Discovering Sound Patterns in the Native Language[1]

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Abstract

Infants make their first contacts with their native language through its sound patterns. Research over the past twenty years has demonstrated that infants are well-equipped to perceive subtle distinctions in speech sounds and to cope with the variability that is present in the speech signal. At the same time, it is clear that in order to progress in acquiring a language, infants need to learn about the particular characteristics of the sounds and combinations of sounds that are used in their native language. Recent findings suggest that the time between 6 and 9 months of age may be a particularly fertile one for learning about the sound patterns of one's native language. There are indications that infants are developing sensitivity to distributional properties of sounds in the input at this time. The implications of these findings have for our understanding of processes underlying language acquisition will be considered.

Introduction

Twenty-five years ago, we had little understanding of how infants begin to make sense of the information that is available in the speech signal. At the time, a typical view was that the time course for learning to categorize and discriminate speech contrasts was protracted, and took several years to achieve (Shvachkin, 1973). Then the flood of findings from the first studies of infant speech perception led to a very different view of infants' capacities (Aslin, Pisoni, & Jusczyk, 1983). These studies indicated that within the first few months of life, not only could infants discriminate a wide array of speech contrasts, but that they also demonstrated a number of other sophisticated capacities for dealing with the variability that occurs in the speech signal (Eimas & Miller, 1980; Jusczyk, Pisoni, & Mullennix, 1992; Kuhl, 1979). The picture that emerged from these studies was that rather than requiring a long period of experience to develop speech perception capacities, the infant is innately endowed with these abilities (Eimas, 1974). Of course, whether these capacities were specific to language or reflected more general auditory capacities was, and still is, the subject of considerable debate (Eimas, 1982; Jusczyk, 1982; Kuhl, 1981).

As impressive as the demonstrations of the basic speech perception capacities of infant are, it is also clear that the infant has much to learn about the particulars of the sound structure of the native language. The organization of sound patterns in a particular language can differ on any of a number of dimensions (e.g., phonetic categories, phonotactic ordering constraints, rhythms, word stress patterns, tone structure, morphology, etc.) from that of another language. Thus, although innate perceptual capacities may provide a rough categorization of speech input, infants must still learn the details governing the organization of sound patterns within the native language. When do infants begin to learn about these aspects of the native language? Recent evidence suggests that the infant gains considerable information about the sound patterns of the native language during the first year of life. In what follows, I will review some of this evidence and its implications for language acquisition. I focus first on how sensitivity to global aspects of native language sound patterns develops. Then I present evidence regarding sensitivity to more fine-grained aspects of the sound structure of the native language. Finally, I suggest some ways in which information about global and fine-grained properties of native language sound structure may interact to promote the acquisition of information about other levels of linguistic organization.

Global Properties

At the grossest level, one could ask about when infants develop the capacity to distinguish utterances in the language that they are learning

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from ones in another language. Such a capacity would prove to be especially important for infants growing up in multi-lingual societies. Without some rudimentary capacity to separate utterances in one language from another, the task of discovering the underlying grammatical organization of a language would be virtually impossible. The generalizations that one might extract from a set of utterances from several different languages would not necessarily be revealing about the organization underlying any of the particular languages. Mehler et al. (1988) demonstrated that even newborn infants apparently have some capacity to distinguish utterances in one language from those in another. Specifically, they found that French newborns gave evidence of distinguishing utterances in French from ones in Russian. One of the remarkable aspects of these results was the fact that the infants were exposed to a wide variety of different utterances. Thus, it appears that the infants were extracting some general properties that hold across utterances within a particular language. Moreover, the same pattern of results obtained even when the speech samples were low-pass filtered at 400 Hz, suggesting that the infants may have be responding to prosodic differences (i.e., rhythm, stress, and intonation) between the two languages.

Given some indication that infants are sensitive to prosodic differences which could serve to distinguish utterances in one language from another, one can begin to investigate what information they are able to extract about the prosodic organization of their native language. In particular, are they sensitive to any sort of prosodic marking of important linguistic units in the speech stream? In other words, could the infant use information available in the speech signal as a stepping stone to learning about the grammatical properties of the language? One way in which prosodic information could be helpful in this process is by marking linguistically relevant processing units, such as clauses and phrases. The language learner needs to be able to recover such structures in order to work out the syntactic organization of the language. Without some sense of which portions of the speech signal should be grouped together for further analysis, the learner would be unable to derive the appropriate generalizations about the grammar of the language. Such would be the case if a learner mistakenly grouped a portion of one clause with a portion of an entirely different clause.

There are indications from studies with speech directed to adults (Lehiste, 1973; Nakatani & Schaffer, 1978; Price et al., 1991; Scott, 1982) and to children (Bernstein-Ratner, 1985; Fisher, 1991; Lederer & Kelly, 1991) that important syntactic units are often marked by changes in prosody such as changes in pitch contour, increased syllable durations and pausing. Naturally, in order for such information to be valuable to language learners, they must first have some capacity for detecting these kinds of prosodic changes in the speech stream. Several years ago, we (Hirsh-Pasek et al., 1987) set out to investigate whether infants are sensitive to prosodic marking of linguistically relevant units such as clauses. To do so, we collected a speech corpus from a mother talking to her 18 month old infant. We selected a number of different samples from the corpus and modified them to create two different versions of each sample. For one set of samples (Coincident versions) we inserted a series of 1 sec silent pauses at the boundary between two successive clauses. For the other versions of these samples (Noncoincident versions), we inserted an equal number of silent pauses but at locations between words within a clause. We reasoned that if infants were sensitive to prosodic markers of clause boundaries, they might find the passages with the pauses at the clause boundaries preferable to those with pauses at within clause locations.

The method that we used was a version of the headturn preference procedure (see Hirsh-Pasek et al., 1987 for a detailed description). The infant was seated on a caretaker's lap in the middle of a three sided enclosure. On the side facing the infant was a green light mounted at eye level which could be flashed to attract the infant's attention to center. A red light was mounted on each of the two side-panels and behind each of these lights was a small loudspeaker. An observer sat behind the center panel and observed the infant through a small hole in the panel. She held a response box which had a series of buttons which were used to initiate and terminate test trials and to indicate when the infant was oriented in the direction of the red light on the side panel. The response box was tethered to a PDP 11/73 computer which selected the appropriate speech sample for a given trial, played the samples out, and recorded the duration of the infant's looking time in the direction of the flashing side panel light. At the start of an experimental trial, the green light at the center panel began to flash. When the observer was satisfied that the infant was facing midline, she pressed a button on the response box which turned off the green light and caused one of the two red side panel lights to begin flashing. When the infant oriented in the

direction of the side light, the observer pressed another button which initiated the speech sample and began timing the infant's looking time. Whenever the infant looked away, the observer pressed another button which stopped the timer, and if the infant looked away for more than 2 sec., terminated the trial. If the infant looked away for less than 2 sec. and then looked back at the light, the timer was re-started and the trial continued either until the sample was completed or the infant turned away for 2 consecutive sec. Each infant heard 6 Coincident and 6 Noncoincident samples during the test phase.

Our results indicated that 9 month old American infants' listening times to the Coincident samples were significantly longer than to the Noncoincident samples. In subsequent studies (Jusczyk, 1989), we demonstrated that even infants as young as 4 1/2 months of age listened significantly longer to the Coincident samples. We also explored whether the prosodic information alone was sufficient to produce the longer listening times to the Coincident samples. For this purpose, we low-pass filtered the Coincident and Noncoincident samples at 400 Hz to eliminate most of the available phonetic information in the samples. Six month old infants exposed to these low-pass filtered samples displayed the same listening preferences for the Coincident versions. These results suggest that attention to prosodic markers of clausal units could help infants to segment the speech stream in a linguistically relevant manner.

There are indications that the kinds of prosodic changes that occur at clause boundaries in English, also occur for many other languages (Cruttenden, 1986). Hence, it may be that infants are responding to the Coincident versions of the samples, not because they have picked up something specific to English prosodic structure. Rather, their responsiveness to these types of prosodic changes may reflect more general processing of the input. Some support for the latter view comes from other studies that we have conducted. First, 4 1/2 month old American infants also listened significantly longer to Coincident versions of samples in an unfamiliar language (Polish) than they did to Noncoincident versions (Jusczyk, 1989). Second, studies with musical stimuli (Mozart minuets) indicate that 4 1/2 month olds listen significantly longer to samples with pauses inserted at musical phrase boundaries than they do to samples with pauses inserted in the middle of musical phrases (Jusczyk & Krumhansl, 1993; Krumhansl & Jusczyk, 1990). Interestingly enough, the cue that appear to signal musical phrase boundaries for infants are a decline in pitch and a lengthening of the final note at the musical phrase boundary. These cues parallel ones associated with clause boundaries (i.e., decline in pitch and clause-final syllable lengthening). Consequently, young infants' sensitivity to prosodic markers of clausal units may be an aspect of a more general tendency associated with auditory event perception.

Subclausal units

Although it is conceivable that infants may not need to learn about the particulars of prosodic structure in order to detect clausal units in their native language, the same cannot be said for subclausal units. The organization of units within clauses differs considerably from language to language. In languages like English, which use word order to indicate important grammatical relations, one might expect to find some prosodic marking of information which occurs together within the same phrase. However, case languages like Polish use affixes to mark grammatical relations and allow much freedom in ordering words within a clause. Two words within the same could be separated by words from other phrases. Thus, any prosodic marking of phrasal units in Polish would likely look very different from that which occurs in English. For this reason, one would expect that infants need to discover how any prosodic marking of subclausal units occurs in their native language.

Jusczyk et al. (1992) investigated when American infants might show sensitivity to prosodic marking of major phrasal units (Subject Phrase; Predicate Phrase) in English. Once again they modified speech directed to an 18 month old and inserted 1 sec. pauses either at (Coincident versions) or within (Noncoincident versions) phrasal units. An example of a typical Coincident sample (where / indicates the inserted pause) is the following:

"Many different kinds of animals / live in the zoo. The dangerous wild animals / stay in cages. Some of the animals / are friendly and like to be petted. .."

The Noncoincident version of the same sample goes as follows:

"Many different kinds / of animals live in the zoo. The dangerous / wild animals stay in cages. Some / of the animals are friendly and like to be petted..."

At 6 months of age, the infants' listening times to the Coincident and Noncoincident versions did not differ significantly. However, by 9 months of age, the infants had significantly longer listening times for the Coincident versions of the samples. Thus, in contrast to the results observed for clausal units, sensitivity to prosodic markers of phrasal units in English does not appear to develop until some time between 6 and 9 months of age. Jusczyk et al. speculated that this is because infants may require more familiarity with native language sound structures before they can detect prosodic marking of phrasal units. In any case, the results of this study indicate that infants are picking up information about the prosodic organization of their native language well before their first birthday. Just how far the infant can go towards acquiring the syntactic structure of the language is still an open question. However, there are indications that prosodic organization does not always line up with syntactic organization (Beckman & Edwards, 1990; Gee & Grosjean, 1983; Morgan, Meier, & Newport, 1987). Discussion of how infants may be able to cope with these sorts of prosodic/syntactic mismatches will be taken up in the final section of the paper.

Global features as organizers of the input

The findings demonstrating that infants appear to be sensitive to potential prosodic markers of grammatical units in the input are in line with the view known as prosodic bootstrapping (Gleitman & Wanner, 1982; Morgan, 1986; Peters, 1983). Briefly, this view suggests that the infant may be able to gain access to important aspects of the syntactic organization of language by attending to prosodic markers in the speech stream. However, in order for a prosodic bootstrapping account of language acquisition to be viable at least three conditions need to hold. First, there must be evidence for acoustic markers of syntactic units in child-directed speech. Second, the potential prosodic correlates must be ones that infants are able to detect in the speech stream. Third, there must be some indication that infants actually rely on these correlates in organizing the input. As noted above, there is evidence for the first of these conditions (Bernstein-Ratner, 1985; Fisher, 1991; Lederer & Kelly, 1991) and the studies just reviewed provide some indication that infants are able to detect such cues in the input. To this point, I have not considered any evidence regarding the third condition. However, a recent study (Mandel, Jusczyk, & Kemler Nelson, 1993) has begun to take the first steps in this direction.

How might it be determined whether infants actually do make use of prosodic structure in organizing the speech input that they hear? In other words do these prosodic markers serve any psychologically real function in infants' speech processing? The issue here is akin to one that was faced by psycholinguists in the early 1960's when they tried to convince skeptical behaviorists that clausal and phrasal units really do play some role in how adults process speech. One successful procedure was to demonstrate that materials organized into linguistic units were actually better remembered than arbitrary groupings of the same materials (Epstein, 1961). Mandel et al. decided to adopt a similar method in their study with infants. Specifically, they sought to determine whether speech information is better remembered by infants when it occurs in the context of sentential prosody as opposed to a list format. Two-month-old infants were tested using the High Amplitude Sucking (HAS) measure because this procedure had been used effectively in the past to investigate infants' memory for speech (Jusczyk et al., 1992). Mandel et al. hypothesized that if prosody helps infants in organizing the input during on-line processing, then memory for words should be better in a sentential context than in a list. The sentential materials for the experiment included 3 sentences which were recorded as part of a group of 30 sentences. The list materials included the same sequences of words in the same order. These were recorded as part of a longer list of 75 unrelated words. Half of the infants in the study heard the sentences, and the other half heard the lists. The overall durations of the list sequences were equated to the comparable sentences. During the preshift phase of the experiment the infant heard either a single sentence or list sequence (e.g.., "The rat chased white mice"). When the infant's sucking response habituated to this stimulus, the preshift phase ended and was followed by a two-minute silent interval in which a series of colorful slides were presented. Then the postshift phase began. The infants heard either the same stimulus as in the preshift phase (Control), one that differed by a single word (1 Phonetic Change e.g., "The cat chased white mice"), or one that differed by two words (2 Phonetic Changes e.g., "The cat raced white mice"). The results indicated that not only were infants more likely to increase their sucking in response to changes involving two words rather than one, but also that performance was significantly better for the sentential materials than for the lists. Thus, the results indicate that

even 2-month-olds are able to benefit from the organization offered by sentential prosody in remembering speech information. This suggests that not only are infants sensitive to prosodic markers in the speech stream but that these may play a role in how infants remember speech.

Of course, the full extent of the infant's ability to use prosodic information in organizing the input is yet to be determined. In particular, it would be useful to obtain information regarding the effectiveness of sub-clausal units. Unfortunately, since the available data suggest that sensitivity to prosodic marking of such units does not develop until around 9 months of age, new procedures will have to be used to investigate this matter.

Fine-grained Properties

Many of the most striking differences that we observe among the sound patterns of different languages have to do with the nature of their phonetic segments and syllable structures and how these are organized into words in the language. As noted at the outset, soon after birth infants demonstrate the capacity to discriminate many subtle differences among speech sounds. Still one can ask about when these capacities are used to provide infants with information about the presence and organization of the more fine-grained properties of native language sound patterns. Indeed, there are indications that the use of information about word stress patterns (Cutler & Carter, 1987; Cutler & Norris, 1988) and ordering constraints on phonetic segments (Church, 1987) could provide the listener with useful information about word boundaries in the speech stream.

Detecting regularities in word stress

Certainly, one of the important tasks facing the language learner is to identify the boundaries between distinct words in the input. We know that in fluent speech these boundaries are often obscured and that this presents real problems for machine recognition of words (Klatt, 1980) Recently, Cutler and her colleagues (Cutler & Butterfield, 1992; Cutler & Carter, 1987; Cutler & Norris, 1988) has put forth an intriguing suggestion as to how English listeners might cope with the problem of isolating words in the speech stream. Cutler noted that in conversational speech, the overwhelming majority of words are either monosyllables or multisyllabic words which begin with a strong syllable. On the basis of this finding, she proposes that English listeners could make a plausible first pass at segmenting the input into words by simply finding the strong syllables and assuming that each begins a new word.

Could English language learners benefit from a similar strategy? Interestingly enough, a recent study suggests that the tendencies which Cutler observed in her adult corpus are if anything exaggerated in speech directed to children (Kelly & Martin, in press). Naturally, the only way that children could benefit from this fact regarding word stress in conversational speech is if they first detected that there is a predominant pattern in the input. So the first question to be addressed is when , if at all, do English learning infants become sensitive to the predominant stress pattern of English words? Jusczyk, Cutler and Redanz (1993) addressed this issue by presenting American infants with lists of bi-syllabic English words that either followed (i.e., strong/weak) or did not follow (i.e., weak/strong) the predominant stress pattern. The infants were tested using the headturn preference paradigm. On a given test trial the infant heard a list of bisyllabic low-frequency English words which had the same stress pattern. On 6 trials, the words had a strong/weak pattern and on the other 6, they had a weak/strong pattern. When 6 month olds were tested, they showed no difference in how long they listened to each type of list. However, when 9 month olds were tested on the same lists, they listened significantly longer to the lists of strong/weak words. Moreover, when the lists were low-pass filtered, the 9 month olds continued to favor the strong/weak patterns, which suggests that they are not simply responding to the words on the basis of some phonetic properties. Rather, it looks as though, some time between 6 and 9 months of age, sensitivity to the predominant stress pattern of English words is developing in American infants.

Sensitivity to phonotactic constraints

One important way in which languages differ is in terms of which elementary sounds and combinations of sounds that they use to create words. Thus, out of the set of all possible phonetic segments that can appear in human languages, the words of a particular language are drawn from only a selected subset. Thus, English lacks the vowel [y] which appears in French words such as "tu", and French lacks the sound [θ] which appears in English words such as "thin". But languages also differ in another important way, namely, in the way in which they

order the segments that they do use in forming words (i.e., their phonotactic constraints). So, although both English and Polish contain the segments [b, d, k, t], they differ in whether these can be combined at the onset of words. Polish allows sequences such as "kto" and "dba", but in English such sequences could only occur across a syllable boundary as in "blacktop" or "redbird". Given that one of the important tasks facing the language learner is to build up a vocabulary or lexicon in the native language. We can begin to ask about when the infant begins to recognize whether a sequence of sounds could be a possible word in his or her native language.

To address this question, Jusczyk, Friederici,Wessels, Svenkerud, and Jusczyk, (1993) tested infants on lists of unfamiliar words, either from their native language or from a foreign language. A bilingual Dutch/English talker was used to record the stimulus materials. These two languages were chosen because they have very similar prosodic structures, but differ in terms of which phones they use and the orderings of phonetic segments which they permit. For example, Dutch does not allow the vowel that appears in English words like "few". English does not contain words that begin with the sound at the beginning of the Dutch word "gouda". Dutch, but not English, allows sequences like [kn] and [zw] to begin syllables. English , but not Dutch, permits segments like [d] or [b] to end syllables.

The headturn preference procedure was used to test the infants on 6 Dutch and 6 English lists of words. Jusczyk et al. found that at 6 months, American infants did not listen significantly longer to either list. However, at 9 months of age, American infants listened significantly longer to the English lists. To determine whether the infants might be responding on the basis of prosodic (rather than phonetic or phonotactic) differences, the lists were low-pass filtered. Without access to the phonetic and phonotactic information, the infants showed no tendency to listen significantly longer to the native language lists. In another experiment, Jusczyk et al. investigated whether violations of native language phonotactic constraints alone might influence infants to listen longer to native language word lists. This time, Dutch 9 month olds were tested along with American 9 month olds. The results indicated that each group listened longer to the lists in their own native language. Hence, there does appear to be some indication here that, by 9 months of age, infants have picked up some information about the kinds of phonetic sequences which can appear in words in the language that they are acquiring.[2]

There are also some indications that the developing sensitivity to phonotactic patterns of the native language may go well beyond what is needed to distinguish native from foreign language patterns. In particular, recent research (Jusczyk, Charles-Luce, & Luce, in preparation) suggests that infants may be sensitive to the frequency with which certain phonotactic sequences occur in native language words. In this case, all of the phonotactic sequences presented to infants were permissible in English words. However, some of the sequences occur with great regularity within English words, and other sequences are only infrequently observed. Information about the prevalence of such sequences in the input could have important implications for structuring the lexicon to facilitate word recognition.

In order to investigate whether infants are sensitive to the distribution of such sequences in speech input, Jusczyk et al. prepared lists of CVC items. Six of the lists were composed of items whose phonetic sequences occur with high frequency in English; the other 6 lists contained items with sequences that appear with low frequency in English words. Once again, 6 month old infants did not listen to one type of list significantly longer than to the other. However, when the same infants were tested at 9 months of age, they had significantly longer listening times for the lists embodying the items with the high frequency phonotactic patterns.

The results of these studies suggest that infants are not only learning about the fine-grained structure of native language word patterns, but that they are remarkably sensitive to the distribution of these patterns in the input. Sensitivity to these aspects of the input may have important implications both for how the lexicon becomes organized and for the development of the recognition of words in fluent speech. This general issue is discussed elsewhere in considerable detail (Jusczyk, 1992; Jusczyk, 1993).

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[2] This study also produced some indication that when there are marked prosodic differences between native and foreign language words, then sensitivity to the native language patterns may develop as young as 6 months of age. Specifically, American infants displayed significant preferences for English word lists over Norwegian word lists. The prosodic structure of Norwegian words is differs from English in a number of ways (see Jusczyk et al., 1993 for further details).

Discovering words in the input

The fact that infants between 6 and 9 months of age appear to be acquiring considerable information about native language sound patterns leads one to ask about when they begin to recognize words in fluent speech. Certainly, there are reports that infants begin comprehending some words at around 9 months of age (Huttenlocher, 1974).

How might infants begin to learn to recognize words in the speech stream. One possibility is that they first learn to identify words heard in isolation and then match their representations of these words to patterns heard in fluent speech (Suomi, 1993). However, there are some problems with this approach. First, the acoustic characteristics of a word spoken in sentential context may differ considerably from one spoken in isolation (Klatt, 1980). Second, certain sound patterns associated with monosyllabic words (e.g., "can") may occur as parts of larger words (e.g. , "candle", "toucan", "candidate", etc.) Third, some words in the language, such as function words, are unlikely to ever be heard in isolation. Consequently, even if some word learning does occur by first recognizing the sound pattern of a word in isolation, there must also be other routes to learning words. One such alternative is that when children are taught new words in sentential contexts, these items are placed in prominent positions in the utterance such as at the ends of sentences (Woodward & Aslin, 1990).

To begin to explore these issues, Jusczyk and Aslin (Jusczyk & Aslin, in preparation) modified the headturn preference paradigm to see whether infants who were familiarized with a particular word, heard in isolation, would be more likely to listen to sentences containing that word. Four different monosyllabic words were chosen for the study -- "feet", "bike", "cup" and "dog". Fifteen repetitions of each word were recorded and digitized. In addition, four passages, each containing 6 sentences, were recorded. For a given passage, the same test word appeared in all 6 sentences. The position of the test word within the sentences was varied so that it occurred twice at the beginning, middle and end of the sentences. An example of one of the passages is the following:

"The cup was bright and shiny. A clown drank from the red cup. The other one picked up the big cup. His cup was filled with milk. Meg put her cup back on the table. Some milk from your cup spilled on the rug."

At the start of each experimental session, 7 1/2 month old infants were familiarized with two of the words on alternating trials until they accumulated 30 sec. of listening time to each word. Half of the infants were familiarized with "cup" and "dog" and the other half were familiarized with "bike" and "feet". Then the test phase began. During this phase, each of the four passages was played. The passages were randomly ordered within a block of four passages. There were 4 such blocks during the test phase. Listening times to each of the passages were recorded to determine whether infants listened longer to the passages containing the familiar target words. The results indicated that the passages with the familiar target words had significantly longer listening times than the ones with the unfamiliar target words. At each test session, the infants' parents completed a questionnaire. The questionnaire asked about the words that they thought their infant "knew", and asked the parents to rate the likelihood that the infants knew the familiar or unfamiliar targets. There was no indication that the infant's prior knowledge of the words played any significant role in the listening times recorded in the experiment. Nor was there any indication, irrespective of the initial familiarization period, that infants found one of the passages simply more interesting to listen to. On the basis of these results, Jusczyk and Aslin concluded that exposure to the target words in isolation made them more likely to attend to passages containing these words. Thus, 7 1/2 month olds demonstrate some capacity to recognize a word in sentential contexts after first hearing it in isolation.

Although the capacity that 7 1/2 month olds displayed in going from isolated words to words in sentential contexts is impressive, one could argue that it is a lot easier to learn words this way than the other way around. That is, the task for the learner would seem to be considerably more difficult if she had to learn the word first from sentential contexts. To investigate this possibility, Jusczyk and Aslin decided to familiarize the infants with two of the passages first and then see whether the infants would listen longer to the target words that appeared in these. During the familiarization phase, on alternate trials, the infants heard two of the passages until they accumulated 45 sec. of listening time to each. In the test phase, the stimuli were the repetitions of the four target words produced in isolation (e.g., "dog", "dog", "dog", ... , "dog"). Evidently the infants had some capacity to recognize the repeated word from the passages because they listened

significantly longer to the target words from these passages.

Could it have been that the infants were successful because the target words were more strongly emphasized in the sentences than the surrounding words? Acoustic analyses conducted on the passages indicated that this was not the case. The target words were seldom the first or even second most strongly stressed words in the sentences. In fact, sometimes they were even the fourth most stressed items in the sentences.

Many questions remain about how precisely detailed the representations are that infants develop about the words in this situation. However, it does appear to be the case that, by 7 1/2 months, infants have some rudimentary capacity to detect the occurrence of a particular word in sentential contexts. That word recognition processes may begin to develop at this time seems consistent with the other developments taking place in learning about fine-grained properties of native language sound patterns.

How Global and Fine-grained Properties May Interact During Language Acquisition

The picture to this point shows that infants are developing sensitivity to many aspects of native language sound structure during the period between 6 and 9 months of age. In addition to the evidence presented here, there are also indications that infants are developing sensitivity to native language vowel categories (Grieser & Kuhl, 1989; Kuhl, 1991; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Werker, Lloyd, & Pegg, 1993). Moreover, the period covered by the growth in sensitivity to native language sound structure also seems to parallel roughly the decline in sensitivity to certain foreign language speech contrasts (Best, 1991; Best et al., 1990; Best, McRoberts, & Sithole, 1988; Polka & Werker, 1991; Werker & Lalonde, 1988; Werker & Tees, 1984). Thus, it is clear that during this time infants are learning about how sound patterns are structured in their native language.

The fact that infants display such sensitivity to the distribution of sound patterns in the input raises some interesting issues about the role of such information in language acquisition. Although there have been some attempts to account for the acquisition of grammatical structures in terms of distributional properties of items in the input to the child (Maratsos & Chalkley, 1981), the traditional view holds that the input is simply too noisy and full of errors to permit the child to derive the correct grammatical categories and relations (Chomsky, 1965). However, given the recent findings on possible prosodic markers of grammatical units in speech directed to children and the data demonstrating that infants appear to be sensitive to such markers, how far could prosodic bootstrapping take the infant towards working out the syntactic organization of the native language?

There is good reason to believe that reliance on prosodic features of the input will only take the infant so far in discovering the syntactic organization. First, prosodic boundaries do not always correspond to syntactic boundaries in the input (Hayes, 1989; Nespor & Vogel, 1986; Selkirk, 1981). Second, these kinds of prosodic/syntactic boundary mismatches even occur in the types of sentences likely to be directed to children who are beginning to acquire language. In the following two sentences, a typical talker is likely to produce a prosodic break between the subject and predicate phrase in the first case, but not the second. Any prosodic break in the latter is more likely to come between the verb and its complement (Fisher, 1991).

(1) Ellen / threw the ball.
(2) She threw / the ball.

In fact, even 2 year olds are more likely to produce a prosodic boundary between the verb and its complement in sentences like (2). This is because a weakly stressed pronoun subject like "she" tends to be phonologically joined to a following stressed verb. In cases like this, the subject and verb tend to form a prosodic unit. As a result, there is no prosodic marking of the syntactic boundary between the subject and predicate in sentences like (2).

What, then, can we make of the data reported by Jusczyk et al. (Jusczyk et al., 1992) indicating that infants listened significantly longer to passages with pauses inserted between the subject and predicate phrases? It turns out that only about 15% of the spontaneous speech samples used by Jusczyk et al. contained mismatches of the sort found in (2). Because these items were dispersed throughout the speech samples, it was not possible to determine just how infants responded to them. For this reason, Gerken, Jusczyk, and Mandel (submitted) designed a new set of stimulus materials which allowed for a direct comparison of structures like those in (1) and (2). Half of the infants heard pairs of sentences with lexical noun phrase subjects like sentence (1). Coincident versions of

these sentences were prepared by inserting a 1 sec. pause between the Subject and Predicate phrases. Noncoincident versions of the same sentences had pauses inserted between the verb and its complement. The other half of the infants heard Coincident and Noncoincident versions of sentences with pronoun subjects like (2) which were prepared in analogous fashion. Nine month olds who heard the sentences with the lexical noun phrase subjects behaved exactly like the infants in the Jusczyk et al. study -- i.e., they listened significantly longer to the Coincident versions of the samples. In contrast, 9 month olds exposed to the sentences with pronoun subjects did not show a significant preference for either the Coincident or Noncoincident versions. The pattern of responding in this case was consistent with the behavior of the talker who had produced these samples. She typically produced the pronoun sentences without any sentence-internal prosodic boundary cues.

How, then, do infants learn to extract information about the syntactic structure of sentences like (2)? One possibility is that they have access to situations in which pronouns like "she" are prosodically marked as included in units separate from the predicate. Of course, for this information to be useful, the infants would have to be capable of recognizing a pronoun like "she" when it occurs in different sentential contexts. The recent findings by Jusczyk and Aslin (in preparation) showing that 7 1/2 month olds do detect familiar words in sentential contexts suggests that they may be able to draw on information regarding the appearance of a particular word in different contexts. The next question is whether the appropriate contexts in which the pronoun and verb belong to different prosodic units actually occurs in the kind of speech directed to children. In fact, Yes-no questions (e.g., "Did she / throw the ball?") provide just such a context. In these cases, there is a tendency for the pronoun and auxiliary to form a prosodic group which is separate from the Predicate phrase. When Gerken et al. tested 9 month olds on materials like these, they found that infants listened significantly longer to passages in which a pause was inserted between the Subject and Predicate phrases.

The point to be made here is that even when the prosodic units do not match the syntactic organization of the utterances, infants may be able to draw upon other information that they have picked up about native language sound patterns to help resolve potential conflicts. Learning to recognize words in different contexts is one such source of information. Furthermore, there is no reason why these additional sources of information must necessarily be limited to the sound properties of the native language. Information gained about the semantic and syntactic properties of the language could also be brought to bear in resolving such mismatches.

The solution just offered about how such conflicts may be resolved does assume that infants are sensitive to paraphrases and other re-organizations of words that occur in utterances in the input. We know that paraphrases are often common in parental dialogues with children, but what evidence is there that infants may attend to these? Preliminary findings from a study which I am conducting in collaboration with LouAnn Gerken and Deborah Kemler Nelson suggests that infants' attention may be drawn to such recombinations of words. Using the headturn preference procedure, we familiarized 9 month olds with pairs of sentences which had either the same syntactic structure, such as (3) and (4) or different syntactic structures, such as (4) and (5).

(3) The farmer's wife saw the devout man in church.
(4) The bus driver heard the big truck on the curb.
(5)The farmer's wife saw that the brown cow escaped.

During the test phase, the infants heard the original versions of the sentences plus two new sentences. For half of the infants, the new sentences had the structure of (4) but were composed of entirely different lexical items. For the other half of the infants, the new sentences consisted of recombinations of words from the familiar sentences (e.g., "The bus driver saw that the brown cow escaped"). The interesting finding that emerged was that the longest listening times occurred for the condition in which the familiar words were recombined across sentences with different syntactic structures. Although we are currently following up this experiment by using new materials with a different kind of syntactic contrast, these first results appear to indicate that 9 month olds are attentive to rearrangements of the same words into different sentence structures. Should this pattern prove replicable in subsequent experiments, it would provide support for the notion that attention to the distribution of information within utterances may help the infant to go beyond prosodic organization towards syntactic organization.

In conclusion, there is evidence that within the first year of life infants acquire important information about the sound structure of the native language. Not only are they sensitive to the global prosodic organization of the input, but

they also appear to pick up information about the more fine-grained features of native language sound patterns relating to its phonetic and phonotactic organization. The early grounding which infants gain with respect to the sound structure of the language may also help them in acquiring information about other levels of linguistic organization. Just how far information in the sound structure of the input can bootstrap the acquisition of other levels remains to be determined. However, it seems likely that the developing knowledge of sound structure helps the infant to converge on the grammatical organization of the native language.

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