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Talking to children matters: Early language experience strengthens processing and builds vocabulary

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Abstract

Infants differ substantially in their rates of language growth, and slower growth predicts later academic difficulties. This study explored how the amount of speech to infants in Spanish-speaking families low in socioeconomic status (SES) influenced the development of children's skill in real-time language processing and vocabulary learning. All-day recordings of parent-infant interactions at home revealed striking variability among families in how much speech caregivers addressed to their child. Infants who experienced more child-directed speech became more efficient in processing familiar words in real time and had larger expressive vocabularies by 24 months, although speech simply overheard by the child was unrelated to vocabulary outcomes. Mediation analyses showed that the effect of child-directed speech on expressive vocabulary was explained by infants' language-processing efficiency, suggesting that richer language experience strengthens processing skills that facilitate language growth.

Keywords

Language Development; Poverty; Environmental Effects; Individual Differences; Cognitive Processes

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At any given age, there is wide variability among children in their levels of language proficiency (Fenson et al., 1994). Although differences in verbal abilities among individuals are influenced to some extent by genetic factors (Oliver & Plomin, 2007), the contributions of early experience to such differences are also substantial. Factors associated with socioeconomic status (SES) are strongly associated with variation in language outcomes. By the time they enter kindergarten, children from disadvantaged backgrounds differ significantly from their more advantaged peers in verbal and other cognitive abilities (Ramey & Ramey, 2004), disparities that are predictive of later academic success or failure (Hart & Risley, 1995; Lee & Burkam, 2002). Identifying the environmental factors that shape these consequential differences in early language proficiency is critical for remediating the growing achievement gaps between children from impoverished and affluent families (Duncan & Murnane, 2011).

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AW and AF developed study concept and designed study. AW performed research and data analysis. AW and AF wrote the paper.

What accounts for differences among children in their early language growth? One source of variability in rates of language learning is differential access to language and gesture from caregivers. Some parents talk more and use richer vocabulary and gesture in interactions with infants than do others, and such differences in the quantity and quality of language input account in part for later disparities among children in lexical and grammatical development, both within and between socio-economic groups (Hart & Risley, 1995; Hoff, 2003a; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Pan, Rowe, Singer, & Snow, 2005; Rowe & Goldin-Meadow, 2009). A second source of variability in language learning relates to infants' speech processing skills. Differences among infants in phonological discrimination (Tsao, Liu, & Kuhl, 2004) and spoken word recognition (Fernald, Perfors, & Marchman, 2006; Singh, Steven Reznick, & Xuehua, 2012) predict early vocabulary growth. In experimental studies in which infants look at pictures of familiar objects as one object is named, their speed and accuracy in recognizing the object name and identifying the correct picture in real time predicts both early vocabulary development and later language and cognitive skills (Fernald & Marchman, 2011; Fernald et al., 2006; Marchman & Fernald, 2008).

These studies show that children's language outcomes are linked both to early experience with language and to speech processing skills in infancy, but it is not well understood how these two influences work together over development to promote vocabulary growth. Here we investigate two alternative possibilities: One is that language experience and language-processing skill are separate factors that contribute independently to lexical development. That is, variation in children's vocabulary growth could result from differences in children's exposure to speech – and thus in their opportunities to learn new words – or from pre-existing differences in children's ability to process speech efficiently, with some children better able to take advantage of the learning opportunities available to them.

Another possibility is that early experience with language actually influences the development of efficiency in real-time language processing. That is, experience in hearing language from caregivers may sharpen infants' skill in processing speech, and hence improve their ability to learn from future language input. A recent study comparing infants from higher- and lower-SES families found that significant disparities in language processing efficiency were already present by 18 months of age (Fernald, Marchman, & Weisleder, 2013), suggesting that experiential factors associated with SES may contribute to differences in processing skill. In addition, one previous study showed that infants exposed to richer language input were more efficient in language processing (Hurtado, Marchman, & Fernald, 2008). However, in this study the relation between language experience and processing efficiency could be explained by children's vocabulary size. To address this gap, we ask here: Is early experience with language linked to the development of efficiency in language processing? And if so, do differences in processing efficiency mediate the well-established relation between early language experience and later vocabulary knowledge? Answers to these questions will help us understand the developmental pathways linking early language experience, speech-processing efficiency and vocabulary growth.

Method

We focus on infants from low-SES Latino families, a rapidly growing population of children in the U.S. at risk for academic difficulties (Reardon & Galindo, 2009). Rather than relying on short samples of mothers' speech with an observer present (Hurtado et al., 2008; Pan et al., 2005), we collected more extensive and representative recordings of infants' interactions with family members during a typical day at home. We examine how these naturalistic measures of caregiver speech relate to experimental measures of language processing and to parent report of expressive vocabulary.

Participants

Participants were 29 Spanish-learning infants (19 F, 10 M) tested at the ages of 19 and 24 months. Parents reported that all infants were full-term and typically developing. An additional 6 children were excluded from the sample because the home recordings were not conducted properly (n=3), the computer malfunctioned during testing (n=2), or the infant received a diagnosis of developmental delay during the course of the study (n=1). Median family income ranged from < $25,000 to $75,000 per year, with 79% of families reporting a yearly income below the federal poverty line. Although parents varied in years of education, most had not completed high school. Maternal education ranged from 4 – 16 years (M = 10, SD = 3) and was used as the primary index of SES, controlled in all analyses. All parents were native speakers of Spanish and all children heard Spanish as the primary language in the home, with less than 25% exposure to English from adults or other children.

Measures of the Home Language Environment

To measure adult speech accessible to infants in different families, audio-recordings were made during a typical day at home when the child was 19 months old. A digital recorder in the chest pocket of specialized clothing worn by the child enabled unobtrusive recording of both child-directed and overheard speech in daily interactions among family members (Ford, Baer, Xu, Yapanel, & Gray, 2009). Parents were asked to record their child "during a typical day in the home", and to keep a logbook indicating the locations in which the recording was conducted, who was present, the main activities the child was engaged in, and whether anything atypical occurred.

Families recorded for an average of 11 hours (range: 4-16) over the course of 1-6 days. Using information recorded in the logbooks, we selected for each family the longest available recording that represented a typical day. Estimates of adult word counts based on these recordings were highly correlated with adult word counts aggregated over all days of recording (r = .84, p < .001). After eliminating nap times, the final sample of recordings had an average duration of 7 hours (range: 3-13). Differences in the length of these recordings were controlled for in all analyses.

The home recordings were analyzed by LENA analysis software (Xu, Yapanel, & Gray, 2009). This software processes the audio files and yields estimates of different components of the infant's language environment, including the *number of adult word tokens* and the *number of child vocalizations*. The accuracy of these estimates for English-language recordings has been established in previous studies (Xu et al., 2009; Oller et al., 2010; Oetting, Hartfield & Pruitt, 2009). To assess the accuracy of the adult word estimates in Spanish-language environments, 60-min samples from 10 of the current home recordings were transcribed by native Spanish-speakers otherwise uninvolved in this research. This analysis revealed a high correlation between automated estimates of adult words and transcriber-based word counts ($r = .80$), confirming that the LENA system provides reliable estimates of adult words in Spanish language environments (further details can be found in the Supporting Methods available online).

To differentiate between speech directed to the child and speech overheard by the child, native Spanish-speaking coders listened to each of the home recordings and classified each 5-min segment as containing speech that was predominantly "child-directed" or "overheard". The number of adult word tokens in segments classified as child-directed, divided by the duration of the recording, served as our measure of "child-directed speech"; the number of adult word tokens in segments classified as overheard, divided by the duration of the recording, served as our measure of "overheard speech"; the number of speech-like vocalizations produced by the target child in segments classified as child-directed, divided by the duration of the recording, served as our measure of "child vocalizations" (see Supporting Methods for further details).

Measures of Expressive Vocabulary

At 24 months, parents completed the MacArthur-Bates Inventario del Desarrollo de Habilidades Comunicativas: Palabras y Enuciados (Inventario II) (Jackson-Maldonado et al., 2003), the Spanish-language version of the MacArthur-Bates Communicative Development Inventories (MCDI). Productive vocabulary scores were based on the number of words parents reported their child "comprende y dice" ("understands and says").

Measures of Language-Processing Efficiency

In the "looking-while-listening" (LWL) task (Fernald, Zangl, Portillo, & Marchman, 2008), infants were presented with pairs of images (e.g., a dog and a baby) while hearing sentences naming one of the pictures. Children were tested on words that are frequent in child-directed speech and are familiar to most children in the participants' age range, based on the MCDI lexical norms (Dale & Fenson, 1996). At 19 months, the eight target nouns were: el perro *'doggie'*, el libro *'book'*, el jugo *'juice'*, el globo *'balloon'*, el zapato *'shoe'*, el plátano *'banana'*, la pelota *'ball'*, and la galleta *'cookie'*. At 24 months, four additional familiar words were included: el caballo *'horse'*, el pájaro *'bird'*, la cuchara *'spoon'*, and la manzana *'apple'*. All of the words were presented in simple sentence frames ending with the target noun (e.g., *Mira el perro.* 'Look at the doggie.').

The speech stimuli were recorded by a native Spanish-speaking adult female and edited for prosodic comparability. Visual stimuli consisted of digital pictures of objects presented in yoked pairs. The pairs were matched for visual salience, the grammatical gender of the object name, and lexical familiarity (based on the MCDI lexical norms; Dale & Fenson, 1996). Each object was presented an equal number of times as target or distracter. Table S1 in the Supplemental Material available online lists the word pairs as presented in the experiments at 19 and at 24 months.

Children sat on their parent's lap about 60 cm from the screen, and parents wore opaque sunglasses to block their view of the images. On each trial, two pictures were presented in silence for 2 s, followed by a ca. 3-s speech stimulus, and a 1-s silent period during which the pictures remained on-screen. At 19 months, the 8 target nouns were presented four times each, for a total of 32 test trials; at 24 months, the 12 target nouns were presented three times each, for a total of 36 test trials. Side of target presentation was counter-balanced across trials, and trial-order was counter-balanced across participants. The entire test session lasted 4 - 5 min.

Children's looking patterns were video-recorded. Subsequently, highly trained coders blind to target location coded the child's gaze patterns. On each frame, coders noted whether the child was fixating the left or right pictures, in transition between the two pictures, or looking away from both. A second coder independently re-coded all trials for 28% of the participants at each age. The proportion of frames on which observers agreed within a single frame was 99%.

Speech processing efficiency was calculated as the proportion of time the infant spent fixating the target picture out of total time looking at either the target or distracter picture, within 300-1800 ms from target word onset (Fernald et al., 2008). Only those trials on which the child was looking at either the target or distracter picture at the onset of the target noun were included in these analyses. This measure of efficiency captures children's tendency to *shift rapidly toward* the target picture when initially looking at the distracter, as well as their tendency *to maintain attention* to the target when they are already looking at it.

Results

Among these low-SES families, there was striking variability in the total amount of adult speech accessible to the infant, which ranged from almost 29,000 adult words to fewer than 2,000 words over a 10-hour day (Figure 1). When only talk addressed directly to the child was considered, these differences were even more extreme: in one family, caregivers spoke more than 12,000 words to the infant, while in another the infant heard only 670 words of child-directed speech over an entire day, an 18-fold difference in the amount of child-directed speech available to these two children. These differences in parental engagement were uncorrelated with maternal education ($r = .29$, $p = .13$). In addition, amount of child-directed speech was not correlated with amount of overheard speech ($r = .17$, $p = .38$), suggesting that the observed differences in speech to children were not due to overall differences in talkativeness among families, but rather to caregivers' degree of verbal engagement with their infants.

Links between Language Experience and Vocabulary

We next asked whether differences among families in amount of speech available to infants predicted children's vocabulary six months later. Those children who heard more child-directed speech at 19 months had larger vocabularies at 24 months ($r = 0.57$, $p < 0.01$), consistent with previous findings (Hoff, 2003a; Hurtado et al., 2008). In contrast, differences in exposure to overheard speech directed to other adults and children were not related to vocabulary size ($r = .25$, $p = .2$), suggesting that language spoken directly to the child is more supportive of early lexical development than speech simply overheard by the child. One alternative possibility is that infants with more precocious language skills tend to vocalize more often, eliciting more speech from their caregivers. If so, and if infants who produce more speech early on have larger productive vocabularies at 24 months, this might account for the relation between child-directed speech and later vocabulary (Newport, Gleitman, & Gleitman, 1977). To examine this possibility, we first analyzed the relation between infant vocalizations and child-directed speech at 19 months. Infants who vocalized more often did hear more child-directed speech ($r = .41$, $p < .05$), suggesting some degree of concordance between infants' and caregivers' vocalizations. However, even after controlling for infant vocalizations at 19 months, the relation between child-directed speech and 24-month vocabulary remained robust ($r = 0.51$, $p < 0.01$). This suggests that over and above differences in infants' expressive language skill early on, exposure to child-directed speech predicted later vocabulary size.

Links between Language Experience and Language Processing

These results support previous findings showing that early language experience predicts later vocabulary knowledge. But are children who hear more child-directed speech also more efficient in processing familiar words in real time? Amount of exposure to child-directed speech was reliably correlated with children's processing efficiency at 19 ($r = 0.44$, $p < 0.05$) and 24 months ($r = 0.51$, $p < 0.01$) (Figures 2 and 3b illustrate these relations). Moreover, controlling for differences in processing at 19 months, children who heard more child-directed speech were more efficient in language processing at 24 months than those who heard less child-directed speech ($r = 0.47$, $p < 0.05$). This indicates that amount of exposure to child-directed speech explained *gains in processing efficiency* from 19 to 24 months. Importantly, the relation between child-directed speech and processing efficiency at 24 months remained significant when controlling for differences in 24-month vocabulary size ($r = 0.39$, $p < 0.05$). This indicates that over and above differences in vocabulary knowledge, children who were exposed to more child-directed speech were better able to identify familiar words during real-time language processing.

Can Differences in Processing Explain the Link between Language Experience and Vocabulary?

Next we ask whether the effect of language experience on processing efficiency helps explain the well-established relation between child-directed speech and vocabulary. We used mediation analysis to examine whether processing skill at 19 months accounted for the link between child-directed speech and 24-month vocabulary (while controlling for maternal education, recording length, and infant vocalizations at 19 months). The scatter plots in Fig. 3 illustrate the first three steps of the mediation analysis: 1) Exposure to child-directed speech at 19 months predicted vocabulary at 24 months (leftmost panel), 2) Exposure to child-directed speech also predicted processing efficiency at 19 months (middle panel), and 3) 19-month processing efficiency predicted 24-month vocabulary (rightmost panel), even when controlling for child-directed speech. Finally, a critical condition for mediation is that the path coefficient between the predictor variable (child-directed speech) and the outcome variable (vocabulary) be significantly reduced when the mediator variable (processing efficiency) is included in the model. As shown at the bottom of Figure 3, the parameter estimate for the effect of child-directed speech on vocabulary was reduced from 12.61 to 7.41 when processing efficiency was included in the model. A bootstrap (Preacher & Hayes, 2004) testing the significance of the indirect effect gave a 95% confidence interval (corrected for bias) of 0.44 to 13.61. This confirms that the mediation was significant, and suggests that language experience promotes vocabulary development at least in part via its influence on processing efficiency. The final model explained 47% of the variance in children's vocabularies at 24 months.

Are Differences in Processing Efficiency Explained by Infants' Knowledge of the Target Words?

One potential concern is that some children may have been unfamiliar with some of the target words used in the study, in which case variability in processing efficiency might simply reflect differences in children's knowledge of these words. To control for this possibility, we collected an independent measure of each participant's familiarity with the target words. Using a list of only the words used in the study, parents were asked whether their child "understood" each target word. According to parents' reports, all of the target words were understood by 66% of the children at 19 months, and 72% of the children at 24 months. For each child, we removed those trials with target words they were reported not to understand and then recomputed the processing efficiency measures. After re-running the mediation model reported above, the pattern of results remained the same: Child-directed speech was related to processing efficiency at 19 months ($r = 0.40$, $p < 0.05$), and 19-month processing efficiency predicted vocabulary at 24 months ($r = 0.53$, $p < 0.01$), even when controlling for CDS ($r = 0.41$, $p < 0.05$). Finally, the parameter estimate for the effect of CDS on vocabulary was significantly reduced from 12.61 to 8.75 when processing efficiency was included in the model, indicating that processing efficiency mediated the link between child-directed speech and vocabulary.

In a final analysis we included only those children whose mean accuracy was greater than .50 at 19 months ($n = 22$), thus excluding those whose performance was at or below the chance level overall. This analysis revealed even stronger correlations between child-directed speech and processing efficiency ($r = 0.58$, $p < 0.01$), and between processing efficiency and later vocabulary ($r = 0.62$, $p < 0.01$). Moreover, even in this smaller sample, processing efficiency mediated the link between CDS and vocabulary, i.e., the parameter estimate for the effect of child-directed speech on vocabulary was significantly reduced from 15.61 to 8.86 when processing efficiency was included in the model. These results provide further evidence that differences in processing efficiency do not simply reflect variability in children's all-or-none knowledge of the target words. Instead, differences in how quickly and reliably children interpret familiar words in real time reflect variability in a cognitive skill that facilitates further language learning.

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Discussion

This research yielded three main results: First, we found that variation in infants' experience with child-directed speech in low-SES Spanish-speaking families predicted children's later vocabulary. This result replicates other studies linking caregiver speech and vocabulary development in low-SES children (Hurtado et al., 2008; Pan et al., 2005), but goes beyond earlier research by using all-day recordings of daily interactions in the home to sample children's early language environments. Thus our measures of child-directed speech minimize potential artifacts introduced by the presence of an observer or by parents' reactions to a laboratory setting. Second, by recording interactions with multiple family members and identifying different sources of adult speech accessible to the child, we found that it was only speech addressed directly to the infant, and not speech in adult conversations overheard by the child, that facilitated vocabulary learning at this age, consistent with recent studies of children in middle-class English-speaking families in the U.S. (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2012) and in Yucatec Mayan families (Shneidman & Goldin-Meadow, 2012).

Third, the most important discovery in this research was that speech-processing efficiency mediated the relation between child-directed speech and vocabulary. This shows that a critical step in the path from early language experience to later vocabulary knowledge is the influence of language exposure on infants' speech-processing skill. In previous studies, one explanation proposed for the association between exposure to more child-directed speech and faster vocabulary growth has been that more diverse language from caregivers provides children with more models to learn from as they begin to build a lexicon. Our findings reveal an additional mechanism by which differences in early language experience lead to differences in vocabulary size: Infants who hear more talk have more opportunities to interpret language, and to exercise skills such as segmenting speech and accessing lexical representations that are vital to word learning (Saffran, Newport, & Aslin, 1996; Gershkoff-Stowe, 2002). As a result, infants with more exposure to child-directed speech are faster and more accurate to orient to familiar words in real-time, enabling them to learn new words more quickly and facilitating rapid vocabulary growth.

Our results also give rise to a challenging question: What factors explain the striking disparities observed between families in amount of verbal stimulation provided to infants? Studies comparing advantaged and disadvantaged families show that SES-differences are linked to variability both in speech and gesture directed to children and in children's language outcomes (Hoff, 2003a; Huttenlocher et al., 2010; Rowe & Goldin-Meadow, 2009). However, in such between-group comparisons, differences in caregiver input are confounded with many other factors associated with SES that could also lead to variability in language learning – such as parental education, access to resources, living in crowded conditions, and family stress levels (Evans, 2004). By focusing here on differences within a homogeneous group of disadvantaged families, rather than on differences between SES groups, variability in these confounding factors was reduced. Given this more narrow focus, it was surprising to discover differences in amount of child-directed speech between families that were almost as large as those reported in the landmark study by Hart and Risley (1995), whose sample spanned a broad demographic range from poverty-level to professional families. While they found significant differences between SES groups - with a 20-fold difference in verbal stimulation between those parents who were the most and least verbally engaged with their infants - our findings revealed an 18-fold difference in caregiver talk to infants *within* a demographically more homogeneous group of disadvantaged families. Moreover, the differences in parental engagement observed within this low-SES sample were not correlated with maternal education. An important implication of these findings is that although variability in parenting behaviors is consistently linked to factors related to SES, there is also considerable variability in parental verbal engagement that is independent of social class.

In ongoing research, we are exploring other factors that could explain observed differences in children's language environments. Previous studies have discussed several such factors, including variability in parents’ own verbal abilities or conversational style (Hoff-Ginsberg, 1991), in the activities that parents tend to engage in with their children (Hoff, 2003b), and in parental stress and emotional well-being (Conger, McCartey, Yang, Lahey, & Kropp, 1984). In addition, some studies have found that parents from different socio-cultural groups have different beliefs about the role they play in children's communicative development (Heath, 1983), and Rowe (2008) found that parents’ knowledge and beliefs about child development mediated the relation between SES and caregiver speech to children. Although not assessed in the current study, parental beliefs are an important factor to consider in explaining differences in caregivers’ tendency to engage infants in language-rich interactions, given that these beliefs may be more malleable than other influential factors.

Our results reveal that caregiver talk has direct as well as indirect influences on lexical development. More exposure to child-directed speech not only provides more models for learning words but also sharpens infants’ emerging lexical processing skills, with cascading benefits for vocabulary learning. If increased opportunities for verbal interaction can strengthen critical processing skills that enable more efficient learning, then interventions aimed at increasing parents’ verbal engagement with their infants have the potential to change the course of vocabulary growth and, in turn, to improve later outcomes for disadvantaged children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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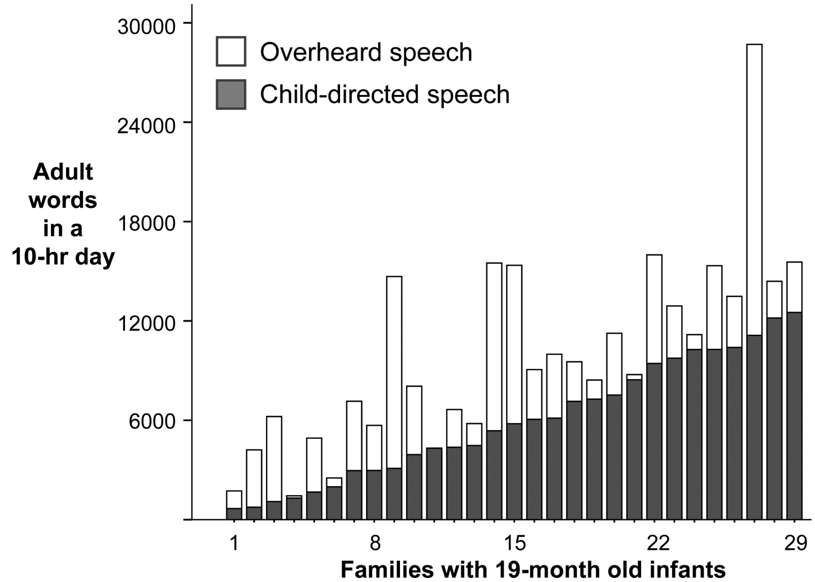

Figure 1.

Variability across 29 families in the amount of adult speech infants heard in a typical day at home. The height of each bar indicates the total number of adult words spoken in proximity to the target child in one family, calculated by averaging the word counts per waking hour and extrapolating to a 10-hr day. The proportion of total words that was child-directed speech is indicated in black, with overheard speech in white.

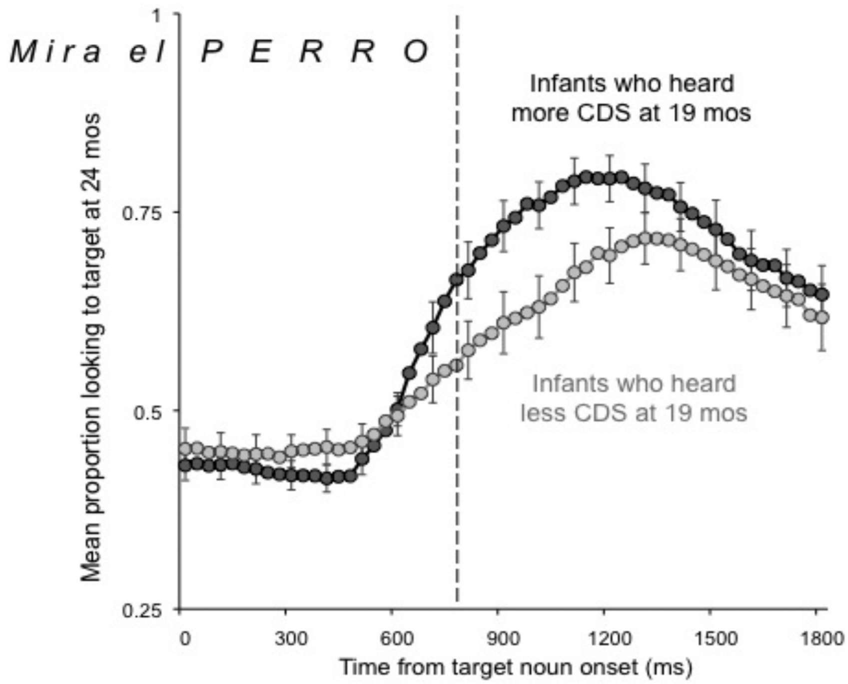

Figure 2.

Mean proportion of trials on which children looked to the target picture, measured from the onset of the target noun. Black and grey lines represent children's looking time at 24 months, based on a median split of adult words directed to the child at 19 months. The top line shows the time course of looking behavior for children who heard more child-directed speech (CDS) at home; the lower line shows looking time for children who heard less CDS. The dashed vertical line represents target noun offset; error bars represent SEs over participants.

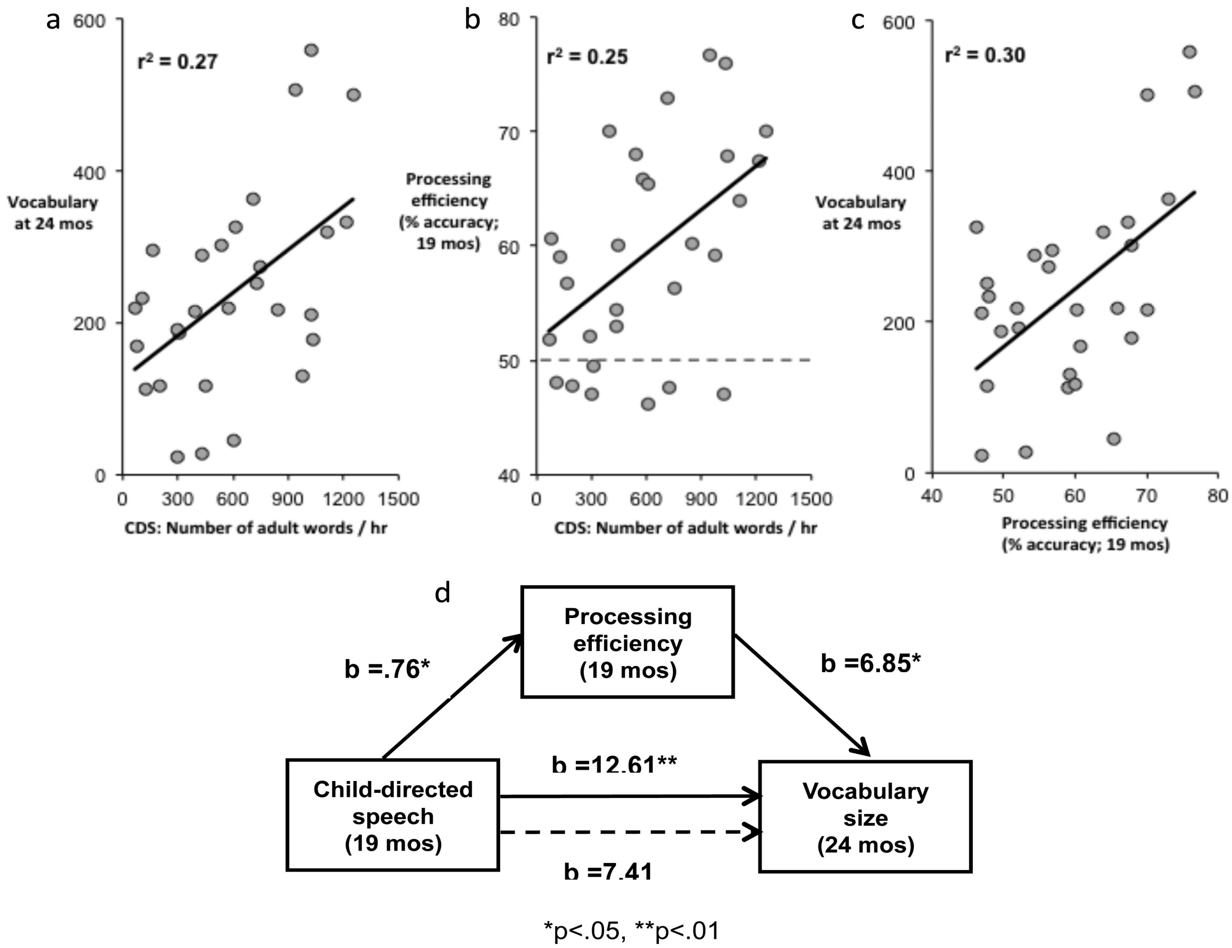

Fig. 3.

The three scatter plots (with best-fitting regression lines) show zero-order correlations between (a) vocabulary size (number of words) at 24 months and child-directed speech at home, (b) processing efficiency (mean percentage of time spent looking to the target picture) at 19 months and child-directed speech, and (c) vocabulary size at 24 months and processing efficiency at 19 months. The mediation model (d) shows the link between child-directed speech at 19 months and vocabulary size at 24 months, as mediated by processing efficiency at 19 months. Along the lower path, the solid and dashed arrows show results when the mediator was not included and was included in the model, respectively. Asterisks indicate significant paths (*$p < .05$, **$p < .01$).