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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 slow growth predicts later academic difficulties. In this study, we explored how the amount of speech directed to infants in Spanish-speaking families low in socioeconomic status 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 the age of 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, which suggests 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, children show wide variability 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 related to 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), and these disparities 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).

What accounts for differences among children in 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 gestures 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 SES groups (Hart & Risley, 1995; Hoff, 2003b; 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, Reznick, & Xuehua, 2012) predict early vocabulary growth. In experimental studies in which infants look at pictures of familiar objects as one object is named, the

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infants' 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 et al., 2006; Fernald & Marchman, 2012; Marchman & Fernald, 2008).

These studies have shown 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 during development to promote vocabulary growth. In the research reported here, we investigated 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—as well as from preexisting differences in children's ability to process speech efficiently, whereby some children are better able to take advantage of the learning opportunities available to them.

Another possibility is that early experience with language 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. Our recent study comparing infants from higher- and lower-SES families showed that significant disparities in language-processing efficiency were already present when children were 18 months of age (Fernald, Marchman, & Weisleder, 2013), which suggests 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 latter study, the relation between language experience and processing efficiency could be explained by children's vocabulary size. To address this gap, we asked the following questions: 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 further the understanding of the developmental pathways linking early language experience, speech-processing efficiency, and vocabulary growth.

Method

We focused on infants from low-SES Latino families, a rapidly growing population of children in the United States 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 examined how these naturalistic measures of caregiver speech related to experimental measures of language processing and to parent reports of expressive vocabulary.

Participants

Participants were 29 Spanish-learning infants (19 females, 10 males) 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). Family income ranged from less than $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 to 16 years (M = 10, SD = 3) and was used as the primary index of SES, controlled in all analyses. All parents were native Spanish speakers, and Spanish was the primary language in the homes of all of the children, with English constituting less than 25% of the language spoken in the home.

Measures of the home language environment

To measure adult speech accessible to infants in different families, we made audio recordings 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 log of 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 were recorded for an average of 11 hr (range = 4–16) over the course of 1 to 6 days. Using information recorded in parents' logs, 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 we eliminated nap times, the final sample of recordings had an average duration of 7 hr (range = 3–13). Differences in the length of these recordings were controlled for in all analyses.

The home recordings were analyzed using LENA analysis software (Xu, Yapanel, & Gray, 2009). This software was used to process the audio files and yield 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 (Oetting, Hartfield, & Pruitt, 2009; Oller et al., 2010; Xu et al., 2009). To assess the accuracy of the adult word estimates in Spanish-language environments, we asked native Spanish speakers otherwise uninvolved in this research to transcribe 60-min samples from 10 of the home recordings. Our analysis of these transcriptions revealed a high correlation between automated estimates of adult words and transcriber-based word counts (r = .80), which confirmed that the LENA system provided reliable estimates of adult words in Spanish-language environments (further details can be found in Supporting Methods in the Supplemental Material available online).

To differentiate between speech directed to the child and speech overheard by the child, we had native Spanish-speaking coders listen to each of the home recordings and classify 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; and the number of speechlike 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 in the Supplemental Material for further details). From these measures, we estimated the number of words or vocalizations per hour and in a 10-hr waking day.

Measures of expressive vocabulary

When the children were 24 months old, parents completed the MacArthur-Bates Inventario del Desarrollo de Habilidades Comunicativas: Palabras y Enunciados (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 that their child understood and said ("*comprende y dice*").

Measures of language-processing efficiency

In the looking-while-listening task (Fernald, Zangl, Portillo, & Marchman, 2008), infants were presented with pairs of images (e.g., of 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). When children were 19 months old, the eight target nouns were *el perro* (dog), *el libro* (book), *el jugo* (juice), *el globo* (balloon), *el zapato* (shoe), *el plátano* (banana), *la pelota* (ball), and *la galleta* (cookie). When children were 24 months old, 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, for example, "*Mira el perro*" ("Look at the dog").

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 on the basis of MCDI lexical norms (Dale & Fenson, 1996). Each object was presented an equal number of times as a target and as a distracter. Table S1 in the Supplemental Material lists the word pairs as presented in the experiments at 19 and 24 months.

Children sat on their parent's lap approximately 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 an approximately 3-s speech stimulus and a 1-s silent period during which the pictures remained on-screen. When children were 19 months old, the 8 target nouns were presented four times each for a total of 32 test trials; when children were 24 months old, the 12 target nouns were presented three times each for a total of 36 test trials. Side of target presentation was counterbalanced across trials, and trial order was counterbalanced across participants. The entire test session lasted 4 to 5 min.

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

Speech-processing efficiency was calculated as the proportion of time the infant spent fixating the target picture out of total time spent looking at either the target or the distracter picture, within 300 to 1,800 ms of target-word onset (Fernald et al., 2008). Only those trials on which the child was looking at either the target or the distracter picture at the onset of the target noun were included in these analyses. This measure of efficiency captured children's tendency to shift rapidly toward the target picture after initially looking at the distracter, as well as their tendency to maintain attention to the target when they were already looking at it. See Videos S1 and S2 and Legends for Supplemental Videos in the Supplemental Material to view videos of children participating in the looking-while-listening task.

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 the course of 10 hr (see Fig. 1 for variability across the 29 participating families). 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, whereas in another family, the infant heard only 670 words of child-directed speech during 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 ($r = .17$, $p = .38$), which suggests that the observed differences in speech directed 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 6 months later. Those children who heard more child-directed speech at 19 months had larger vocabularies at 24 months ($r = .57$, $p < .01$), a result consistent with previous findings (Hoff, 2003b; Hurtado et al., 2008). In contrast, differences in exposure to overheard speech directed to other adults and children were not related to infants' vocabulary size ($r = .25$, $p = .2$), which suggests that language spoken directly to infants is more supportive of early lexical development than is speech simply overheard by infants.

One alternative possibility is that infants with more precocious language skills tend to vocalize more often, eliciting more speech from their caregivers. If this is true, 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 ($r = .41$, $p < .05$), which suggests some degree of concordance between infants' and caregivers' vocalizations. However, even after controlling for infant vocalizations at 19 months, we

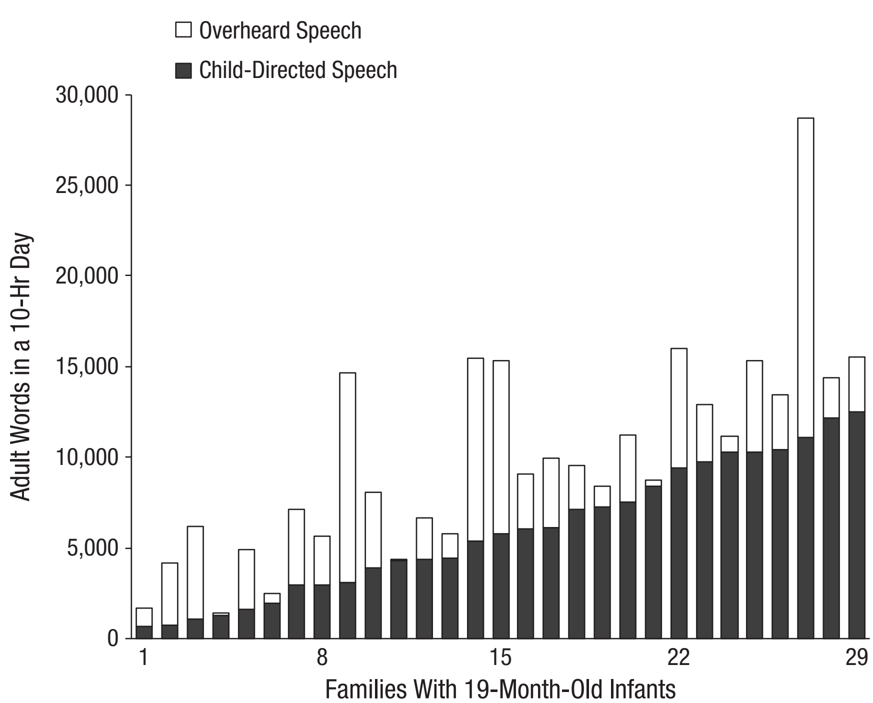

Fig. 1. Mean number of words that infants heard adults speak in a typical day at home for each family and each type of speech.

found that the relation between child-directed speech and infants' vocabulary at 24 months remained robust ($r = .51$, $p < .01$). This result 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 months ($r = .44$, $p < .05$) and at 24 months ($r = .51$, $p < .01$; see Figs. 2 and 3b for illustrations of these relations). Moreover, controlling for differences in processing at 19 months, we found that children who heard more child-directed speech were more efficient in language processing at 24 months than were those who heard less child-directed speech ($r = .47$, $p < .05$). This result indicates that amount of exposure to child-directed speech explained gains in processing efficiency from 19 to 24 months. A particularly important finding was that the relation between child-directed speech and processing efficiency at 24 months remained significant when controlling for differences in vocabulary size at 24 months ($r = .39$, $p < .05$). This result 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 asked 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 Figure 3 illustrate the first three steps

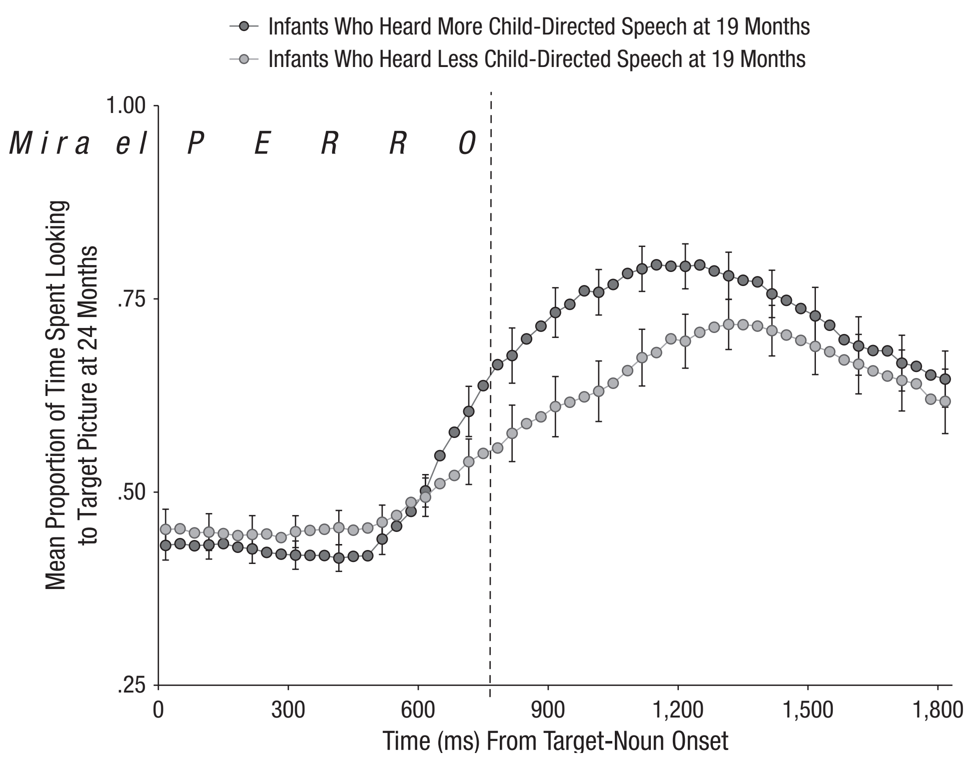

Fig. 2. Mean proportion of trials on which 24-month-old children looked to the target picture, measured from the onset of the target noun. Infants who heard more child-directed speech at 19 months and infants who heard less child-directed speech at 19 months were grouped on the basis of a median split. The dashed vertical line represents target-noun offset; error bars represent standard errors across participants.

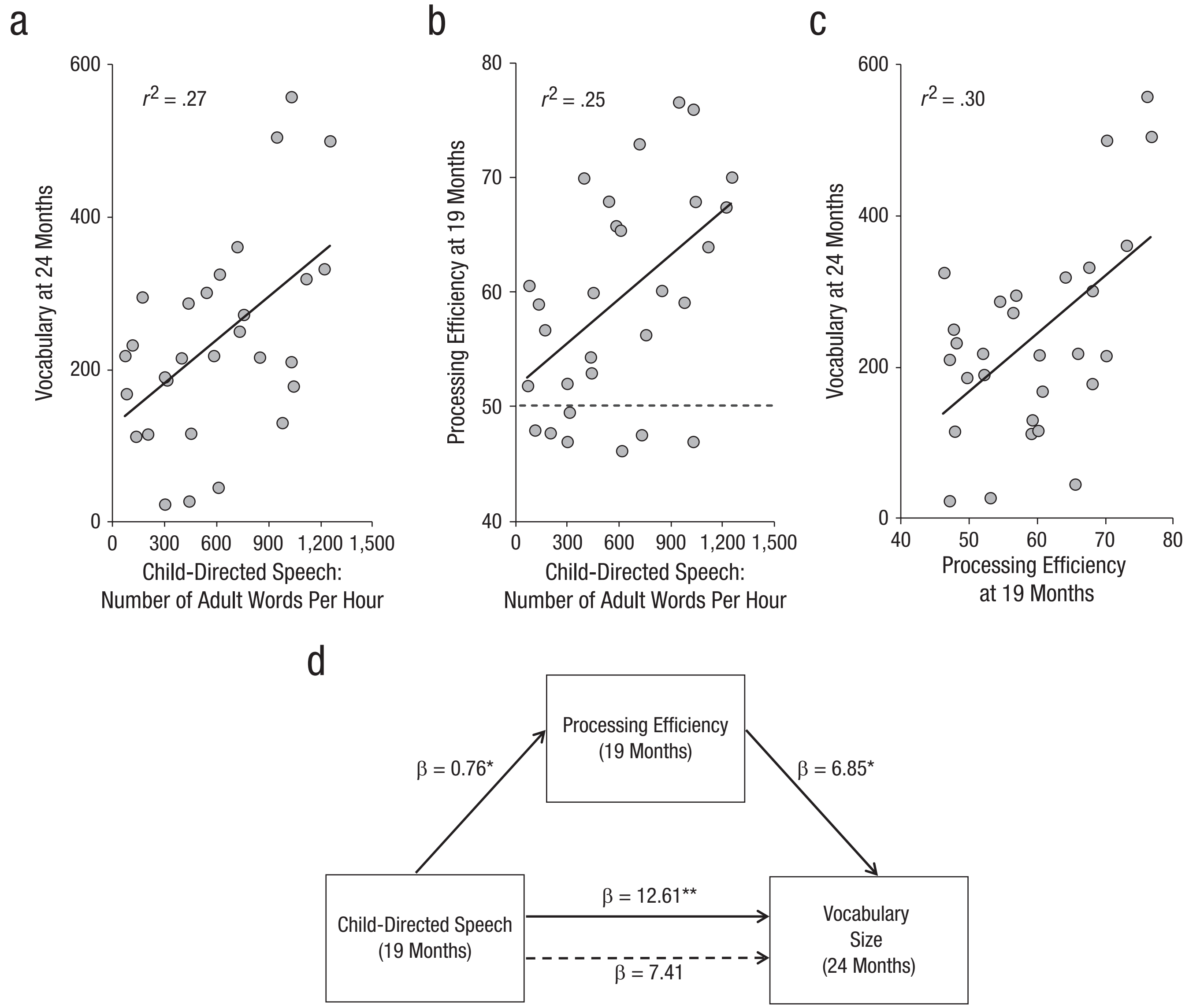

Fig. 3. Results. The three scatter plots (with best-fitting regression lines) show zero-order correlations between (a) vocabulary size (number of words) at 24 months and child-directed speech at home, (b) processing efficiency (mean percentage of time spent looking to the target picture) at 19 months and child-directed speech, and (c) vocabulary size at 24 months and processing efficiency at 19 months. Vocabulary size was measured as the number of words produced on the MacArthur-Bates Inventario del Desarrollo de Habilidades Comunicativas: Palabras y Enunciados (Jackson-Maldonado et al., 2003). The mediation model (d) shows the effect of child-directed speech at 19 months on 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 (* $p < .05$, ** $p < .01$).

of the mediation analysis: Exposure to child-directed speech at 19 months predicted vocabulary at 24 months (Fig. 3a); exposure to child-directed speech also predicted processing efficiency at 19 months (Fig. 3b); and processing efficiency at 19 months predicted vocabulary at 24 months (Fig. 3c), even when we controlled 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 in Figure 3d, 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 analysis (Preacher & Hayes, 2004) of the significance of the indirect effect yielded a 95% confidence interval (corrected for bias) of 0.44 to 13.61. This result confirmed 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 certain 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, we asked parents 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 by 72% of the children at 24 months. For each child, we removed those trials containing target words that the child was reported not to understand and then recomputed the processing efficiency measures. After rerunning the mediation model reported earlier, we found that the pattern of results remained the same: Child-directed speech was related to processing efficiency at 19 months ($r = .40$, $p < .05$), and processing efficiency at 19 months predicted vocabulary at 24 months ($r = .53$, $p < .01$), even when controlling for child-directed speech ($r = .41$, $p < .05$). Finally, the parameter estimate for the effect of child-directed speech on vocabulary was significantly reduced from 12.61 to 8.75 when processing efficiency was included in the model, which indicates that processing efficiency mediated the link between child-directed speech and vocabulary.

In a final analysis, we included only those children whose mean level of accuracy was greater than 50% at 19 months ($n = 22$), thus excluding those whose overall level of performance was at or below chance level. This analysis revealed even stronger correlations between child-directed speech and processing efficiency ($r = .58$, $p < .01$) and between processing efficiency and later vocabulary ($r = .62$, $p < .01$). Moreover, even in this smaller sample, processing efficiency mediated the link between child-directed speech 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-nothing 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.

Discussion

This research yielded three main results. First, we found that variation in experience with child-directed speech in low-SES Spanish-speaking families predicted children's later vocabulary. This result replicates findings from other studies linking caregiver speech and vocabulary development in low-SES children (Hurtado et al., 2008; Pan et al., 2005), but our study went 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 minimized 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 only speech addressed directly to the infant, and not speech in adult conversations overheard by the child, facilitated vocabulary learning at this age, a result consistent with recent findings from studies of children in middle-class English-speaking families in the United States (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013) and in Yucatec Mayan families (Shneidman & Goldin-Meadow, 2012).

Third, and most important, speech-processing efficiency mediated the relation between child-directed speech and vocabulary. This result 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 (e.g., Hoff, 2003b; Rowe & Goldin-Meadow, 2009). 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 that are vital to word learning, such as segmenting speech and accessing lexical representations (Gershkoff-Stowe, 2002; Saffran, Newport, & Aslin, 1996). As a result, infants with more exposure to child-directed speech orient to familiar words more quickly and accurately when interpreting speech in real time, which enables them to learn new words and facilitates rapid vocabulary growth.

Our results also give rise to a challenging question: What factors explain the striking disparities observed between families in the amount of verbal stimulation provided to infants? Studies comparing advantaged and disadvantaged families have shown that SES differences are linked to variability both in speech and gesture directed to children and in children's language outcomes (Hoff, 2003b; 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, crowded living conditions, and family stress levels (Evans, 2004). By focusing on differences within a homogeneous group of disadvantaged families, rather than on differences between SES groups, we reduced variability in these confounding factors.

Given this narrower focus, it was surprising to discover differences in the amount of child-directed speech between families that were almost as large as those differences reported in the landmark study by Hart and Risley (1995), whose sample spanned a broad demographic range from poverty-level to professional families. Although Hart and Risley found significant differences between SES groups, with a 20-fold difference in verbal stimulation between parents who were the most and the least verbally engaged with their infants, our findings revealed an 18-fold difference in caregiver talk to infants within a more demographically 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, 2003a), and in parental stress and emotional well-being (Conger, McCarty, Yang, Lahey, & Kropp, 1984). In addition, some studies have found that parents from different sociocultural 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 one 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.

Author Contributions

A. Weisleder and A. Fernald developed the study concept and designed the study. A. Weisleder performed the research and analyzed the data. A. Weisleder and A. Fernald drafted the manuscript.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

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