9

Acquiring Linguistic Structure

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This chapter is an overview of what scientists currently know about human sensitivity to linguistic form during infancy. We can think of language form at two levels: a sub-meaning level that includes the sounds that combine to make words in a spoken language, and a meaning level that includes words and phrases that combine to make sentences. The ability to generate new combinations at both of these levels is what gives human language its infinite creativity. It is standard when discussing linguistic form to subdivide the territory into linguistic categories of various sorts (e.g., the phonological category "stop consonants" or the syntactic category "nouns") and rules, principles, or statistical regularities describing the typical ways in which these categories are combined (e.g., a stop cannot follow a liquid in word initial position in English).

The inclusion of such a chapter in a book on language development would probably not even have been considered 20 years ago. Why has the topic of infants' sensitivity to linguistic form become one of so much interest? I can identify two reasons, one methodological and one theoretical. The first is that, largely for technological reasons, the earliest studies of infant sensitivity to language asked questions about young learners' ability to discriminate acoustic–phonetic forms without any reference field (e.g., Eimas, Siqueland, Jusczyk, & Vigorrito, 1971; Werker & Tees, 1984). Later studies examining infants' sensitivity to linguistic units larger than individual speech sound or syllables continued to use discrimination, not association with reference, as the method of choice (e.g., Hirsh-Pasek et al., 1987; Jusczyk & Aslin, 1995). As the questions asked of infants using form discrimination measures became more and more linguistically sophisticated, it became clear that sensitivity to form may precede in many respects the ability to map forms to meanings (Gómez & Gerken, 2000; Naigles, 2002; see Naigles & Swensen, this volume).

A second reason for the field's interest in infants' sensitivity to linguistic form concerns the debate about whether language is learnable using a set of general purpose learning mechanisms, or whether we must posit strong innate constraints on the language acquisition process (e.g., Chomsky, 1981; see Saffran & Thiessen, this volume). This debate has often focused on linguistic form, particularly syntactic form. An argument favoring nativist views of language development is that any set of data can potentially give rise to an infinite number of generalizations. How can a learner be sure that she is making the correct generalization, given the data? The nativist solution to this question is to posit that learners are born strongly constrained to consider only a very restricted set of possible generalizations. In the limit, a single input datum might trigger the correct generalization in a particular linguistic domain (e.g., whether sentences require overt subjects; Hyams, 1986).

Contrary to such views, the recent research on infants' sensitivity to linguistic form hints at the possibility that, given a reasonable subset of the input data, infants are capable of converging on the appropriate linguistic generalizations, possibly using general purpose learning mechanisms coupled with general purpose perceptual/conceptual constraints. The logical observation that any set of input admits multiple possible generalizations which somehow must be constrained can be kept distinct from an empirical claim about the nature of the input – the "poverty of the stimulus" argument. This argument states that certain critical types of linguistic data are so rare that learners are not exposed to them early in language development (see Pullum & Scholz, 2002 and responses). Nevertheless, nativists argue, children have knowledge of the formal principles underlying the putatively unheard data. I return briefly to the poverty of the stimulus argument in the final section.

The data that I present in this chapter all come from experiments in which 6- to 18-month-old infants are tested on their preference for one auditory stimulus type versus another, with preference defined as greater attention to one stimulus type than the other over multiple trials in a controlled setting. In some studies, infants are tested on their ability to discriminate two types of stimuli based on existing knowledge they had when entering the laboratory. In other studies, infants are familiarized with new auditory stimuli and then tested to determine whether they can discriminate the newly familiarized stimuli from very similar stimuli. The question each researcher is asking is whether infants can discriminate two types of stimuli based on form alone, without assessing their interpretation of utterances. The careful reader will note that in some studies discrimination is reflected in greater attention to familiar forms, while in other studies there is greater attention to novel forms. Which type of preference is observed in which type of experiment may be related to how well infants were able to encode the relevant properties of the stimulus before testing, which itself is probably affected by the age of the infant, the length of exposure before testing, the complexity of the stimulus, and the complexity of the testing environment. At this point in the development of the field, researchers focus on whether or not infants demonstrate significant discrimination, regardless of the direction.

The next two sections address what is known about infants' sensitivity to phonological and syntactic form, in terms of categories and combinatorial regularities. The final section addresses what, if anything, the findings of infant sensitivity to linguistic form tell us about the nature of language development.

Sensitivity to Phonological Form

Languages of the world demonstrate a variety of patterns in the sounds that they use. For example, they select a subset of all possible humanly producible and perceivable sounds, and they do so in such a way that the sounds can be organized along a small number of dimensions (i.e., phonetic features such as voicing). Languages also restrict which sounds can occur in sequence, and again, they do so based not on particular sounds, but on featurally defined sound classes. Finally, languages assign stress to syllables of multi-syllabic words based on certain abstract properties, such as syllable shape (e.g., consonant–vowel–consonant) and position in a word (e.g., second to last). Below, we will consider what is known about infants' sensitivity to information in the speech signal relevant in each of these three areas.

Sensitivity to phonetic features

Let us begin this section by considering how infants determine what acoustic differences are relevant in their language and which are not. We might naïvely assume that infants lose their ability to discriminate sounds that are not in the input. However, such an assumption misses the point that many acoustic differences that are phonemic in one language appear in another language as allophones (contextually conditioned variants) of a single phoneme. For example, English-speakers have the option of releasing or not releasing and aspirating word final stops. Thus, English-learning infants may be exposed to both released and unreleased stops, but this phonetic difference does not affect meaning in English. The same acoustic difference does affect meaning in Hindi. What causes the English-learning infant and the Hindi-learning infant, both of whom hear variation in aspiration in their input, to treat aspiration differently?

One class of hypotheses is based on the observation that infants show a decline in non-native consonant discrimination at roughly the period of development that they begin to recognize and produce first words (e.g., Best, 1995; Jusczyk, 1985; MacKain, 1982; Werker & Pegg, 1992). Perhaps associating word forms with meanings as part of building a lexicon causes learners to focus on which aspects of form are relevant to meaning and which are not. A potential problem with this view is that infants' ability to discriminate non-native vowel sounds declines at about 6 months, a time at which word learning is not obviously underway (Kuhl et al., 1992; Polka & Werker, 1994). If a non-lexical mechanism for perceptual change exists for vowels, the same mechanism may explain developmental change in consonant perception as well. Another problem with views that depend on word learning for change in speech sound discrimination is that infants appear to have difficulty discriminating minimal word pairs at the early stage of word learning (Stager & Werker, 1997; Werker, Fennell, Corcoran, & Stager, 2002; see Polka, Rvachew, & Mattock, this volume). For example, an infant who easily discriminates *ba* from *pa* might have difficulty discriminating *bear* from *pear* in the early stages of word learning. It is difficult to see how such an infant could use word–meaning pairs to focus on voicing as an important feature of English words. Finally, even if a learner were able to use the meaning distinction between "bear" and "pear" to determine that /b/ and /p/ are distinct, this realization by itself does nothing to help them determine that the feature voicing is distinctive in English. In other words, do learners need to encounter a minimal pair that contrasts each possible pair of English phonemes (e.g., /b/ vs. /p/, /d/ vs. /t/, /z/ vs. /s/, etc.)? Or does determining that the phonetic feature voicing is important for distinguishing one pair of phonemes "buy" the infant a whole set of distinctions that depend on the feature voicing? The question of infants' sensitivity to phonetic features is important in the discussion in this and the following two sections.

Another hypothesis about the mechanism that underlies infants' focus on the phonetic features that are relevant in the target language concerns their attention to the statistical properties of their input (e.g., Guenther & Gjaja, 1996; Maye, Werker, & Gerken, 2002). On this view, an English-learning infant might hear a continuum of different degrees of aspiration on word final stops, with most of the values clustering around a particular point in the acoustic distribution. That is, English-learning infants are likely to hear a unimodal distribution of aspiration. Hindi-learning infants are also likely to hear a range of aspiration values; however, the values should cluster around two points in the distribution – one for segments in which the speaker intends aspiration and the other for intentionally unaspirated segments. Thus, the Hindi-learner is exposed to a bimodal distribution of this acoustic variable.

Research by Maye and colleagues suggests that even 6-month-olds respond differently to uni- versus bimodal distributions of speech sounds (Maye et al., 2002). Six- and 8-month-old infants were exposed for about two minutes to syllables that varied along the acoustic dimension represented by the endpoints of [d] as in *day* and the unaspirated [t] in *stay* along with filler stimuli (adult English-speakers perceive both endpoints as /d/). All infants heard all of the stimuli from an eight-token continuum. However, half of the infants heard a stimulus set in which most tokens came from the middle of the continuum (tokens 4 & 5, unimodal group), while the other half heard a set in which most tokens came from near the endpoints (tokens 2 & 7, bimodal group). During test, infants' listening times were measured as they were exposed to trials comprising either an ongoing alternation between the two endpoints (tokens 1 & 8, alternating trials) or a single stimulus from the continuum repeated (tokens 1 or 8, non-alternating trials). Each trial ended when the infant stopped fixating the visual target for a predetermined time. Only infants from the bimodal group responded differentially to the alternating versus non-alternating trials.

One interpretation of these findings is that exposure to a bimodal distribution helped infants determine that the acoustic dimension in question was potentially relevant. By contrast, exposure to a unimodal distribution made it more likely that infants would ignore the same acoustic difference. These results suggest that infants are able to perform some sort of tacit descriptive statistics on acoustic input. Does this statistical analysis reveal which speech sounds are distinct from each other in a pair-by-pair fashion (e.g., /pa/ vs. /ba/, /ta/ vs. /da/, etc.), or does it also reveal more abstract ways in which speech sounds might differ from each other (i.e., phonetic features)? Maye and Weiss (2003) found that 8-month-olds familiarized with a bimodal [d]~[t] continuum like that described in the preceding paragraph were able to discriminate a different, [g]~[k], continuum, which is based on the same phonetic feature. By contrast, infants exposed to a unimodal [d]~[t] continuum were not able to discriminate the [g]~[k] continuum. These data indicate that infants are able to generalize a contrast discovered via the statistics over one pair of sounds to another pair of sounds differing on the same featural dimension. It is interesting to note that adults exposed to stimuli similar to those employed by Maye and Weiss failed to generalize (Maye & Gerken, 2001). However, Maye and Weiss used multiple versions of each token in the continuum, while the study with adults did not. Therefore, we cannot determine at this point whether infants are more adept at featural generalization than adults, or if infants in the existing experiments were presented with stimuli that better promoted feature-based generalization.

Sensitivity to segment sequences

Two lines of research suggest that infants are sensitive to segment sequences in the speech stream. The first line was begun by Peter Jusczyk and colleagues, and it demonstrates that infants are able to discriminate words composed of sequences of segments that occur frequently in the infants' native language from less frequent (or entirely absent) sequences (Gerken & Zamuner, in press; Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; Jusczyk, Luce, & Charles-Luce, 1994; Sebastián Gallés & Bosch, 2002). The second line of research demonstrates that infants are able to learn new segment-sequencing patterns in a brief laboratory exposure. In one study of the latter sort, Chambers, Onishi, and Fisher (2003) familiarized 16.5-month-old infants with consonant–vowel–consonant (CVC) syllables in which particular consonants were artificially restricted to either initial or final position (e.g., /bæp/ not /pæb/). During test, infants listened significantly longer to new syllables that violated the familiarized positional constraints than to new syllables that obeyed them. In this study, infants could have responded based on familiar segment-by-syllable position correlations (e.g., b first, p last). That is, there is no evidence that they encoded the sequence constraints in terms of features.

Two similar studies suggest that infants are able to encode segment sequences in terms of featural relations. Saffran and Thiessen (2003) familiarized 9-month-olds with words with a consistent word-shape template. For example, in one condition of their second experiment, infants were familiarized with CVCCVC words which had the pattern +V, –V, +V, –V on the four consonants (e.g., /gutbap/). Infants were then tested to determine if they were able to segment from fluent speech new words that fit versus did not fit the familiarized pattern. The familiarization and test words were designed so that no particular sequence of consonants occurred in both familiarization and test (e.g., g_tb_p occurred in familiarization but not in test, and g_kb_p occurred in test but not in familiarization). Therefore, the influence of the familiarization phase on infants' preference during test was probably due to word templates specified in terms of features, not specific phonemes.

A similar point is made by Seidl and Buckley (2005), who demonstrated that 9-month-olds exposed to a phonological pattern instantiated with one set of segments could recognize the pattern instantiated in another set of segments. In one condition of one experiment, infants were familiarized with stimuli that exhibited the restriction that fricatives and affricates occurred only between two vowels, and no stops occurred in that position (e.g., [pasat nodʒɛt mitʃa]). During test, infants discriminated stimuli that adhered to the restriction from stimuli that did not, even though the set of fricatives, stops, and vowels used in the test stimuli were different from those used during familiarization. These data, like those of Maye and Weiss (2003) and Saffran and Thiessen (2003), suggest that infants generalize about the sound properties of their language based on phonetic features.

Sensitivity to properties affecting stress assignment

As for infants' sensitivity to stress assignment principles, research has followed a trajectory similar to that of explorations of sensitivity to segment sequences. Early studies asked whether infants are sensitive to the canonical stress pattern of their language, while later studies asked what infants can learn about stress assignment principles in a brief laboratory exposure. Beginning with what infants know about the stress properties of their own language, Jusczyk, Cutler, and Redanz (1993) demonstrated that 9-month-old American infants listen longer to disyllabic words exhibiting a trochaic pattern (strong–weak) than an iambic pattern (weak–strong). The vast majority of disyllabic words in English exhibit a trochaic pattern (Cutler & Carter, 1987), and it appears that English-learning infants have noticed this statistical bias in their language (also see Echols, Crowhurst, & Childers, 1997; Thiessen & Saffran, 2003).

The trochaic bias in English words can be seen to stem from a set of stress assignment principles such as those in (1a–d), below (e.g., Hogg & McCully, 1987).

(1) a. Stress penultimate (second to last) syllables
    b. Stress heavy syllables (CV with long vowel or CVC(C)(C))
    c. Avoid two stressed syllables in sequence
    d. Alternate stress from right to left.

Turk, Jusczyk, and Gerken (1995) asked whether infants were sensitive to the principle that heavy syllables should receive stress, examining infants' listening time to trochaic versus iambic words in which the strong syllable was light (a CVC with a short vowel). They found that syllable weight is not a necessary component of the strong–weak preference observed by Jusczyk, Cutler, et al. (1993). However, the third experiment in the published series, plus additional unpublished experiments, make it clear that infants are sensitive to syllable weight and to the typical patterns of heavy and light syllables that occur in English words.

Gerken (2004) further explored infants' sensitivity to stress assignment principles, utilizing principles and stimuli created by Guest, Dell, and Cole (2000) for a study with adults. In the infant study, 6- and 9-month-olds were familiarized with five types of three- to five-syllable words from one of two artificial languages that differed in most of their stress assignment principles. No single familiarization word type exhibited all of the stress assignment principles for the language. During test, infants heard new words with different stress patterns from the ones heard during familiarization, although the test words of each language were consistent with the stress assignment principles of that language. Importantly, Language 1 and Language 2 test words had the same stress patterns, and differed only in the placement of a heavy (CVC) syllable. For example, *do-TON-re-MI-fa* was a test word from Language 1, and *do-RE-mi-TON-fa* was a test word from Language 2 (capital letters indicate stressed syllables). Nine-month-olds discriminated the test words, suggesting that they were able to generalize to new words by combining information from the different types of words encountered during familiarization. Six-month-olds did not discriminate the test words.

Can we conclude from this study that infants infer stress assignment principles like (1a–d)? One barrier to drawing such a conclusion is that the only heavy syllable used by Gerken (2004) was *TON*. Therefore, infants might have determined that *TON* should be stressed, while not drawing the more abstract conclusion that heavy syllables should be stressed. Unpublished follow-up studies suggest a more complicated story. Infants failed to generalize to test stimuli with a different heavy syllable than the one heard during familiarization. However, if multiple heavy syllables were heard during familiarization, infants were able to generalize to a new heavy syllable at test. These data suggest that infants are not prepared to infer a principle like "stress heavy syllables" from encountering a single heavy syllable. However, they do appear to generalize based on categories like "heavy syllable" if they hear a small number of exemplars from that category.

Summary of sensitivity to phonological form

The studies of infants' sensitivity to phonological form reveal at least two properties common across phonological domains. First, infants demonstrate sensitivity to the segment inventory, segment sequences, and stress properties of their native language at about 9 months of age, although sensitivity to the vowel inventory appears somewhat earlier. Second, infants are remarkably skilled at detecting phonological patterns in stimuli presented in brief laboratory visits, and they appear to be able to generalize beyond the particular stimuli that they have encountered when given appropriate evidence. In the domain of segment inventories, appropriate evidence for the existence of a featurally based segment category may be a bimodal distribution of acoustic–phonetic tokens along a particular acoustic dimension, and perhaps multiple instances of each token. In the domain of segment sequences, there has not been a systematic exploration of what evidence is required for featurally based generalization. For example, although it seems unlikely that infants familiarized with a set of pVsVC tokens would show evidence of having induced a stop–V–fricative–VC pattern, we do not yet know the limits on infants' generalization in this domain. In the domain of stress assignment, we have some preliminary evidence that multiple instances of a category (e.g., heavy syllable) are needed for generalization.

One question raised by the work on infants' sensitivity to phonological form is whether infants are in any sense biologically prepared to entertain certain categories of sound experience, or whether any readily perceivable acoustic dimension can serve as a basis for a category. Another way of framing the question is whether segments, segment sequences, or stress assignment principles that are found among the world's languages can be learned more readily by human infants than other equally complex categories that are not found in natural language. Researchers are just beginning to address this question. At the present time, the answer appears to be that arbitrary patterns are learnable (Chambers et al., 2003; Seidl & Buckley, 2005), although patterns that are characterizable in terms of disjunctions (e.g., words begin with /p/ or /s/) may suffer a disadvantage in generalization (Saffran & Thiessen, 2003). Much more research is needed on the sound stimulus properties required for generalization.

Sensitivity to Syntactic Form

Although the mantra of generative linguists over the past 50 years has been that syntax is logically distinct from meaning (e.g., Chomsky, 1965), many diagnostics of syntactic structure involve assessing meaning. For example, the fact that *him* in (2), below, cannot refer to Bill is taken as evidence about the structural constraints on coreference. Surely it makes little sense to assess learners' sensitivity to such constraints before they can understand sentences like (2).

(2) *Bill$_i$ likes him$_i$.

Nevertheless, there are at least two aspects of syntactic sensitivity that can, in principle, be assessed in the absence of sentence interpretation: word order and syntactic categories. Although both of these components of syntax ultimately influence sentence interpretation, they can also be assessed to some extent on their own. For example, regardless of what meaning is intended, (3a) is not a possible sentence of English, because it violates English word order. Similarly, you may not know what *zig*, *rif*, or *nug* mean, but if you hear these words used in sentence (3b), you can feel confident that (3c) is a grammatical sentence. Researchers studying infants' sensitivity to syntactic form have taken advantage of these non-interpretational aspects of syntax to study early sensitivity to the orders of word-like units and to syntactic categories.

(3) a. *Dog the cat the chased.
b. The zigs were riffing the nugs.
c. Look at those zigs rif.

Sensitivity to the order of word-like units

As in the studies of sensitivity to phonological form, the first studies examining infants' sensitivity to the syntactic form involved the form of language the infant was already learning. Shady, Gerken, and Jusczyk (1995) presented 10.5-month-olds with normal English sentences as well as sentences in which determiners and nouns were reversed, resulting in phrases like *kitten the*. The stimuli were recorded using a speech synthesizer to avoid disruptions in prosody that are likely to occur when a human talker produces ungrammatical sentences. Infants listened longer to the unmodified sentences, suggesting that they were able to tell the difference between the two types of stimuli. Similar studies presented 10- to 12-month-old infants with normal English sentences versus sentences in which a subset of grammatical morphemes was replaced by nonsense syllables. Infants could discriminate the grammatical and ungrammatical stimuli (4a vs. 4b, below), but not stimuli in which nonsense words replaced content words (4a vs. 4c; Shady, 1996; Shafer, Shucard, Shucard, & Gerken, 1998).

(4) a. There was once a little kitten who was born in a dark, cozy closet.
 b. There [ki] once [gu] little kitten who [ki] born in [gu] dark, cozy closet.
 c. There was once a little [mafIt] who was [tɛk] in a dark, cozy closet.

This pattern of results suggests that the information carried by grammatical morphemes was more salient to infants than particular content words, which they may or may not have recognized. Santelmann and Jusczyk (1998) showed that 18-month-olds, but not 15-month-olds, are able to detect violations in dependencies between English morphemes, such as auxiliary *is* and progressive suffix *-ing* (e.g., *Grandma is singing* vs. *Grandma can singing*), only when the distance between the two morphemes was between one and three syllables.

Although these studies indicate that infants are sensitive to aspects of their input that might serve as "cues" to an aspect of adult syntax, we cannot take such cue sensitivity to indicate that these infants have knowledge of English phrase structure. Rather, cue sensitivity merely indicates that infants have encoded frequently occurring patterns in their native language. For example, in the Shady et al. (1995) study, many of the ungrammatical sentences contained two grammatical morphemes in sequence (e.g., *a that*). Such sequences are virtually non-existent in English, and infants were probably responding to this and similar aspects of the stimuli, as opposed to any tacit expectation for determiners to precede nouns.

Because it is difficult to separate sensitivity to syntactic structure and frequency of occurrence in the native language, researchers studying infants' generalizations over sentence-like stimuli have turned to familiarization studies like those discussed in the section on infants' sensitivity to phonological form. In one such study, Gómez and Gerken (1999) presented 12-month-olds with a subset of strings produced by one of two finite state grammars. The two grammars began and ended in the same CVC nonsense words, with the only difference being the string-internal sequences of words allowed. In one study, half of the infants were familiarized for about two minutes with strings from Grammar 1 and half with strings from Grammar 2. For example, *VOT PEL* was a legal sequence in strings of Grammar 1, but not Grammar 2. During test, both groups of infants heard new strings from the two grammars. Infants showed a significant preference for the new strings generated by their familiarization grammar. This study showed that infants learned about the sequential dependencies of the words in their familiarization grammar and applied this knowledge to new strings during test.

Table 9.1 AAB familiarization stimuli used by Marcus et al. (1999)

A	*B*			
	di	*je*	*li*	*we*
le	leledi	leleje	leleli	lelewe
wi	wiwidi	wiwije	wiwili	wiwiwe
ji	jijidi	jijije	jijili	jijiwe
de	dededi	dedeje	dedeli	dedewe

One important property of Grammar 1, and not Grammar 2, was that certain words were allowed to repeat in sequence. For example, *VOT PEL PEL JIC* was a legal string in Grammar 1. By contrast, Grammar 2 contained strings in which the same word occurred in multiple string positions with other words intervening (e.g., *PEL RUD JIC VOT RUD*). These repetitions and alternations might allow learners to recognize the abstract form of some of the strings in their familiarization language, even if the test items contained new vocabulary. To test this possibility, Gómez and Gerken (1999) paired each word from the familiarization vocabulary with a new word in the test vocabulary (e.g., JED, FIM, TUP, DAK, SOG were matched with VOT, PEL, JIC, RUD, TAM, respectively). Thus, an infant who heard a string like JED-FIM-FIM-TUP in training might hear a string like VOT-PEL-PEL-JIC in test (both strings were generated by Grammar 1). Again, infants showed a preference for strings that were consistent with their familiarization grammar, suggesting that they had discerned the pattern of repetitions and alternations of the two grammars (also see Gómez & Gerken, 1998).

In a similar series of studies, Marcus, Vijayan, Rao, and Vishton (1999) exposed 7-month-olds to three-minute speech samples of strings with ABA (*wi-di-wi* and *de-li-de*) or ABB (*wi-di-di* and *de-li-li*) patterns. During test, infants heard strings with the same pattern they had heard during training as well as the other pattern, both instantiated in new vocabulary (e.g., *ba-po-ba* vs. *ba-po-po*). Infants trained on ABA stimuli preferred ABB stimuli at test, while infants trained on ABB stimuli preferred ABA stimuli at test (i.e., a novelty preference). These results, coupled with those of Gómez and Gerken (1999), make clear that infants can generalize beyond specific word order based on patterns of repeating or alternating elements.

A follow-up study using a subset of the stimuli used by Marcus et al. (1999) sheds some light on the conditions under which infants do and do not generalize beyond the specifics of their input (Gerken, 2006). The stimuli from the AAB condition of the Marcus et al. study are shown in Table 9.1. If one considers all of the information in the table, a succinct generalization is that all strings have an AAB form. The same is true if one considers just the four stimuli on the diagonal. However, if one considers the stimuli in the first column, all of the strings not only have an AAB form but also end in the syllable *di*. Which generalization is correct? Recall, the observation that a set of input data can give rise to multiple generalizations has been used as an argument that learners are innately constrained to make some generalizations and not others (see above).

To determine which generalization infants made, Gerken (2006) familiarized 9-month-olds with one of four sets of stimuli: AAB stimuli from the diagonal of Table 9.1, ABA stimuli from the diagonal (ledile, wijewi, jiliji, dewede), AAB stimuli from the first column of Table 9.1, and ABA stimuli from the first column (ledile, widiwi, jidiji, dedide). At test, infants heard new AAB and ABA strings. The rationale was if infants discerned either an AAB or ABA pattern in the familiarization stimuli, they would be able to discriminate the new AAB and ABA test strings, replicating Marcus et al. (1999). In fact, only infants who were familiarized with stimuli from the diagonal discriminated the test strings, suggesting that infants familiarized with the first column made the more local "contains *di*" generalization. This interpretation was confirmed in a second study, in which infants familiarized with the first column (either the AAB or ABA version) were tested on new strings in which the B element was the syllable *di*. In this study, infants were able to discriminate AAB from ABA test stimuli. These studies suggest that the type of form-based generalization learners make is very much dependent on the specific properties of the input they encounter. Although we cannot yet determine how infants select one generalization out of a number of possibilities, the answer to that question will help us to compare nativist versus learning accounts of language development.

The input required for infants to make a particular generalization has been explored in another set of studies that focus on the conditions under which infants discern long distance dependency relations. Gómez (2002) familiarized 18-month-olds with an artificial grammar of the form AXB and CXD, in which there is a dependency between the A and B elements and between the C and D elements. Importantly, she found that it was only when the middle element was selected from a large pool (24) that infants could detect the relation between the first and third elements in the grammar. Gómez interprets her result to mean that infants attempt to process the strings in terms of sequential dependencies (A–X, X–B) until some point at which doing so becomes unfeasible. Thus, the processing resources required to encode stimuli in one manner versus another may be one factor driving the particular generalizations that learners make.

Sensitivity to syntactic categories

Researchers have begun to examine, in addition to word order, infants' sensitivity to the distributional correlates of syntactic categories. The basic research strategy is to test infants' sensitivity to morpho-phonemic paradigms, as exemplified for Russian noun gender in Table 9.2 (Gerken, Wilson, & Lewis, 2005). Seventeen-month-old infants were familiarized for two minutes with the non-emboldened words in Table 9.2. Note that if infants were able to detect that the case endings *u* and *oj* occurred on one set of words and *ya* and *yem* occurred on another set, they might be tacitly able to predict the withheld emboldened words. During test, infants heard on alternate trials the grammatical emboldened words and ungrammatical words created by combining masculine nouns with feminine case endings and vice versa. Infants were able to discriminate the

Table 9.2 Russian feminine and masculine nouns, each with two case endings

Feminine nouns					
polkoj	rubashkoj	ruchkoj	**vannoj**	knigoj	korovoj
polku	rubashku	ruchku	vannu	knigu	**korovu**
Masculine nouns					
uchitel'ya	stroitel'ya	zhitel'ya	**medved'ya**	korn'ya	pisar'ya
uchitel'yem	stroitel'yem	zhitel'yem	medved'yem	korn'yem	**pisar'yem**

Words in bold were withheld during familiarization and comprised the grammatical test items. An apostrophe after a consonant indicates that the consonant is palatalized in Russian. Ungrammatical words were *vannya*, *korovyem*, *medevedoj*, *pisaru*.

grammatical from ungrammatical items, suggesting that they had discerned the paradigm (Gerken et al., 2005). It is important to note that 12-month-old infants were unable to discern the Russian gender paradigm shown in Table 9.2. However, infants at that age demonstrate a potential precursor to the categorization ability shown by 17-month-olds (for details see Gómez & LaKusta, 2004).

It is also important to note, however, that infants, like adults, were able to discriminate grammatical from ungrammatical items only when a subset of the words contained a second cue to category membership. Note that a subset of the feminine words in Table 9.2 end in *k* and a subset of the masculine words end in *tel*. Studies with adults and children tested in a paradigm completion format suggest that they too are unable to discern the structure of a morpho-phonological paradigm unless morphological markers to categories are supplemented with semantics, phonology, or additional morphology (Braine, 1987; Frigo & McDonald, 1998; Mintz, 2002; Wilson, 2000). Gerken et al. (2005) suggest that requiring multiple cues to syntactic categories protects learners from overgeneralizing category structure.

Other researchers have investigated infants' sensitivity to morpho-phonological paradigms in their native language (Höhle, Weissenborn, Kiefer, Schulz, & Schmitz, 2004). Researchers familiarized 14- to 16-month-old German learners with two nonsense words in either a noun context (preceded by a determiner) or a verb context (preceded by a pronoun). The infants then heard passages in which the new words were used as nouns or verbs. Infants who were familiarized with phrases in which the novel word was used as a noun preferred passages in which it was used as a verb. These results suggest that infants track the morphological contexts that occur with particular nouns. When they hear a new word in a noun context, they expect that the new word will also appear in other noun contexts. This expectation may be a sign of infants' having formed proto-syntactic categories.

Summary of infants' sensitivity to syntactic form

The studies of infants' sensitivity to syntactic form, like the studies examining sensitivity to phonological form, indicate that infants are skilled at detecting patterns in language and are able to generalize beyond the particular stimuli that they have encountered when given appropriate evidence. The age at which sensitivity to possible precursors of syntax appears varies considerably from 7 months (Marcus et al., 1999) to the middle of the second year (Gerken et al., 2005; Gómez, 2002; Höhle et al., 2004).

As in the case of the studies on infants' sensitivity to phonological form, we can ask how the data on infants' sensitivity to syntactic form is related to what we know about syntactic structures and categories in human language. The studies on word order suggest that infants are sensitive to the order of particular elements in a string, to patterns of repeating and alternating elements, and to correlations between non-adjacent items. Although languages make some limited use of repeated morphemes (i.e., reduplication), repetition of the same word or morpheme is not typically viewed as central to morpho-syntax. Similarly, long distance dependencies in natural languages occur across constituents without a fixed length (e.g., Arielle called her soccer-playing friend, Sara, up). The studies on infants' sensitivity to morpho-phonological paradigms may better reflect processes that occur in the acquisition of natural language syntax (e.g., Braine, 1987). However, it is important to note that the syntactic categories derived via morpho-phonological cues are simply groups of words that appear in similar morpho-syntactic contexts. That is, they are not labeled for the learner as *noun*, *verb*, etc. Therefore, in theories that hold labeled syntactic categories to be crucial (e.g., Baker, 2001), categories created based on morpho-phonological cues alone may be of limited use (see Pinker, 1984).

What Early Sensitivity to Linguistic Form Tells Us about Language Development

Throughout the chapter, hints about developmental sequence can be found in statements like "17-month-olds, but not 12-month-olds discriminated . . .". The reader is cautioned that almost none of these developmental differences is statistically reliable, thereby making it very difficult in most of the research reported to determine a developmental timeline or developmental mechanisms. Nevertheless, we can attempt to construct a rough timeline for the infant abilities discussed in this chapter.

The studies on phonological form presented in this chapter suggest that 9-month-old infants are sensitive to the basic categories of phonology, including phonetic features and syllable shapes, and to at least some of the principles by which these categories are combined. The studies on syntactic form suggest that infants are sensitive to the ordering of word-like units by 7 months, and perhaps before. However, infants' ability to track the information required to infer syntactic categories has not been shown in infants younger than 14 months.

What do these studies, which demonstrate infants' sensitivity to linguistic form in the absence of meaning, tell us about language development? The ability to generalize beyond our linguistic experience to produce and comprehend new utterances based on an arbitrary, multi-leveled, system has been taken as the great mystery of human language. The studies presented in this chapter demonstrate that infants have a remarkable ability to keep track of the specifics of the form of their input and, importantly, to generalize to new forms given sufficient evidence that generalization is warranted. Does this mean that the abilities documented in the studies presented here reflect the beginnings of language development?

In considering the answer to that question, we must keep in mind that the ability to generalize across fairly complex patterns is not the unique domain of human language but rather can be seen in a host of non-humans. For example, the types of generalization by infants reported by Marcus et al. (1999) and Gerken (2006) can be seen in honey bees, pigeons, and cotton-top tamarins (Cumming & Berryman, 1961; Giurfa, Zhang, Jenett, Menzel, & Srinivasan, 2001; Hauser, Weiss, & Marcus, 2002). By contrast, other human linguistic abilities may have no parallel in non-humans (e.g., Fitch & Hauser, 2004; Hauser, Chomsky, & Fitch, 2002; Hauser, Newport, & Aslin, 2001). For example, humans, but not cotton-top tamarins, can learn a grammar of the form A^nB^n, which generates strings like (AB, AABB, AAABBB, etc.). Because only humans have communication systems with the power of human language, should we consider only abilities seen in humans and not other animals when we contemplate the mechanisms of language development? If so, many of the studies reported here will ultimately be dismissed as irrelevant to language development, although they may inform us about human learning more generally.

Alternatively, we can view the process of language development as one in which learners must use their pattern detection and categorization skills to discern the patterns and categories employed by human language. On this view, some of these skills may well be shared by other species. A similar argument has been made about categorical perception for speech sounds, which can be seen in species other than humans (e.g., Kuhl & Miller, 1975). It is now generally accepted that human speech perception has taken advantage of a general auditory property also found in other animals (Aslin, Pisoni, & Jusczyk, 1983). One barrier to the view that language develops from the application of general, but powerful, learning mechanisms to linguistic data is the argument of "poverty of the stimulus," which states that children are not exposed to linguistic structures of certain types that nevertheless appear to be part of their early knowledge of language (e.g., Chomsky, 1980). If relevant input from which patterns and categories can be detected does not exist, even the most computationally skilled learner cannot acquire a language. Although there is growing skepticism about the degree to which the input is truly impoverished (e.g., Elman, 2003; Lewis & Elman, 2001; Pullum & Scholz, 2002), much more work needs to be done to determine if there are indeed critical gaps in the infants' experience.

In the mean time, however, explorations of infants' sensitivity to linguistic form provide us with a potentially important view of the infant's world. They have the potential to inform us about what abstract structures are relatively easy and difficult to detect. Further, as infant studies come systematically to examine sensitivity to forms like those found in languages of the world, they have the potential to change how we view human language and its development.

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