# Chapter 7
# The Miracle Year:
## From Basic Structure to Social Communication

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## ABSTRACT

*In recent years, a functional perspective on infant communication has emerged whereby infants' production of vocal sounds is understood not only in terms of the acoustic properties of those sounds, but also in terms of the sounds that regulate and are regulated by social interactions with those hearing them. Here, the authors synthesize findings across several disciplines to characterize this holistic view of infant language learning. The goal is to interpret classic and more recent behavioral findings (e.g., on infants' preferences) in light of data on pre- and postnatal neurophysiological responses to the environment (e.g., fetal heart rate, cortical blood flow). Language learning is a complex process that takes place at multiple levels across multiple systems; this review is an attempt to embrace this complexity and provide an integrated account of how these systems interact to support language learning.*

## INTRODUCTION

We know that a great deal of language development takes place in the first year of life. During this initial period, infants are immersed in the ambient language(s), which—together with a dynamic period of neural development—support rapid and robust language learning. A key factor in this process is the infant's own active elicitation of responses from his or her caregivers. This communicative give-and-take creates an environment rich in linguistic structure, providing input that is fundamental for language development to take place. In this chapter, we will review data that highlight the dynamic nature of caregiver-child interaction and how this impacts multiple systems in support of language learning. Specifically, we will discuss the degree to which children enter

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the world neurally primed to learn the ambient language(s), the learnable structures that are inherent in languages, and how communicative interaction between caregivers and infants potentiates and supports their learning of these structures.

## LEARNING ABOUT SOUND STRUCTURE IN UTERO

Strict interpretations of language development as completely experience driven or completely innately guided have softened in recent years, concomitant with accumulating evidence that changes in the environment have substantial effects on language outcome. Indeed, there is evidence that environmental tuning is at work in utero, thus demonstrating that, by the time an infant is born, biology and environment have already combined to set the process of language learning in motion.

Research on prenatal infants, while difficult to conduct, has been important to our emerging understanding of how exposure to sound in the womb gives babies a head start with language. The womb acts as a low-pass filter for sounds in the mother's environment (Gerhardt, et al., 1990). This includes the voices of those around her and her own. Furthermore, where others' voices vary in intensity depending on where they are relative to the mother, the mother's own voice is present for the developing fetus at a relatively constant volume and with more clarity than other voices, given the internal nature of the source (e.g., mother's vocal folds, articulators). This means that, in addition to the external voice, internal bone and membrane conduction supplements the signal, providing infants with a relatively robust and consistent source of speech input. How this signal interacts with the maturation of the infant's auditory system is important to informing our understanding of what infants have already learned about language when they enter the world.

Using changes in the fetal heart rate as their dependent measure, Lecanuet et al. (1995) obtained some of the first physiological data to suggest that fetal hearing occurs before 28 gestational weeks. In fact, the fetus appears to respond to sound at 22 gestational weeks (Hepper & Shahidullah, 1994) and habituates to repeated sounds around 32 gestational weeks (Morokuma, et al., 2004). Moreover, as infants near term, their sensitivity to more complex auditory stimuli improves, allowing them to perceive variations in music (Kisilevsky, et al., 2004) and to differentiate between familiar and novel rhymes (DeCasper, et al., 1994). Thus, the concept of "experience," rather than strictly referring to information available to the infant postnatally, implies a currently unknown threshold in prenatal auditory processing as well. Needless to say, this has not simplified theoretical debates about the degree to which nature and nurture come into play in early language development; it has only served to push the focal age for this debate earlier. However, these data represent an important advance in our understanding of the toolkit with which infants enter the world.

With the understanding that birth is not the initial point at which infants are exposed to environmental sounds, behavioral researchers have capitalized on measures of infant attention to establish the degree to which prenatal experiences underlie postnatal perceptual biases. This work has made it clear that fetal exposure to sound instills infants with a variety of sensitivities available upon arrival in the postnatal world. For example, newborns can discriminate speech from non-speech when played forward, but not backwards (Ramus, et al., 2000). In terms of language specific characteristics, neonates prefer their native language over another, unfamiliar language (Moon, Panneton-Cooper, & Fifer, 1993), can distinguish between stress patterns of different multisyllabic words (Moon, et al., 1993), and can categorically discriminate lexical versus grammatical words (Shi, Werker, & Morgan, 1999). Finally, 3-day-olds are sensitive to word boundaries (Christophe, et al., 1994), can distinguish between two rhythmically dissimilar languages (Mehler, et al., 1988; Nazzi, Bertoncini,

& Mehler, 1998; Ramus, et al., 2000), and can differentiate between acceptable and unacceptable syllable forms (Bertoncini & Mehler, 1981). These represent just a sampling of the behavioral findings demonstrating that mechanisms at work prenatally position neonates to successfully navigate language learning postnatally.

Recent findings using Near-Infrared Spectroscopy (NIRS), an infant-friendly technique for measuring changes in cortical blood flow, have added support to this view. For example, Peña et al. (2003) used NIRS to test neonates between 2 and 5 days of age while they listened to recorded speech samples in a familiar (e.g., native) language. They found that the familiar language elicited focal regions of activation, including in the dorsolateral prefrontal cortex, the primary and auditory association cortices, and the supramarginal gyrus (a portion of Wernicke's area). In particular, the results were more pronounced in the left relative to the right temporal cortex and in response to forward relative to backward speech. More recently, Saito et al. (2007) presented neonates with infant- and adult-directed speech. Also using NIRS, these researchers found both behavioral and neurophysiological indicators of discrimination: infants attended more to infant-directed than adult-directed speech and produced greater hemodynamic responses to the former than the latter, specifically in bilateral frontal regions.

Even more recently, May et al. (2011) used NIRS to record blood flow changes in neonates while they were exposed to auditory-only, low-pass filtered sentences in familiar (English) and unfamiliar (Tagalog) speech. The samples were presented both forward and backwards. Results showed changes in activity in the same measurement channels in response to forward but not backward speech in both languages, and no difference in lateralization was observed across them. These findings suggest that the same cortical regions are involved in processing familiar and unfamiliar speech in the earliest stages of postnatal life. However, the results from this study should be interpreted with caution, since the infants showed no significant difference in response to forward and backward speech in the familiar speech condition, a finding that contrasts with Peña et al.'s (2003) results obtained using unfiltered speech. The authors of the more recent study suggested that the low-pass filtering may have emphasized prosodic over segmental cues, thus driving the bilateral patterns of activation observed, as well as the atypical results for forward and backward English. It is worth noting that the same stimuli were used in a behavioral study in which bilingual exposure in utero to English and Tagalog resulted in discrimination of the two languages postnatally (Byers-Heinlein, et al., 2010).

These neonate data begin to address sensitivities instilled via the prenatal environment. Of course, any familiar-language biases observed in newborns are magnified quickly with additional postnatal exposure. Several NIRS studies have focused on establishing cortical processing patterns in older infants in response to familiar and unfamiliar speech samples. For example, Minagawa-Kawai et al. (2011) exposed monolingual Japanese 4-month-olds to auditory-only sentences delivered by a male or female speaker in the infants' own or another language. Analyses revealed left-lateralized hemodynamic activity for familiar compared with unfamiliar speech conditions, regardless of speaker. In my own research using NIRS, I too have found evidence of left-lateralized processing of a familiar language in 6-to-9-month-old infants (Bortfeld, Wruck, & Boas, 2007; Bortfeld, Fava, & Boas, 2009). A source of confusion in the NIRS literature, at present, is the variable combination of ages and stimuli that have been tested (for a review, see Fava, Hull, & Bortfeld, 2011). Current research in my lab is focused on systematically testing infants of different ages using the same well-controlled stimuli. This is a necessary step before any strong conclusions can be drawn about pre- versus postnatal influences on the cortical foundations supporting behavioral biases observed in preverbal infants. Regardless, these behavioral biases reveal sensitivities that are instilled in utero and continue to be actively shaped postnatally in the service of language development. The signal itself is clearly a powerful force in this process.

The preceding highlights how prenatal exposure shapes infants' sensitivities to some basic structural aspects of the speech signal. Infants likewise respond to acoustically carried social cues. The best example of this is that neonates, who have been processing a wealth of maternal speech prenatally, have a strong preference for stimuli presented in their mother's voice. In a seminal study, Decasper and Fifer (1980) used an operant-choice sucking procedure to test three-day-old infants on their voice preferences. The researchers found that, even given only minimal postnatal maternal contact, an infant's sucking response was greater when it produced the maternal voice than when it produced another female's voice. However, infants' prenatal familiarity with other structural aspects of the speech signal influences their postnatal preferences as well. In a subsequent study, Decasper and Spence (1986) asked women to read a passage aloud each day during the last six weeks of their pregnancy. The infants were then tested postnatally using the same operant-choice sucking procedure to see whether they preferred the familiar passage (e.g., that read to them in utero) over a novel passage that they had never been exposed to prior to test. Results indicated that the infants did, indeed, find the familiar passage more reinforcing, while a control group demonstrated no preference for one or the other passage. Together, these studies highlight the multiple forces that influence a child's learning while still in utero. These forces interact to shape both brain and behavior in ways that continue to manifest postnatally.

These preferences manifest in utero as well. To establish whether or not this was the case, Kisilevsky et al. (2003) investigated the developmental time course of an infant's preference for mother over other by testing the ability of human fetuses to recognize their own mother's voice relative to the voice of an unfamiliar woman via fetal heart rate. The researchers placed a loudspeaker at about 10 cm above the mother's abdomen and played three stimulus trials, each beginning with silence and continuing with a voice (either that of the mother or of an unfamiliar woman) and, finally, ending again with silence. Results showed that fetal heart rate increased during exposure to the mother's voice relative to the baseline established during the silent segment of that trial, but that the heart rate decreased for an unfamiliar woman's voice relative to its baseline. These dynamic heart rate changes demonstrate that infants can differentiate between the mother's voice and that of a stranger while still in the womb. This learning extends to other structural characteristics as well. In earlier work, Decasper et al. found that fetuses, 37 weeks old, were able to differentially respond to nursery rhymes that their mothers had recited daily for the previous four weeks (Decasper, et al., 1994). Recent blood flow data support these behavioral findings. For example, using a novel fMRI procedure to test fetal responses to sensory stimuli, Jardri et al. (2012) recently observed cortical activation in response to the mother's voice at the beginning of the third trimester of pregnancy. This represents the first in vivo evidence for the development of maternal voice recognition in fetuses between 33 and 34 weeks of gestation. In short, the mother's voice stimulates not only maturation of the fetal auditory system, but also rudimentary social biases that will serve as the foundation for normal postnatal emotional development.

Interestingly, although newborns will work harder (by sucking more) to elicit maternal voices over another female's voice, they will not alter their patterns of sucking to elicit paternal voices over another male's voice. Using an operant choice procedure, Decasper and Prescott (1984) tested newborns to determine whether they would prefer the father's voice to that of other males. The data revealed no specific preference, one way or the other. Subsequent studies by the same researchers revealed that the infants could discriminate between the voices but that the voices lacked reinforcing value, thus failing to elicit differential sucking. Similarly, in another study, young infants did not show a change in heart rate after hearing the father's voice but did after hearing the mother's voice (Ockleford, et al., 1988). Importantly, the lack of heart rate change in response to the father's voice was not due to an inability to discriminate among male voices.

Overall, then, infants appear to prefer their mother's voice to that of a female stranger, yet they do not appear to prefer the voice of their father (Ward & Cooper, 1999) relative to that of a male stranger. These and other findings add support to the notion that early preferences for speech are specific to the mother's vocalizations and that they are already present in utero. Although one might assume that the father's voice is a relatively high frequency stimulus for the developing fetus, at least in most cases, the combination of frequency and source robustness of the mother's voice appears to give this particular auditory signal precedence over all other acoustic stimuli that are available to the infant prenatally. Beyond speaker-specific preferences, fetuses are also learning about structural aspects of the speech signal that will form the foundation for postnatal language development.

## POSTNATAL PREFERENCES: EMERGING SENSITIVITY TO STRUCTURE IN THE SIGNAL

Although infants initially prefer maternal vocalizations over all others, additional work has revealed that this preference is encouraged by mothers' tendency to use the exaggerated intonation when speaking to their infants. In an important early study, Mehler et al. (1978) found that 30-day-old infants only preferred their mothers' vocalizations over an unfamiliar woman's if the mothers' voices were properly intoned. If the mothers spoke with a flat intonation, infants showed no difference in their preference for their own mother's voice relative to the vocalizations of the female stranger. However, mothers typically do speak in an animated manner when addressing their infants, and this form of speech has come to be called "motherese" (Newport, 1975). It is precisely this bias on the part of mothers, as well as infants' preference for it, that has made motherese, or infant-directed speech, one of the focal areas of research for understanding infant communication.

Infant-directed speech is characterized by a variety of prosodic cues, such as exaggerated stress and pitch changes. These appear to help infants locate phrase boundaries (Jusczyk, 1997), decode syntactic structures of sentences (Morgan & Demuth, 1996), and come to a primitive form of semantic differentiation (Mehler, et al., 1988). Early on, researchers posited that the exaggerated pitch contours in infant-directed speech were useful to language development precisely because they attract and hold attention, improve sound localization, and improve awareness of contrast and coherence (Fernald & Simon, 1984). Indeed, behavioral data from infants over the first year of life support this argument. For example, prosodic cues are among the first that infants use to distinguish between languages (Cutler, Dahan, & van Donselaar, 1997), thus allowing them to differentiate native from non-native speech at birth. Moreover, infants can distinguish low-pass filtered infant-directed speech from similarly filtered adult-directed speech (Cooper & Aslin, 1994) in the first month of life. In addition, since boundaries of prosodic units are also often word boundaries, infants can use prosody to at least begin to segment fluent speech (Christophe & Dupoux, 1996). Thus prosody, particularly infant-directed prosody, makes speech salient. As such, it is an early and important contributor to language learning.

As has been discussed, the mother's voice is something infants come into the world recognizing and preferring, but the infant-directedness of speech interacts with this familiarity in important ways. For example, Cooper et al. (1997) found that if mothers' voices were even only somewhat intoned, then one-month-olds preferred the mother's voice over that of an unfamiliar woman regardless of whether that woman was speaking directly to the infant or to another adult. This lack of preference between infant-directed speech and adult-directed speech held only for maternal vocalizations. When the researchers replaced maternal vocalizations with vocalizations of unfamiliar women, infants then preferred the infant-directed speech over the adult-directed speech. Why is it that infants prefer infant-directed over adult-directed speech among strangers, but display no preference between the two when their mothers are the ones doing the speaking? The reason may be due to the fact that early in infancy, infants have had the most experience with speech via their mother's voice. Thus, a mother's vocalization has formed the foundation for language learning, with the developing infant's initial postnatal preferences for her voice overriding the structural attraction of infant-directed speech. In other words, infants allocate more attentional resource towards their mothers' speech, and thus prefer it, as a function of the established emotional bond between them (Purhonen, et al., 2003).

This changes quickly given experience in the postnatal environment, with infants' preferences—for the mother's voice, in particular, and for infant-directed speech, in general—beginning to interact to orient them towards important sensory information in their environment. Indeed, as infants gain experience postnatally, they develop a significant preference for maternal infant-directed speech over all other forms of their mother's speech. This is because, as infants become increasingly social, their mothers begin to increase their use of exaggerated—infant-directed—speech to engage them. When speaking to their infants, mothers increase the pitch of their voices and expand the range and variability in pitch. In addition, they repeat themselves, a lot. Infants likewise are attracted to these properties, quickly learning to listen when their mothers' attention is on them. This coincides with mothers producing infant-directed speech. With the of gain experience through each interaction, infants thus begin to show a general preference for maternal infant-directed speech over maternal adult-directed speech (in contrast to a general preference for the mother's voice), thus highlighting how postnatal experience further shapes infants' preferences.

Important to this argument is whether or not mothers speak in an exaggerated way to their infants across cultures; Fernald and colleagues have shown this to be the case (Fernald, et al., 1989; Fernald & Morikawa, 1993). Thus, it may be that the infant-directedness of speech is a key factor in infants' language learning. While this point is debatable (and is, in fact, vigorously debated [see Hoff, 2006, for a review]), it does seem that infants develop their preference for maternal infant-directed speech postnatally, and are thus not biologically predisposed to exhibit such a preference. They do, however, enter the world with a bias to listen to the mother's voice and this is a significant factor in the development of communication, and thus, language.

While the acoustical properties of infant-directed speech appear to underlie its effectiveness in attracting infants' attention, the particular components that drive infants' extended preference for the form are less clear. There is evidence that the preference for affective speech likewise begins very early in infancy. For example, infants are able to discriminate between positive and negative emotions when they are born (Mastropieri & Turkewitz, 1999), and they respond differently to positive and negative emotions as conveyed by tone of voice (Fernald, 1992; Papousek, et al., 1990). It is thus unsurprising that the positive affect in infant-directed speech predicts a positive attitude and thus captures infants' attention more than neutral or negative speech are able to. Positive affect in any form of speech encourages infants to pay attention to the person producing it, particularly familiar individuals (e.g., caregivers), whereas negative speech may pose a threat and motivate an infant to withdraw from the speaker in whatever way possible. Therefore, understanding the influence of the affective quality of infant-directed speech has become the focus of much recent research.

In an important initial study on this issue, Kitamura and Burnham (1998) found that, when speakers' pitch characteristics were varied but the affect remained uniformly positive, infants did *not* show a preference for infant-directed speech relative to adult-directed speech. Conversely, when a speaker's pitch characteristics were held constant but their affect varied, then infants did demonstrate a preference for the infant-directed speech. This experiment provides a clear demonstration of the importance of the affective component of infant-directed speech—as distinguishable from pitch alone—in the preference that infants convey for it. Of course, people are generally happy when they address infants, so the issues of pitch and affect are tightly intertwined and thus difficult to pull apart. In a subsequent study, Singh, Morgan, and Best (2002) constructed stimuli in which affect and pitch were manipulated independently. They likewise found no preference for infant-directed over adult-directed speech given constant (positive) affect. The researchers did notice, however, that when adult-directed speech contained more positive affect than the infant-directed speech, infants preferred it. This shows that the higher and more variable pitch characteristics of infant-directed speech are not sufficient to determine infants' speech preferences. Rather, the (positive) affective properties of speech directed to infants interact with the tendency to exaggerate pitch contours, driving infants' preference for and attention to it. Since "happy talk" draws infants' attention in a positive way, caregivers (and doting others) are more inclined to manipulate their vocal acoustics to elicit this response. Indeed, and perhaps unsurprisingly, adults rate infants' facial responses to infant-directed speech as more "attractive" than their facial responses to adult-directed speech (Werker & McLeod, 1989). Thus, infants' preference for positive emotion, along with adults' inclination to produce happy talk when speaking to infants, are important contributors to their emerging preference for infant-directed speech.

All of this may seem fairly obvious, but clear documentation of the forces driving infant preference matter at least in part because the positivity underlying this form of speech has been shown to affect infant development as well. In recent years, advances in infant-friendly neurophysiological techniques (e.g., NIRS, discussed earlier) have allowed researchers to link previously established behavioral preferences to underlying neural processes. For example, maternally produced infant-directed speech has been shown to increase activity in infants' frontal cortex, a region important to the development of emotion processing capabilities into adulthood (Naoi, et al., 2011). Frontal lobe development is related to positive emotions and positive interactions between mothers and infants (Davidson & Fox, 1982; Dawson, et al., 1999), and may thus contribute to the strength of the emotional bond between mother and infant (Purhonen, et al., 2004). Indeed, when neonates' cortical activity was assessed while they listened to stories read by their mothers in either infant- or adult-directed speech, there was greater frontal lobe activity during the infant-directed speech readings (Saito, et al., 2007). In short, the emotional properties of infant-directed speech contribute to positive interactions with caregivers, which in turn may serve as the basis for social learning by providing infants with the opportunity to interpret emotional signals from others and to react to them (Naoi, et al., 2011).

Maternally produced infant-directed speech not only has a strong influence on infants' processing of emotions, but also on the establishment of the communication process itself. In a study comparing infants' electrophysiological responses to words pronounced by their mother and by an unfamiliar woman, researchers found that early evoked auditory components were accelerated in response to the mother's voice relative to the stranger's voice, and that infants were in turn better able to learn words from their mothers (Dehaene-Lambertz, et al., 2010). Maternal vocalizations likewise elicited more neural activity from the left hemisphere, particularly in the posterior temporal lobe (Dehaene-Lambertz, et al., 2010; Purhonen, et al., 2004), revealing a network of cortical regions that will eventually emerge as the hub supporting language processing in the developing brain. Maternal infant-directed speech affects early development of this language network in a variety of ways. First, infants strengthen emotional bonds by allocating attentional resources to their own mother's voice (Purhonen, et al., 2004). Attending to the mother's speech can be highly rewarding for infants, providing additional motivation for them to devote their attention to and selectively prefer their mothers' speech over the speech of others (Barker & Newman, 2004; Cooper, et al., 1997). By securing attention, infant-directed speech allows infants to gain experience with the structure of their native language, while making language-related events more salient to the infant (Naoi, et al., 2011). Infants can then begin segmenting the speech stream and learning the myriad object-label associations in their world (Graf Estes, et al., 2007), a difficult process that is the foundation of subsequent language development.

The findings reviewed thus far serve to clarify the relationship between infants' speech preferences and processing biases. Clearly, maternal infant-directed speech is a key component in infants' early language learning. The earliest infant preferences tend toward the perceptually salient, language-general (even non-linguistic) aspects of an auditory scene, including infant-directed speech and positive affect (Mastropieri & Turkewicz, 1999; Singh, et al., 2002) as reviewed here. Generally, infants can rely on their caregivers to produce speech full of such characteristics and language development proceeds normally. However, what happens to an infant's language when these aspects of the speech signal are compromised, as is the case in the speech of depressed mothers?

Positive speech greatly affects infants' social and linguistic development and, not surprisingly, there is growing evidence that an abundance of negative or neutral speech can have a detrimental effect on early development. For example, Weinberg and Tronick (1998) found that infants as young as three months are sensitive to their mothers' depression. Indeed, depressed mothers differ from non-depressed mothers in their affect and in the style of interaction they display with their infants. Depressed mothers express less positive effect, are less responsive, and tend to be emotionally withdrawn from their infants (Bigatti, et al., 2001). In turn, infants of depressed mothers show impairment on a number of typical functions, including social, emotional, and cognitive ones (Weinberg & Tronick, 1998). While much research has been devoted to the negative effects of maternal depression on infant developmental outcomes in general, it has been more difficult to determine whether these effects directly relate to changes in the expression of emotion in the maternal speech itself.

Given that the affective quality of mothers' speech plays a role in language learning, it stands to reason that the lack of positive affect in depressed mothers' speech should affect this process. Indeed, Breznitz and Sherman (1987) found that depressed mothers vocalize less often and do not respond as quickly to the cessation of their children's speech as non-depressed mothers do. Since these depressed mothers do not reinforce communication, their children learn to keep interaction to a minimum and speak less in general. Similarly, Bigatti et al. (2001) observed that depressed mothers engage in fewer literacy-enhancing behaviors with their children than non-depressed mothers. When their children were four years old, the children of depressed mothers scored lower on measures of language ability; by age five, maternal depression affected the children's performance in school (Bigatti, et al., 2001). Additionally, depressed mothers were found to be less likely to use complex language with their children (e.g., questions, explanations, suggestions), which in turn affected the children's language abilities (Bigatti, et al., 2001). These are just a handful of the results showing that negative maternal affect, both specific to speech and conveyed more generally, contributes to poor developmental outcomes, including language outcomes, in the children exposed to it.

While the general affective difference in speech produced by depressed mothers relative to non-depressed mothers is a factor in early language development, the quantity and complexity of language used by these mothers also appears to play a role. Many of the studies reviewed here focused on the effects of maternal depression on language in children well past infancy. However, research on the relationship between the sheer volume of language exposure during early infancy and subsequent language learning highlights another avenue by which maternal depression can influence the learning process, even in the first year of a child's life. In the next section, we review findings on the contribution of quantity of exposure to language development.

## QUANTITY VS. QUALITY? BOTH INFLUENCE ACQUISITION OF STRUCTURE FROM THE SIGNAL

From the inception of formal study of infant- and child-directed speech, researchers have noted the high frequency of exact and periphrastic repetitions of phrases and sentences (Ferguson, 1964; Snow, 1972); the individual words contained in these phrases and sentences necessarily are repeated as well. In addition to speech quality, quantity of exposure has emerged as a key factor in the language learning process. Interestingly, quantity is something that was long taken for granted as a relative constant. In a seminal study, however, Hart and Risley (1995) demonstrated that the raw number of words children hear varies enormously as a function of a family's socioeconomic status, with average income families producing up to double the number of words as is produced by lower income families. These researchers made the (then provocative) suggestion that such differences in frequency of exposure might underlie the reliable differences in literacy outcomes observed as children from these families enter and proceed through formal education.

A wealth of research conducted since Hart and Risley's (1995) study has shown that the amount of language that infants and young children are exposed to before the age of three is, indeed, positively correlated with ensuing language production skills and cognitive development more generally (e.g., Arterberry, et al., 2007; Bornstein & Haynes, 1998; Huttenlocher, 1991, 1998; Pan, et al., 2005; Shonkoff & Phillips, 2000). This is often mediated by socioeconomic status (Hoff, 2003). It stands to reason then that the amount of language infants experience—even during the earliest stages of postnatal life—should affect the acquisition process. To understand how this may be, it helps to understand that particular aspects of language structure are consistent across languages. In recent years, researchers have demonstrated that infants are highly sensitive to such structure, particularly when they have ample language around them from which to extract structural regularities (cf. Gogate, Bolzani, & Betancourt, 2006).

Earlier, we reviewed findings on the influence of prosody (particularly that employed in infant-directed speech) on how infants attend to speech. We observed that, while prosodic form varies across languages, the infant-directedness of mothers' speech to infants does not. This prosodic structure helps infants separate continuous speech into smaller "chunks." Young learners can then use a variety of distributional strategies to pull words out of the chunks themselves. The simplest example of this is that *a priori* knowledge of certain high frequency words (e.g., the infant's own name) (Bortfeld, et al., 2005) can help further delineate where other words begin and end. In other words, while prosodic organization of speech provides initial edges in otherwise continuous speech, continued exposure to the regular patterns within the smaller "chunks" of speech those edges create allows infants to break them down further. This does, in fact, appear to be the case, as a wealth of recent evidence has highlighted different forms of structural information in the speech signal.

As demonstrated by Saffran and colleagues (Saffran, Aslin, & Newport, 1996), infants deal with the speech segmentation problem at least in part by taking advantage of distributions inherent in the signal. In their study, infants were exposed to artificial languages that were synthesized so that there were no acoustic cues to word boundaries and no silences between syllables. The languages consisted of concatenated strings of trisyllabic nonsense words. Despite having no acoustic cues to guide the segmentation process, infants were able to distinguish between the languages' words (consistent trisyllabic strings) and "part words" (in this case, trisyllables created by pairing the syllable from the end of one word with the first two syllables of another) when these subsequently were presented to them in isolation. The researchers argued that the only way infants could distinguish words from part words in these experiments was on the basis of the statistical coherence between syllables of words as compared to the lack of statistical coherence between part word syllables. Although words occurred more frequently than part words in the original experiment, the researchers subsequently demonstrated that infants' ability was not simply a function of word frequency. Rather, infants discriminated words from part words on the basis of differences in their transitional probabilities (that is, the odds that one syllable would follow another) because the transitional probabilities are higher between syllables that are part of the same word and thus consistently occur together relative to those between part word syllables (Aslin, et al., 1998).

The original research on this matter employed speech stimuli with nothing but statistical form, a design feature that was necessary to establish that infants can segment speech on the basis of statistical cues alone. Subsequent research has demonstrated that statistical structure interacts with a variety of other cues to structure, such as the prosodic contours inherent in infant-directed speech (Bortfeld & Morgan, 2010; Hay, et al., 2011). While a review of the details of this more recent research is beyond the scope of this chapter, suffice it to say that infants are learning about language based on cues such as word frequency, structural distributions within and between words, and acoustic cues highlighting which words go together. It follows that the more speech an infant hears, the more likely he or she will have access to such cues as a guide to learning language. Consistent with Hart and Risley's (1995) original argument, there is now plenty of evidence that early differences in the amount of speech children are exposed to influences language ability in subsequent years of life. Indeed, researchers have returned to the rather obvious conclusion that language begins with simple exposure (and lots of it), inspiring a new generation of "talk-to-your-children" public service announcements. If structure is inherent in the signal, then exposure to more of that signal will better allow a child to learn the structure. The caveat to this is that the child must be ready (developmentally speaking) to pick up on that structure; thus the interaction between environment and organism matters (see Gogate & Hollich, 2010).

However, if exposure matters, does it matter where the exposure is coming from? The push to get kids listening to more language—any language—has, in fact, raised as many questions about language learning as the research it was based on answered. For example, is overheard speech (e.g., speech between other speakers) as helpful as speech directed to the child him- or herself? Does speech from electronic media count towards the total exposure tally? Does it matter if the speech is infant-directed, or will adult-directed speech serve the same purpose? These are just a sampling of the questions that the push for more exposure has raised. Of course, things are rarely as simple as they seem, and research suggests that mere exposure to speech is not sufficient for the development of language (e.g., Kuhl, Tsao, & Liu, 2003).

## THE BEGINNING OF RECIPROCAL COMMUNICATION

An emerging view is that the most critical aspect of adults' speech to infants is that it fosters attempts on the infants' part to actually speak. Speech that does not foster a child's own speech, such as electronic television programs, may actually be counterproductive in helping children learn language. Data support this view. In a recent study, Zimmerman et al. (2009) observed that the frequency of adult-child conversations was associated with robust language development. Conversely, after controlling specifically for interactive speech, no correlation was found between exposure to speech from television and other media and a child's subsequent language development. Rather, it appears that heavy media exposure during the early childhood years has a deleterious effect on language learning outcomes. Just a handful of these negative effects are: delays in language development, poor overall language development, poor reading skills, poor math skills, and problems with attention (Zimmerman, et al., 2005, 2007, 2009). One way that media can produce these negative outcomes is simply by reducing a child's opportunities for verbal interactions with his or her caregivers. Adding support to this argument are data showing that the number of conversational turns that adult caregivers and their children share is positively correlated with scores on a well-validated measure of language development (Zimmerman, et al., 2009). Clearly, two-sided conversations are extremely important for language learning to proceed. Therefore, parents should not only be encouraged to provide their children with language input by speaking and reading to them, but they should try to get their young children speaking as much as possible too.

Language is embedded in a social context and language learning takes place in the context of responsive social exchanges between caregivers and children. Of course, caregivers can elicit speech from their infants and young children in a variety of ways, particularly by being sensitive to their language abilities and responding to their efforts to speak in a supportive and contingent manner. Adults are most efficient at promoting language development when they calibrate their own speech to be just challenging enough for their child, making it neither so simplistic that the child learns nothing from the model, nor so sophisticated that the child is confused. Because maintaining adult speech in this range depends on a caregiver being in touch with his or her child's rapidly changing abilities, a caregiver's own frequent exposure to the child's language (e.g., through active conversation) will help guide appropriate tuning to the child's specific developmental level (Zimmerman, et al., 2009).

How do conversations between caregivers and infants proceed, given their inherent one-sidedness? Recent research on this topic has demonstrated that optimum occasions for language learning occur when adult speech is focused on and relevant to an infant's own attentional focus. Caregivers who are responsive to the foci of their infants' attention may specifically support advances in language development by providing labels for objects and events when they are receiving joint attention, thereby easing the challenge to infants of matching linguistic symbols to their referents and reinforcing the social-communicative function of language itself. On the other hand, there is some evidence that follow-in labeling does not work, at least initially (Gogate, Bolzani, & Betancourt, 2006). Thus, there is likely a developmental shift from responsiveness to lead-in and follow-in labeling. Indeed, when caregivers are particularly sensitive to their infants' interests and abilities, they will often match the semantic and syntactic content of their utterances to the children's level of understanding. For example, maternal speech that systematically matches infants' own speech on a variety of features strongly predicts children's linguistic abilities (Tamis-LeMonda, et al., 2001; Gogate & Hollich, 2010). Mothers who respond to their children's communicative attempts during exploratory bouts key into the same topics of interest as their infants. The children "signal" choices about communication and mothers react to those signals in a sensitive manner. In this way, mothers provide infants with semantically relevant and interpretable speech because they follow up on topics introduced by the child him- or herself.

Aside from simply providing appropriate language structure at the appropriate time, direct, contingent interaction allows parents to provide error correction, whether explicitly or implicitly. Poverty-of-the-stimulus arguments (Chomsky, 1980) notwithstanding, early language development has been shown to benefit from active correction of errors by adult speakers. More conversations mean more opportunities for mistakes and corrections to be made, not to mention an increase in opportunities for children to use and consolidate newly acquired language. Finally, more conversation is a sign of greater adult responsiveness to a child's communication (Zimmerman, et al., 2009), and thus the quality of the child's model for how to coordinate his or her attention with that of the social partner. A child's coordination skills have been shown to influence development of representational abilities in subsequent activities, such as in the language used during play (Adamson, et al., 2004; Carpenter, et al., 1998; Delgado, et al., 2002; McCune, 1995; Morales, et al., 1998). Finally, the prevalence of "two-sided conversations" between caregivers and infants relate to the subsequent achievement of several language milestones (Nicely, et al., 1999; Rollins, 2003; Tamis-LeMonda, et al., 2001).

Beginning at the earliest stages of communication, infants' noncry vocalizations serve as salient social signals, and caregivers (socially and emotionally) reinforce these vocalizations. Indeed, contingent vocal responses to prelinguistic vocalizations are a typical characteristic of caregivers' reinforcing behavior. For example, Goldstein and colleagues have determined that caregivers spontaneously respond to 30-50% of noncry sounds in interactions with their infants (Goldstein & West, 1999). Moreover, this responsiveness is associated with subsequent development of phonology and speech (Goldstein & Schwade, 2008; Goldstein, et al., 2003; Gros-Louis, et al., 2006).

Several factors have been identified in this process. First, maternal feedback to prelinguistic vocalizations influences the production of more developmentally advanced vocalizations, suggesting that the influence of maternal responsiveness on vocal development starts during the prelinguistic phase. In an analysis of unstructured play sessions between mothers and infants, mothers responded contingently to prelinguistic vocalizations over 70% of the time, and with more vocal responses than any other kind of response (e.g., gazes, smiling, physical contact; Gros-Louis, et al., 2006). Therefore, the form of behavioral responses from social partners can encourage infants' own production of particular vocalizations, vocal development (through the introduction of new sounds), and efforts to improvise approximating speech sounds. Second, adults' sensitivity to differences in prelinguistic vocalizations suggests that they may respond differently to different sounds, serving as a scaffold for language development. For example, mothers not only provided contingent responses to their infants' vocalizations, but those responses were also specific to particular vocalization types (Gros-Louis, et al., 2006). Mothers provided distinct verbal feedback to vowel-like and consonant-vowel vocalizations, giving interactive-vocal responses significantly more to consonant-vowel clusters than to vowel-like sounds. These, in turn, resulted in an increase in the production of more developmentally advanced vocalizations on the part of the infants (Gros-Louis, et al., 2006). Thus, co-occurring responses by mothers, in addition to their contingent responses, provide information to infants about the effectiveness of their vocal production. In this way, mothers encourage the use of particular sounds, giving them meaning, and frame interactions with infants through them (Papousek & Papousek, 1989).

However, much of this research is correlational. To examine the role of caretaker-child interaction in vocal development in a more controlled way (i.e., beyond observations of natural, spontaneous interaction scenarios), Goldstein et al. instructed mothers precisely *when* to respond to infant vocalizations (Goldstein, King, & West, 2003). Half of the infant-mother pairs tested were trained to respond contingently to infants' vocalizations with nonvocal social responses like smiling and touching, while the other half were instructed to respond based on the response schedules of the mothers in the contingent group, but to do so non-contingently. Infants who received social feedback contingent on their vocalizations produced more developmentally advanced vocalizations during the manipulation as well as after maternal responding was no longer being manipulated compared to those infants who received feedback independent of when they vocalized. Similar results have been observed in studies of unstructured mother-infant interactions (e.g., Hsu & Vogel, 2003).

In yet another study, when caregivers responded contingently to infants' vocalizations with speech, infants structured their own sounds to match the phonological patterns they heard (Goldstein & Schwade, 2008). For example, when infants were given vowel sounds as feedback, they produced more vowel sounds, but when they were given words as feedback, they produced more consonant-vowel combinations. This demonstrates that infant vocalizations can themselves be operantly conditioned with appropriate social reinforcement. In fact, changes in vocalizing in response to high levels of social reinforcement are a key characteristic of infant-caregiver dyadic interaction, and infants who learn the contingency between their own vocalizations and the responses of their caregivers have thus learned to influence the behavior of social partners, an important step forward in early communicative development.

In short, caregivers' contingent and positive responses to infants' vocalizations influence and advance these prelinguistic productions. Infants learn that their own vocalizations elicit responses, marking the beginning of their use of vocalizations as bids for social interaction. In this way, infants learn to guide the structure of interactions and to predict the outcome of ensuing interactions (i.e., to communicate). Thus, a functional perspective has emerged whereby infants' sounds can be understood not only in terms of their acoustic properties but also in terms of their ability to regulate and be regulated by social interactions with receivers of the sounds. This is infant communication.

## CONCLUSION AND FUTURE DIRECTIONS

Communication is inherently social. At the earliest stages of development, infants are being influenced by the sounds around them. Subsequently, caregivers' biases to communicate in particular ways help infants focus their attention specifically on speech sounds. The structure of the speech signal together with the contingent structure of the infant-caregiver interaction serve to highlight regularities in speech and in interactive form; infants respond to this, as reflected physiologically, and in their subsequent productions of new vocal forms. Particular maternal responses, such as imitations and expansions, correlate positively with language development. Through these responses, infants appear to learn the association between the production of certain sounds and their outcomes. Finally, caregivers' input during social interactions and early "conversations" scaffold language learning by providing information about activities and objects that are the focus of infants' attention in the first place. Much of the data available on reciprocal communication effects are behavioral in nature, though neurophysiological measures are beginning to expand the story these data tell. Future research will need to broaden the body of evidence for this by linking the two in real time. As with the influence of prenatal exposure to sound and, specifically, to the mother's voice, evidence from a range of measures is needed before more definitive statements can be made. Such data will contribute to our understanding of the interplay between language development and important competencies, both social and emotional. Nonetheless, it is clear that socially guided communication is fundamental to infants' initial vocal development and lays the foundation for subsequent advances in language learning.

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