoff, 1986), and adults' replies to infants' pointing may relate to their later language (e.g., Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). Future work could include gesture use in a more comprehensive model estimating the temporal contributions of many early social skills to later language.

A direct effect of imitation on expressive vocabulary for LR infants and not HR infants may have been found because of the way in which motor imitation was operationalized in this study. Early imitation is thought to have two main functions: to increase social reciprocity and to help children learn through example (Uzgiris, 1981). For LR infants, imitation may enrich the overall interactivity of their social interactions directly, by leading to more engagement and more frequent interactions that foster language, as well as indirectly, by acting through RJA. In contrast, it may be the case that HR infants benefit primarily from the learning function of imitation, rather than from the social reciprocity function, and as such could learn to imitate actions (especially those of functional relevance to them) but may not avail themselves of the social function, which might be the link to learning language. Using measures of imitation that have a greater number of validated, diverse items (e.g., Young et al., 2011) and that capture qualitative differences in early imitation-related social vs. learning functions (e.g., Ingersoll, 2012), imitative style (Hobson & Hobson, 2008), or intention understanding (Meltzoff, 2007) could further elucidate the role of imitation in later expressive language for infants at high compared to low risk for ASD.

In contrast to previous studies that have studied older children (i.e., preschoolers) with ASD (e.g., Ingersoll & Meyer, 2011; McDuffie, Yoder, & Stone, 2005; Stone & Yoder, 2001; Toth et al., 2006), this study found that for children at risk for ASD, there was no significant direct effect between 12-month motor imitation and 18-month expressive vocabulary. One possible explanation for this finding is that imitation in HR infants younger than 12 months may more strongly affect language outcome, while in older children, social-communicative skill deficits may have persisted and stabilized and therefore may have a different functional relation to language ability. One study found that imitation at 20 months predicted 42-month receptive, but not expressive language (Charman et al., 2003). The rate at which infants' language develops complicates efforts to compare research studies on social-communicative skills; different skills may be more predictive of and important for language development at different ages. HR children who are later diagnosed or not diagnosed with ASD may also exhibit differing and more variable developmental trajectories of early social communicative skills compared to TD children (e.g., Landa, Gross, Stuart, & Flaherty, 2013), such that the more distal relation between 12-month motor imitation and 18-month expressive vocabulary may be less likely to be significant for HR infants, some of whom will be later diagnosed

with ASD, compared to LR infants. The majority of research on language development in relation to ASD has studied children at 3 to 4 years of age, after diagnosis. In addition, imitation was operationalized and measured differently across these studies. Directly comparing these studies to new prospective studies of HR and LR infants in the first two years may lead to misperceptions about the relative importance of social-communicative skills at different ages.

There were several limitations of this study. The sample exhibited high average maternal education level and a lack of racial/ethnic diversity, which hinders the external validity of the results. The motor imitation task used in this study was more directive than naturalistic in nature, preventing us from examining the nuance in types and functions of imitation that might differentially influence language development. Expressive vocabulary was measured by parent report, which may have produced a biased estimate; however, parent-report and experimenter-administered measures of expressive language have been found to be strongly correlated at this age (e.g., Luyster, Kadlec, Carter, & Tager-Flusberg, 2008; Fenson et al., 2007), suggesting that parent-reported expressive vocabulary is a reasonable index of this construct. This study may have lacked the power to examine moderation of the mediation model by ASD diagnosis. However, the sample used in this study is of a typical size compared to other studies of high-risk infants in the literature. This sample characterizes children by ASD risk, not diagnosis. Although only about 7–19% of infants at risk for ASD will be diagnosed with the disorder, an additional proportion of HR infants experience delays in language and social skills, while the majority of infants do not experience any delays (Constantino et al., 2010; Grønberg et al., 2013; Messinger et al., 2013). HR infants as a group may therefore display wide variability in early social-communicative skills and language (Stone et al., 2007). It will be important to conduct further analyses comparing HR infants who are later diagnosed with ASD, HR infants without ASD, and typically developing LR infants to gain additional information about potentially distinct developmental pathways. Finally, it should be noted that this study demonstrates evidence for one specific developmental model of language growth. We recognize that other potential models employing different constructs and/or time points may also help to explain infants' language development. This study used a longitudinal correlational design, and as such precludes us from making causal conclusions about the nature of language development.

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. The study used advanced statistical methods to study the processes of language development. Including infants at both high and low risk for ASD in the same study allowed for comparison between groups and provided evidence that (1) language development occurs via some of the same developmental processes, regardless of ASD risk, and (2) specific early skills, such as RJA, may be especially important for children at risk for ASD.

Future research would benefit from investigating the role of early social-communicative skills such as all types of imitation, RJA, and gesture on infants' language ability as it continues to increase after 18 months of age. Multiple early skills should be incorporated into more comprehensive, transactional path models 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.

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References

- Ahktar 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 DK, Lord C, Risi S, DiLavore PS, 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 DA (1995). Understanding the link between joint attention and language In Moore C, Dunham PJ (Eds.), *Joint attention; its origins and role in development* (131–158). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
- Bates E, Benigni L, Bretherton I, Camaioni L, & Volterra V (1977). From gesture to the first word: On cognitive and social prerequisites In Lewis M & Rosenblum LA, (Eds.), *Interaction, conversation, and the development of language* (247–207). New York: John Wiley & Sons.
- 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 BF, & Rogers SJ (2002). Interrelations among social-cognitive skills in young children with autism. *Journal of Autism and Developmental Disorders*, 32(2), 91–106. [PubMed: 12058847]
- CDC. (2014). Prevalence of autism spectrum disorders among children 8 years old—autism and developmental disabilities monitoring network, 11 sites, United States, 2010. *MMWR Surveill Summ*, 63, 1–21.
- Charman T, Baron-Cohen S, Swettenham GB, 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
- Cole DA, & Maxwell SE (2003). Testing mediational models with longitudinal data: Questions and tips in the use of structural equation modeling. *Journal of Abnormal Psychology*, 112(4), 558–77. doi:10.1037/0021-843X.112.4.558 [PubMed: 14674869]
- Constantino JN, Zhang Y, Frazier T, Abbacchi AM, & 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 [PubMed: 20889652]

- 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), 271–83. doi:10.1037/0012-1649.40.2.271 [PubMed: 14979766]
- Dawson G, Jones EJJ, Merkle K, Venema K, Lowy R, Faja S, ... Webb SJ (2012). Early behavioral intervention is associated with normalized brain activity in young children with autism. *Journal of the American Academy of Child and Adolescent Psychiatry*, 51(11), 1150–9. doi:10.1016/j.jaac.2012.08.018 [PubMed: 23101741]
- Delgado CEF, Peter M, Crowson M, Markus J, Yale M, & Schwartz H (2002). Responding to joint attention and language development: a comparison of target locations. *Journal of Speech, Language, and Hearing Research*, 45(4), 715–9.
- Farrant BM, Maybery MT, & 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, Marchman VA, Thal DJ, Dale PS, Reznick JS, & 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 [PubMed: 17181712]
- Goldfield BA, & Reznick SJ (1990). Early lexical acquisition: Rate, content, and the vocabulary spurt. *Journal of Child Language*, 17, 171–183. [PubMed: 2312640]
- Goldin-Meadow S, Goodrich W, Sauer E, & Iverson J (2007). Young children use their hands to tell their mothers what to say. *Developmental Science*, 10(6), 778–85. doi:10.1111/j.1467-7687.2007.00636.x [PubMed: 17973795]
- Golinkoff RM (1986). 'I beg your pardon?': The preverbal negotiation of failed messages. *Journal of Child Language*, 13, 455–476. doi: 10.1017/S0305000900006826 [PubMed: 3793809]
- Goods KS, Ishijima E, Chang Y-C, & Kasari C (2013). Preschool based JASPER intervention in minimally verbal children with autism: Pilot RCT. *Journal of Autism and Developmental Disorders*, 43(5), 1050–6. doi:10.1007/s10803-012-1644-3 [PubMed: 22965298]
- Grønberg TK, Schendel DE, & Parner ET (2013). Recurrence of autism spectrum disorders in full- and half-siblings and trends over time: A population-based cohort study. *JAMA Pediatrics*, 167 1–7. doi:10.1001/jamapediatrics.2013.2259
- Hayes AF (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York: Guilford Press.
- Hobson RP, & Hobson JA (2008). Dissociable aspects of imitation: A study in autism. *Journal of Experimental Child Psychology*, 101(3), 170–185. doi:10.1016/j.jecp.2008.04.007 [PubMed: 18572186]
- Hus V, Pickles A, Cook EH Jr., Risi S, & Lord C (2007). Using the Autism Diagnostic Interview–Revised to increase phenotypic homogeneity in genetic studies of autism. *Biological Psychiatry*, 61, 438–448. [PubMed: 17276746]
- Ibañez LV, Grantz CJ, & Messinger DS (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. [PubMed: 25632273]
- 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. *Journal of Autism and Developmental Disorders*, 36(4), 487–505. doi:10.1007/s10803-006-0089-y [PubMed: 16568355]
- Ingersoll B (2008). The effect of context on imitation skills in children with autism. *Research in Autism Spectrum Disorders*, 2(2), 332–340. doi:10.1016/j.rasd.2007.08.003
- 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 (2012). Brief report: Effect of a focused imitation intervention on social functioning in children with autism. *Journal of Autism and Developmental Disorders*, 42(8), 1768–73. doi:10.1007/s10803-011-1423-6 [PubMed: 22146934]

- Jones SS (2007). Imitation in infancy: The development of mimicry. *Psychological Science*, 18(7), 593–9. doi:10.1111/j.1467-9280.2007.01945.x [PubMed: 17614867]
- Kuhl PK (2007). Is speech learning “gated” by the social brain? *Developmental Science*, 10(1), 110–20. doi:10.1111/j.1467-7687.2007.00572.x [PubMed: 17181708]
- Landa RJ, Gross AL, Stuart EA, & Faherty A (2013). Developmental trajectories in children with and without autism spectrum disorders: The first 3 years. *Child Development*, 84(2), 429–442. doi:10.1111/j.1467-8624.2012.01870.x [PubMed: 23110514]
- Lord C, Risi S, Lambrecht L, Cook EH, Leventhal BL, DiLavore PC, 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, *Journal of Autism and Developmental Disorders*, 30(3), 205–23. [PubMed: 11055457]
- Lord C, Risi S, & Pickles A (2004). Trajectory of language development in autistic spectrum disorders In Rice ML & Warren SF (Eds.), *Developmental language disorders: From phenotypes to etiologies* (7–29). Mahwah, NJ: Erlbaum.
- Luyster RJ, Kadlec MB, Carter A, & Tager-Flusberg H (2008). Language assessment and development in toddlers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 38(8), 1426–38. doi:10.1007/s10803-007-0510-1 [PubMed: 18188685]
- MacKinnon DP, Fairchild AJ, & Fritz MS (2007). Mediation analysis. *Annual Review of Psychology*, 58, 593–614. doi:10.1146/annurev.psych.58.110405.085542
- Malesa E, Foss-Feig J, Yoder P, Warren Z, Walden T, & Stone W (2012). Predicting language and social outcomes at age 5 for later-born siblings of children with autism spectrum disorders. *Autism*, 0, 1–13. doi:10.1177/1362361312444628
- Masten AS, & Cicchetti D (2010). Developmental cascades. *Development and Psychopathology*, 22(3), 491–5. doi:10.1017/S0954579410000222 [PubMed: 20576173]
- Maxwell SE, Cole D, & Mitchell M (2011). Bias in cross-sectional analyses of longitudinal mediation: Partial and complete mediation under an autoregressive model. *Multivariate Behavioral Research*, 46(5), 816–841. doi:10.1080/00273171.2011.606716 [PubMed: 26736047]
- McDuffie A, Yoder P, & Stone W (2005). Prelinguistic predictors of vocabulary in young children with autism spectrum disorders. *Journal of Speech, Language, and Hearing Research*, 48, 1080–1097.
- 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. *Journal of Autism and Developmental Disorders*, 37, 401–412 [PubMed: 16900404]
- 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 Baron-Cohen S, Tager-Flusberg H, & Cohen D (Eds.), *Understanding other minds: Perspectives from autism* (35–366). New York: Oxford University Press.
- Meltzoff AN (2007). The “like me” framework for recognizing and becoming an intentional agent. *Acta Psychologica*, 124(1), 26–43. doi:10.1016/j.actpsy.2006.09.005 [PubMed: 17081488]
- Messinger D, Young GS, Ozonoff S, Dobkins K, Carter A, Zwaigenbaum L, Landa RJ, 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 [PubMed: 23452686]
- Morales M, Mundy P, Delgado CE, Yale M, Messinger D, Neal R, & Schwartz HK (2000). Responding to joint attention across the 6- through 24-month age period and early language acquisition. *Journal of Applied Developmental Psychology*, 21(3), 283–298.
- Mullen E (1995). *Mullen Scales of Early Learning*. Circle Pines, MN: America Guidance Service.
- Mundy P, Sigman M, & Kasari C (1994). Joint attention, developmental level, and symptom presentation in young children with autism. *Development & Psychopathology*, 6, 389–401.
- 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, Block J, Delgado C, Pomares Y, Hecke AV Van, & Paradé MV (2007). Individual differences and the development of joint attention in infancy. *Child Development*, 78(3), 938–954. [PubMed: 17517014]

- Mundy P, Sullivan L, & Mastergeorge AM (2009). A parallel and distributed-processing model of joint attention, social cognition, and autism. *Autism Research*, 2, 2–21. [PubMed: 19358304]
- Nadel J, Guerini C, Peze A, & Rivet C (1999). The evolving nature of imitation as a format for communication In Nadel J, & Butterworth G (Eds.), *Imitation in infancy* (209–233). Cambridge, UK: Cambridge University Press.
- Ozonoff S, Young GS, Carter A, Messinger D, Yirmiya N, Zwaigenbaum L, ... & Stone WL (2011). Recurrence risk for autism spectrum disorders: A baby siblings research consortium study. *Pediatrics*, 128, e488–e495. [PubMed: 21844053]
- Parladé MV, & Iverson JM (2012). The interplay between language, gesture, and affect during communicative transition: A dynamic systems approach. *Developmental Psychology*, 47(3), 820–33. doi:10.1037/a0021811
- Pinborough-Zimmerman J, Satterfield R, Miller J, Bilder D, Hossain S, & McMahon W (2007). Communication disorders: Prevalence and comorbid intellectual disability, autism, and emotional/behavioral disorders. *American Journal of Speech-Language Pathology*, 16, 359–367. doi:10.1044/1058-0360(2007/039) [PubMed: 17971495]
- Preacher KJ, Rucker DD, & Hayes AF (2007). Addressing moderated mediation hypotheses: Theory, methods, and prescriptions. *Multivariate Behavioral Research*, 42(1), 185–227. doi:10.1080/00273170701341316 [PubMed: 26821081]
- Presmanes AG, Walden TA., Stone WL, & Yoder PJ (2007). Effects of different attentional cues on responding to joint attention in younger siblings of children with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 37(1), 133–44. doi:10.1007/s10803-006-0338-0 [PubMed: 17186366]
- Rogers SJ, & Pennington BF (1991). A theoretical approach to the deficits in infantile autism. *Development and Psychopathology*, 3, 137–162.
- Rogers SJ, Hepburn SL, Stackhouse T, & Wehner E (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Journal of Child Psychology and Psychiatry*, 44(5), 763–81. [PubMed: 12831120]
- Rogers SJ, & Vismara LA (2008). Evidence-based comprehensive treatments for early autism. *Journal of Clinical Child and Adolescent Psychology*, 37(1), 8–38. doi:10.1080/15374410701817808 [PubMed: 18444052]
- 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.
- Schafer JL, & Graham JW (2002). Missing data: Our view of the state of the art. *Psychological Methods*, 7(2), 147–177. doi:10.1037//1082-989X.7.2.147 [PubMed: 12090408]
- Selig JP, & Preacher KJ (2009). Mediation models for longitudinal data in developmental research. *Research in Human Development*, 6(2–3), 144–164. doi:10.1080/15427600902911247
- Sigman M, & Ruskin E (1999). Continuity and change in the social competence of children with autism, Down syndrome, and developmental delays. *Monographs of the Society for Research in Child Development*, 64, Serial No. 256.
- 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. [PubMed: 18999331]
- Stone WL, Ousley OY, & Littleford CD (1997). Motor imitation in young children with autism: What's the object? *Journal of Abnormal Child Psychology*, 25(6), 475–85. [PubMed: 9468108]
- Stone WL, Coonrod EE, & Ousley OY (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. [PubMed: 11261472]
- Stone W, & Yoder P (2001). Predicting spoken language level in children with autism spectrum disorders. *Autism*, 5(4) 341–361. [PubMed: 11777253]
- Stone WL, Coonrod EF, Turner LM, & Pozdol SL (2004). Psychometric properties of the STAT for early autism screening. *Journal of Autism and Developmental Disorders*, 34(6), 691–701. [PubMed: 15679188]

- Stone WL, McMahon CR, Yoder PJ, & Walden TA (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 [PubMed: 17404136]
- Stone WL, McMahon CR, & Henderson LM (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. [PubMed: 18805947]
- 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 [PubMed: 17216332]
- Tomasello M (1995). Joint attention as social cognition In Moore C & Dunham PJ (Eds.), *Joint attention: Its origins and role in development*, (103–130). New York: Lawrence Erlbaum Associates, Inc.
- 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. *Journal of Autism and Developmental Disorders*, 36, 993–1005. [PubMed: 16845578]
- Turner LM, & Stone WL (2007). Variability in outcome for children with an ASD diagnosis at age 2. *Journal of Child Psychology and Psychiatry*, 48(8), 793–802. doi:10.1111/j.1469-7610.2007.01744.x [PubMed: 17683451]
- Uzgiris I (1981). Two functions of imitation in infancy. *International Journal of Behavioral Development*, 4, 1–12.
- Walton KM, & Ingersoll BR (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
- 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 [PubMed: 23921662]
- Young GS, Rogers SJ, 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. [PubMed: 21910524]
- 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 [PubMed: 15749241]

Figure 1.
Expressive vocabulary growth over time.
Error bars represent $\pm$ one standard error of the mean.

Figure 2.

Final mediation model: Conditional indirect effect for all infants.

The indirect effect is significant across all infants, whereas the direct effect is significant for LR but not HR infants. Values are unstandardized regression coefficients. Significant effects are described in bold.

Table 1.

Demographic Characteristics of the Sample

	HR Infants (<i>n</i> = 50)	LR Infants (<i>n</i> = 34)
Infant Age at Visit (months)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
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)
Infant Gender	# (%)	# (%)
Female	21 (42)	18 (53)
Male	29 (58)	16 (47)
Infant Race/Ethnicity	# (%)	# (%)
Caucasian	36 (72)	30 (88)
Multiracial	8 (16)	3 (9)
Other	6 (12)	1 (3)
Maternal Level of Education	# (%)	# (%)
HS diploma only	9 (18)	2 (6)
Associates or Bachelor's degree	22 (44)	15 (44)
Masters degree or higher	13 (26)	16 (47)
No response	6 (12)	1 (3)

Table 2.

Means (Standard Deviations) for Study Variables

Construct	Age (months)	HR Infants	LR Infants	All Infants
Cognitive Ability ^a	12	103.86 (11.97)	107.94 (10.46)	105.53 (11.49)
Motor 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 Vocabulary	12	4.88 (6.99)	5.59 (7.50)	5.17 (7.16)
	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)

^a Cognitive ability was assessed using the Mullen Scales of Early Learning (MSEL; Mullen, 1995), Early Learning Composite (ELC).

Table 3.**Correlations Among Study Variables**

	1	2	3	4	5	6	7
1. Cog. Ability (12 months)	--	.12	.20	.21	.05	.08	.15
2. Imitation (12 months)	.09	--	-.21	.16	.03	.24	.37*
3. RJA (12 months)	.35*	-.04	--	.36*	-.08	-.26	-.11
4. RJA (15 months)	.11	.11	.43**	--	.16	.09	.19
5. EV (12 months)	.38**	-.11	.12	.02	--	.47**	.22
6. EV (15 months)	.39**	-.01	-.01	-.15	.69**	--	.82
7. EV (18 months)	.36**	-.05	-.06	-.05	.52**	.82**	--

*
 $p < .05$.

**
 $p < .01$.

Correlations for LR infants are displayed above the diagonal on the upper right, while correlations for HR infants are displayed below the diagonal on the lower left.

Cog. = Cognitive. Imitation = motor imitation. RJA = responding to joint attention. EV = expressive vocabulary

Table 4.

Final Model: Indirect Effect for All Infants, Direct Effect Conditional on Risk Group

15-month RJA (mediator)				
	Model	Coeff (B)	SE	p
12-month imitation	<i>a</i>	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	<i>c'</i> (HR)	-4.56	5.25	0.39
15-month RJA	<i>b</i>	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

Note: Imitation = motor imitation; EV = expressive vocabulary; RJA=responding to joint attention. LLCI = lower limit of 95% confidence interval; ULCI = upper limit of 95% confidence interval; cov = covariate. Risk group coded as 0 = HR, 1 = LR.