Parent coaching increases conversational turns and advances infant language development

Naja Ferjan Ramírez[a,1], Sarah Roseberry Lytle[b], and Patricia K. Kuhl[b,c,1]

[a]Department of Linguistics, University of Washington, Seattle, WA 98195; [b]Institute for Learning & Brain Sciences, University of Washington, Seattle, WA 98195; and [c]Department of Speech and Hearing Sciences, University of Washington, Seattle, WA 98195

Parental language input is one of the best predictors of children's language achievement. Parentese, a near-universal speaking style distinguished by higher pitch, slower tempo, and exaggerated intonation, has been documented in speech directed toward young children in many countries. Previous research shows that the use of parentese and parent–child turn-taking are both associated with advances in children's language learning. We conducted a randomized controlled trial to determine whether a parent coaching intervention delivered when the infants are 6, 10, and 14 mo of age can enhance parental language input and whether this, in turn, changes the trajectory of child language development between 6 and 18 mo of age. Families of typically developing 6-mo-old infants (n = 71) were randomly assigned to intervention and control groups. Naturalistic first-person audio recordings of the infants' home language environment and vocalizations were recorded when the infants were 6, 10, 14, and 18 mo of age. After the 6-, 10-, and 14-mo recordings, intervention, but not control parents attended individual coaching appointments to receive linguistic feedback, listen to language input in their own recordings, and discuss age-appropriate activities that promote language growth. Intervention significantly enhanced parental use of parentese and parent–child turn-taking between 6 and 18 mo. Increases in both variables were significantly correlated with children's language growth during the same period, and children's language outcomes at 18 mo. Using parentese, a socially and linguistically enhanced speaking style, improves children's social language turn-taking and language skills. Research-based interventions targeting social aspects of parent–child interactions can enhance language outcomes.

parentese speech | conversational turns | language intervention | parent coaching | social interaction

In the 1960s, anthropologists and linguists documenting speaking patterns across diverse languages noted an unusual speech "register" when adults addressed their young children (1). Originally termed "baby talk," this pattern of speaking had a simpler phonology and grammar, fewer and simpler lexical items, a higher pitch, unusual intonation contours (1), and was observed being used by mothers, fathers, and siblings across many cultures, in both spoken and signed languages (2–4). Later research on infant-directed speech, then termed "motherese" and eventually "parentese" because both genders used it, revealed a unique acoustic signature. Adults speaking parentese used a nearly octave increase in habitual pitch, spoke with exaggerated pitch contours, and used a significantly slower tempo with elongated vowels (5–7).

Infants were shown in several studies to prefer parentese when given a choice between parentese and standard adult-directed speech (8–10). Infants' preference for parentese gathered sufficient scientific attention to merit two large studies examining the robustness of the effect across cultures and languages. The first (11), examined data across 34 experiments and reported a robust effect size (Cohen's d = 0.72) for a preference of infant- over adult-directed speech by infants. The second, published by the *ManyBabiesConsortium* (12), involved studies from 67 laboratories across North America, Europe, and Asia, and reported a significant effect size across all studies (Cohen's d = 0.35).

Young children prefer it, but does parentese assist children's language development? Early writers commenting on infant-directed speech were not encouraging, and warned that its use might damage children's language development (13). However, further analyses suggested that parentese was fully grammatical, used words referencing observable objects and actions, and phonology that avoided complex consonant clusters (14–16). Acoustic analyses showed that the vowels contained in parentese are temporally and spectrally expanded across languages (17, 18), making it easier for infants to discriminate phonetic differences (19), and that this parental adjustment in speech is in turn correlated with infants' speech discrimination skills (20). These new data led authors to argue that parentese might assist language development in infants (2, 18, 20). Subsequent laboratory studies confirmed that the use of parentese facilitates specific aspects of infants' language learning and processing (10, 20–24), and recent studies using natural recordings in children's homes linked exposure to parentese, particularly in one-on-one situations, with enhanced child language outcomes (25–27).

The scientific question these data raise focuses on the value of parentese: Why is it beneficial for young children? As cited above, an obvious feature of parentese is that it simplifies and sometimes exaggerates the structure of language, arguably making language easier to learn (14, 18). However, another feature of parentese may provide a more fundamental explanation: Parentese enhances social communication; its simplified syntax, slower tempo, and melodic intonation contours evoke a social response (28, 29). Moreover, its timing gives children ample opportunity to

Significance

How parents talk to infants is strongly associated with children's language development, but many parents are not aware of this. We assigned families of 6-mo-old infants to a parent coaching intervention group or a no-coaching control group to determine whether specific parental language variables ("parentese") can be enhanced through intervention. Naturalistic audio recordings were made in both groups at 6, 10, 14, and 18 mo of age. Parent coaching reviewed parents' use of parentese from recordings and discussed the social engagement that promotes children's language skills. Intervention increased parental use of parentese and parent-child turn-taking; both were correlated with children's language growth and outcomes. Parental interventions targeting social components of language input have the potential to improve children's language outcomes.

babble or talk in response. Our previous work established that enhanced use of parentese between 6 and 14 mo increases infant babbling measured concurrently, as well as word production at 14 mo, suggesting that the use of parentese increases infant communication as well as their language skills (30).

The Present Study

The present study investigates the effects of a parent coaching intervention on the trajectory of change in certain variables in parental language input and, in turn, trajectories in child vocalizations and child language outcomes. The literature demonstrates that a child's early language environment is a key predictor of the child's later language skills (31–33). Children's language ability at Kindergarten entry, which is rooted in language development in infancy, is the single best predictor of school achievement through elementary grades (34–37). Although early studies have linked parental language quantity to children's language outcomes (31), recent research indicates that the sheer number of adult words (adult word count, AWC) is insufficient to account for variability in children's language development (33). Various linguistic aspects of parental speech and various measures of parental language quality, such as diversity of vocabulary, type-token ratio, mean length of utterance, or use of decontextualized language (38–40), as well as social aspects of parent–child interaction—such as joint attention, responsiveness, and contingent back-and-forth exchanges (33, 41, 42)—have been shown to be related to children's language growth. Recent studies call for language interventions targeting parental language quality and social aspects of parent–child language interaction (33, 43).

One intervention approach, adopted in the present study and in a limited number of previous studies (44–48), is to target specific aspects of parental language input to determine whether they are malleable, and if so, whether enhancements in these aspects lead to measurable changes in child language outcomes. We chose parentese as an entry point because it is used across cultures, and is present in most American households, but its frequency varies considerably (25–27, 30). Another important aspect of our approach was to recruit families ranging in socioeconomic status (SES), in order to assess the potential role of SES on the effects of intervention. Our previous work shows that the use of parentese can be enhanced through parent coaching, and that this has immediate and positive effects on child language at 14 mo (30). Our objective here was to examine the durability and robustness of parent coaching, received when the infants were 6-, 10-, and 14-mo old. We evaluate the effects of a parent coaching intervention on the trajectory of change between 6 and 18 mo in: 1) Parental speech quantity, 2) parental speaking style (use of parentese vs. standard speech), 3) parent–child turn-taking, and 4) children's vocalizations. Finally, we evaluate the effects of intervention on child language outcomes at 18 mo.

Families of typically developing 6-mo-old infants ($n = 71$ after exclusions and attrition) were randomly assigned to either the parent coaching condition (intervention, I), or no coaching condition (control, C). SES was assessed with the Hollingshead Index (49) and varied widely, but was matched between the two groups. The groups were also matched on children's age, gender, and number of adults and siblings living in the household. All families provided naturalistic first-person recordings of the infants' home language environment and vocalizations when the infants were 6-, 10-, 14-, and 18-mo of age, obtained through audio recorders [LENA; LENA Pro Version 3.4.0 (50)] placed into pockets of infant vests. At 18 mo, families filled out the MacArthur–Bates Communicative Development Inventory, Words and Sentences (CDI), a reliable and valid parent survey for assessing language and communication development from 16 to 30 mo (36, 51), to provide an additional assessment of children's language.

Using techniques borrowed from the behavior-change literature (52), including increasing parental knowledge, behavior monitoring

based on quantitative and qualitative feedback, and behavior modeling, we designed a four-step intervention program. At 6, 10, and 14 mo, I group, but not C group parents attended individual coaching appointments, which consisted of the following four steps:

First, the coach provided quantitative and qualitative linguistic feedback on measures of parental language quantity, speaking style, and parent–child turn-taking, derived from the families' latest recordings. Each family's data were compared to research-based distributional data (25, 53), and the coach explained that these measures have been shown in research to affect language growth. The coach also explained how and why these measures may vary from family to family, from day to day, or from context to context throughout the day. The coach explained that social contexts in which parents use parentese and engage the child in contingent back and forth exchanges may be particularly beneficial for language development.

Second, the coach played audio samples from the families' most recent recordings to highlight examples of parentese and turn-taking. For each family, the audio clips were hand-selected prior to the appointment to highlight the intervention behaviors in parents' own speech. For each selected clip, parents were asked to first identify the intervention behavior, and then discussed with the coach why and how the behavior may positively affect their child's language growth.

Third, the coach discussed age-appropriate daily routines in the form of Vroom Brain Building Moments (https://www.vroom.org/) that promote language interactions. The coach gave a set of Vroom cards to the parents at each appointment. These cards contain information about opportunities for language input and social interaction through daily routines, such as diaper changes, meals, or trips to the grocery store. Through discussion, the coach encouraged parents to think of additional similar scenarios for social and language interactions in their own lives (i.e., bath time, bus rides). Parents received an age-appropriate book, and were encouraged to engage the child in positive, language rich daily activities.

Fourth, the coach discussed the child's next expected language milestone (i.e., canonical babbling, first words, word combinations), and developmentally appropriate strategies to support language growth through the use of intervention behaviors.

Based on our previous finding that the use of parentese can be enhanced through parent coaching, and that this immediately and positively affects child language (30), we hypothesized that: 1) The intervention will increase parental use of parentese between 6 and 18 mo, but not their use of standard speech, or the overall quantity of speech; 2) the intervention will produce measurable enhancements in parent–child turn-taking between 6 and 18 mo; 3) the intervention will enhance the frequency of children's vocalizations between 6 and 18 mo and will produce enhanced child language outcomes at 18 mo, 4 mo after the third coaching appointment.

Results

At baseline (6 mo), families were assessed on demographic measures and language measures, including child "talkativeness" ("%Child Babbling"), the automatically derived LENA estimates of AWC (the number of adult words over a 12-h day), conversational turn count (CTC; an estimate of back and forth exchanges between the child and an adult over a 12-h recording day), and child vocalization count (CVC; an estimate of speech-related vocalizations produced by the child over a 12-h day), as well as measures of parental speaking style assessed by manual coding of LENA recordings ("%Parentese Speech" and "%Standard Speech") (see *Methods* for description of measures). Preliminary analyses showed that none of the demographic or language measures differed between the two groups at baseline ($Ps > 0.1$) (Table 1).

Trajectory of Change in Parent Language, Parent–Child Turn-Taking, and Child Vocalizations. Changes in trajectories of parent language, parent–child turn-taking, and child vocalizations between 6 and 18 mo were assessed by conducting repeated-measures

ANOVA with Group (I, C) and Time (6, 10, 14, 18 mo) as independent variables, separately for AWC, %Parentese Speech, and %Standard Speech (parent measures), CTC (parent–child measure), and CVC (child measure). The Greenhouse–Geiser correction for nonsphericity was used for all measures and the degrees-of-freedom are adjusted accordingly.

For the three parent measures, there were no significant main effects of Group. Significant main effects of Time were identified for %Parentese Speech $F(2.76, 187.23) = 31.00$, $P < 0.001$, $\eta_p^2 = 0.31$, and %Standard Speech $F(2.66, 181.31) = 31.34$, $P < 0.001$, $\eta_p^2 = 0.32$, but not AWC ($P > 0.10$). As hypothesized, the impact of I was indicated by a significant interaction between Group and Time for %Parentese Speech $F(2.75, 187.22) = 2.96$, $P = 0.038$, $\eta_p^2 = 0.04$ (Fig. 1A), but not for %Standard Speech or AWC ($Ps > 0.10$). I families showed greater increases in parentese across time compared to C families.

For CTC, there was a significant main effect of Group $F(1, 67) = 12.08$, $P = 0.001$, $\eta_p^2 = 0.15$, a significant main effect of Time, $F(1.88, 126.19) = 47.5$, $P < 0.001$, $\eta_p^2 = 0.42$, and a significant interaction between Group and Time, $F(1.88, 126.19) = 4.58$, $P = 0.014$, $\eta_p^2 = 0.064$, with I families showing a greater increase in CTCs than C families (Fig. 1B).

For CVC, there was a significant main effect of Group $F(1, 67) = 13.96$, $P < 0.001$, $\eta_p^2 = 0.17$, a significant main effect of Time $F(2.02, 135.04) = 39.33$, $P < 0.001$, $\eta_p^2 = 0.37$, and a significant Group-by-Time interaction $F(2.02, 135.04) = 6.18$, $P = 0.003$, $\eta_p^2 = 0.08$, with I children showing greater increases in CVCs over time compared to C children (Fig. 1C).

SES and Intervention Effects. We next examined whether the above-described intervention effects on parent language, parent–child turn-taking, and child vocalizations, were related to families' SES. For the three measures significantly impacted by the intervention (%Parentese Speech, CTC, and CVC), we first calculated the change scores between 6 and 18 mo. Mean change scores (SD) across groups were: %Parentese Speech, mean = 18.5 (15.9); CTC, mean = 289.3 (257.2); and CVC, mean = 794.6 (780.4). Changes in these three measures between 6 and 18 mo were not significantly correlated with SES when all I and C families were considered as a single group (rs between 0.05 and 0.15, all $Ps > 0.1$), or when the I and the C groups were considered separately (all rs between −0.06 and 0.33, all $Ps > 0.1$). A lack of relationship between SES and the intervention effects was confirmed with follow-up covariance analyses, conducted for the three significant Group-by-Time interactions, which remained significant after controlling for SES: %Parentese Speech, $F(2.74, 183.40) = 2.96$, $P = 0.038$, $\eta_p^2 = 0.04$; CTC, $F(1.86, 122.53) = 4.69$, $P = 0.013$, $\eta_p^2 = 0.07$; CVC, $F(2.00, 131.93) = 6.22$, $P = 0.003$, $\eta_p^2 = 0.09$. Together, these results show that changes in the three measures impacted by the intervention were not related to families' SES.

Child Language Outcomes at 18 Mo. Child language outcomes were assessed in two ways: Observed production of child words in LENA recordings (%Child Words) (*Methods*) and parent report (CDI Words) (36, 51). To test for differences between I and C groups, a t test was conducted separately for %Child Words and CDI Words measured at 18 mo. There was a significant effect of Group for %Child Words $t(68) = 3.00$, $P = 0.004$, $d = 0.78$, and CDI Words $t(68) = 2.03$, $P = 0.046$, $d = 0.53$ (Fig. 2). For both measures, the I group outperformed the C group, and both effects remained significant after controlling for SES (covariance analysis): %Child Words $F(1, 67) = 9.53$, $P = 0.003$, $\eta_p^2 = 0.125$ and CDI Words $F(1, 67) = 4.07$, $P = 0.048$, $\eta_p^2 = 0.06$.

To confirm that our measure of the observed infant language (%Child Words as coded from the recordings) and parent report of infant language (CDI Words) at 18 mo were congruent, we examined the correlation between these two measures. The observed infant language and parental reports were correlated, $r(68) = 0.52$, $P < 0.001$, and this relationship did not differ significantly by group ($P = 0.45$).

Correlations Between Parent and Child Language. To consider whether enhancements in parental language and parent–child turn-taking were related to changes in child vocalizations between 6 and 18 mo, we examined the correlations between the change scores for %Parentese Speech, CTC, and CVC in all participating families. The change in CTC between 6 and 18 mo was significantly correlated with the change in CVC during the same time period, $r(68) = 0.79$, $P < 0.001$ (Fig. 3A).

To consider whether enhancements in parental language and parent–child turn-taking were related to child language outcomes at 18 mo, we examined the correlations between the change scores and child outcomes. The change in %Parentese Speech between 6 and 18 mo was significantly correlated with %Child Words at 18 mo $r(68) = 0.32$, $P = 0.008$ (Fig. 3B), and the change in CTC between 6 and 18 mo was significantly correlated with %Child Words at 18 mo $r(68) = 0.68$, $P < 0.001$, and CDI Words at 18 mo $r(67) = 0.49$, $P < 0.001$ (Fig. 3 C and D).

We considered the possibility that these significant correlations were driven by SES, or by children's level of %Child Babbling at baseline (Table 1), but this was not the case: All significant correlations remained significant after controlling for SES and baseline babbling (rs between 0.28 and 0.78, Ps between 0.02 and 0.000).

Discussion

The present study was designed to test three specific hypotheses: That a parent coaching intervention delivered at 6, 10, and 14 mo would: 1) Increase parental use of parentese speech, but not parental use of standard speech, or the overall quantity of parental speech; 2) increase parent–child turn-taking between 6 and 18 mo; and 3) lead to enhanced growth in child vocalizations during the same time period, and enhanced language outcomes at 18 mo, 4 mo after the third coaching appointment. The results support our hypotheses. Parents who received coaching increased their use of parentese and were engaged with their child in more

Table 1. Baseline measures in intervention (I) and control (C) groups

|	I (*n* = 48; 25 boys) mean (SD)	C (*n* = 23; 11 boys) mean (SD)
Siblings in household	0.6 (0.9)	0.4 (0.5)
Adults in household	2.3 (0.6)	2.3 (1.1)
SES	49.9 (9.9)	49.5 (11.0)
AWC	17887.1 (6649.5)	16341.2 (6064.9)
CTC	357.1 (115.2)	309.7 (110.0)
CVC	1261.7 (394.1)	1156.9 (303.1)
%Parentese Speech	42.5 (18.4)	47.2 (18.1)
%Standard Speech	32.4 (15.0)	30.3 (10.6)
%Child Babbling	26.6 (7.1)	29.9 (11.7)
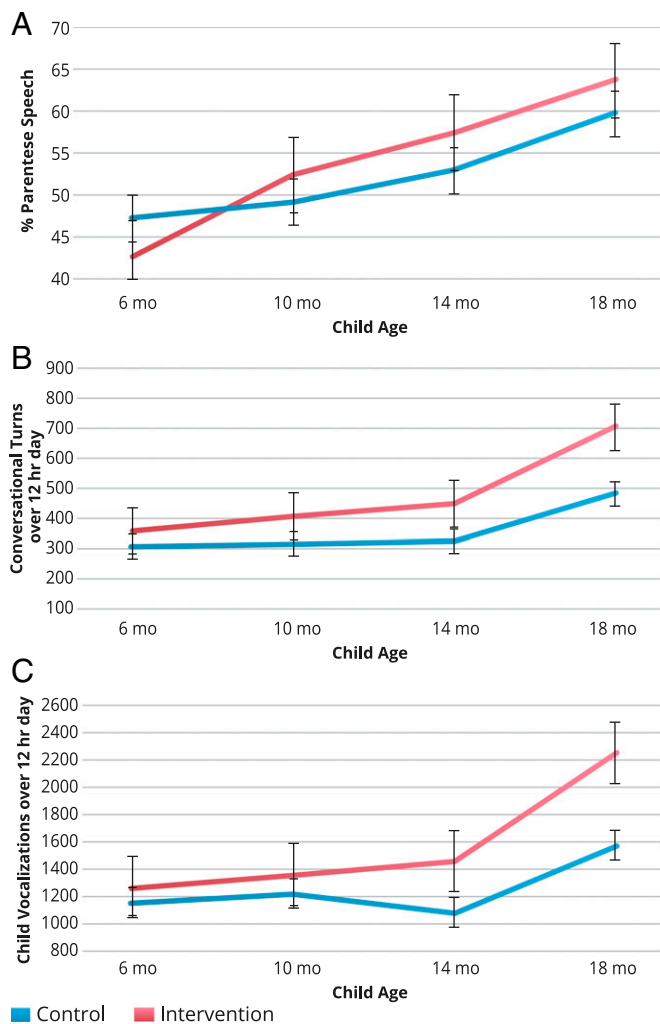
Fig. 1. Parent language, parent–child turn-taking, and child vocalizations between 6 and 18 mo. (*A*) Mean percentages of parental use of parentese (%Parentese Speech; *n* = 70); (*B*) mean number of conversational turns over a 12-h day (CTC; *n* = 69); and (*C*) mean number of children's vocalizations (CVC) over a 12-h day (*n* = 69) at 6, 10, 14, and 18 mo in the I (red) and C (blue) groups. Error bars indicate SEM.

conversational turns compared to parents who did not receive coaching. Their children, in turn, increased their production of speech-related vocalizations significantly more between 6 and 18 mo, and produced more words at 18 mo. Importantly, the growth in parentese and turn-taking between 6 and 18 mo was positively correlated with the growth in children's vocalizations during the same time period and with children's 18-mo language outcomes, suggesting that parental and child language behaviors coevolved.

We have previously shown that parentese can be enhanced by parent coaching, and that this has immediate effects on child language (30). The data presented here further support the notion that experimental manipulation of parental language input is possible, across a range of SES backgrounds. We show that enhancements in parental social communication skills are both robust and durable, and suggest that the effects of parent coaching between 6 and 18 mo put both parents and children on a trajectory of enhanced social communication, evidenced by an increase in conversational turn-taking that we measured in the I group. As such, we argue that the present study presents evidence for a social benefit of parentese. It should be noted that the present study

measured the effects of the intervention on a predetermined set of social interaction and child language variables. It is, of course, possible that the intervention changed other parental and child behaviors that were not assessed here. It should also be noted that the present study focuses on young children in the early stages of productive speech. Previous research shows that some aspects of parental input may relate more to child language development at different developmental stages than others (40), and future studies should investigate the importance of parentese and other social aspects of parental speech at later ages. However, previous research also indicates that differences in language skills in infancy are predictive of subsequent stages in language development (36, 51, 54, 55), and suggests that enhancement in parental social behaviors achieved through intervention could have cascading effects on infant speech development over time. Follow-up studies should assess children's language skills with objective language measures in the laboratory, as well as assess children's language-related brain function and structure, to monitor the potential effects of interventions in infancy on long-term language, cognitive, and neural outcomes.

Previous studies demonstrate that, while parents may know that talking with their child promotes language learning, they are rarely aware of the specific aspects of their own language behaviors (46, 47, 53). Although all families in the present sample already used parentese at baseline, conversation during the coaching appointments revealed that the vast majority of parents were unaware of its positive effects on children's language growth, struggled to name specific moments of the day when they use parentese, and were often surprised to hear themselves using it in the recordings. Our approach was to raise their awareness by highlighting the research behind parentese and other social aspects of parent–child interactions, and by demonstrating to parents, through listening to their own recordings, that they can interact with their infant in ways that promote language growth. We provided qualitative and quantitative linguistic feedback, and explained how and why each language measure can vary from day to day, from family to family, and from context to context. Finally, we gave parents concrete language tips and, through discussion of their own daily routines, encouraged them to think of additional scenarios in which they can use language and interact with their infant. Parents were generally grateful to leave the appointments
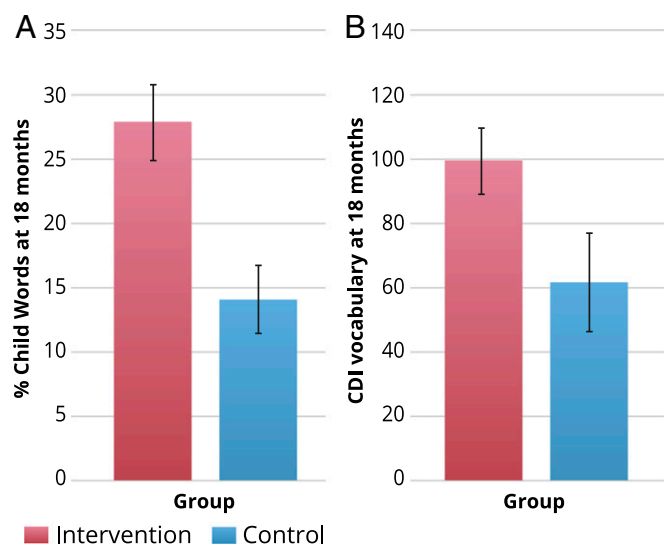
Fig. 2. Child language outcomes at 18 mo. (*A*) Mean percentage of observed child words in LENA recordings (%Child Words; *n* = 70) at 18 mo; (*B*) mean vocabulary size as estimated by the CDI at 18 mo (CDI Words; *n* = 70), in the I (red) and C (blue) groups. Error bars indicate SEM.
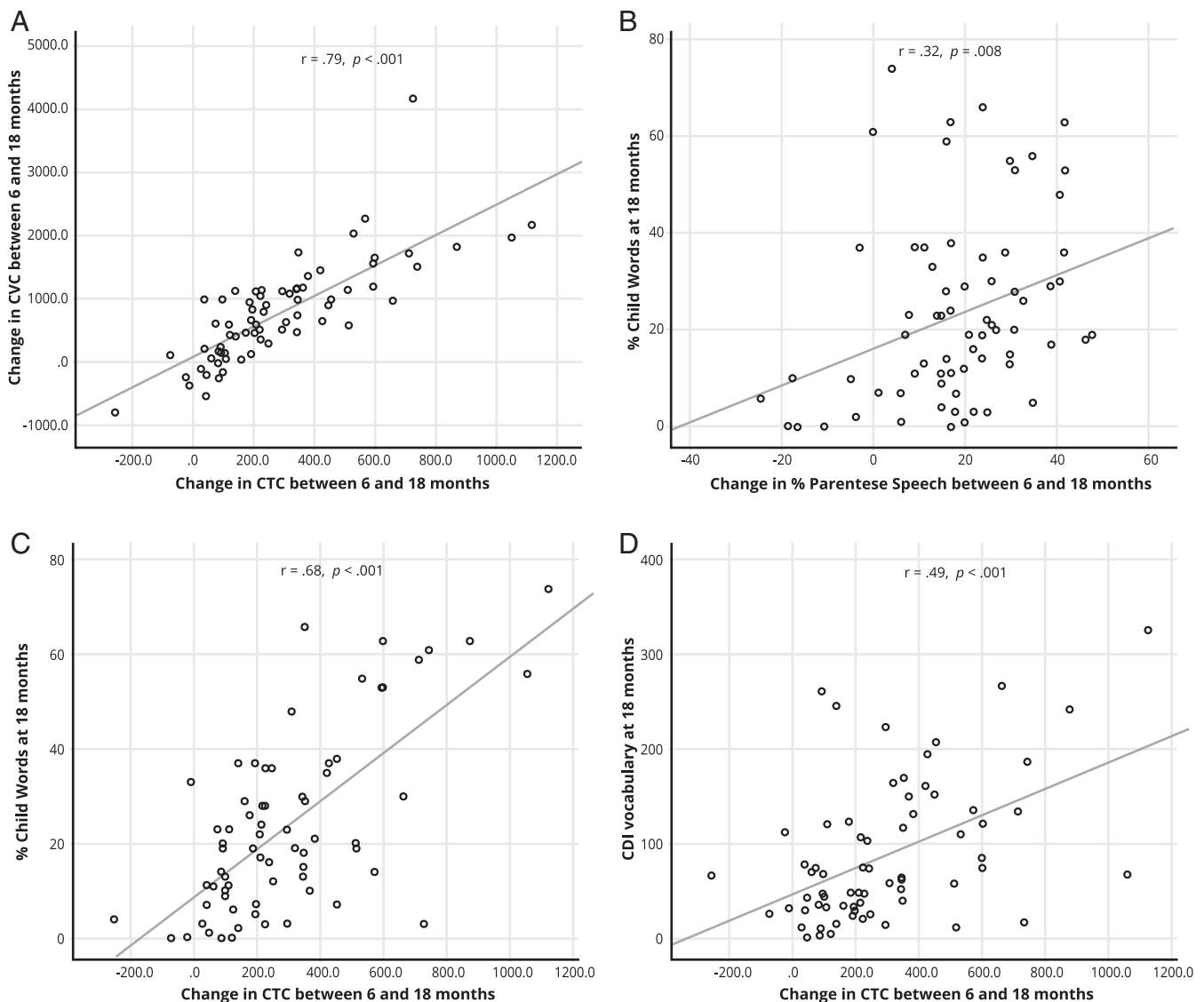
Fig. 3. Correlations between parent language, parent-child turn-taking, and child language in all participating families (I and C). (*A*) Change in CTC between 6 and 18 mo and change in CVC between 6 and 18 mo (*n* = 69). (*B*) Change in %Parentese Speech between 6 and 18 mo and Child Words at 18 mo (*n* = 69). (*C*) Change in CTC between 6 and 18 mo and Child Words at 18 mo (*n* = 69). (*D*) Change in CTC between 6 and 18 mo and CDI vocabulary at 18 mo (*n* = 68).

with new ideas to implement at home. The results presented here support the notion that complex scientific information can successfully be explained to nonscientists (parents) to leverage their use of specific language behaviors and have a powerful effect on children's learning (56). While the findings described here apply to a broad range of SES backgrounds, it remains to be seen how they generalize to other populations, such as bi/multilingual families, clinical populations, or cultures where parent–child verbal interaction is limited (57).

The present study illuminates the debate about the specific mechanisms by which parentese enhances children's language growth. With its dramatic changes in the pitch of the voice (10), as well as exaggerated facial movements (58), parentese conveys a positive emotion that makes the speaker sound "happy" (29, 59). This combination attracts and holds infants' attention (9), which could increase the quality or quantity of language uptake (60). Furthermore, we established here that both parentese and conversational turns are related to enhanced language growth, which adds to the growing body of work linking language learning to social processes. The importance of a social context in language

learning was demonstrated earlier in studies of foreign-language exposure at 9 mo of age, a "sensitive period" in phonetic learning (61). In the original study, infants experienced a foreign language while interacting socially with live tutors as opposed to receiving the identical language input delivered via video (61). Results demonstrated that live social interaction resulted in rapid and robust learning of the sounds that was equivalent to that of 9-mo-olds living in the foreign country, but that exposure via video produced no learning whatsoever (61). Analysis of the social (eye gaze) behaviors during these interactions were positively related to neural measures of phoneme and word learning, and infants' attention in the live, interactive social settings was higher than when watching the same material via video (61), suggesting that social skills play a critical role in language learning (62).

The social interaction promoted by parentese has been relatively neglected as a cause of increased language learning in favor of explanations that parentese enhances learning because it enriches the linguistic signal (14). Language uptake during parent–child turn-taking may be enhanced as a result of social processes, such as gaze-following (62–64), which has been related

to children's vocabulary size (42). Contingency or reciprocity in parents' reactions to children's vocalization increases their complexity (65), which is consistent with our previous data demonstrating that the parent intervention increased concurrent infant babbling, itself a positive predictor of the child's future language (30). Through back and forth exchanges, parents provide contingent feedback that is constantly adjusted to their infants' linguistic needs, and infants, in turn, adjust their vocalizations in response to parental vocalizations (66–69), thereby creating a positive feedback loop (70).

Early language learning depends on infants' social interest in the people around them, their appreciation of others' communicative intentions, and their desire to engage with adults through imitation (42, 71). Studies using advanced neuroimaging in the form of magnetoencephalography reveal an auditory–motor link that is activated as infants listen to speech: Auditory presentations of speech activate speech motor planning areas, such as Broca's area and the cerebellum that allow infants to respond with their own vocalizations as early as 7 mo of age (72). The acoustic and visual features of parentese may represent an ideal signal both linguistically and socially that activates the social brain systems underlying infants' motivation to learn language (60, 72, 73). Research on children aged 4 to 6 y demonstrates that the number of conversational turns during parent–child language interactions correlates positively with stronger more coherent white-matter track connectivity in the language areas of the brain, an effect independent of SES (74). While further studies will be necessary to fully unpack the underlying mechanisms through which social language interaction enhances infant language development, the present study demonstrates that translational science can create successful interventions and has the potential to improve children's language learning.

Methods

Participants. Seventy-nine families were recruited through the University of Washington Subjects Pool. The inclusion criteria included: 1) Full term and born within 14 d of due date, 2) normal birth weight (6 to 10 lbs), 3) no birth or postnatal complications, and 4) English as the only language spoken in the home. SES was assessed with the Hollingshead Index (49), a widely used measure, which codes parent educational attainment and occupational prestige to generate a number between 8 and 66. While the relationship between SES and language development is well documented, researchers have yet to reach consensus on the most effective measure of SES (75). In addition to the Hollingshead Index scores, we also collected information about parental education and families' monthly income. These three SES-related measures were strongly correlated in the present sample, (rs between 0.56 and 0.7, Ps < 0.001). We use the Hollingshead Index scores for all reported SES analyses because we used this index initially to achieve an SES balance between the groups, and we have verified that none of the reported results change if the other two SES-related measures are used instead. Participating families were of working- to upper-middle class backgrounds, with a mean Hollingshead Index of 49.6 (SD = 10.3), and a range from 30 (e.g., both parents with high school diploma/some college, working in sales or construction) to 66 [e.g., both parents with advanced degrees, working as professionals (30)].

Families were randomly assigned (30) to the Parent Coaching (PC) condition (n = 33, SES: mean = 50.1, SD = 10.6), PC Plus Group Support (PC+) condition (PC+; n = 22, SES: mean = 48.8, SD = 9.6), or C condition (n = 24, SES: mean = 49.4, SD = 10.8). The PC+ condition included the same procedures as the PC condition, in addition to a 1-h social gathering with 8 to 12 other participating PC+ families at each data collection point (6, 10, 14 mo), the purpose of which was to give families an opportunity to share their experiences about their attempts to use language with their child. We had initially hypothesized that the PC+ gatherings would provide an additional advantage. However, our previous work shows that this was not the case (30), and this finding was replicated here with a preliminary analysis showing no significant differences between the PC and PC+ conditions on any parental or child language variables studied here (all Ps > 0.10). The two conditions were therefore collapsed into a single group (I; n = 55).

Of the 79 families, two I group families withdrew after the 6-mo data collection, and one withdrew after the 14-mo data collection. Two additional

I group families relocated and were not able to attend the 14-mo individual coaching appointment in person. One I group family was excluded because it was discovered that the child began receiving language input in Spanish at home at age 15 mo. Additionally, two families (one I and one C) were excluded because parents reported a diagnosis of developmental delay at 18 mo. This yielded a total of 71 families (48 I and 23 C; 90%) in the present analyses. Experimental procedures were approved by the Institutional Review Board of the University of Washington and informed consent was obtained from parents. The study conforms to the US Federal Policy for the Protection of Human Subjects.

Study Design. All enrolled I and C families attended an individual orientation visit in our laboratory prior to baseline data collection. During this visit, all I and C families were given the same information about the purpose of the study: They were informed that we are studying the relationship between language input and language development. Families also signed informed consent, and were familiarized with the LENA recorders. At each data collection point, families were reminded by phone or email (parents' choice) to complete the recordings and mail the recorders back. All communication about the logistics of the study was completed by a research assistant, was consistent between the two groups, and was kept entirely separate from the parent coaching appointments. The only procedural difference between the two groups were the coaching appointments (attended only by the I group), and took place after the completed recordings and 4 mo prior to the next scheduled recording.

All 71 families completed the recordings at 6, 10, and 14 mo. At 18 mo, one I family did not provide a recording due to extensive travel. At 18 mo, families were asked to complete the CDI, Words and Sentences (36, 51). All 48 I families and 22 of 23 C families provided a completed questionnaire.

Parent Coaching. Following the 6-, 10-, and 14-mo recordings, I families attended individual coaching appointments. Both parents were invited to the appointments; however, 108 of 144 appointments (75%) were attended by mothers only. We had previously shown that there was no effect of having both parents versus one parent present at the appointments (30), and we replicated this finding here with a preliminary analysis showing that there are no significant differences between these two conditions on any parental or child variables studied here (all Ps > 0.10). All I families were therefore analyzed as a single group in the analyses reported here. The individual coaching sessions were ~45 min long and took place an average of 24 d (SD = 7.9) after the recording.

LENA Data Collection, Preparation, and Coding. I and C families received two LENA recorders in the mail at 6, 10, 14, and 18 mo and were instructed to use one recorder on each day of a "typical" weekend, defined as two consecutive days when both parents were home and not working, as close as possible to the child's 6-, 10-, 14-, and 18-mo birthday (on average 3 d away, and not different between I and C group at any data collection point; all Ps > 0.10). Parents were asked to start each recording in the morning when the child woke up, go about their day as usual, and turn off the recorder at night when the child went to sleep. All families were also asked to keep a simple list of most relevant activities for each day (i.e., 9:00 to 10:00 AM: grocery shopping; 10:00 to 11:00 AM: nap).

Initial attempts to record were unsuccessful for 11 of 283 completed recordings (e.g., recorder was accidentally turned off, malfunctioned, or was not turned on). In 9 of these 11 cases, the families were able to record again on two consecutive weekend days the following weekend. Two of the 11 rerecording attempts came from nonconsecutive weekend days, due to equipment failure, followed by the families' inability to record a full 2-d weekend within an acceptable timeframe. The average duration of the recordings was 12 h and 49 min (range: 8 h and 44 min to 16 h), and did not differ between the I and the C group at any data collection point (Ps > 0.10). The groups also did not differ in terms of the number of siblings or adults in the household, or on any of the baseline demographic or language measure (all Ps > 0.1) (Table 1).

LENA Automatic Counts. Following data collection, the LENA audio recordings were downloaded to a computer and analyzed by the LENA software, which uses advanced algorithms and statistical modeling to provide an estimate of three primary language-related measures: The number of adult words heard by the child (AWC), the number of child's language-related vocalizations (CVC; nonspeech sounds, such as coughing or crying, are excluded), and the number of adult-child back-and-forth exchanges (CTC), where each CT is defined as a discrete pair of an adult utterance followed by a child utterance, or vice versa, with no more than a 5-s pause between the two (53). Comparisons between LENA's estimates and human transcription demonstrate that

LENA's sensitivity (i.e., how many LENA-labeled segments are assigned the same label by a human coder) is high for AWC (82%) and CVC (76%) (76, 77). Note that LENA does not differentiate between child-directed and overheard speech, and that AWC therefore represents the aggregate of both child-directed and overheard speech by nearby adults.

Because CTC is derived from AWC and CVC, the original LENA reliability studies did not assess its reliability separately. For this reason, and because CTC was a critical measure in the current study, we conducted a supplemental analysis in which human researchers manually coded conversational turns in a portion of the 18-mo data (details under *Manual Coding of Conversational Turns*, below).

For each recording day, the LENA software produces an estimate of AWC, CTC, and CVC for the entire duration of the recording. Because the recordings varied in duration, projected 12-h values were used for all three LENA automatic measures at all data collection points. The 12-h projections are generated automatically for recordings at least 10 h in length, and represent the interpolated values for AWC, CTC, and CVC at the 12-h mark for the day's recording (47). In all but 11 of 283 recordings, both recording days were longer than 10 h, and an average of both days' 12-h projection was used. Of the remaining 11 recordings, 10 had 1 recording day with a projected 12-h value, which was therefore used in the automatic counts' analyses of AWC, CTC, and CVC. One recording (at 10 mo) was not included in the automatic counts' analyses of AWC, CTC, and CVC because both recording days were too short to yield the 12-h projected values.

LENA Manual Analyses. Following the previously described procedures (25–27, 30), the LENA audio files were processed using the LENA Advanced Data Extractor Tool (ADEX) to automatically identify segments for further manual analyses. Each participant's two daily recordings were segmented into 30-s intervals. For each of the 2 recording days, 50 intervals with the highest AWC that were at least 3-min apart were automatically selected, yielding a total of 100 30-s coding intervals per participant per age. Intervals were identified based on AWC in order to avoid coding when there is no social or linguistic activity (for example, during naps).

Ten research assistants, blind to family's condition assignment, were trained to code the selected intervals. All coders were members of our research team, had prior experience coding parentese and infant vocalizations, and used the same audio files, training, reliability assessment, and variable definitions as previously described (25–27, 30). During training, coders listened to examples of each coding category (see list below). To distinguish parentese from standard speech, the same criteria were adopted as previously described (25–27, 30). These analyses independently verified that the intervals defined as parentese or standard speech contained the acoustic differences characteristic of these two speech styles [i.e., higher pitch and larger pitch range for parentese (25)]. In these analyses, 60 occurrences of the word "you" were analyzed. The 60 occurrences of "you" represented 30 pairs (30 produced as parentese and 30 as standard speech) produced by the same adult addressing the same infant. Mean pitch and pitch range were significantly higher for parentese than standard speech ($Ps < 0.001$) (25).

Coders listened to each 30-s interval and entered a "YES" or a "NO" for each of the following coding categories: 1) Parentese (6, 10, 14, 18 mo): Mother, father, or other adult spoke directly to the infant, parentese speech was used, and one or more than one adult voice was recorded during the interval. 2) Standard speech (6, 10, 14, 18 mo): Mother, father, or other adult spoke directly to the infant, standard speech was used, and one or more than one adult voice was recorded during the interval. 3) Child babbling (6 mo): Child producing fully resonant vowels, consonant–vowel syllables, variegated strings of consonant-vowel syllables, speech utterances intermixed with nonspeech, and word-like strings (see also table 2 in refs. 25 and 30).

4) Child words (18 mo): Child producing one or more than one English word(s). Infant vocalizations were counted as words if they were recognized by the coder as English words.

Note that the coding categories are nonexhaustive and nonmutually exclusive; that is, a given interval may contain parentese and standard speech, or just parentese or just standard speech, with or without infant babbling or words. The resulting matrix of YES and NO responses for each 30-s interval indicated that a specific category occurred or did not occur in that interval. The data matrices were aggregated to provide relative time use data by calculating the percentage of intervals coded for each category: The total percentage of intervals with parentese speech (%Parentese Speech) and standard speech (%Standard Speech) at each age, the total percent of coded intervals with infant babbling at 6 mo (%Child Babbling), and the total percent of coded intervals with child words at 18 mo (%Child Words).

To evaluate intercoder reliability, all coders were tested independently with a training file, producing an intraclass correlation of 0.95 for %Parentese Speech, 0.94 for %Standard Speech, 0.95 for %Child Babbling, and 0.90 for %Child Words. This indicates effective training and reliable coding, as was the case in previous studies using the same methodology (25–27, 30).

Manual Coding of Conversational Turns. Conversational turns were manually coded in a subset of the 18-mo data. The same 100 30-s segments per participant were used as for the coding of other parental and child variables described above. Three coders listened to 100 30-s audio segments per family, and manually identified conversational turns: Discrete pairs of an adult utterance followed by a child utterance, or vice versa, with no more than a 5-s pause between the two. These supplemental analyses showed that the I and the C group differed significantly in the mean number of conversational turns per 30-s segment, as identified by human coders in the 18-mo dataset (I group: mean = 1.45, SD = 0.73; C group: mean = 1.02, SD = 0.54; $P < 0.014$). This is in agreement with our main findings presented in *Results*, which were based on LENA's CTC estimates over 12 h (Fig. 1*B*).

Other Methodological Considerations. An inherent weakness of studies that use recording devices is the potential Hawthorne effect: The notion that an individual's knowledge of being recorded may result in positively modifying their behavior. Although it is not possible to rule out that parents behaved differently on recording days, we took several steps to minimize this potential confound. First, at each time point, families were recorded over 2 entire weekend days, and parents and infants were measured. Sustaining an altered behavioral pattern (in an adult or in an infant) over 2 ~13-h recording days, while going about one's usual day is challenging. Second, segments for manual analysis were selected with an automatic algorithm. Therefore, even if parents suspect what the researchers are looking for, they are unable to predict which segments of their speech recorded over two 13-h days will be selected for manual analyses.

Data Availability Statement. All data discussed in the paper are available under the following link: http://ilabs.uw.edu/ferjan-ramirez-et-al-2019.

1. C. Ferguson, Baby talk in six languages. *Am. Anthropol.* **66**, 103–114 (1964).
2. A. Fernald, Intonation and communicative intent in mothers' speech to infants: Is the melody the message? *Child Dev.* **60**, 1497–1510 (1989).
3. J. S. Reilly, U. Bellugi, Competition on the face: Affect and language in ASL motherese. *J. Child Lang.* **23**, 219–239 (1996).
4. M. Soderstrom, Beyond Babytalk: Re-evaluating the nature and content of speech input to preverbal infants. *Dev. Rev.* **27**, 501–532 (2007).
5. A. Fernald, T. Simon, Expanded intonation contours in mothers' speech to newborns. *Dev. Psychol.* **20**, 104–113 (1984).
6. D. L. Grieser, P. K. Kuhl, Maternal speech to infants in a tonal language: Support for universal prosodic features in motherese. *Dev. Psychol.* **24**, 14–20 (1988).
7. D. N. Stern, S. Spieker, R. K. Barnett, K. MacKain, The prosody of maternal speech: Infant age and context related changes. *J. Child Lang.* **10**, 1–15 (1983).
8. R. P. Cooper, R. N. Aslin, Developmental differences in infant attention to the spectral properties of infant-directed speech. *Child Dev.* **65**, 1663–1677 (1994).

9. A. Fernald, Four-month-old infants prefer to listen to motherese. *Infant Behav. Dev.* **8**, 181–195 (1985).
10. A. Fernald, P. K. Kuhl, Acoustic determinants of infant preference for motherese speech. *Infant Behav. Dev.* **10**, 279–293 (1987).
11. C. Dunst, E. Gorman, D. Hamby, Preference for infant-directed speech in preverbal young children. *Cent. Early Literacy Learn.* **5**, 1–13 (2012).
12. E. Bergelson, C. Bergmann, K. Byers-Heinlein, A. Cristia, R. Cusack, Quantifying sources of variability in infancy research using the infant-directed speech preference. PsyArXiv Preprints, 10.31234/osf.io/s98ab (14 April 2017).
13. D. McCarthy, "Language development in children" in *Manual of Child Psychology*, L. Carmichael, Ed. (Wiley, 1954), pp. 492–630.
14. E. L. Newport, H. Gleitman, L. R. Gleitman, "Mother, I'd rather do it myself: Some effects and non-effects of maternal speech style" in *Talking to Children*, C. E. Snow, C. A. Ferguson, Eds. (Cambridge University Press, Cambridge, UK, 1977), pp. 109–149.

Ferjan Ramírez et al.

15. J. R. Phillips, Syntax and vocabulary of mothers' speech to young children: Age and sex comparisons. *Child Dev.* **44**, 182–185 (1973).

16. C. E. Snow, The development of conversation between mothers and babies. *J. Child Lang.* **4**, 1–22 (1977).

17. D. Burnham, C. Kitamura, U. Vollmer-Conna, What's new, pussycat? On talking to babies and animals. *Science* **296**, 1435 (2002).

18. P. K. Kuhl et al., Cross-language analysis of phonetic units in language addressed to infants. *Science* **277**, 684–686 (1997).

19. A. R. Bradlow, G. M. Torretta, D. B. Pisoni, Intelligibility of normal speech I: Global and fine-grained acoustic-phonetic talker characteristics. *Speech Commun.* **20**, 255–272 (1996).

20. H.-M. Liu, P. K. Kuhl, F.-M. Tsao, An association between mothers' speech clarity and infants' speech discrimination skills. *Dev. Sci.* **6**, F1–F10 (2003).

21. K. Hirsh-Pasek et al., Clauses are perceptual units for young infants. *Cognition* **26**, 269–286 (1987).

22. W. Ma, R. M. Golinkoff, D. Houston, K. Hirsh-Pasek, Word learning in infant- and adult-directed speech. *Lang. Learn. Dev.* **7**, 185–201 (2011).

23. E. D. Theissen, E. A. Hill, J. R. Saffran, Infant-directed speech facilitates word segmentation. *Infancy* **7**, 53–71 (2005).

24. L. J. Trainor, R. N. Desjardins, Pitch characteristics of infant-directed speech affect infants' ability to discriminate vowels. *Psychon. Bull. Rev.* **9**, 335–340 (2002).

25. N. Ramírez-Esparza, A. García-Sierra, P. K. Kuhl, Look who's talking: Speech style and social context in language input to infants are linked to concurrent and future speech development. *Dev. Sci.* **17**, 880–891 (2014).

26. N. Ramírez-Esparza, A. García-Sierra, P. K. Kuhl, The impact of early social interactions on later language development in Spanish-English bilingual infants. *Child Dev.* **88**, 1216–1234 (2017).

27. N. Ramírez-Esparza, A. García-Sierra, P. K. Kuhl, Look who's talking NOW! Parentese speech, social context, and language development across time. *Front. Psychol.* **8**, 1008 (2017).

28. R. M. Golinkoff, D. D. Can, M. Soderstrom, K. Hirsh-Pasek, (Baby) Talk to me: The social context of infant-directed speech and its effects on early language acquisition. *Curr. Dir. Psychol. Sci.* **24**, 339–344 (2015).

29. V. C. Tartter, Happy talk: Perceptual and acoustic effects of smiling on speech. *Percept. Psychophys.* **27**, 24–27 (1980).

30. N. Ferjan Ramírez, S. R. Lytle, M. Fish, P. K. Kuhl, Parent coaching at 6 and 10 months improves language outcomes at 14 months: A randomized controlled trial. *Dev. Sci.* **22**, e12762 (2019).

31. B. Hart, T. Risley, *Meaningful Differences in the Everyday Experience of Young American Children* (Brookes, Baltimore, MD, 1995).

32. A. Weisleder, A. Fernald, Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychol. Sci.* **24**, 2143–2152 (2013).

33. K. Hirsh-Pasek et al., The contribution of early communication to low-income children's language success. *Psychol. Sci.* **26**, 1071–1083 (2015).

34. A. D. Pace, R. M. Alper, M. J. Burchinal, R. M. Golinkoff, K. Hirsh-Pasek, Measuring success: Within and cross-domain predictors of academic and social trajectories in elementary school. *Early Child. Res. Q.* **46**, 112–125 (2019).

35. E. Hoff, Interpreting the early language trajectories of children from low-SES and language minority homes: Implications for closing achievement gaps. *Dev. Psychol.* **49**, 4–14 (2013).

36. L. Fenson et al., Variability in early communicative development. *Monogr. Soc. Res. Child Dev.* **59**, 1–173, discussion 174–185 (1994).

37. P. K. Kuhl et al., Phonetic learning as a pathway to language: New data and native language magnet theory expanded (NLM-e). *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **363**, 979–1000 (2008).

38. E. Hoff, The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development* **74**, 1368–1378 (2003).

39. J. Huttenlocher, H. Waterfall, M. Vasilyeva, J. Vevea, L. V. Hedges, Sources of variability in children's language growth. *Cognit. Psychol.* **61**, 343–365 (2010).

40. M. L. Rowe, A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Dev.* **83**, 1762–1774 (2012).

41. C. S. Tamis-LeMonda, Y. Kuchirko, L. Song, Why is infant language learning facilitated by parental responsiveness? *Curr. Dir. Psychol. Sci.* **23**, 121–126 (2014).

42. R. Brooks, A. N. Meltzoff, The development of gaze following and its relation to language. *Dev. Sci.* **8**, 535–543 (2005).

43. R. M. Golinkoff, E. Hoff, M. L. Rowe, C. S. Tamis-LeMonda, K. Hirsh-Pasek, Language matters: Denying the existence of the 30-million-word gap has serious consequences. *Child Dev.* **90**, 985–992 (2019).

44. K. Leech, R. Wei, J. R. Harring, M. L. Rowe, A brief parent-focused intervention to improve preschoolers' conversational skills and school readiness. *Dev. Psychol.* **54**, 15–28 (2018).

45. M. McGillion, J. M. Pine, J. S. Herbert, D. Matthews, A randomised controlled trial to test the effect of promoting caregiver contingent talk on language development in infants from diverse socioeconomic status backgrounds. *J. Child Psychol. Psychiatry* **58**, 1122–1131 (2017).

46. D. Suskind et al., An exploratory study of 'quantitative linguistic feedback': Effect of LENA feedback on adult language production. *Comm. Disord. Q.* **34**, 199–209 (2013).

47. D. L. Suskind et al., A parent-directed language intervention for children of low socioeconomic status: A randomized controlled pilot study. *J. Child Lang.* **43**, 366–406 (2016).

48. M. L. Rowe, K. A. Leech, A parent intervention with a growth mindset approach improves children's early gesture and vocabulary development. *Dev. Sci.* **22**, e12792 (2019).

49. A. B. Hollingshead, Four factor index of social status. *Yale J. Sociol.* **8**, 21–52 (2011).

50. LENA, LENA Pro, Version 3.4.0 (LENA, Boulder, CO, 2015).

51. L. Fenson et al., *MacArthur-Bates Communicative Development Inventories: User's Guide and Technical Manual* (Brookes, 2007).

52. C. Abraham, S. Michie, A taxonomy of behavior change techniques used in interventions. *Health Psychol.* **27**, 379–387 (2008).

53. J. Gilkerson et al., Mapping the early language environment using all-day recordings and automated analysis. *Am. J. Speech Lang. Pathol.* **26**, 248–265 (2017).

54. E. Bates, P. Dale, D. Thal, "Individual differences and their implications for theories of language development" in *Handbook of Child Language*, P. Fletcher, B. MacWhinney, Eds. (Basil Blackwell, 1995), pp. 96–151.

55. M. L. Rowe, S. Goldin-Meadow, Differences in early gesture explain SES disparities in child vocabulary size at school entry. *Science* **323**, 951–953 (2009).

56. J. P. Shonkoff, S. N. Bales, Science does not speak for itself: Translating child development research for the public and its policymakers. *Child Dev.* **82**, 17–32 (2011).

57. A. Weber, A. Fernald, Y. Diop, When cultural norms discourage talking to babies: Effectiveness of a parenting program in rural Senegal. *Child Dev.* **88**, 1513–1526 (2017).

58. J. F. Werker, J. E. Pegg, P. J. McLeod, A cross-language investigation of infant preference for infant-directed communication. *Infant Behav. Dev.* **17**, 323–333 (1994).

59. L. Singh, J. L. Morgan, C. Best, Infants' listening preferences: Baby talk or happy talk? *Infancy* **3**, 365–394 (2002).

60. P. K. Kuhl, Is speech learning 'gated' by the social brain? *Dev. Sci.* **10**, 110–120 (2007).

61. P. K. Kuhl, F.-M. Tsao, H.-M. Liu, foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proc. Natl. Acad. Sci. U.S.A.* **100**, 9096–9101 (2003).

62. B. T. Conboy, R. Brooks, A. N. Meltzoff, P. K. Kuhl, Social interaction in infants' learning of second-language phonetics: An exploration of brain-behavior relations. *Dev. Neuropsychol.* **40**, 216–229 (2015).

63. D. A. Baldwin, "Understanding the link between joint attention and language" in *Joint Attention: Its Origins and Role in Development*, C. Moore, P. J. Dunham, Eds. (Lawrence Erlbaum Associates, 1995), pp. 131–158.

64. R. Brooks, A. N. Meltzoff, The importance of eyes: How infants interpret adult looking behavior. *Dev. Psychol.* **38**, 958–966 (2002).

65. M. H. Goldstein, A. P. King, M. J. West, Social interaction shapes babbling: Testing parallels between birdsong and speech. *Proc. Natl. Acad. Sci. U.S.A.* **100**, 8030–8035 (2003).

66. H. C. Braarud, K. M. Stormark, Prosodic modification and verbal adjustments in mothers' speech during face-to-face interaction with their two to four-month-old infants: A double video study. *Soc. Dev.* **17**, 1074–1084 (2008).

67. M. H. Bornstein, C. S. Tamis-LeMonda, O. M. Haynes, First words in the second year: Continuity, stability, and models of concurrent and predictive correspondence in vocabulary and verbal responsiveness across age and context. *Infant Behav. Dev.* **22**, 65–85 (1999).

68. M. H. Goldstein, J. A. Schwade, Social feedback to infants' babbling facilitates rapid phonological learning. *Psychol. Sci.* **19**, 515–523 (2008).

69. N. A. Smith, L. J. Trainor, Infant-directed speech is modulated by infant feedback. *Infancy* **13**, 410–420 (2008).

70. A. S. Warlaumont, J. A. Richards, J. Gilkerson, D. K. Oller, A social feedback loop for speech development and its reduction in autism. *Psychol. Sci.* **25**, 1314–1324 (2014).

71. M. Tomasello, "The key is social cognition" in *Language and Thought*, D. Gentner, S. Kuczaj, Eds. (MIT Press, 2003), pp. 47–58.

72. P. K. Kuhl, R. R. Ramírez, A. Bosseler, J.-F. Lin, T. Imada, Infants' brain responses to speech suggest analysis by synthesis. *Proc. Natl. Acad. Sci. U.S.A.* **111**, 11238–11245 (2014).

73. S. R. Lytle, A. Garcia-Sierra, P. K. Kuhl, Two are better than one: Infant language learning from video improves in the presence of peers. *Proc. Natl. Acad. Sci. U.S.A.* **115**, 9859–9866 (2018).

74. R. R. Romeo et al., Beyond the 30-million-word-gap: Children's conversational exposure is associated with language-related brain function. *Psychol. Sci.* **29**, 700–710 (2018).

75. A. Pace, R. Luo, K. Hirsh-Pasek, R. M. Golinkoff, Identifying pathways between socioeconomic status and language development. *Annu. Rev. Linguist.* **3**, 285–308 (2017).

76. D. Xu, J. A. Richards, J. Gilkerson, Automated analysis of child phonetic production using naturalistic recordings. *J. Speech Lang. Hear. Res.* **57**, 1638–1650 (2014).

77. F. J. Zimmerman et al., Teaching by listening: The importance of adult-child conversations to language development. *Pediatrics* **124**, 342–349 (2009).