Prenatal Language Learning

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Full Text: Headnote ABSTRACT: Although it is often ignored or denied by investigators of language learning, prenatal language learning is an important aspect of human development. During the third trimester of gestation, a baby in the womb can hear the mother's voice clearly, and makes use of this ability by learning the rhythms, tones, and sequences of whatever languages the mother speaks. These phonological patterns do not stand apart from context, but instead are experienced as integral parts of the mother's moods and activities. By building up neural patterns in the brain, the baby gets a head start on the phonological contours, grammars, and uses of the mother's languages. That language learning begins before birth is an idea that is gradually gaining acceptance among neurolinguists and other researchers. That prenatal language learning can be affected by actions of the mother was demonstrated in these pages, in an article by Lafuente and colleagues (Lafuente, Grifol, Segarra, Soriano, Gorba, &Montesinos, 1997). As the 101 babies in this study get older, further reports by Lafuente et al. are expected to reveal more long-term effects of their prenatal training. In the meantime, it may be useful to attempt to summarize what is known and what is suspected about prenatal language learning. In the following pages, I will first describe the developmental sequences of hearing and speech. Then I will summarize the evidence for, and the nature of, prenatal language learning. Finally, I will discuss some implications of current knowledge for students of language development and for families who will observe the process in action. DEVELOPMENT OF HEARING With or without prenatal language learning, some things are well known about the physiological and behavioral aspects of language learning. Let us review them. Although the underpinnings of hearing and speech may be intimately intertwined, they develop on different time schedules, hearing long before speech. Hearing is a capability shared by all mammals, and one for which there appears to be no very special developmental advantage for human beings. Physical and neural development of hearing occurs early in the life of the human fetus. "The vestibular system starts to develop early in the first months and is finished after 4 1⁄2 months of uterine life" (Tomatis, 1987, p. 25). "By just 20 weeks in utero the auditory apparatus of a fetus is structurally comparable to that of an adult" (Chamberlain, 1987, p. 73). Neural development follows rapidly. "At 5 1⁄2 months of prenatal life the cochlear nerve is myelinized. The influence of the cochlear system expands quickly as it takes in the vestibular system" (Tomatis, 1987, p. 25). That the hearing system is operational before the end of normal gestation was shown by Eisenberg (1969, as summarized by Chamberlain, 1987, p. 73), who "found that seventh-month prematures responded autonomically and behaviorally to a number of acoustic variables." Birnholz and Benacerraf (1983) used high-resolution ultrasound imaging to record eye-blinks of fetuses in response to "a vibro-acoustic noise source" of 110-dB output intensity "applied firmly to the maternal abdomen directly overlying a fetal ear." These authors found that "responses were first elicited between 24 and 25 weeks of gestational age and were present consistently after 28 weeks" (p. 516). They concluded that "hearing is established as a functionally interactive sensation by the start of the third trimester for the specific stimulus used and with the restriction to short latency craniofacial motor reactions" (p. 517). Mehler and Dupoux (1994) wrote that the hearing of newborns "is excellent. They are whizzes at auditory perception, recognition, and memorization. From their first moments and, according to certain studies, even during the last weeks of pregnancy, their auditory equipment is in perfect order" (p. 51). Immediately after birth, auditory discrimination is evident. "Human response to sound begins in the third trimester of life and by birth reaches sophisticated levels . . . , especially with respect to speech," said DeCasper and Fifer (1980, p. 1174). "{A} newborn infant younger than 3 days of age can not only discriminate its mother's voice but also will work to produce her voice in preference to the voice of another female" (p. 1175). These researchers put nonnutritive nipples in infants' mouths and gave feedback to the infants in the form of their mothers' voices or another female's voice depending on the pattern of sucking. Infants "learned how to produce the mother's voice and produced it more often than the other voice" (p. 1174). DeCasper and Fifer offered the opinion that the auditory competence of newborns "probably subserves a variety of developmental functions such as language acquisition . . . and mother-infant bonding" (p. 1174). Summarizing recent research about the infant's knowledge of language, Mehler and Christophe (1995) reported that at the age of 4 days, infants can distinguish language from other sounds, and have already begun to prefer not only their mother's voice but also their mother's language. Babies seem to discern a language by its prosodie properties such as intonation and rhythm (Aslin, 1987, p. 77; Mehler &Dupoux, 1994, p. 154). French, English, and Japanese, for example, follow three different patterns. Mehler and Dupoux explained: When we hear a French person talk, a temporal regularity emerges: the duration of vowels is more or less constant. But this is not the case in English. Here, vowels vary in duration according to whether or not they are accented. In Japanese, periodicity is marked by morae, units shorter than the syllable but longer than the phoneme. (p. 159) As Cutler (1994) observed, the rhythm of one's native speech-whether it is to be based on stress, syllable, or mora-is set only once, and that early in life. Otake, Hatano, Cutler &Mehler, (1993) suggested that, shortly after birth, French infants already understand that their language is syllable-timed, English infants understand that their language is stress-timed, and Japanese infants understand that their language is mora-timed. These authors proposed that "the child's endowment in this respect might be thought of as a process of determining the smallest occurring level of regularity in the speech input with which it is presented" (p. 276). By a process of "prosodie bootstrapping," the young child "loses its newborn impartiality toward the range of possible rhythmic structures available in language, and begin[s] to exhibit preferential behavior" (p. 276). Is the newborn really impartial toward the rhythms of languages? If so, by what means do newborns distinguish the sounds of languages as rapidly as they do? One answer is that auditory impressions are received by innate and specialized processes. "Percepts of auditory events are organized entities . . . and result from processes innately given" (Eimas &Miller, 1992, p. 345). Among the perceptual capabilities of infants are (a) the ability to give precedence to speech sounds over other sounds (Whalen &Liberman, 1987), (b) apprehension of prosodie elements such as intonation and rhythm (Mehler &Dupoux, 1994, p. 154), and (c) perceptual categorization of phonetic distinctions that are peculiar to human languages (Eimas, 1985). The third perceptual capability has been the object of considerable research (see, for example, Eimas, 1985; Kühl, Williams, Lacerda, Stevens, &Lindblom, 1992). The general conclusions are that newborn infants are equipped with perceptual prototypes or "magnets" (categorical perceptions) by which they can perceive and group every phonetic distinction of every human language. Studdert-Kennedy (1991, pp. 15-16) cautioned that categorical perception is a mode of processing shared by many vertebrates, and therefore should not be construed as peculiar to human beings, much less to human speech. That human beings employ the ability to good effect in perceiving speech is, however, undeniable, and some innate abilities, such as the categorical perception of voice onset tune (Simos &Molfese, 1997) seem unique to human beings. Mehler and Dupoux (1994) summarized infants' abilities to hear languages: Human infants, then, know how to discriminate all the minimal potential differences used in natural languages. They can discern changes in the speaker, intonation, or delivery . . . But very quickly, on contact with their environment, they incorporate statistical regularities that limit their attention to categories pertinent to what becomes their native language. (p. 172) Over the course of the first year of life, infants gradually lose the ability to perceive distinctions that are absent from their linguistic environments; thereafter, as infants mature into adulthood, the loss is hardened into virtual inaccessibility. Thus a newborn Japanese baby has no difficulty distinguishing /r/from /l/(sounds that are distinguished in English but not in Japanese) but, as Eimas (1985, p. 52) reported, "native adult Japanese speakers are virtually unable to perceive the distinction between the sounds of /r/and /l/without special training." We may summarize the human development of the ability to hear languages as follows. Halfway between conception and birth, the auditory apparatus of the fetus is virtually complete. Neural support follows rapidly, and by the beginning of the third trimester, a baby in the womb hears well. The baby hears the mother's voice. A few days after birth, a newborn recognizes and prefers his or her mother's voice and the languages she has spoken. At first, the newborn can distinguish every sound of every human language but rapid neural development in the first year after birth gradually makes the infant an expert in only those languages that he or she hears. DEVELOPMENT OF SPEECH Evolution does not follow optimum, or even smooth, courses. In The Biology and Evolution of Language, Lieberman (1984) described "a 'mosaic' principle that appears to govern the process of evolution. . . . We are put together in bits and pieces that evolved separately" (p. 6). Speech is accomplished within the human respiratory system, which lieberman said is "a Rube Goldberg system, but it works and has a logic based on its particular evolutionary history" (1984, p. viii). Lenneberg (1967, chapter 3) noted that breathing patterns are significantly changed during speech, and that fine muscles of the larynx, chin, tongue and lips "must be activated (or de-activated) at such rapid succession that a neuronal firing order must be assumed that functions with an accuracy of milliseconds. This can be accomplished only by automatisms consisting of intricate time-patterns" (1967, p. 120). How does such an intricate Rube Goldberg system develop during gestation and infancy?

Table 1
Physiological Factors Underlying the Speech Capability of Infants Before and After Three Months of Age*

Before three months	*After three months*
Due to the shape of the ribs, the infant cannot effect a steady subglottal air pressure	The infant can effect a steady subglottal air pressure, permitting long episodes of phonation
Tongue and larynx high, like all terrestrial mammals	Larynx and back of tongue lowered
Nose breathing obligatory	Mouth breathing begins
The infant cannot pronounce the vowels [i], [u], and [a]	The infant can pronounce the vowels [i], [u], and [a]

*Based on Lieberman (1984).

The following account is based on Lieberman (1984) with exceptions as noted. A number of physiological factors suggest that the human ability to vocalize undergoes a qualitative change at about three months after birth (Table 1). At birth, the human infant has certain physiological traits that work against speech. The infant's ribs are structured in such a way as to prevent the steady expiration that adults use in long episodes of phonation. The neonate's tongue and larynx are high in the throat, causing nose breathing and making possible simultaneous breathing and swallowing, but preventing mouth breathing. Due to the structure of the tongue and larynx, the baby cannot form certain vowels. All of these factors change after about three months, making vocalization possible and leading into an intensive period of routinizing. With respect to the quality of vowels, for example, lieberman (citing Landahl, 1982) summarized: There is a gradual and consistent improvement in children's production of the vowels of English from the earliest stages of babbling well into the stage (at age 3 years) where the children are producing multiword sentences and are conversing with adults. (1984, p. 222) Truby (1975) described infant vocalizations as "alinguistic as far as 'vowel spectra' and 'consonant... spectra' are concerned" (p. 73), and warned that perceived similarities to adult vocalizations are likely to be fortuitous and irrelevant. He wrote that the crying of a neonate can, however, be found to reflect the speech rhythms and intonations of the mother tongue (p. 57). In addition to physiological factors that lead to speech readiness at three months after birth, some behavioral factors lead to the same result. Before about six weeks of age, the infant's vocal productions are limited to crying and babbling, which nevertheless afford practice that establishes the neuromotor skills necessary for human speech. As early as six weeks, the infant can imitate the intonation contours of his or her mother's languages. The infant begins to seek interaction and empathy with the mother (Trevarthen &Aitken, 1994). At three months, the infant can engage in social vocalizing, including conversational turn-taking. Thus, before words have much meaning for the infant, he or she can nevertheless produce the form of a conversation in the mother tongue. Lieberman's "model for the acquisition of speech" envisioned simultaneous neural and physiological development, with common neural structures serving both the production and interpretation of speech. These changes result from both innate maturational factors and the development of specific skills of the degree of difficulty of "activities like performing on the flying trapeze" (p. 200). In the evolution of speech, the human system for respiration and speech evolved differently from that of all other mammals including Neanderthal man. The development of speech and the vocal apparatus making speech possible was phylogenetically late (perhaps as recent as 250,000 years ago), and is ontogenetically not complete until about three months after birth. This extraordinary apparatus, with its heightened potential for allowing its possessors to choke to death, must have had some special reason for survival. lieberman's explanation was that the resulting ability to communicate outweighed the disadvantages: "In more advanced cultural settings the communicative language of modern Homo sapiens may have yielded the selective advantage that outweighed the vegetative advantages of the nonhuman supralaryngeal airway" (1984, p. 286). Such is the description of the development of hearing and speech in human infants. At birth, they can clearly hear every sound of every human language. Three months after birth, they can begin to produce the sounds of their mother's languages. Newborn babies have extraordinary language skills. It is unsatisfying to leave the question here, with the proposition that newborns are revealed to have remarkable, apparently inborn, language-perceiving capabilities at the moment they begin to breath, and that in the first two days after birth these capabilities fix on whatever language the individual hears. In order to ascertain when and how a newborn develops these skills,we must review evidence of language learning before birth. WHAT IS KNOWN ABOUT PRENATAL LANGUAGE LEARNING There is a widespread but mistaken belief that a baby's mental life does not begin until after birth (Chamberlain, 1997), and conventional researchers (for example, Owens, 1996, p. 160) typically describe the first stage of language learning as beginning no earlier than birth. Lenneberg (1967), thinking of the beginning of language learning as characterized by a "definite increase in communicative behavior and interest in language" (p. 130), described the beginning point as about two years of age, although he described "vocalizations," beginning with cooing, as beginning at about 12 weeks (1967, p. 128). Brown (1973) defined "Stage I" of language development as characterized by a mean length of utterance of 1.75 morphemes, a value that was reached as early as 18 months of age by one of his subjects. At this level, children were producing "a rather short list of semantic propositions and relations (between 8 and 15)," and "these meanings seem to represent linguistically the sensori-motor intelligence which develops, according to Piaget's research, Ui the 18 months or so which normally precedes stage I" (p. 64). In these descriptions of the first stage of language learning, both Lenneberg and Brown were attempting to describe the first production of patterns peculiar to the mother tongue. If, however, we base the criterion not on production but on recognition, then the beginning of language learning will be seen to occur (as every mother knows) long before 18 months of age. Research concentrating on abilities to recognize language and distinguish languages has demonstrated these abilities shortly after birth. If newborn infants can distinguish their mothers' voices (DeCasper &Fifer, 1980) and their mothers' languages (Mehler &Christophe, 1995), we are moved to inquire: How do they do it? Mehler and Christophe (1995, p. 951) flirted with the hypothesis that "the syllable (or something correlated with it) is the universal structure in terms of which speech is represented at birth." "Another possible interpretation," they continued, is that French newborns "have already realized that French is syllable-based." They described this explanation as "implausible" based on the fact that the infants are only a few days old (p. 951). Certainly this second explanation is implausible if it rests on either genetic predisposition (that French babies have unique syllable-timing genes) or extraordinarily rapid acquisition of language sensitivity in the few days after birth. The fact that French babies recognize and prefer their syllable-based language does not seem implausible, however, if it is viewed as a result of prenatal learning. Like good detectives, let us look for motive, means, and opportunity for prenatal language learning. Motive Motive is easily established. An integral element in the design of human beings is the learning of at least one language. Unlike all other animals, human babies are naturally equipped to learn languages quickly and thoroughly. On this point, all students of language learning agree. The innate human ability to use language has attracted the interest of the very best researchers (see, for example, Chomsky, 1986; Nelson, 1996). Language is complex, yet the human infant learns it amazingly quickly, and immediately puts it to service in seeking intersubjective understanding with his or her caregivers (Trevarthen &Aitken, 1994). It is likely that there is considerable survival value associated with knowing one's mother's language at the earliest possible age. Then the beginning of learning, too, would have survival value if it is early-and the earlier the better. This is the "motive" for prenatal language learning. Given motive, then, let us examine the means and opportunity for prenatal language learning. Means We have seen that prenatal development of auditory function is such as to allow the infant considerable auditory experience. Early studies showed that the fetus can hear. Peiper (1925) studied fetal movement in response to sound. As Carmichael described Peiper's experiment: It was obvious [to Peiper] that sounds would be much muffled on their way to the fetus. Therefore a very loud sound was chosen as a stimulus, an automobile horn being used. The experimenter waited until the fetus was absolutely quiet and the mother had been prepared so that she would not herself respond to the stimulus. Incidentally, it proved impossible to train all mothers in this way. (Carmichael, 1970, p. 529) Aslin (1987) pointed out that, although "startle responses are quite easy to elicit in young infants by presenting a very intense acoustic stimulus, . . . startle responses have not proven to be sensitive indices of auditory functions" (p. 6). More subtle procedures have followed from the realization that sounds available to the fetus are of fairly good quality. Aslin wrote that "sounds below 1000 Hz are attenuated very little as they pass through the mother's abdomen to the amniotic sac." Armitage, Baldwin and Vince (1980) implanted microphones in the amniotic sacs of sheep, and reported clear reception of sounds of "drinking, eating, swallowing, rumination, and sometimes heavy breathing" (p. 1174). External sounds were attenuated by about 30 dB, with the result that "conversation at normal levels outside the animal could often, but not always, be understood when transmitted from inside" (p. 1174). These authors suggested "that the auditory experience of the fetal mammal may be considerably more extensive, more varied, and . . . possibly of greater postnatal significance than has been believed" (p. 1174). Mehler and Dupoux (1994, p. 163) held that prenatal learning is "possible, but not very probable." They gave as their reason that "amniotic fluid greatly distorts the acoustic signal. ... The fetus hears mostly stomach rumblings and various other noises" (p. 163), and they likened the sound quality in the womb to hearing a conversation with one's head submerged in a bathtub (p. 154). Later, however, the senior author may have modified his view. Mehler and Christophe, (1995: 947) noted that "the main properties that [newborn] infants pay attention to are carried by the lower 400 Hz of the spectrum." This observation, they said, "confirms the fact that infants probably rely on some gross properties of utterances to categorize them (their prosody)" (p. 947). Conduction of sound through the mother's body to the fetus would make the rhythm and tone of the mother's speech available to guide the growth of the brain of the developing human being. Neurological evidence suggests that neuronal growth in the brain is responsive to sounds heard during the last months of pregnancy. The last stage of gestation, from about the 24th gestational week (the ruleof-thumb lower limit for the likely survival of infants born prematurely) until birth, is a period of rapid neuronal organization and maturation. During this stage, "cortical neurons respond to incoming fibers by an exuberant formation of complex but distinctive dendritic arborizations and by the establishment of an uncountable number of synapses" (Marín-Padilla, 1993, p. 68). In conjunction with this rapid neuronal development, fetal language learning may occur at an accelerating pace. Although cortical neuropil continues its exuberant growth after birth, many basic patterns are already developed. We know that dendrites grow in response to sensory input; one of the major sources of sensory input to the third-trimester fetus is acoustic input. As Schwartz (1997, p. 22) put it, the fetus is participating in an "auditory amphitheater." It is easy to imagine that the basic prosodie patterns of one's mother tongue guide the growth of cortical neuropil before birth, and that the mother's speech intonations and rhythms establish characteristic neural patterns in the perinatal brain. Methods of detecting prenatal learning generally involve examining postnatal effects of prenatal stimuli. Aslin (1987, p. 58) noted the presence of "auditory preferences immediately after birth that could only have been induced by prenatal auditory exposure." Aslin interpreted DeCasper and Fifer's (1980) finding that newborns prefer their mothers' voices as suggesting "that the maternal voice preference may have been induced by prenatal exposure" (p. 67). Aslin cited further evidence of prenatal learning indicating that infants do not prefer their fathers' voices over other male voices. Newborns do prefer to listen to a tape recorded prose passage that was read aloud by the mother during the latter stages of her pregnancy compared to a prose passage not read during her pregnancy . . . and newborns prefer a melody that was sung by the mother during her pregnancy to a melody that was not sung during her pregnancy, (p. 67) We may summarize the conclusions about the means of prenatal language learning by saying that, at least by the beginning of the third trimester, the physiological capabilities of the ear and brain clearly are in place for the brain's development of neural patterns peculiar to human speech and, in particular to the mother's speech. Opportunity As to opportunity for prenatal language learning, mothers are social beings who speak on innumerable occasions and in various moods. Are these opportunities wasted on the unborn infant? Certainly not. Pregnant mothers report that babies in the womb are sometimes awake and responsive, especially in the last trimester of pregnancy. The third trimester thus offers an excellent opportunity to build into the baby's neural processes those patterns of timing, rhythm, intonation and loudness that will help him or her during a lifetime of coping with social and emotional reality. There are many subtle elements of language that the baby might begin to learn before birth. Two examples are pausing and modulation. Pausing during speech is one such subtle element. We pause to breathe, to listen to a response, and to think. But we do not pause just anywhere. There are places and rhythms for pausing. Another subtle element is changing key. As we listen to others, we understand low voices and high voices alike, without any effort at transposing the key. When responding to another person, we choose a key that is related to the key of what we have just heard, but modulated away from it in a complex way. Pausing and modulation are not the sort of thing that anyone learns in school; they are things that "everybody knows," but they are subtly different in different languages. They are examples of what a baby in the womb can begin to build into his or her neural fundament. Even without special effort on the part of mothers, unborn babies benefit from whatever speech they can hear. They have the opportunity to internalize not only the sound patterns of the mother's languages, but also to put these sound patterns in context. The fetus undoubtedly experiences the mother's mental states, such as stress, relaxation, sleeping, waking, aerobic exercise, contentment, and anger (Rhighetti, 1996; Schwartz, 1997). Thus the infant begins to build combined impressions of how the sense of situation goes with the mother's changes in tone, loudness, rapidity, rhythm, and voice quality. Language use is, after all, not a context-free activity, but is always apposite to situations, and the primary characteristic of any situation is the mental state of the participant. The mother's language is never sterile syntax or vocabulary. Her language is, instead, inextricably bound to her experiences, and that inextricable binding is what the fetus experiences and builds into the neural makeup of the brain. If we attempt to describe a developmental process that is normal and expected-so normal as to go virtually unnoticed-a useful procedure is to consider those rare cases when it might be absent. With respect to prenatal language learning, we might examine cases in which mothers do not speak, or speak relatively little. Chamberlain (1987) summarized some work of Truby and Lind (1965) as follows: With the aid of acoustic spectrograms that yield cryprints as unique as fingerprints, Truby and Lind (1965) discovered that fetuses were receiving and storing speech features transmitted from the mother-obviously by some mechanism of hearing. Babies of mute mothers didn't cry at all or cried strangely, as if they had missed their speech lessons in utero. (Chamberlain, 1987, p. 74) Although babies in the womb begin building neural tissue and massive patterns of synapses to match the mother's language, such development is by no means complete at birth. We have seen that, after birth, a baby can still hear every sound in every language (Aslin, 1987, p. 71). Has the newborn's specialization in the mother's language precluded other languages? No; the newborn can still learn any human language with ease, but has a head start on his or her mother's language. This arrangement fits in with the fact that in human societies, most-but not quite all-infants are raised by speakers of their mother tongue. Summary In the current understanding, prenatal language learning, occurring as it does during the time when basic patterns of neural connection are being established in the brain, must be accorded a fundamental role in language learning. It appears to set the base line for hearing and speaking, especially with respect to patterns of rhythm, intonation, loudness and softness, division into phrases, and voice qualityall of these in the context of the mental states in which the mother usually utters them. As an experience that is played out in sequences over time, language heard by the unborn baby sets the basic patterns of phonological sequences as they relate to meaning. LANGUAGE AND THE BRAIN Among linguists, lack of interest Ui prenatal language learning often stems from a particular view of what a language really is. For the last 40 years, many linguists have believed that a language is composed of sound symbols with arbitrarily assigned meanings (words), whose arrangement into sentences follows elaborate and often very subtle rules (grammar). Such a highly symbolic and rule-bound body of knowledge would obviously be beyond the mental powers of a fetus or even an infant to learn. In fact, learning the rules seems so difficult that researchers have been moved to propose that the basic rules of grammar are innate, passed on genetically like a spider's know-how for building a web. This theoretical position is known as Universal Grammar, or UG (for a good explanation of UG, see Cook &Newson, 1996). Recently, however, less mechanistic and more process-oriented notions of the nature of language have arisen. The idea that language consists primarily of phonological sequences is receiving widespread attention. Those who see language as phonological sequences find a natural interest in prenatal and perinatal language learning. Language as Phonological Sequences We saw that the use of language involves extraordinarily complex combinations of neural and muscular activity. Lashley (1951) used language as an example of the general problem of the serial ordering of behavior, the essential point of which is "the existence of generalized schemata of action which determine the sequence of specific acts, acts which in themselves or in their associations seem to have no temporal valence" (p. 122). That Lashley included language as an example is noteworthy, for he offered an evocative account of the neurological basis of grammar (an account that was all but neglected in subsequent approaches to grammar as a formal system). According to Lashley, "syntax is a generalized pattern imposed upon the specific acts as they occur" (p. 119). First, expressive units are primed, that is, "an aggregate of word units is partially activated or readied," awaiting ordering into a sequence of sounds. Then, with the application of phonological temporal sequences, rhythm, and certain types of integration, the mind imposes a final form for motor execution. Lashley's statement on rhythm might itself serve as a model sentence for teaching elocution. "The skilled extemporaneous speaker rounds his phrases and speaks with a definite though not regular rhythm" (p. 127). Now further evidence is available on the physiological processes that underlie language behavior. We may properly inquire about the manner in which syntactical results proceed from physiological processes, and in particular whether an understanding of phonology solves questions previously thought of as grammatical (Mohanan, 1992). A suggestion that the prosody of utterances that a child hears contributes to his or her developing sense of syntax began to be heard in the early 1980's. The term prosodic bootstrapping was applied to the phenomenon. Although Morgan and Demuth (1996, p. 2) later suggested that, because "several forms of information are available in input speech-phonetic, phonotactic, prosodic, stochastic-" the term phonological bootstrapping would be more general. Hirsh-Pasek, Tucker, and Golinkoff (1996) summarized research on the prosodic bootstrapping hypothesis and concluded that prosody by itself cannot go the whole way to providing syntax. "Evidence from psychology, linguistics, and computational linguistics all points to the same conclusion. Prosody does not map transparently onto syntax" (p. 449). That may be so, but it is not of great importance if we drop the assumption that there is a "system" of syntax to be learned. The notion of bootstrapping implies that there is something to bootstrap to. If there is no system to bootstrap to, then what goes on is some kind of learning, but our ideas of it no longer need be constrained by assuming a terminus ad quern, a structured system of rules toward which learning must lead. Research shows that, before his or her first birthday, the infant has learned clause patterns and sentence prosody. Hirsh-Pasek, Kemler Nelson, Jusczyk, Cassidy, Druss, and Kennedy (1987) found that seven to ten month old infants can detect "acoustic correlates of clausal units in English" (p. 2), at least when the clauses are spoken in motherese. Thus, even before they speak, infants are sensitive to large, complex patterns of spoken thoughts. Locke (1988, p. 13) suggested that overall patterns are acquired before words: There has been increasing attention to the prospect that young children's words may not he words at all, at least in the sense that adult listeners use and perceive words. Beginning especially with Waterson (1971), it became evident that the young speaker might be producing something more continuous than the series of discrete segments and syllables that listeners perceive when they hear a word, something rather closer to the acoustic wave that one sees in spectograms. Waterson observed that there was little segmental and syllabic congruence between Ps and her own forms. But when analyzed for featural content, irrespective of sequence, there was greater correspondence between adult and child forms. Waterson concluded that Ps speech was best specified in prosodie terms at the phonological level of analysis. A similar finding was reported by Peters (1977). Peters studied a child named Minh, and observed that by about 18 months, Minh was producing two kinds of speech: Analytic, which progressed in the way child language researchers normally describe, from one-word utterances to two-word utterances, and so on; and Gestalt, "utterances in which, although the segmentai fidelity was not very great, the combination of syllables, stress, intonation, and such segments as could be distinguished combined to give a very good impression of sentencehood," (pp. 563-564). As early as 11 months of age, Peters said, Minh's speech showed that he was "learning the tune before the words" (p. 563). The Place of Grammar Ellis (1996) explored the consequences of the proposition that language can be understood primarily as phonological sequences. In this view, as he said (p. 91), "much of language acquisition is in fact sequence learning and . . . abstract grammatical knowledge comes from analysis of sequence information." Phonological sequences are "chunked" in long-term memory (LTM), in a way that serves both speaking and hearing: 'The same cognitive system that stores LTM for phonological sequences perceives incoming phonological sequences. Thus, the tuning of phonological LTM to regular sequences allows more ready perception of input that contains regular sequences." In discussing UG (innateness) as an explanation of grammar, Ellis said he would place that explanation last: "I am sufficiently agnostic not to acknowledge the last possibility until it has been shown that distributional, prosodic, and semantic sources of information are clearly insufficient to cue syntactic class" (1996, p. 117). The UG quest has been for those syntactic regularities that parsimoniously describe languages (Chomsky, 1965, pp. 18-27), yet descriptive adequacy has been repeatedly frustrated by exceptions, as Pawley and Syder (1983) and others have shown. Under the circumstances, it is useful to consider turning the problem inside out. In this view, we might think of languages as composed of rich and various expressions following general phonological patterns. The mind generalizes, constantly, uncontrollably. In hearing and remembering phonological patterns, the mind generalizes about them, too, seeking always to simplify the process of interpreting the senses, and therefore seeking to know in what circumstances a pattern is appropriate, and what its limits are. In this view, grammar is the set of default options that native speakers revert to in cases of doubt (including, of course, cases in which linguists seek native speakers' judgments of grammaticality). Grammar is a generalization after the fact. Grammatical generalizations, produced in this way, are likely to admit of patterns, some of them grand and some of them subtle, and all of them subject to exceptions. They are exactly the kind of phenomena that can occupy the attentions of excellent researchers for lifetimes-but even that fact can never make them causes, but only the effects of mental processing. As we have seen, the profundity of prenatal learning places it in position at least partly to supplant theories that envision genetic transmission of syntactic frames. Just as Devlin, Daniels, and Roeder (1997) showed that much of IQ is not genetic but instead a result of interaction with the mother, so it appears that much of grammar is not genetic but is instead taken from the speech of the mother as phonological prototypes, not as rules. A Single System for All Aspects of Language I have mentioned in passing that speech and hearing are served by the same "neural structures" (lieberman, 1984) or "cognitive system" (Ellis, 1996). In discussing language as phonological sequences, it is important to emphasize that phonology does not exist by itself as a separate mental process, but is instead inseparable from meaning. Miller (1990) mused that this inseparability may be a unique characteristic of human mental processing: Human language is the happy result of bringing together two systems that all higher organisms must have: a representational system and a communication systern. ... A representational system is necessary if an organism is going to move around purposefully in its environment; a communication system is necessary if J an organism is going to interact with others of its own kind.... It is certainly true 'that human beings are not the only animals capable of a complex representational intelligence, nor are they the only animals that communicate. But human beings >do seem to be the only animals hi which a single system serves both functions. (1990, p. 12) The fact that sound and meaning are aspects of a single process of doing language means, of course, that they are learned together. This is another reason linguists have been slow to recognize prenatal language learning. If meaning is thought of as the complex symbolic system of adults, then it is obvious that infants, much less fetuses, are incapable of handling it. But meaning is not primarily abstract and symbolic; it is emotional. Meaning seems to start in the limbic system of the midbrain, with feelings and moods (Cytowic, 1996, pp. 100-106). An emotional stance is part of every meaning-and that part is available to the fetus even before hearing. Because of this, prenatal learning establishes the basic system for the integrated processing of sound and meaning. Peters's (1977) description of Minh, who could express meaningful sentences even though the words didn't make sense, is an example of the early integration of sound and meaning. It seems clear, that the most fundamental neural structures for the uniquely human integration of sound and meaning are established in the fetal brain. The development includes both particularization and generalization. Each developing baby grows neural tissues in response to his or her own environment and no other. Patterns that repeat themselves-common elements of different experiences-are strengthened in a way that we might call generalization. So it is that the babies in the womb develop not only fundamental skills but also the fundamental integration of sound and meaning that makes them uniquely human. ADVICE TO FAMILIES Some popular books of advice on prenatal care (for example, Ludington-Hoe, 1985) recommend that expectant families play music or read regularly to the unborn child, in the hope of improving the child's intelligence or musical or language ability. Other books offer less than enthusiastic support for these practices. For example, Eisenberg, Murkoff, and Hathaway (1991, p. 187) cautioned that "what [these practices] will mean in the long run isn't really clear." The difference of opinion is due to the absence of general understanding of prenatal learning. The previous pages are an attempt to summarize current knowledge about linguistic development in the womb. Not everything is known, of course, but it is enough, perhaps, to allow some comments on what families can expect and what they can do. From available evidence, without any special attention from parents, fetuses have been wresting with learning and understanding for millenia. They are in that business, and they do it far better and more subtly than we can imagine. What, then, is the family's motive for affecting the course of prenatal learning? Is the motive to give the child a competitive leg up in the IQ wars of a formal educational system? That is a culturally specific, and some would say wrongheaded, goal. What the fetus is learning is far more fundamental than cramming for tests. For the family, then, a better motive is to help the fetus prepare for full and rich participation in the social life and the emotional and meaningful activities of the surrounding society. Musical Activities Much has been written about music for prenatal learning, as though it were some kind of pre-language appropriate for babies before baby talk. It is not that, but it has its role. Music is a special kind of language-simpler and more stylized than natural languages-a distillation of the almost random rhythms and tones of natural sounds. I am not sure if human beings have an innate aesthetic sense, but if they do, surely it is manifested in their reactions to music. Music is understandable on its own level, but familiarity with it also feeds through into activities of daily experience. On its own level, music can be a profound experience for the fetus. One of its effects can be to relieve stress. Schwartz (1997, p. 20) applied this principle in his practice of anesthesiology. He asked couples what they and their baby wanted to hear during their C-sections. In each case, the effect of the music was to relieve stress, but the requests themselves ranged from Beethoven piano sonatas to Bruce Springsteen's "Born in the USA," which, Schwartz observed, "did seem fitting for the occasion." Fetal experience with music also affects the later life of the child. Lafuente et al. (1997) conducted an experiment in which violin sounds were regularly played to 101 babies in the womb beginning at about 28 weeks of pregnancy. These authors reported that the effects at six months after birth included statistically significant differences (with a control group of 71 infants) in, among other things, the infants' ability to interact with others and to initiate vocal sounds. It seems likely that music is effective both for guiding the feelings of the unborn baby and for instilling a fundamental responsiveness to the music of the mother's culture. What kind of music is best? Because the baby is learning what emotions go with what sounds, a mother should consider (1) what kind of music deeply moves her, and (2) what kind of music she performs herself. In the experiment of Lafuente et al., violin music was presented in recorded form. Although the results were positive, I wonder how many of the mothers liked violin music. I wonder if any of the mothers actually played the violin themselves. Presenting recorded sounds to the fetus runs the risk of associating them with feelings that they are irrelevant or even annoying. Far better, I think, to offer music to which the mother responds with her whole feeling and body. If that is violin music, well and good. If it is Bruce Springsteen, also well and good. What is important is that the music be offered together with an attitude toward it that the family wants to build into the baby's brain. That attitude should, I think, be one of deep appreciation of experiences that are aesthetically pleasing and relevant to the family's culture. Of course the most sincere and immediate experience of music is that which the mother performs herself. If she sings or plays an instrument she might choose her favorite popular songs or folk songs from her girlhood. One might suppose, although without evidence, that musical experience before birth leads to musical talent in the adult. This may be what happened in Mozart's case. Mozart, who never wrote a sour note in his life, said that he did not so much compose music but rather simply wrote down what he heard in his head. It is tempting to speculate that Mozart's brain combined a genetic talent for music with frequent exposure to it from the moment of his conception. But, before modern parents undertake to produce a Mozart, they should first make sure that they are beginning with genes of musical genius (an impossible task just now)! To summarize the influence of music: evidence from recent research is showing that playing music to the baby in the womb seems to galvanize his or her mental processes, with results such as increasing the baby's alertness and inclination to interact with the environment. There is some evidence that playing music enhances the baby's language skills. If, however, it is language skill that is wanted in the first place, a more direct approach would be to offer language itself. Language Activities In general, real activities that engage the mother's full interest seem best-and the more the merrier, provided the family remembers the unborn baby's need for frequent rest and relaxation from stress. Because the baby derives meaning from the mother's true emotional state, things that are boring to the mother are not likely to have the greatest impact on the baby. If the mother is bored by Peter Rabbit, she should not read it to the baby. If she is annoyed by violin music, she should not play it to the baby. When I said that the unborn baby begins to learn the mother's languages, I carefully put the "s" on languages. Different languages have very different voices, rhythms, sequences, etc., the very things that give them distinctive feelings and styles. Unborn babies learn the rudiments of as many languages as they hear, so of course the recommendation is that if you want your baby to be comfortable with more than one language, speak more than one language. I should comment on two typical worries. (1) Don't worry about giving equal time to each language; equal time is almost never natural. Instead, just try to offer some minimal experience in each language. (2) Don't worry about confusing the baby. Babies do not get confused about languages because human minds always understand utterances in terms of situations, and within any language one thing always leads to another within the same speech feeling. These two "don't worries" apply to unborn babies and to children after birth-even to adults. The father's role in all this should be as big as he can make it. Of course the baby cannot hear his voice as clearly as the mother's, nor can the baby gain intimate knowledge of his mood, heartbeat, etc. But the baby can hear him, and that is important. The father speaks with a different voice and often with rhythms and sequences different from the mother's speech. Perhaps more important, he holds up one end of dialogues. The baby is learning that speech is not always, or not even primarily, a solo activity, but instead involves giving and taking according to very subtle rules of exchange. So the father can perform a vital function simply by being in the room and conversing with the mother. I hope I have sufficiently emphasized that language does not exist by itself, but instead is inextricably bound with other human activities, notably those of exchanging meaning and achieving intersubjective understanding. Those few children who have been raised without language have also been socially and psychologically backward (e.g., Curtiss, 1977; Shattuck, 1994). The effect of parental speech is not to teach language by itself, but to teach whole experiences-sound, meaning, and feeling-in bundles. Experienced parents know that what the baby learns after birth is often different from what was intended. This is true, too, of the baby before birth. You may read Shakespeare to the unborn baby until you are blue in the face. You may even succeed in inscribing iambic pentameter into the baby's precious neural circuits. What you cannot do (if you do not genuinely like Shakespere) is to prevent the baby's learning the simultaneous reaction, "this stuff is boring, and if you read it until you are blue in the face, it only gets more boring." Beautiful and heartfelt words, like beautiful music, can be understood for what they are. But don't try to fake beauty. Take it as it comes-to you. Don't try to fake happiness; you can't fool the baby. If reading The Giving Tree (Silverstein, 1964) makes you cry, then read it that way, as something beautiful and sad. If some songs make you dance, then dance. The baby will get the message all the more clearly. Relax and know that you are presenting experiences to the baby. In general, don't try to simplify for the baby. The reason is, you don't know what you are doing. Nobody does. The sounds of a language consist not only of vowels and consonants, but also of tone, duration, voice quality, loudness, silence, etc.-and combinations of these that are sequenced in ways that are partly familiar and partly new. These sounds, in turn, occur as simultaneous aspects of a flow of feelings, moods, and meanings. If you try to simplify, you may cause disarray in what would otherwise be meaningful wholes. For this reason, it is better not to try to simplify, but to present language in all its complexity, at normal speed, as it naturally occurs. Know that you are presenting the baby with all kinds of experiences. The fetal child is likely to be paying attention not just when you sit down to read to him or her. The baby is your silent partner through all the day's activities. And if you think about it a moment, you realize that you wouldn't want the baby not to have the day's variety of experiences. Laughing, shouting, crying, joy, grim determination-all are part of daily human experience, and you don't want the baby to miss any of them or to fail to know the sound of your voice in each case. The most important recommendation, then, is simply lots of talking. Talk to all the people in your life, talk to the baby, talk to yourself, talk on the telephone, talk back to the TV, read, sing-everything as the mood strikes you. You are striving to give the baby the gift of gab, and that is no simple thing. It is the ability to produce more than a hundred or a thousand or a million different things to say, each in a different situation, using that infinitely variable instrument, the human voice. References

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