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RESEARCH ARTICLE

Caregiver sensitivity predicts infant language use, and infant language complexity predicts caregiver language complexity, in the context of possible emerging autism

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Abstract

While theory supports *bidirectional* effects between caregiver sensitivity and language use, and infant language acquisition—both caregiver-to-infant and also infant-to-caregiver effects—empirical research has chiefly explored the former *unidirectional* path. In the context of infants showing early signs of autism, we investigated prospective bidirectional associations with 6-min free-play interaction samples collected for 103 caregivers and their infants (mean age 12-months; and followed up 6-months later). We anticipated that measures of caregiver sensitivity/language input and infant language would show within-domain temporal stability/continuity, but also that there would be predictive associations from *earlier* caregiver input to *subsequent* child language, and vice versa. Caregiver sensitive responsiveness (from the Manchester Assessment of Caregiver–Infant interaction [MACI]) predicted subsequent infant word tokens (i.e., amount of language, coded following the Systematic Analysis of Language Transcripts [SALT]). Further, earlier infant Mean Length of Utterance (MLU; reflecting language complexity, also derived from SALT coding) predicted later caregiver MLU, even when controlling for variability in infant ages and clear within-domain temporal stability/continuity in key measures (i.e., caregiver sensitive responsiveness and infant word tokens; and infant and caregiver MLU). These data add empirical

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support to theorization on how caregiver input can be both supportive of, and potentially influenced by, infant capacities, when infants have social-communication differences and/or communication/language delays suggestive of possible emerging autism.

Lay Summary

Although researchers think caregiver and infant behaviors both play a role in infant language development, most research has examined specifically how caregiver behaviors influence child language outcomes. Here, we investigated evidence for both caregiver-to-infant and infant-to-caregiver roles within 6-min free-play videos collected with 103 caregiver-infant pairs seen at two assessments approximately 6 months apart. Infants were first seen around age 12 months following referral due to early signs of autism. We rated the free-play videos for caregiver sensitive responsiveness and a range of aspects of caregiver and infant language, including number of words and language complexity. We found that caregiver sensitive responsiveness at around 12 months of infant age predicted the number of words infants used at around 18 months, and also that earlier infant language complexity predicted later caregiver language complexity. We ruled out that these links could simply be due to differences in infant ages and the natural tendency for these factors to show some stability over time. These data add evidence to theory about how caregivers can be both supportive of, and influenced by, their infants' own capacities, when infants have social-communication differences and/or communication/language delays indicating possible emerging autism.

KEYWORDS

caregiver sensitive responsiveness, emerging autism, infancy, language, mean length of utterance, parent–child interaction, transactional theory

INTRODUCTION

Language acquisition begins in the first year of life and is a foundational skill with broad developmental implications. Language is fundamental for communicating with others, but also prerequisite for the advancement of other skills, such as literacy (Snowling & Hulme, 2021) and the broad skill domains of prosocial behavior and attention control (Bretherton et al., 2013). There is also evidence in the context of autism that early language skills predict social, academic, adaptive, and vocational outcomes into adolescence and adulthood (Durkin et al., 2011; Gillespie-Lynch et al., 2012). However, many young autistic children present with language-learning delays or differences alongside their core autism features (Georgiou & Spanoudis, 2021) and a substantial evidence base seeks to explain the reasons for and implications of these, by studying the clinical presentation of children with autism or at increased likelihood thereof, from the first year of life through early childhood.

Adult input and infant language development

It has long been theorized that infants acquire language through social interaction with their primary caregivers (Bruner, 1975). Various features of caregiver interaction behavior—including the quantity, quality, and responsiveness of adult communicative and linguistic contributions during caregiver-child interactions—are proposed to shape infants' early language trajectories (Naigles, 2013; Rowe, 2012; Smith et al., 2021). Quantity of caregiver input refers to the amount of adult language used during interaction with the child, while input quality concerns the semantic and syntactic diversity of an adult's contributions (Smith et al., 2021). Sensitive responsiveness reflects the extent to which caregiver interaction behaviors are promptly timed and congruent with the child's attentional focus (Bornstein et al., 2007), including but not limited to caregiver talk (e.g., see Bottema-Beutel et al., 2018, for recent review of the latter). As with infant language development which shows trait-like qualities (i.e., strong temporal stability/continuity, such that early-life skills predict those in later life; McKean et al., 2017; Song & So, 2021), there is also evidence for the trait-like nature of caregiver communicative interaction behaviors—such as responsiveness, warmth and engagement—which likewise show stability over time (Else-Quest et al., 2011).

A substantial empirical evidence base supports theory around socially-mediated infant language acquisition in the context of early childhood autism. Infant exposure to more adult words at ages 9 and 15 months has been associated with better later language skills at age 24 months, in both infants from families with/without a history of autism, and among infants themselves with/without autism (Swanson et al., 2019). Regarding the quality of language input, Fusaroli et al. (2019) found that autistic preschoolers whose parents had produced longer utterances earlier in the children's lives themselves used longer utterances and had larger vocabularies. Regarding caregiver sensitive responsiveness, positive associations have been reported with child language outcomes across myriad studies of parents with young autistic children or with infants at increased likelihood of autism (usually operationalized on the basis of having an older diagnosed sibling, and often referred to as "infant siblings"; Crandall et al., 2019; Edmunds et al., 2019; Green et al., 2010; Hudry et al., 2013), albeit with some null findings (see Choi et al., 2020).

The broader developmental literature also provides some evidence that adult contributions to interaction are influenced by characteristics or behaviors of the child. For example, adults have been found to respond more (i.e., greater *quantity* of caregiver linguistic response) to child vocalizations that are speech-like, whether in the context of typical development (Gros-Louis et al., 2014) or autism (Warlaumont et al. 2014). Choi et al. (2020) recently showed positive associations between the standardized language scores of 18-month-old "infant siblings" and the subsequent *quality* of caregiver linguistic input (operationalized as mean length of utterance; MLU). Finally, Hudry et al. (2013) demonstrated a link between child scores on standardized language assessment and parent communicative "synchrony" (i.e., an indicator of caregiver sensitive responsiveness).

Uni- or bidirectional association?

Some research has shown *bidirectionality* of prospective associations, from earlier infant skills to caregiver contributions, and on to subsequent infant outcomes. For example, further to an association of child speech-like vocalizations and greater quantity of adult responses, Warlaumont et al. (2014) also demonstrated that prompt parental responsiveness following child speech-like vocalizations was associated with increased later likelihood of these vocalizations. Choi et al. (2020)'s recent "infant siblings" study also evidenced reciprocity of associations between parent and infant language. Here, further to the association of 18-month infant language with subsequent parent MLU was positive association of parent MLU with subsequent infant language. Compared to the extent of research into the path from caregiver input to child language acquisition, there has been relatively little examination of the potential for child skills and behaviors to shape their language-learning environment, via the opportunities children present for caregiver responsiveness and/or linguistic input.

Exploring how infant skills relate to caregiver interaction behaviors may be especially important in contexts of possible emerging neurodivergence. These studies could highlight "naturally arising" parent interaction differences; knowledge that can be used to support parents to understand and mitigate potential disruptions in reciprocal interaction cycles for their children's more optimal outcomes. The suggestion that young children who provide fewer linguistic cues and/or present qualitatively different emerging social behaviors from "the norm" may influence or limit opportunities for parent language scaffolding is not new (e.g., see Snow, 1995) but has received relatively little attention compared to the path from parent input to child language outcomes. Further, with the exception of Choi et al. (2020), who recently explored the relative influence of *quantity*, *quality* and sensitive responsiveness of adult input—finding only parent MLU (as an indicator of quality) to be related to later language in "infant siblings"—there has been scant consideration of how caregiver input may be linked to and influenced by child language.

The need for research with community-identified infants

A further gap in the evidence on caregiver-child interaction related to language acquisition in autism arises from research having been conducted primarily in two sampling contexts. One represents toddlers/young children with a confirmed autism diagnosis. Because most children with autism are not diagnosed until around age 4 or during the second year of life at the earliest (Bent et al., 2017; van't Hof et al., 2021), it is difficult to draw confident conclusions around directional influences on caregiver-child interaction and language development from these data collected well outside of the normative language acquisition period.

The second context represents "infant sibling" studies, which offer the opportunity to track development from early in life, in samples of individuals at increased likelihood of autism. Autism recurrence among infant siblings is estimated around 20% (Ozonoff et al., 2011) and "infant sibling" study designs typically compare outcomes for siblings with and without later-identified autism, and outcomes of the whole sibling group against age-matched controls with no close family history of autism (e.g., Choi et al., 2020). The potential benefits of this prospective and enriched sampling approach may be countered, however, by the fact that the younger siblings of children with autism may not be representative of the population of children with autism (Micheletti et al., 2020). Further, there is questionable generalizability of insights drawn from "infant sibling" studies to the broader population of caregivers raising young autistic children, as parents in the latter group share the experience of having already raised an autistic child, and may arguably therefore have modified interaction with their young infant (Wan et al., 2013).

An alternative approach offering benefits of an enriched sample without the potential limitations of the "infant sibling" design is the early identification and prospective tracking of *clinically-indicated* infants identified from the community. We adopted such an approach to examine the directionality of prospective associations between measures of caregiver sensitive responsiveness and quantity and quality of language input, and measures of quantity and quality of infant language. Specifically, we drew on data available from a cohort of infants showing signs of possible emerging autism, first seen around mean age 12 months and followed up around mean age 18 months. Given the extant literature reporting consistent associations between child language and both caregiver sensitive responsiveness (Crandall et al., 2019; Edmunds et al., 2019; Green et al., 2010; Hudry et al., 2013) and amount/diversity of linguistic input (Fusaroli et al., 2019; Swanson et al., 2019), we hypothesized that there would be evidence of prospective bi-directional association; specifically, (1) from earlier caregiver sensitive responsiveness and/or language quantity/quality to later child language quantity/quality, and (2) from earlier child language quantity/quality to later caregiver sensitive responsiveness and/or language input. We also anticipated that the strength of effects might be stronger from caregiver-to-child than from child-to-caregiver, whilst noting that the latter has received little research attention to date.

METHODS

Design, participants and assessment procedure

Approval for the broader study—a randomized controlled trial (RCT) of pre-emptive intervention for infants identified with early behavioral signs of autism (see Whitehouse et al., 2019 for more information)—was provided by the Child and Adolescent Health Service Ethics Committee (2016008EP; 8th June, 2016). Across two sites (Perth and Melbourne, Australia), 103 infants were enrolled between ages 9–15 months. Each infant met the key eligibility criterion of showing at least three of five key early signs of autism according to the Social Attention and Communication Surveillance-Revised (SACS-R) 12-month checklist (Barbaro & Dissanayake, 2013)—limited/absent use of eye contact, proto-declarative pointing, social gestures, imitation, and response to name—for which the positive predictive value of an early childhood autism diagnosis is estimated at 74% (Barbaro et al., 2022). Other eligibility criteria for the trial included sufficient caregiver English language to participate fully in trial activities (including possible intervention), no intention to relocate away from the trial sites across a planned 2-year follow-up period, and no infant diagnosis of significant conditions known to impact development (including birth <32 weeks' gestational age).

Baseline assessment with each infant and a nominated parent/primary caregiver was completed within 4 weeks of referral and eligibility confirmation, at a university/clinic setting. Infants were then randomly assigned to receive either the trial caregiver-mediated video-aided intervention (iBASIS-VIPP) or community services as usual (see Whitehouse et al., 2019 for more information about intervention). Follow-up assessments were completed approximately 6 months post baseline (immediately after completion of the intervention for those randomized to that group), with all but six families retained to this follow-up (94%).

Measures

At both baseline and follow-up assessment, infants completed a number of established clinical/behavioral phenotyping assessments, and parents/caregivers provided demographic information and responses on established parent-report measures. Two key measures included to characterize participants here are detailed elsewhere for this cohort, at baseline and follow-up assessments (Hudry et al., 2021; Whitehouse et al., 2019). Briefly, the examiner-administered Mullen Scales of Early Learning (MSEL; Mullen, 1995) is a norm-referenced developmental/cognitive assessment regularly included in early childhood autism research, from which we used age-equivalence (AE) scores across the four key scales to derive summary indices of verbal and non-verbal AE for infant characterization (i.e., taking the average of receptive and expressive AEs, and the average of visual reception and fine motor AEs, respectively). Further, the Autism Observation Scale for Infants (AOSI; Bryson et al., 2008) is a semi-structured, play-based assessment appraising emerging autism behaviors, with total scores ranging from 0 to 38. Higher scores reflect a greater extent of behavioral autism signs, with previous research suggesting a threshold of nine provides good predictive accuracy for a likely later autism diagnosis (Brian et al., 2008; Bryson et al., 2007).

Interaction sampling

At each assessment, researchers also filmed a 6-min sample of caregiver-infant free-play with a standard set of toys provided, permitting the subsequent coding of caregiver-infant interaction behavior. Caregiver sensitivity ratings, and a range of language measures for both caregiver and infant were generated by researchers kept blinded to all other data collected from infants/families, including intervention group allocation and assessment timepoint (achieved by coding baseline and follow-up videos interspersed together and in random order).

The Manchester Assessment of Caregiver–Infant interaction (MACI; Wan et al., 2017) is an eight-item global rating measure of relational qualities of caregiver-infant interaction, developed for the context of possible emerging autism (Wan et al., 2013) and showing change with early intervention (Green et al., 2015; Whitehouse et al., 2019). MACI Caregiver Sensitive Responsiveness (SR) evaluates the extent to which the caregiver responds promptly and congruently to the infant's behaviors and affective state, including but not limited to child communication. This single scale is rated from 1 (minimal) to 7 (high) by trained coders, following thorough video review and considering all aspects of caregiver behavior—taking detailed narrative notes during a first pass and rating interaction qualities across further pass/es. This scale demonstrates good validity in relation to self-report measures of mood and parental bonding in a normative sample (Wan et al., 2017).

Measures of caregiver language use and infant emerging language were derived from the same interaction videos, by different personnel, using software and transcription/coding conventions of the Systematic Analysis of Language Transcripts (SALT-NZAU; see Miller et al., 2011 for coding conventions). For each caregiver and infant, we calculated Word Tokens (i.e., total number of words), Word Types (i.e., number of unique words), and mean length of utterance (MLU in morphemes) from SALT-NZAU software (see also Hudry et al., in press). While language sampling analysis recommends a minimum of 50 utterances for accurate appraisal (Miller et al., 2011), our treatment of 6-min parent–child interaction clips as natural language samples and application of SALT coding yielded approximately 20 utterances per sample for these infants at mean age 18-months (Hudry et al., in press). We have previously shown validity of this method for sampling emerging infant language, reporting positive associations between SALT-derived and concurrent examiner-rated and parent-report measures—specifically, moderate associations for Infant Word Tokens and Types ($r = 0.48$–0.55, $p < 0.001$) and small positive associations for Infant MLU ($r = 0.25$–0.34, $p < 0.05$) with MSEL Expressive Language scores and MacArthur Bates Communicative Development Inventories (MCDI; Fenson et al., 2007) expressive vocabulary counts (Hudry et al., in press). Given the infant's limited expressive language, particularly at baseline assessment (around mean age 12-months), we also estimated the rate of non-word vocalizations via 15-s interval time-sampling procedure (following Alston and James-Roberts 2005), for maximum score of 24 (across the 6-min video sample).

Within-study assessment of inter-rater reliability, achieved through double coding of 15% of video-taped samples, evidenced good agreement (two-way mixed model Intra-Class Correlations [ICCs] for absolute agreement) on MACI Caregiver SR (ICC = 0.67) and excellent agreement for SALT-derived measures: Caregiver Word Tokens (ICC = 1.000), Word Types (ICC = 0.998) and MLU (ICC = 0.999) and Infant Vocalizations (ICC = 0.897), Word Tokens (=0.900), Word Types (=0.918), and MLU (ICC = 0.709).

Analysis plan

A preliminary examination for potential impact of intervention group assignment on key measures of interest here revealed no significant between-group differences (pair-wise comparisons on all key measures returned $p \geq 0.158$, $d \leq 0.29$, 95%CI spanning zero) so we proceeded as planned, treating all infants/families as one cohort for the current analyses. Following initial examination of descriptive data and zero-order correlations between the various measures of caregiver input and infant language, we used cross-lagged path models to explore directionality of predictive associations between measures of caregiver and infant behavior that were significantly correlated, controlling for temporal stability/continuity of measures. Analyses were conducted in M*plus* (Wang & Wang, 2019) using the maximum likelihood robust (MLR) estimator to handle non-normal data. Goodness-of-fit was evaluated using the Comparative Fit Index (CFI; Bentler, 1990) and standardized root mean square residual (SRMR), commonly used indexes that perform well with relatively small samples sizes, within low degrees of freedom (Chen, 2007; Tabachnick & Fidell, 2013). A well-fitted model should have SRMR < 0.05 (but acceptable up to 0.08; Hu & Bentler, 1999) and CFI ≥ 0.90 (Hooper et al., 2008). We used the Wald test to determine the equivalence of cross-lagged paths within each model.

RESULTS

Table 1 presents descriptive data for participants as recorded at baseline assessment. The infants were mostly male and included around one third first-born children, and 20% "infant siblings" of an older diagnosed child. Caregivers were mostly the infants' biological mothers and well educated. Table 2 presents descriptive data for key measures of interest here: MACI Caregiver SR, and caregiver and infant quality and quantity of language use.

Outlier datapoints were evident across the various measures of caregiver and infant language (i.e., word tokens, types, MLU). Caregiver data were otherwise normally distributed, and so these outlier datapoints (between 1 and 4 cases per measure) were Winsorised (i.e., substituted with value just above/below nearest non-outlier datapoint; Tabachnick & Fidell, 2013) before further analysis. As the infant language measures all evidenced significant skew, requiring non-parametric analysis, we did not adjust for outliers (between 1 and 5 cases per measure; but nine high outliers for baseline word tokens).

TABLE 1 Baseline characteristics of participating infants and caregivers

	n (%)	Mean (SD) range
Infant characteristics		
Chronological age (months)		11.88 (2.00) 9–16
Male sex	70 (68.0%)	
First born	38 (36.9%)	
MSEL non-verbal age equivalence[t]		12.36 (2.73) 6–20.5
MSEL verbal age equivalence[tt]		8.99 (2.45) 3–16
AOSI total score		9.49 (4.22) 1–26
Family characteristics		
Mother completed university degree	62 (60.2%)	
Annual household income ≥AUD $50,000[a]	84 (91.3%)	

Abbreviations: AOSI, Autism Observation Scale for Infants; MSEL, Mullen Scales of Early Learning.
[a]$n = 11$ cases missing data.
[t]Average of visual reception and fine motor scale age-equivalence scores.
[tt]Average of receptive and expressive language scale age-equivalence scores.

TABLE 2 Descriptive statistics for key caregiver and infant measures: Mean (SD) range

	Baseline ($n = 103$; age ~ 12 months)	Follow-up ($n = 96$; age ~ 18 months)
Caregiver		
Sensitive responsiveness	4.28 (1.46) 1–7	4.93 (0.99) 2–7
Word tokens	324.5 (110.7) 12–619	348.4 (119.8) 29–672
Word types	95.08 (24.37) 11–144	103.9 (25.80) 19–159
Mean length of utterance	2.89 (0.70) 1.29–5.38	3.04 (0.68) 1.44–6.15
Infant		
Estimated vocalizations	11.42 (6.26) 0–24	9.46 (5.78) 0–23
Word tokens	6.56 (10.31) 0–55	17.44 (19.88) 0–122
Word types	3.56 (4.42) 0–23	9.20 (8.84) 0–44
Mean length of utterance	0.78 (0.59) 0–3.0	1.03 (0.39) 0–1.6

Table 3 summarizes zero-order correlations between the caregiver and infant measures. Due to evident multicollinearity between word types and tokens for both caregivers (baseline $r = 0.80$, $p < 0.001$; follow-up $r = 0.82$, $p < 0.001$) and infants (baseline $r_s = 0.98$, $p < 0.001$; follow-up $r_s = 0.96$, $p < 0.001$), we excluded word types from further analysis (and have omitted these from Table 3), retaining *tokens* as the single measure of quantity of caregiver language input and infant production. Multicollinearity was also evident between infant word tokens and MLU at baseline, but not at follow-up (see Table 3) so both were retained for subsequent analysis as differentiable indicators of variety vs. complexity of infant language.

Alongside a range of significant correlations between measures taken concurrently at each timepoint (i.e., various caregiver and various infant measures within-participant, and between-participants within-dyad), two significant prospective cross-domain correlations were evident (i.e., between a caregiver measure at one timepoint and an infant measure at the other): (1) baseline MACI Caregiver SR with follow-up Infant Word Tokens ($r_s = 0.39$; $p < 0.001$), and (2) baseline Infant MLU with follow-up Caregiver MLU ($r = 0.26$; $p = 0.009$). Cross-lagged panel analysis was used to further examine these potential predictive effects—between caregiver input and child language—controlling for association between baseline-levels of each of these measures, and within-measure temporal stability/continuity. Given robust growth in language skills across the second year of life and substantial variability in age for infants in this cohort, we included age at follow-up assessment as a covariate in the cross-lagged models to examine the relative predictive effects among caregiver input and child language measures beyond that possibly explained by child age.

Figure 1 represents the first of two models concerning MACI Caregiver SR and Infant Word Tokens. Model fit was acceptable according to SRMR (0.065), but below the acceptable level for CFI (0.703; as often occurs when measures are weakly correlated; Wang & Wang, 2019). Some temporal stability/continuity was evident for both MACI Caregiver SR and Infant Word Tokens, and while there was no significant association between MACI Caregiver SR and Infant Word Tokens at baseline, there was evidence of association at follow-up. Consistent with the pattern of findings from zero-order correlations, and here controlling for child age and other elements in the model, the path from baseline Infant Word Tokens to follow-up MACI Caregiver SR was non-significant. However, the path from baseline MACI Caregiver SR to Infant Word Tokens was statistically significant, and the Wald test indicated non-equivalence of cross-lagged paths within this model, $\chi^2 = 12.37$, $p < 0.001$.

Figure 2 shows the second model, with Caregiver and Infant MLU at baseline and follow-up entered respectively as predictors and outcomes. Here, model fit was acceptable according to both SRMR (0.042) and CFI (0.964). Again, temporal stability/continuity was evident for both Infant MLU and particularly for Caregiver MLU. There was no significant association between concurrent measures of MLU for Caregiver and Infant at either baseline or follow-up; the path from baseline Caregiver MLU to follow-up Infant MLU was also non-significant. Again, consistent with the pattern of zero-order correlations, the sole significant path was the cross-lagged effect from baseline Infant MLU to follow-up Caregiver MLU (and not from baseline Caregiver MLU

TABLE 3 Zero-order correlations between measures of caregiver input and infant language at baseline and follow-up assessment

	Baseline						Follow-up				
	Caregiver			Infant			Caregiver			Infant	
	SR	MLU	Tokens	Voc.	MLU[t]	Tokens[t]	SR	MLU	Tokens	Voc.	MLU[t]
Baseline caregiver											
MLU	0.16										
Word tokens	0.16	0.51***									
Baseline infant											
Vocalizations	−0.22*	−0.18	−0.11								
MLU[t]	0.09	0.02	0.04	0.16							
Word Tokens[t]	0.14	−0.08	−0.07	0.11	0.81***						
Follow-up caregiver											
SR	0.23*	0.09	0.03	0.02	0.07	0.02					
MLU	0.14	0.54***	0.33***	−0.09	0.26**	0.11	−0.04				
Word tokens	0.13	0.28**	0.64***	−0.09	0.18	0.09	0.00	0.57***			
Follow-up infant											
Vocalizations	−0.04	−0.14	−0.10	0.03	−0.02	−0.02	−0.03	0.05	0.02		
MLU[t]	0.16	−0.10	−0.03	0.09	0.19	0.20	0.09	−0.05	−0.04	0.02	
Word tokens[t]	0.39***	0.07	−0.03	−0.03	0.31**	0.33*	0.27**	−0.02	−0.07	−0.18	0.52***

Note: Shading is to draw readers' attention to key correlations (cross-domain, temporally cross-lagged) of interest, as opposed to other cells which reflect within-domain and within-timepoint correlations that are controlled for in subsequent analyses.
Abbreviations: MLU, mean length of utterance; SR, MACI caregiver sensitive responsiveness.
[t]non-parametric (Spearman's ρ) correlations.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

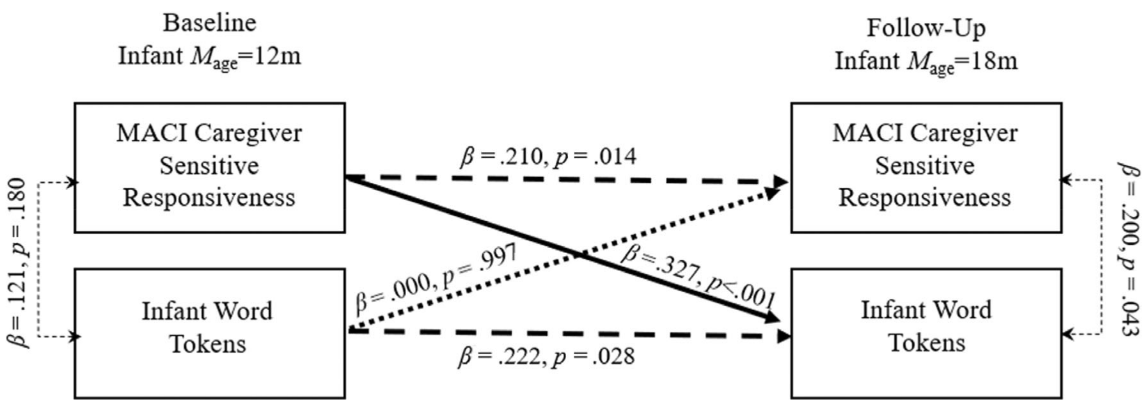

FIGURE 1 Cross-lagged path model showing predictive association of baseline MACI caregiver sensitive responsiveness for subsequent infant word tokens (bold line), and non-significant association between baseline infant word tokens and subsequent caregiver sensitive responsiveness (dotted line), controlling for temporal stability/continuity in measures of the two constructs (dashed lines) and infant age.

to follow-up Infant MLU), with the Wald test indicating non-equivalence of these cross-lagged paths, $\chi^2 = 6.31$, $p = 0.012$.

DISCUSSION

We examined the directionality of prospective associations between measures of caregiver sensitive responsiveness and quantity and quality of language input, and measures of infant emerging language, drawing on data from infants identified with early signs of autism around mean age 12 months. Across a 6-month follow-up period, we hypothesized that there would be evidence of bi-directional *cross-lagged* associations, with potentially stronger effects for caregiver-to-child than for child-to-caregiver paths. We found partial support; evidence of two significant cross-lagged effects for one caregiver-to-child path and one child-to-caregiver path. Specifically, ratings of earlier caregiver sensitive responsiveness were

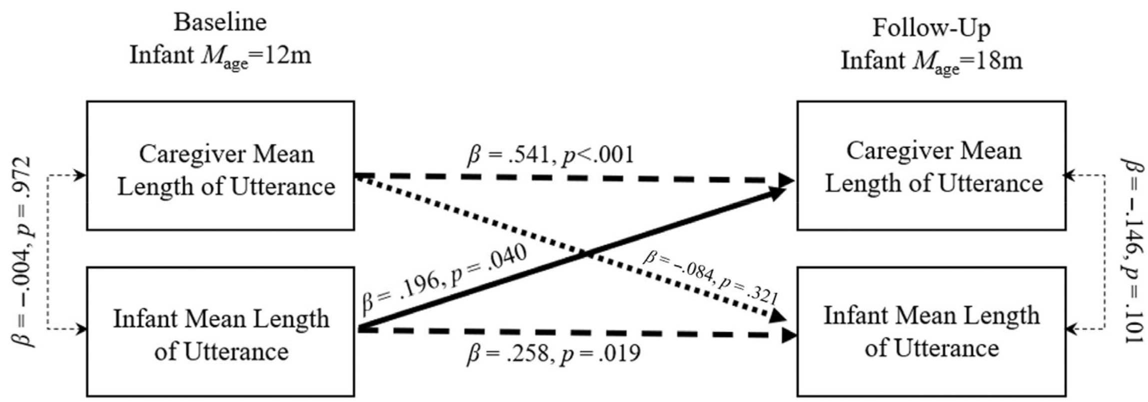

FIGURE 2 Cross-lagged path model showing predictive association of baseline infant MLU for subsequent caregiver MLU (bold line), and non-significant association between baseline caregiver MLU and subsequent infant MLU (dotted line), controlling for temporal stability/continuity in measures of each (dashed lines) and infant age.

associated with later infant language quantity (word tokens), while earlier infant language quality was associated with later caregiver language quality (i.e., MLU). In both cases, associations remained when controlling for stability of measures and child age.

Caregiver sensitive responsiveness

While there has been substantial research into language acquisition in early childhood autism, there has been limited consideration of the differential and/or combined effects of various aspects of caregiver input on child outcomes (but see Bottema-Beutel et al., 2018, for a recent review on "caregiver talk"). Our findings replicate past research showing the predictive value of caregiver sensitive responsiveness for infant language development (Edmunds et al., 2019; McDuffie & Yoder, 2010), extending evidence to the unique context of community-identified infants showing early signs of autism around age 12 months. Our observed association of earlier caregiver sensitive responsiveness (operationalized broadly, including but not limited to "caregiver talk") with later child language quantity (word tokens) is consistent with notions of sensitive dyadic interaction providing a solid foundation for child language acquisition through joint attention and scaffolded mapping of words onto objects (Pepper & Weitzman, 2004; Song et al., 2014). Again, this effect was maintained within a path model which accounted for the moderate temporal stability/continuity of each factor and variability in child ages.

Unexpectedly given previous research, we saw no evidence of concurrent associations between caregiver sensitive responsiveness and quantity of child language at ~12 months of age, and significant weak concurrent association 6 months later. Our study design precludes causal conclusions. However, this pattern of concurrent vs. prospective cross-lagged associations suggests early caregiver sensitive responsiveness, broadly defined, might play a supportive role for child language acquisition from the first year of life, even if not yet showing evidence of concurrent association with child language. We also found no evidence of prospective association between early indicators of specific caregiver linguistic input (quantity or quality) and subsequent child language, in contrast to previous findings with caregivers and young diagnosed children (Fusaroli et al., 2019; Swanson et al., 2019) and caregivers with "infant siblings" (Choi et al., 2020). There was nevertheless clear evidence of convergent associations among the various aspects of caregiver contribution and within-measure temporal stability/continuity.

That ratings of broad caregiver sensitive responsiveness alone—and not the amount or quality/complexity of more specific caregiver language input, as identified by Choi et al. (2020)—were key to the subsequent language of the infants in our cohort, might be explained by population sampling differences. Choi et al.'s participants were selected because of family history of autism versus our selection of infants showing early behavioral signs of autism. Language acquisition is thought to be influenced by an infant's capacity for sustained as well as joint attention (Arunachalam & Luyster, 2016). So the differential nature of our cohort versus that of Choi et al. (2020) might explain our observed predictive association of broader caregiver sensitive responsiveness for child language outcomes versus their observed effect of caregiver linguistic input for child language acquisition. That is, for infants presenting with emerging signs of autism and language delay, subsequent language acquisition may be more importantly linked to caregiver sensitive responsiveness, broadly defined, than to specific adult linguistic input per se.

Opportunities for caregiver input arising from infant ability

Clear evidence of within-measure consistency aligned with our expectation that caregiver sensitive responsiveness, and quantity and quality of linguistic input during caregiver-child interaction would show temporal stability; a trait-like quality. While we found no predictive value of caregiver linguistic input for child language outcomes, the pattern of predictive association of follow-up caregiver MLU from baseline infant MLU could be taken as further evidence of caregiver sensitivity around infant language acquisition. Here, our observation that caregivers whose infants produced more complex early speech subsequently produced more complex speech themselves mirrors another finding by Choi et al. (2020): that 18-month-olds' language was associated with parent MLU 6 months later.

Again, it is somewhat surprising that potentially sensitively-adapted caregiver linguistic input was specific to quality/complexity (i.e., MLU) and not also evident for quantity of linguistic input (word tokens) or broadly-rated sensitive responsiveness. Unlike Choi et al. (2020), we found no evidence of bi-directional association—no predictive path from earlier caregiver MLU to later infant language, and vice versa—only two unidirectional paths, one caregiver-to-child, and one child-to-caregiver concerning other measures. Again, measurement construct validity was supported through observed within-measure associations over time (i.e., between baseline and follow-up measures of caregiver MLU) and strong convergence of caregiver MLU with other concurrent indicators of caregiver input. Differential findings compared to past research could be due to sampling differences, including clinical characteristics and the specific ages of children at assessment timepoints.

Child-led opportunities for caregiver linguistic input

The magnitude of our observed prospective cross-lagged effect from infant to caregiver MLU was weak, whereas that from caregiver sensitive responsiveness to infant word tokens was moderate, suggesting potentially stronger direction of cross-lagged effect from caregiver-to-child than vice versa. Again, this is consistent with our tentative prediction of relative strength of directional effects. Yet, while our combined examination of a range of inputs, with bi-directional cross-lagged modeling, contributes to our understanding of the transactional nature of caregiver-child interaction for early language acquisition (e.g., see also Bottema-Beutel et al., 2018; Choi et al., 2020; Wan et al., 2013), conclusions about the relative magnitude of directional effects remains reliant on a substantial empirical evidence base.

Relatively little attention has been paid to how young children might constrain opportunities for their caregivers to provide optimizing input if they present with qualitatively different emerging social behaviors or fewer linguistic cues than is usually the case. Another potential interpretation of our observed child-to-caregiver MLU path is that infants may be contributing to the language-learning environment they subsequently experience. That is, those infants who provide more complex linguistic cues for their parents may bring about, and subsequently benefit from, increased complexity of adult linguistic input (Snow, 1995). Conversely, infants whose language is more limited or of relatively lower complexity may effectively disrupt a caregiver's potential to scaffold development through early interaction and engagement, engendering a less language-rich social learning environment (van Balkom et al., 2010). Disentangling potential interpretations here will require further investigation with longitudinal datasets (i.e., multiple assessment timepoints to track temporally-linked paths), and ideally also experimental design that allows genuine causal hypothesis testing.

Quantity versus quality of infant emerging language

Compared to core diagnostic features of the condition, language skills have been understudied in early childhood autism and reflect the main area of parental concerns for their autistic children (Brignell et al., 2018). It may be surprising that few associations—even at zero-order correlation level—presented across the range of infant language measures generated via natural language sampling from our parent–child interaction footage. We have previously reported evidence of reliable blinded coding for this approach, and concurrent convergent validity of derived data against standardized examiner-rated and parent-report measures (with moderate to large associative effect sizes; Hudry et al., in press). Further confidence in these data is also evidenced here in observed: (a) multicollinearity among two indicators of infant language quantity (word tokens and types); (b) convergence across measures of language quantity and quality/complexity; and (c) trait-like temporal stability.

Again, the lack of additional or stronger observed effects related to child language here may be explained by characteristics of the cohort and study design: the young age of children and relatively short follow-up interval; that each infant was showing some early signs of autism; and that the cohort evidenced substantial delay on standardized language assessment. Certainly, we plan to extend this line of enquiry through further analysis of data from this cohort collected at later timepoints into early childhood, when there will likely be greater variability of language development trajectories and outcomes, and more robust effects may be observed. Important for confidence in associative analyses, our infant language data showed good variability consistent with other indicators of strong phenotypic heterogeneity reported elsewhere for this cohort (Chetcuti et al., 2020; Hudry et al., 2021; Whitehouse et al., 2019).

Limitations and future directions

A key limitation of this study was the relatively small sample potentially constraining statistical power. Generalisability may also be limited, including in the context of relative socio-demographic homogeneity for participating families (i.e., mostly highly-educated parents). These limitations may be countered by important strengths: (a) the sample was well characterized, and heterogeneous in terms of child clinical phenotype (i.e., extent of behavioral autism presentation and examiner-assessed verbal and non-verbal developmental abilities), and (b) good variability was evident in key measures of interest to our hypothesis testing. The current data reflect assessment timepoints prior to any attempt to determine individual infants' diagnostic outcomes. Nevertheless, leveraging data from this clinically-indicated cohort brings benefits of an enriched sample—including many infants likely to receive a future autism diagnosis—without the potential limitations of inadvertent sampling bias or a common caregiver child-raising experience, such as might arise within an "infant sibling" design.

The key objective of developmental science is to offer causal conclusions—here, about the relative directional, bidirectional, and transactional effects from caregiver-child interaction for child language growth. We designed the current investigation with the prior knowledge that around 50% of the cohort had experienced a low intensity, in-home parent-mediated intervention for which there had been no evidence of significant proximal benefits for caregiver sensitive responsiveness, nor more distal benefits for child language outcomes, during the 12- to 18-month period (Whitehouse et al., 2019). Hence, we planned to treat the dataset as a single "observational" cohort, and we confirmed the lack of any intervention effect on the novel caregiver and infant measures derived via natural language sampling from interaction footage (Hudry et al., in press). A planned follow-up of this cohort has recently been completed (Whitehouse et al., 2021) and we intend to extend the current line of investigation with the full, longitudinal dataset for this cohort now available. This line of research could also be extended through future dedicated work with larger samples, seeking to promote caregiver responsiveness or increase the quantity and/or quality of caregiver linguistic input. In addition to informing the efficacy of targeted supports, intervention trial designs offer strong potential for causal hypothesis testing, showing how caregiver behavior may be directionally linked to later child skills (such as Green et al., 2010; Pickles et al., 2016 have demonstrated for preschoolers with confirmed autism diagnoses).

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Alston, E., & James-Roberts, I. S. (2005). Home environments of 10-month-old infants selected by the WILSTAAR screen for pre-language difficulties. *International Journal of Language and Communication Disorders*, *40*(2), 123–136. https://doi.org/10.1080/13682820400006861

Arunachalam, S., & Luyster, R. (2016). The integrity of lexical acquisition mechanisms in autism spectrum disorders: A research review. *Autism Research*, *9*, 810–828. https://doi.org/10.1002/aur.1590

Barbaro, J., & Dissanayake, C. (2013). Early markers of autism spectrum disorders in infants and toddlers prospectively identified in the social attention and communication study (SACS). *Autism*, *17*, 64–86.

Barbaro, J., Sadka, N., Gilbert, M., Beattie, E., Li, X., Ridgway, L., Lawson, L., & Dissanayake, C. (2022). Diagnostic accuracy of the social attention and communication surveillance–revised with preschool tool for early autism detection in very young children. *JAMA Network Open*, *5*(3), e2146415. https://doi.org/10.1001/jamanetworkopen.2021.46415

Bent, C. A., Barbaro, J., & Dissanayake, C. (2017). Change in autism diagnoses prior to and following the introduction of DSM-5. *Journal of Autism and Developmental Disorders*, *47*(1), 163–171. https://doi.org/10.1007/s10803-016-2942-y

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*, 238–246. https://doi.org/10.1037/0033-2909.107.2.238

Bornstein, M. H., Hendricks, C., Haynes, O., & Painter, K. (2007). Maternal sensitivity and child responsiveness: Associations with social context, maternal characteristics, and child characteristics in a multivariate analysis. *Infancy*, *12*(2), 189–223.

Bottema-Beutel, K., Lloyd, B., Watson, L., & Yoder, P. (2018). Bidirectional influences of caregiver utterances and supported joint engagement in children with and without autism spectrum disorder. *Autism Research*, *11*(5), 755–765. https://doi.org/10.1002/aur.1928

Bretherton, L., Prior, M., Bavin, E., Cini, E., Eadie, P., & Reilly, S. (2013). Developing relationships between language and behaviour in preschool children from the early language in Victoria study: Implications for intervention. *Emotional and Behavioural Difficulties*, *19*(1), 7–27. https://doi.org/10.1080/13632752.2013.854956

Brian, J., Bryson, S., Garon, N., Roberts, W., Smith, I., Szatmari, P., & Zwaigenbaum, L. (2008). Clinical assessment of autism in high-risk 18-month-olds. *Autism*, *12*, 433–456.

Brignell, A., Morgan, A. T., Woolfenden, S., Klopper, F., May, T., Sarkozy, V., & Williams, K. (2018). A systematic review and meta-analysis of the prognosis of language outcomes for individuals with autism spectrum disorder. *Autism & Developmental Language Impairments*, *3*, 239694151876761. https://doi.org/10.1177/2396941518767610

Bruner, J. (1975). The ontogenesis of speech acts. *Journal of Child Language*, *2*, 1–19.

Bryson, S., Zwaigenbaum, L., Brian, J., Roberts, W., Szatmari, P., Rombough, V., & McDermott, C. (2007). A prospective case series of high-risk infants who developed autism. *Journal of Autism and Developmental Disorders*, *37*, 12–24.

Bryson, S., Zwaigenbaum, L., McDermott, C., Rombough, V., & Brian, J. (2008). The autism observation scale for infants: Scale development and reliability data. *Journal of Autism and Developmental Disorders*, *38*, 731–738.

Chen, F. F. (2007). Sensitivity of goodness of fit indexes to lack of measurement invariance. *Structural Equation Modeling: A Multidisciplinary Journal*, *14*(3), 464–504. https://doi.org/10.1080/10705510701301834

Chetcuti, L., Uljarevic, M., Varcin, K., Boutrus, M., Wan, M., Green, J., Iacono, T., Dissanayake, C., Whitehouse, A., & Hudry, K. (2020). Subgroups of temperament associated with social-emotional difficulties in infants with early signs of autism. *Autism research: Official Journal of the International Society for Autism Research*, *13*, 2094–2101. https://doi.org/10.1002/aur.2381

Choi, B., Nelson, C. A., Rowe, M. L., & Tager-Flusberg, H. (2020). Reciprocal influences between parent input and child language skills in dyads involving high- and low-risk infants for autism spectrum disorder. *Autism Research*, *13*(7), 1168–1183. https://doi.org/10.1002/aur.2270

Crandall, M. C., Bottema-Beutel, K., McDaniel, J., Watson, L. R., & Yoder, P. J. (2019). Children with autism spectrum disorder may learn from caregiver verb input better in certain engagement states. *Journal of Autism and Developmental Disorders*, *49*(8), 3102–3112. https://doi.org/10.1007/s10803-019-04041-w

Durkin, K., Conti-Ramsden, G., & Simkin, Z. (2011). Functional outcomes of adolescents with a history of specific language impairment (SLI) with and without autistic symptomatology. *Journal of Autism and Developmental Disorders*, *42*(1), 123–138. https://doi.org/10.1007/s10803-011-1224-y

Edmunds, S. R., Kover, S. T., & Stone, W. L. (2019). The relation between parent verbal responsiveness and child communication in young children with or at risk for autism spectrum disorder: A systematic review and meta-analysis. *Autism Research*, *12*(5), 715–731. https://doi.org/10.1002/aur.2100

Else-Quest, N. M., Clark, R., & Owen, M. T. (2011). Stability in mother-child interactions from infancy through adolescence. *Parenting: Science and Practice*, *11*(4), 280–287. https://doi.org/10.1080/15295192.2011.613724

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., Reznick, J. S., & Bates, E. (2007). In H. Paul (Ed.), *MacArthur-Bates communicative development inventories* (2nd ed.). Brookes Publishing Co.

Fusaroli, R., Weed, E., Fein, D., & Naigles, L. (2019). Hearing me hearing you: Reciprocal effects between child and parent language in autism and typical development. *Cognition*, *183*, 1–18. https://doi.org/10.1016/j.cognition.2018.10.022

Georgiou, N., & Spanoudis, G. (2021). Developmental language disorder and autism: Commonalities and differences on language. *Brain Sciences*, *11*(5), 589. https://doi.org/10.3390/brainsci11050589

Gillespie-Lynch, K., Sepeta, L., Wang, Y., Marshall, S., Gomez, L., Sigman, M., & Hutman, T. (2012). Early childhood predictors of the social competence of adults with autism. *Journal of Autism and Developmental Disorders*, *42*(2), 161–174. https://doi.org/10.1007/s10803-011-1222-0

Green, J., Charman, T., McConachie, H., Aldred, C., Slonims, V., Howlin, P., Le Couteur, A., Leadbitter, K., Hudry, K., Byford, S., Barrett, B., Temple, K., Macdonald, W., & Pickles, A. (2010). Parent-mediated communication-focused treatment in children with autism (PACT): A randomised controlled trial. *Lancet*, *375*(9732), 2152–2160. https://doi.org/10.1016/s0140-6736(10)60587-9

Green, J., Charman, T., Pickles, A., Wan, M., Elsabbagh, M., Slonims, V., Taylor, C., McNally, J., Booth, R., Gliga, T., Jones, E., Harrop, C., Bedford, R., Johnson, M., & Team, T. B. (2015). Parent-mediated intervention versus no intervention for infants at high risk of autism: A parallel, single-blind, randomised trial. *Lancet Psychiatry*, *2*, 133–140.

Gros-Louis, J., West, M. J., & King, A. P. (2014). Maternal responsiveness and the development of directed vocalizing in social interaction. *Infancy*, *19*(4), 385–408.

Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural equation modelling: Guidelines for determining model fit. *The Electronic Journal of Business Research Methods*, *6*(1), 53–60.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling*, *6*(1), 1–55.

Hudry, K., Aldred, C., Wigham, S., Green, J., Leadbitter, K., Temple, K., Barlow, K., McConachie, H., & PACT Consortium. (2013). Predictors of parent–child interaction style in dyads with autism. *Research in Developmental Disabilities*, *34*(10), 3400–3410. https://doi.org/10.1016/j.ridd.2013.07.015

Hudry, K., Chetcuti, L., Boutrus, M., Pillar, S., Baker, E., Dimov, S., Barbaro, J., Green, J., Whitehouse, A., Varcin, K., & Team, A. (2021). Performance of the autism observation scale for infants with community-ascertained infants showing early signs of autism. *Autism*, *25*(2), 490–501. https://doi.org/10.1177/1362361320965397

Hudry, K., Smith, K., Pillar, S., Varcin, K. J., Bent, C. A., Boutrus, M., Chetcuti, L., Clark, A., Dissanayake, C., Iacono, T., Kennedy, L., Lant, A., Robinson Lake, J., Segal, L., Slonims, V., Taylor, C., Wan, M. W., Green, J., & Whitehouse, A. J. O. (in press). Brief Report: The utility of natural language samples for assessing communication and language in infants referred with early signs of autism. *Research on Child and Adolescent Psychopathology*.

McDuffie, A. S., & Yoder, P. (2010). Types of parent verbal responsiveness that predict language in young children with autism spectrum disorder. *Journal of Speech, Language and Hearing Research*, *53*(4), 1026–1039.

McKean, C., Wraith, D., Eadie, P., Cook, F., Mensah, F., & Reilly, S. (2017). Subgroups in language trajectories from 4 to 11 years: The nature and predictors of stable, improving and decreasing language trajectory groups. *Journal of Child Psychology and Psychiatry*, *58*(10), 1081–1091. https://doi.org/10.1111/jcpp.12790

Micheletti, M., McCracken, C., Constantino, J. N., Mandell, D., Jones, W., & Klin, A. (2020). Research review: Outcomes of 24- to 36-month-old children with autism spectrum disorder vary by ascertainment strategy: A systematic review and meta-analysis. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *61*(1), 4–17. https://doi.org/10.1111/jcpp.13057

Miller, J., Andriacchi, K., & Nockerts, A. (2011). *Assessing language production using SALT software: A Clinician's guide to language sample analysis*. SALT Software LLC.

Mullen, E. (1995). *Mullen scales of early learning*. American Guidance Service.

Naigles, L. (2013). Input and language development in children with autism. *Seminars in Speech and Language*, *34*(4), 237–248. https://doi.org/10.1055/s-0033-1353446

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*(3), e488–e495. https://doi.org/10.1542/peds.2010-2825

Pepper, J., & Weitzman, E. (2004). *It takes two to talk: A practical guide for parents of children with language delays*. The Hanen Centre, Transcontinental Interglobe.

Pickles, A., Le Couteur, A., Leadbitter, K., Salomone, E., Cole-Fletcher, R., Tobin, H., Gammer, I., Lowry, J., Vamvakas, G., Byford, S., Aldred, C., Slonims, V., McConachie, H., Howlin, P., Parr, J. R., Charman, T., & Green, J. (2016). Parent-mediated social communication therapy for young children with autism (PACT): Long-term follow-up of a randomised controlled trial. *The Lancet*, *388*(10059), 2501–2509. https://doi.org/10.1016/s0140-6736(16)31229-6

Rowe, M. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*, 1762–1774. https://doi.org/10.1111/j.1467-8624.2012.01805.x

Smith, J., Levickis, P., Goldfeld, S., Kemp, L., & Conway, L. (2021). Maternal linguistic input and child language in a cohort at risk of experiencing social adversity. *Language Learning and Development*, *17*(3), 254–271. https://doi.org/10.1080/15475441.2021.1875831

Snow, C. (1995). Issues in the study of input: Fine-tuning, universality, individual and developmental differences, and necessary causes. In P. Fletcher & B. MacWhinney (Eds.), *The handbook of child language* (pp. 180–193). Blackwell.

Snowling, M. J., & Hulme, C. (2021). Annual research review: Reading disorders revisited - the critical importance of oral language. *Journal of Child Psychology and Psychiatry*, *62*(5), 635–653. https://doi.org/10.1111/jcpp.13324

Song, L., Spier, E. T., & Tamis-LeMonda, C. S. (2014). Reciprocal influences between maternal language and children's language and cognitive development in low-income families. *Journal of Child Language*, *41*(2), 305–326. https://doi.org/10.1017/S0305000912000700

Song, X. K., & So, W. C. (2021). The influence of child-based factors and parental inputs on expressive language abilities in children with autism spectrum disorder. *Autism*, *13623613211054597*, 1477–1490. https://doi.org/10.1177/13623613211054597

Swanson, M. R., Donovan, K., Paterson, S., Wolff, J. J., Parish-Morris, J., Meera, S. S., Watson, L. R., Estes, A. M., Marrus, N., Elison, J. T., Shen, M. D., McNeilly, H. B., MacIntyre, L., Zwaigenbaum, L., St. John, T., Botteron, K., Dager, S., & Piven, J. (2019). Early language exposure supports later language skills in infants with and without autism. *Autism Research*, *12*, 1784–1795. https://doi.org/10.1002/aur.2163

Tabachnick, B., & Fidell, L. (2013). *Using multivariate statistics* (6th ed.). Pearson.

van Balkom, H., Verhoeven, L., & van Weerdenburg, M. (2010). Conversational behaviour of children with developmental language delay and their caretakers. *International Journal of Language and Communication Disorders*, *45*, 295–319. https://doi.org/10.3109/13682820902994226

van't Hof, M., Tisseur, C., van Berckelear-Onnes, I., van Nieuwenhuyzen, A., Daniels, A. M., Deen, M., Hoek, H. W., & Ester, W. A. (2021). Age at autism spectrum disorder diagnosis: A systematic review and meta-analysis from 2012 to 2019. *Autism*, *25*(4), 862–873. https://doi.org/10.1177/1362361320971107

Wan, M., Brooks, A., Green, J., Abel, K., & Elmadih, A. (2017). Psychometrics and validation of a brief rating measure of parent-infant interaction: Manchester Assessment of Caregiver–Infant interaction. *International Journal of Behavioral Development*, *41*, 542–549.

Wan, M., Green, J., Elsabbagh, M., Johnson, M., Charman, T., Plummer, F., & Team, t. B. (2013). Quality of interaction between at-risk infants and caregiver at 12-15 months is associated with 3-year autism outcome. *Journal of Child Psychology and Psychiatry*, *54*, 763–771.

Wang, J., & Wang, X. (2019). *Structural equation modelling: Applications using Mplus*. John Wiley & Sons.

Warlaumont, A. S., Richards, J. A., Gilkerson, J., & Oller, D. K. (2014). A social feedback loop for speech development and its reduction in autism. *Psychological Science*, *25*(7), 1314–1324. https://doi.org/10.1177/0956797614531023

Whitehouse, A., Varcin, K., Alvares, G., Barbaro, J., Bent, C., Boutrus, M., Chetcuti, L., Cooper, M., Clark, A., Davidson, E., Dimov, S., Dissanayake, C., Doyle, J., Grant, M., Iacono, T., Maybery, M., Pillar, S., Renton, M., Rowbottam, C., … Hudry, K. (2019). Pre-emptive intervention versus treatment as usual for infants showing early behavioural risk signs of autism spectrum disorder: A single-blind, randomised controlled trial. *Lancet Child and Adolescent Health*, *3*, 605–615.

Whitehouse, A., Varcin, K. J., Pillar, S., Billingham, W., Alvares, G. A., Barbaro, J., Bent, C. A., Blenkley, D., Boutrus, M., Chee, A., Chetcuti, L., Clark, A., Davidson, E., Dimov, S., Dissanayake, C., Doyle, J., Grant, M., Green, C. C., Harrap, M., … Hudry, K. (2021). Effect of preemptive intervention on developmental outcomes among infants showing early signs of autism: A randomized clinical trial of outcomes to diagnosis. *JAMA Pediatrics*, *175*(11), e213298. https://doi.org/10.1001/jamapediatrics.2021.3298

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