1 Signal to Syntax: An Overview

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In setting forth the theoretical approach that has provided the most influential logical framework for the study of language acquisition, Chomsky (1965, p. 30) began by noting

> A child who is capable of learning language must have ...
> (i) a technique for representing input signals
> (ii) a way of representing structural information about these signals

Understanding the nature of input signals and of infants' and children's capacities for perceiving and representing such signals are important for formulating complete explanations of the acquisition of language. This is because, as Chomsky noted, no child can learn any particular language in the absence of exposure to, perception of, and representation of input (i.e., speech or signing) from that language. Languages vary in the sounds that they include, in the sequences in which these sounds can be arranged, in the mappings of such sequences onto concepts, in the manners in which meaningful elements may be concatenated to form word-level units, and in the possibilities for combining words to form phrases, clauses, and sentences. Language learners must have some means of determining which of the possible alternatives at each of these levels are manifest in the specific languages they are learning. This can only be provided by appropriate representation of examples drawn from those languages.

Accounts seeking to characterize or explain children's grammatical development, however, generally accord little weight to factors involving perception, representation, or production of speech. Most textbooks on language acquisition include only brief mention of basic results from infant speech perception research and little if any material on children's developing linguistic representations. The recently published *Handbook of Language Acquisition* (Fletcher & MacWhinney, 1995), whose advertising asserts that it is "the definitive encyclopedia of child language," includes no contributions from researchers studying development of speech perception. Whereas naive theories of language acquisition might accord significant explanatory force to children's representations of the speech that they hear, scientific theories, as they have been developed to date, for the most part do not.

The purpose of this volume, and the conference on which it was based, was to bring together an interdisciplinary group of scholars in

order to encourage further consideration of the possibility that children's representation of speech may provide important clues to basic aspects of syntactic categories and configurations that assist children in establishing grammars. After all, children's perceptual analyses of speech *must precede* (both logically and developmentally) application of syntactic or semantic analyses to representations of input utterances. Thus, it is reasonable to inquire whether such perceptual analyses might themselves yield information about some basic properties of grammar.

The notion that clues to syntactic structure may be discovered in speech has come to be known as the "prosodic bootstrapping hypothesis." This term, introduced by Pinker (1984), is unfortunately something of a misnomer. What has been contemplated in earlier accounts advanced by Gleitman and Wanner (1982), Morgan (1986), and Jusczyk, Hirsh-Pasek, Kemler Nelson, Kennedy, Woodward, and Piwoz (1992), as well as newer accounts advanced in many of the chapters in this volume, is not that mature or complete syntactic structures can be read off perceptual representations of input utterances nor that there is a one-to-one correspondence between perceptual cues and grammatical constructs. Rather, these accounts propose that information available in speech may contain clues to certain fundamental syntactic distinctions, providing additional constraints on children's syntactic and semantic analyses, signaling the domains within which such analyses may be efficiently deployed, and helping to ensure that these analyses get started in the proper direction. Thus, the "bootstrapping" part of "prosodic bootstrapping" is accurate.

However, the "prosodic" part is overly confining and, hence, misleading. Many of these accounts do suggest that suprasegmental cues may contribute information useful for acquisition of grammar. The prosody of infant- and child-directed speech is clearly different from that of adult-directed speech (Fernald, Taeschner, Dunn, Papousek, de Boysson-Bardies, & Fukui, 1989; Garnica, 1977), and infants display early sensitivities to prosodic characteristics of speech (Cooper & Aslin, 1994; DeCasper & Fifer, 1980; Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988). Nevertheless, none of these accounts argues that *prosody* is unique in contributing information useful for acquisition. Rather, several forms of information are available in input speech—phonetic, phonotactic, prosodic, stochastic—and any or all of these could contribute to syntactically rich representations of input utterances. As a more appropriately general descriptor, we suggest the term *phonological bootstrapping* as a rubric for hypotheses that children can derive rudimentary grammatical information from their perceptual analyses of input speech.

Before proceeding to our overview of the chapters in this volume, we briefly discuss two overarching issues concerning hypotheses of Phonological Bootstrapping. First, why (other than for the sake of completeness) should such hypotheses be entertained? Second, how should such

hypotheses be evaluated? We draw upon the formal work of Morgan (1986) to illustrate preliminary answers to these questions.

A compelling reason for considering hypotheses of Phonological Bootstrapping is that such hypotheses have the potential to significantly alter the dialectic of the debate over determinants of language acquisition. Inclusion of appropriately rich representations of input may entail modifications of theories of grammatical development, particularly with regard to theoretical characterization of the initial state. This has been formally demonstrated by Morgan (1986). Morgan investigated the learnability-theoretic consequences for induction of "standard" transformational grammars (Chomsky, 1965) of the assumption that children's representation of input utterances includes some surface phrase bracketing information. This theory of grammar was adopted because previous work by Wexler and Culicover (1980) on learnability of this type of grammar—from input explicitly assumed *not* to include any surface phrase bracketing information—was available to serve as a baseline for comparison. The assumption of richer syntactic representations had several consequences. First, learnability could be demonstrated on the basis of simpler data: Morgan's proof required only Degree 1 input (sentences containing, at most, one level of embedding), whereas Wexler and Culicover's proof required Degree 2 input. Requiring only Degree 1 input is a beneficial result because sentences with two or more levels of embedding appear in children's input only rarely (Morgan, 1986). Second, learnability could be demonstrated with many fewer required constraints on grammatical hypotheses, that is, with a simpler theory of Universal Grammar. In place of grammatical constraints that would otherwise be required, Morgan's proof substituted a set of perceptual mechanisms responsible for representation of phrase bracketing.

Although Morgan's learnability result establishes that syntactically rich representations could bear explanatory weight in accounts of acquisition of syntax, it does not bear on the plausibility of assuming such representations. Hypotheses of rich representations of language input must be evaluated with regard to both evidence concerning the nature of speech that infants hear—does such speech incorporate valid cues to aspects of syntactic structure?—and evidence concerning the nature of infants' perceptual abilities—do infants possess capacities for recognizing and exploiting such cues in appropriate fashion? These questions constitute central concerns of the chapters in this volume.

However, there is another factor that must be considered in evaluating hypotheses of Phonological Bootstrapping: The plausibility of any such hypothesis cannot be judged except with reference to a theory of the grammar that is being acquired. In the case of Morgan's (1986) learnability result, not all phrase bracketing needed to be represented. In that proof, the key contribution of representations of surface bracketing was to disambiguate the structural locations of permuted constituents. If the inventory of possible "landing sites" for moved constituents were constrained, then so too would be the amount of bracketing that

would need to be represented in order for this information to make effective contributions to acquisition of grammar.[1] More generally, the presence or absence of cues to particular syntactic distinctions may or may not be relevant given the nature of human grammars and how they are acquired. For example, several chapters in this volume (Fernald & McRoberts, Fisher & Tokura, Gerken, and Jusczyk & Kemler Nelson) note that, in English, prosodic cues fail to indicate that pronominal subjects and verbs are elements of separate syntactic constituents. However, the consequences of "misrepresentation" of the syntactic constituency of pronominal subjects are unknown; without such knowledge, it is impossible to judge how such evidence should be weighed in evaluating hypotheses of Phonological Bootstrapping. An alternative view of such evidence is that the presence or absence of phonological cues to particular distinctions or the existence of particular perceptual capacities in infants may provide clues to the nature of grammar (cf. Steedman, this volume) or to aspects of grammar whose early acquisition is of prime importance (Mazuka, this volume).

We organized our overview of the chapters in this volume to address three issues that might account for the paucity of influence that work on infant perception and representation has had on language acquisition theorizing. First, theoretical and methodological mismatches have tended to impede intellectual interactions among the diverse fields involved in studies of speech, perception, and language acquisition. The chapters in Part I ("The nature, perception, and representation of input speech") address issues relevant to bridging the disciplinary gaps between these fields.

Second, much of the work on the acquisition of syntax has been carried out with weak assumptions about the nature of input representations (typically that infants represent input utterances merely as strings of words or sometimes morphemes). For the most part, these assumptions have been accepted without examination. The chapters in Part II ("Speech and the acquisition of words") discuss aspects of early word-level speech segmentation. These chapters explore the plausibility of the assumption that infants represent input utterances as strings of words, providing evidence on the perceptual and computational capacities entailed by this assumption. Successful word-level segmentation requires sophisticated capacities on the part of language learners, no less sophisticated than those required for representation of additional grammatical properties of input. The capacities for formulating richer representations of the sort contemplated under hypotheses of Phonologi-

[1] On independent grounds, Baltin (1982), working within Extended Standard Theory, proposed a constrained set of landing sites for moved constituents. Several accounts within the Government and Binding tradition (e.g., Chomsky, 1986) have similarly proposed constraints on the output of 'Move α.' It should also be noted that the relevant bracketing would not need to be represented for every sentence token.

cal Bootstrapping are thus likely to be in place by virtue of the need to perform word-level segmentation.

Third, current theories of language have inherited the tenet of structuralist linguistics that the syntactic systems of languages are independent of their sound systems. On this view there is scant reason to believe that children's analyses of speech (regardless of their sophistication) will provide information useful to acquisition of syntax. Chapters in Parts III and IV ("Speech and the acquisition of grammatical morphology and form classes," and "Speech and the acquisition of phrase structure") consider whether in fact children's analyses of speech might provide information useful to the acquisition of morpho-syntax, debating whether language input contains reliable and valid phonotactic, prosodic, and stochastic cues (or sets of cues) to syntactic categories and structures.

Finally, chapters in Part V ("Speech and the acquisition of language") consider bootstrapping in broader developmental perspective, conjecturing about how early advancements in cognition and speech perception may be related and how Phonological Bootstrapping may interact with, and ultimately give way to, more sophisticated syntactic and semantic analyses of language input.

PART I: THE NATURE, PERCEPTION, AND REPRESENTATION OF INPUT SPEECH

Serious consideration of the role of speech in early language acquisition requires examination of several types of evidence. These include results of distributional and phonetic analyses of speech that infants and children hear, findings bearing on infant's perceptual and representational capacities, data on the contributions of phonetic and prosodic factors in sentence processing, and linguistic descriptions of phonological and syntactic systems and their possible interrelations. Forging these diverse types of evidence into a coherent whole faces obstacles commonly encountered in efforts to foster interdisciplinary cooperation (Abrahamsen, 1987): Different disciplines employ different methods, value different types of data, and analyze problems at different levels of abstractness and generality. At the same time, different disciplines may sometimes adopt the same technical terms while assigning them different reference. Thus, disagreements that appear to be substantive may turn out to be largely terminological.

A brief comparison of the fields of infant speech perception and child language acquisition illustrates many of these points. Research in infant speech perception developed directly from the pioneering work on adult perception conducted at Haskins Laboratory (Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Liberman, Delattre, & Cooper, 1952); its methodological lineage can be traced to the early psychophysical work of Helmholtz. In contrast, research in child language acquisition has its roots in diary and case studies by individuals such as Darwin (1877), Dewey (1894), Lewis (1936) and Velten (1943). Studies of

speech perception are experimental; studies of language acquisition tend to be observational or formal. Historically, research in infant speech perception has focused more on infants' abilities for discriminating speech sounds than on any other single issue. While important in its own right, this issue is of little interest to acquisition of grammar, for which data on perception and representation of morphemes, words, phrases, and clauses would be of relevance. Both fields may have interest in *prosody*, but this term is used to refer to different phenomena: In studies of speech perception, as in analyses of speech, the term *prosody* applies to manipulations or measurements of duration, intensity, pitch, or pitch contour, characteristics of suprasegmental aspects of speech that might be considered to be acoustic or "phonetic." In contrast, in studies of language acquisition (particularly those that draw heavily on phonological theory), the term *prosody* applies to phenomena such as meter or stress, and to the word- or phrase-level domains in which these are realized. These phenomena are more "phonemic" in character, inasmuch as they are typically defined with reference to particular linguistic systems. One consequence of this terminological ambiguity is that the debate over the role of prosody in Phonological Bootstrapping is muddied: Accounts adopting more "phonetic" definitions of prosody tend to be more optimistic about the possibility that prosody may contribute to early acquisition of aspects of grammar, whereas accounts adopting more "phonemic" definitions of prosody tend to emphasize the prior learning required to deploy prosodic categories in representing input. This divergence in views is evident in several chapters in this volume.

Essential steps toward reconciling data and arguments from different disciplines include basic familiarity with these data and arguments, as well as understanding of the methodological foundations on which these are based. In this spirit, the chapters in Part I offer a series of brief tutorials on several fields bearing on the possibility of bootstrapping from speech to grammar in early language acquisition; each chapter contains pointers into the associated literature for interested readers to pursue. Eimas provides an overview of research in infant speech perception, summarizing evidence that has been amassed on infants' early processing capacities and on later changes to these capacities as effects of exposure to particular languages. Eimas also discusses the development of methods for assessing infants' linguistic representations, as the field of infant speech perception begins to move beyond issues concerning discrimination and categorization of speech segments. Dresher introduces prosodic theory, providing arguments and linguistic evidence for units in the *prosodic hierarchy*: the phonological word, the phonological phrase, the intonational phrase, and the phonological utterance. Dresher then sketches metrical theory, noting some of the parameters involved and suggesting how these parameters might be set. Lieberman sets the study of prosody in biological perspective, noting that all mammalian species, humans included, use prosody for a variety

of nonlinguistic purposes. Price and Ostendorf outline the methods and goals of research in automatic speech recognition, an area whose precision, explicitness, and rigor might serve as a model for research in language acquisition (these desiderata are exemplified in recent work by Markey, 1994). Price and Ostendorf review results on analyses of prosody (ascertaining which components of prosody signal grammatical distinctions) and note that inclusion of prosodic information may enhance performance of statistical models of speech recognition, even when those models are provided with several other sources of knowledge. This work suggests that prosody and other phonological information may be especially useful to infants, who lack lexical and grammatical knowledge available to mature speakers.

PART II: SPEECH AND THE ACQUISITION OF WORDS

As noted earlier, theories of syntax acquisition commonly adopt the assumption that, prior to acquiring structural knowledge of their language, children can represent input utterances as strings of words. A few theorists have worried over how children might attain proper word-level representations (e.g., Brown, 1973; Peters, 1983). Most often, however, this assumption has been adopted uncritically.

In contrast, the problem of word-level speech segmentation has attracted considerable attention in the adult psycholinguistic literature. As Cutler notes in her chapter, many of these models argue that word segmentation occurs serendipitously, as a byproduct of word recognition. Such models appear to be inappropriate as descriptions of segmentation in acquisition, particularly in the earliest stages, for the simple reason that beginning language learners lack the very lexical knowledge that is required for "serendipitous segmentation." Rather, a bottom-up process exploiting one or more prelexical (or sublexical) units may be required for bootstrapping segmentation. Cutler argues for a "universal rhythmic segmentation hypothesis," according to which listeners adopt whichever unit constitutes the organizational basis for rhythmic structure in their primary language as a prelexical cue to word boundaries. In languages such as English, this unit is the stress foot; in languages such as French, the syllable; in languages such as Japanese, the mora; other units are possible in principle though they have not yet been attested. Cutler reviews evidence from studies of adult speech processing suggesting that English speakers do use the stress foot, French speakers the syllable, and Japanese speakers the mora as preferred units of initial segmentation. Studies by Jusczyk, Cutler, and Redanz (1993) and Morgan (in press) show that 9- and 10-month-old English-learning infants prefer to listen to and more coherently represent bisyllables manifesting the strong–weak rhythmic pattern that constitutes binary stress feet in English and predominates in the English lexicon, as Cutler's hypothesis suggests.

The available evidence is compatible with the possibility that infants exploit speech rhythm in discovering word-level units in fluent speech. However, several questions remain to be addressed. How do infants discover which rhythmic unit is appropriate for their language? How do infants discover the preferred internal rhythmic organization of this unit? How do infants identify the edges of basic rhythmic units? In languages in which words often comprise multiple basic rhythmic units (e.g., French or Japanese), how do infants locate word boundaries? Efficient application of the strategy Cutler suggests for English, the Metrical Segmentation Strategy, requires that listeners be able to discriminate between lexical words and function words. How can infants make such discriminations prior to locating word boundaries? Some of these questions are taken up in chapters in this volume; others remain for future research.

Mehler, Dupoux, Nazzi, and Dehaene-Lambertz address the question of how infants discover the rhythmic unit appropriate for their language. They review evidence showing that very young infants can discriminate stimuli varying in numbers of vowels and can discriminate languages differing in rhythmic structure, even when speech in those languages has been low-pass filtered. Because the information retained in low-pass filtered speech is concentrated in vocalic segments, Mehler et al. argue that vowels are highly salient for infants. Integrating these findings, Mehler et al. propose a model in which representation of the timing and intensity of vowels in utterances allows infants to classify languages into one of a small number of possible rhythmic classes. For example, utterances in which neither intervocalic intervals nor vowel amplitude display much variation might be classified as being drawn from a syllable-timed language such as French, whereas utterances in which high- and low-intensity vowels alternate and intervals between high-intensity vowels display little variation might be classified as being drawn from a stress-timed language such as English. It seems likely, however, that some utterances infants hear will fail to correspond closely to any one rhythmic template. Moreover, because utterances addressed to infants tend to be short (and hence contain small numbers of vowels), the statistical power for deciding whether the distribution of, say, intervocalic intervals observed in a given utterance fits one template or another may be limited. Evaluation of the computational feasibility of this model must await detailed measurements of infant-directed utterances drawn from languages with several different rhythmic structures. In the interim, however, the model that Mehler et al. offer as a first-order language classification device is psychologically appealing as it relies on well-attested perceptual capacities.

Edges of at least some word-level units may be identified by phonotactic patterns. In any language, certain (sequences of) consonants may occur in either syllable onsets or syllable codas; often, however, the edges of words may contain greater numbers or wider repertoires of possible consonants than the edges of word-internal syllables. In their

chapter, Aslin, Woodward, LaMendola, and Bever investigate whether knowledge of phonotactic patterns—specifically, knowledge of those patterns that occur at the ends of utterances—may be sufficient to predict within-utterance word boundaries. Aslin et al. show that back-propagation neural networks trained on utterance-final phonotactic patterns can indeed identify utterance-internal word boundaries with high levels of accuracy. Presumably, infants must eventually integrate phonotactic and rhythmic information in segmenting and recognizing words in fluent speech. What the relative contributions of these and other potentially relevant types of information are, and how and when infants integrate them, are questions that must be answered by further research (see Werker, Lloyd, Pegg, & Polka, this volume, for additional discussion).

Beyond being able to carve up continuous input utterances into appropriate lexical units, infants must be able to recognize specific word tokens as exemplars of particular lexical types. This ability is prerequisite for use of any lexical information, such as using word meanings to infer form class membership or subcategorization frames to constrain hypotheses of sentence structure. In her chapter, Ratner suggests that this problem may be somewhat simplified for children in early stages of acquisition on two grounds. First, the fact that early lexicons are quite sparse entails that phonological neighborhoods will not be at all dense. Thus children may be able to more easily tolerate variability across tokens than are adults, whose lexical neighborhoods are more densely populated. Second, in certain respects, tokens may vary less in infant-directed than in adult-directed speech. For example, VOT ranges tend to be narrower and adults use several optional phonological rules less often in infant-directed speech. On the other hand, as Ratner acknowledges, young children do attend to fine-grained phonetics of input speech (and may be less certain of which phonetic variations fall within or cross phonemic boundaries). Moreover, although tokens may manifest less segmental variability in infant-directed speech, they are likely to manifest greater suprasegmental variability. Aslin et al. note that new words tend to be introduced in utterance-final position, where they tend to be loud, lengthened, and high-pitched (Fernald & Mazzie, 1991). When words later appear in utterance-medial positions, they will have none of these characteristics. At this point, it seems fair to say that neither the dimensions of the problem that infants face nor the processes by which infants solve the token–type problem are as yet well understood. Both of these issues are important topics for future research.

Analyses of input and research demonstrating that infants possess the component perceptual skills required for segmentation necessarily stop short of providing evidence on the nature and ontogenesis of infant segmentation itself. For this, measures of relevant aspects of infant perception and representation will be required, and these are only now beginning to be developed (see Jusczyk & Kemler Nelson, this volume and Werker et al., this volume). An alternative approach is to make in-

ferences about infant segmentation through observations of children's productions (e.g., Peters, 1983). As Echols notes in her chapter, however, disentangling effects of perception, representation, and production factors is a subtle enterprise (see also Gerken, this volume). Echols' earlier analyses of children's productions suggested that children preferentially utter syllables that are either stressed or target-final, but what to attribute children's omissions of unstressed, nonfinal syllables to is unclear. Evidence from 2-year-olds' imitations of stimuli varying in both stress and articulatory difficulty suggests that, by that advanced age, children extract and represent both stressed and unstressed syllables, but, on Echols view, the representation of stress (or, more generally, salience) continues to play a pivotal role in children's choice of which syllables to utter. Echols suggests that this apparent limitation on production may recapitulate earlier limitations on perception and representation of input speech.

Demuth argues, however, that an adequate characterization of children's early words cannot be constructed by appealing to perceptual salience alone. Rather, Demuth contends that the varying shapes of children's early productions reflect sensitivity to the prosodic word structures of languages, conforming to linguistically specified notions of *minimal word*, which are defined in terms of the prosodic hierarchy (see Dresher, this volume). Minimal words comprise binary feet, but the constituency of binary feet varies across languages. The default shape (if neither stress nor syllable weight is specified) for binary feet is the trochaic bisyllable. As children begin to represent lexical stress and syllable weight (for languages whose phonological systems make use of these factors), binary feet can assume new forms, either trochaic or iambic, and either monosyllabic or bisyllabic, depending on the language. In languages with phonological systems in which neither lexical stress nor syllable weight figure, as in Sesotho, the minimal word will remain a trochaic bisyllable. Cross-linguistic evidence comports with these predictions. Demuth concludes that limitations of children's early word-shapes reflect neither perceptual nor representational deficiencies but rather systematic phonological constraints on output forms. One implication of this is that children achieve accurate representations of words in their languages very early in acquisition.

In sum, the chapters in Part II show that infants make substantial progress toward solving the word-level segmentation problem in the first year of life, perhaps completing this process before they begin to produce structured utterances. Thus, the assumption that syntactic analyses are based on representations of input utterances that encode linear orders of words appears to be tenable. Solving the segmentation problem, however, is by no means trivial. To do so, infants must at minimum be able to attend to, discriminate, represent, and integrate metrical, phonotactic, and distributional properties of input speech, all under the guidance of certain preprogrammed constraints on the characteristics of the linguistic unit being sought. In addition, solving the to-

ken–type problem will minimally require capabilities for normalizing across variation in both speaker characteristics and speech rate. An extensive set of perceptual and computational capacities is thus needed for word-level segmentation and lexical access. No evidence exists showing that infants possess such capacities solely for the purpose of discovering words. The chapters in Parts III and IV consider whether these capacities might also suffice to provide infants with representations of basic form classes and fundamental aspects of phrase structure.

PARTS III & IV: SPEECH AND THE ACQUISITION OF GRAMMATICAL MORPHOLOGY, FORM CLASSES, AND PHRASE STRUCTURE

A fundamental tenet of structuralist linguistics, the tradition from which transformational grammar and subsequent developments in contemporary theoretical linguistics emerged, is that grammars are composed of multiple systems that are not reducible to one another. Although in writing about "the arbitrariness of the sign," Saussure (1916/1959) focused primarily on the independence of the sound-shapes of words and their meanings, it is clear that he intended this notion to apply as well to the independence of the sound-shapes of words, their grammatical categories, and their proclivities for combining syntactically with other words. Hockett (1966) employed the term *duality of patterning* to refer specifically to the observed independence of phonology and syntax in human languages.

As Kelly (1992) noted, one legacy of the ascendance of these concepts has been an absence of consideration of possible contributions of phonological information to acquisition of aspects of syntax. Whereas the structuralist claims that, for example, form class is not reducible to phonology and phrase structure is not reducible to prosody may be correct, this does not preclude the possibility that correlations exist between these grammatical domains. What the nature of these correlations might be, how infants might discover them, and whether such correlations are exploited in the course of acquisition are the topics considered in chapters in Parts III and IV. To anticipate somewhat, it does not seem likely that mappings from phonology to form class or to phrase structure are either language-universal or transparent. This might be taken as *prima facie* evidence against the possibility of bootstrapping from speech to these aspects of syntactic structure. However, as we saw earlier, the phonological bases of word-level segmentation are neither language-universal nor transparent either. Infants nevertheless solve the segmentation problem, suggesting that they may possess the perceptual, representational, and computational capacities to exploit whatever phonology–form class or phonology–phrase structure mappings may exist in language input.

Scholars of language have long noted that words can be sorted into two superordinate grammatical categories. This distinction has been variously characterized as *content words* versus *function words, open class items* versus *closed class items,* or *referential morphemes* versus *inflectional morphemes.* Scholars of language acquisition have also long noted that children's early speech contains primarily open class lexical items, and that closed class grammatical function items take some time to appear consistently. Since Abney's (1987) formal syntactic characterization of *lexical* and *functional* categories, linguists have become increasingly concerned with the different grammatical roles played by these two grammatical classes. This concern has generated a rapid growth in studies that have begun to focus anew on the acquisition of grammatical function morphology and its implications for the development of syntactic structure (for example, see Radford, 1990, and chapters in Meisel, 1992, and Lust, Suñer, & Whitman, 1994). Systematically missing from most of these discussions, however, has been any awareness of the phonological differences between grammatical function morphology and lexical form classes, and how these might influence early stages of syntactic analysis or language production (though see Demuth, 1992, 1994). The chapters in Part III deal with these issues from perspectives of perception, representation, and production.

Selkirk provides a novel theoretical treatment of grammatical function morphology in terms of prosodic words. Drawing on previous work involving the prosodic hierarchy and data from English and Serbo-Croatian, she identifies four different ways in which grammatical function words can be prosodically realized. She shows how the surface realization of these four prosodic types of grammatical morphology can be affected by the different ordering, or ranking, of prosodic constraints, in accord with recent optimality theoretic proposals (McCarthy & Prince, in press; Prince & Smolensky, in press). Selkirk shows how the prosodic distinction between weak and strong forms of grammatical function words in English (e.g. auxiliaries, prepositions, object pronouns) can be handled be appealing to three different types of morphosyntactic input structures, all with the same ranking of prosodic constraints. She then demonstrates that different accentual phenomena in dialects of Serbo-Croatian involve the same morphosyntactic structure, but different rankings of prosodic constraints. This chapter therefore provides a detailed analysis of grammatical function words as part of larger prosodic word units. The acquisition of these prosodic structures is an interesting and important study in and of itself. However, there is much a child must learn about prosodic structure before the information discussed here can be used to inform the acquisition of syntactic structure itself.

An alternative possibility is that young children might exploit low-level phonetic and distributional properties of words and syllables in input speech to assign these elements to basic grammatical categories. Morgan, Shi, and Allopenna suggest that the statistical, syntactic and

semantic characteristics of content words and function words universally tend to result in these words having constellations of distinctive phonological (and hence perceptual) characteristics. Arguing on the basis of measures of English and Mandarin infant-directed speech, Morgan et al. show that single measures fail to provide highly valid cues to superordinate form class membership. However, sets of measures considered ensemble are valid predictors, as results of simulations with self-organizing neural networks demonstrate. Noting evidence that, at some time between 6 and 12 months, infants have developed the more sophisticated perceptual and integrative abilities needed to use such higher-order information, Morgan et al. argue that it is possible that infants use cues provided in the input signal as a first pass toward grammatical categorization, even before gaining access to the semantics of words or mastering the phonology of the language being learned. Once rudimentary category membership has been determined, the identification of phrase boundaries and more fine-grained sets of form classes may be facilitated, providing the basis for acquisition of language-particular aspects of syntactic structure.

The arguments advanced by Selkirk and Morgan et al. concern how children might come to represent lexical and functional items as members of distinct grammatical classes. Neither chapter attempts to account for the appearance of functional items in children's productions. It has long been know, however, that functional items do not appear as a class in children's repertoires, but rather emerge one-by-one, in orders that vary across languages but that tend to be stable within languages (Brown, 1973; Slobin, 1982). Peters and Strömqvist propose that the tonal or intonational structure of a language may facilitate the production of grammatical morphology if those morphemes are prosodically salient in some way, where salient may be interpreted as "contrastive" or "different." To evaluate this hypothesis they examine early word productions in Swedish, focusing on interactions between the realization of inflectional morphology and (unmarked) acute versus (marked) grave pitch accent. They suggest that the marked grave accent (fall on stressed syllable, with post-stress rise) may be prosodically salient for children, helping to focus attention on inflectional morphology when producing early words. Examining the early speech of one child, they find that polysyllabic words are initially produced correctly with grave pitch accent and that, around 23 months, with a rise in MLU, the child begins to overgeneralize the unmarked acute accent. Peters and Strömqvist suggest that the grave pitch accent serves as a "spotlight" at the very early stages of acquisition, focusing the child's attention on the word-final grammatical morphology of polysyllabic words. They conclude by suggesting two areas of research needed to test their "spotlight" hypothesis. First, they recognize the need for perceptual studies that will complement the production study presented here. Second, they point to the importance of crosslinguistic studies of production, especially in closely related languages where prosodic phenomena

such as stress-timing, syllable duration, vowel quality, and tonal pitch-accent may vary.

Leonard and Eyer address Peters and Strömqvist's second proposal by comparing SLI (specific language impairment) children's production of grammatical morphology in English, Italian, and Hebrew. Their thesis is that being able to identify and process grammatical morphology may facilitate the acquisition of syntax. However, it has been observed that children with specific language impairment have difficulties with grammatical morphology, as well as with various aspects of syntax. Leonard and Eyer review comparative studies of English, Italian, and Hebrew SLI populations and their MLU controls, showing that the SLI children generally perform worse on grammatical morphology when those forms are in syntactic positions where they are relatively short in duration. However, in cases where grammatical morphemes fall on stressed syllables, as is frequently the case in Hebrew, or in phrase-final lengthened positions, as is often the case in Italian, SLI children perform with increased accuracy. Leonard and Eyer therefore conclude that grammatical morphemes with relatively short durations pose problems for SLI children. Furthermore, they show that languages vary in the extent to which grammatical function morphology is realized by forms with short duration—English has many such forms, whereas Italian and Hebrew have fewer. (Interestingly, Morgan et al., this volume found that vowel duration was an important component of the sets of cues distinguishing content and function words in both English and Mandarin.) If duration is one of the major factors required for linguistic processing, English-speaking SLI children might be expected to omit more grammatical function morphemes than their Italian and Hebrew SLI counterparts, and this seems to be the case. Leonard and Eyer propose that this may then hinder accurate representation of the internal structure of phrases and clauses, thereby interfering with the development of higher level syntactic abilities.

Although the distinction between lexical and functional categories is arguably most basic, this is clearly not the only distinction among form classes that is important for acquisition of grammar. In his chapter, Kelly argues that nouns and verbs may also be differentiated on the basis of phonological cues such as duration of syllables, vowel quality, consonant quality, phoneme type, and number of syllables. Kelly demonstrates that regular phonological cues such as surface stress patterns (iambic vs. trochaic) and number of syllables serve as reliable indicators distinguishing English nouns and verbs, and that both adults and 3- to 4-year-olds have developed strategies for classifying novel words using these phonological cues. Classification in English is enhanced if phonological cues are combined with semantic information, but even in cases where semantics is not available, as in languages with abstract gender classes, use of phonological cues is also effective. Kelly concludes by arguing that phonological cues are both available and ex-

ploited by early language users, and that these cues facilitate the construction of grammatical classes.

In sum, the chapters in Part III point to the presence of phonological, acoustic and statistical/distributional differences between functional and lexical categories, as well as distinctions within the class of lexical items. These differences occur not only in English, but in other languages as well, perhaps universally. Furthermore, several of the chapters suggest that language learners may exploit these types of information from the earliest stages of acquisition, using them to form rudimentary grammatical categories—a necessary prerequisite for the construction of higher levels of syntactic structure. However, these chapters also point to the fact that much more research is needed to determine the relationship between children's early perceptual and production abilities with respect to different grammatical classes and to flesh out the implications this has for the course of language development in both normal and language-delayed populations.

Several early Phonological Bootstrapping proposals suggested that language learners might be able to retrieve information about phrase bracketing from analyses of input speech (e.g., Gleitman & Wanner, 1982; Morgan, 1986; Morgan & Newport, 1981). These proposals were inspired partly by linguistic evidence for links between phonology and syntax (especially at the level of prosodic structure—stress feet, prosodic words, pitch accent, tone, intonation—and its correlation with various syntactic boundaries; cf. Inkelas & Zec 1990), and partly by evidence of phonology–syntax relations from studies of adult-directed speech (e.g., Cooper & Paccia-Cooper, 1980) and adult sentence processing (e.g., Streeter, 1978). As Fernald and McRoberts note, analyses of adult-directed speech have typically proceeded by examining prosodic correlates of known aspects of sentence phrase structure. They point out that the conditional probability involved in such analyses is not the one of concern for language learners, whose task concerns instead attempting to induce sentence structure from observed prosodic phenomena. Thus, cue reliability is of import for learners. Fernald and McRoberts contend that prosodic phenomena are at best moderately reliable cues to phrase structure in adult-directed speech. Moreover, they note that studies of adult speech processing show that listeners assign more weight to syntactic cues than prosodic cues in inferring phrase structure.

The relevance of adult data to evaluation of Phonological Bootstrapping proposals, however, is unclear. Obvious differences exist between adult-directed and infant-directed speech (Fernald et al., 1989), and adult and infant sentence processing capabilities must also be different, by virtue of the vastly different stores of linguistic knowledge that infants and adults possess. Evidence from analyses of adult-directed speech and adult language processing is neither necessary nor sufficient for bootstrapping arguments. Such evidence has played a heuristic,

rather than logical, role in motivating Phonological Bootstrapping proposals.

More to the point, Fernald and McRoberts observe that prosodically delimited stretches of infant-directed speech often fail to correspond to clauses. However, no Phonological Bootstrapping proposals have suggested that clauses are uniquely cued (note that proposals that "clauses are perceptual units" are not equivalent to proposals that "perceptual units are clauses"; cf. Hirsh-Pasek, Kemler Nelson, Jusczyk, Wright Cassidy, Druss, & Kennedy, 1987). The utility of such unique cueing would appear to be minimal, especially since, on all accounts, infants hear few multi-clause utterances. Rather, cueing of various types of phrase groupings, in combination with capacities for limited distributional analyses, is likely to be more informative for inferring the hierarchical organization of clause-level syntactic structure.

Whether prosodic cues in infant-directed speech in fact delimit phrases is subject to dispute. Fernald and McRoberts assert that a significant proportion of infant-directed utterances are sub-phrasal. In contrast, in earlier analyses of child-directed speech, Snow (1972) and Newport (1977) reported that the sentence fragments that occurred were overwhelmingly well-formed phrases. Clearly, the grammatical framework adopted is critical for determining what may and may not constitute phrases. In his chapter, Steedman demonstrates that putative prosody–syntax mismatches disappear given a Combinatory Categorial Grammar (CCG) account of syntax, which draws largely on semantic information from subcategorization frames and admits a wider variety of phrase types than other theories. From a CCG perspective, the child will need access to semantic interpretations, or at least an understanding of conceptual meaning and discourse context, in order to acquire syntactic competence. Of course, adoption of a Phonological Bootstrapping account does not preclude learners' use of semantic information (we return to this point in our discussion of Part V), but, as we noted earlier, children's perceptual analyses of speech must come before semantic analyses of representations of input utterances

A related issue concerns how the prosodic cues that serve to delimit stretches of speech differ across languages. Silence is likely a universal delimiter. Venditti, Jun, and Beckman show in addition how prosodic phenomena such as pitch-accent, boundary tones, intonational phrases, and downstep in Japanese, Korean, and English all bear on prosody–syntax mappings, but each in a distinct fashion. They suggest that general similarities in prosodic organization may reflect basic aspects of grouping and focus. Beyond this, however, prosodic structure and details of prosody–syntax mappings may vary somewhat arbitrarily across languages. Venditti et al.'s arguments are based on analyses of adult-directed utterances. To determine the utility of prosodic structure as a means for bootstrapping syntactic structure for young children, comparable analyses of corpora of infant-directed speech are required, for both qualitative and quantitative reasons. Qualitatively, as we have pointed

out, adult- and infant-directed speech registers often exhibit strikingly different phonological characteristics. Quantitatively, it may be less important to know that particular pairings of prosodic and syntactic structures are possible than to know how often such pairings occur in infants' input.

Fisher and Tokura begin to provide such evidence, reporting on acoustic analyses of spontaneous maternal infant-directed speech in English and Japanese. They suggest that acoustic and distributional correlates of phrase boundaries and given–new information might provide language learners with means of accessing basic syntactic structure. In keeping with observations by Fernald and Mazzie (1991) and Aslin et al. (this volume), they note that new information tends to appear at the ends of utterances, where it is often marked with dramatic pitch changes—reminiscent of Peters and Strömqvist's (this volume) "spotlight" effect. In contrast, pronominal subjects, which are given information, take the form of phonologically reduced elements in English, and are missing altogether in languages like Japanese; hence, NP–VP boundaries are typically unmarked in infant-directed utterances, in which lexical subjects are infrequent. Fisher and Tokura conclude that spontaneous speech may provide infants with both direct and indirect acoustic support for both utterance-level and some aspects of clause-level syntactic structure.

Partial bracketings of phrases within larger utterances may be compatible with several different hierarchical geometries and thus may not provide sufficient bases for representation of sentence phrase structure. However, Mazuka suggests that certain basic configurational parameters can be set early in the acquisition process using suprasegmental prosodic cues. It has long been observed that children generally use correct word order from the onset of two-word utterances, evidence that the parameter governing Head Direction (the order of heads and their complements, such as verbs and their objects) is set from the onset of speech. To do this, the child must have segmented words and phrases, must have some access to semantics, and must have identified parts of speech. Mazuka argues that infants may use global prosodic cues to clauses in a small number of complex sentences to set the parameter governing Branching Direction (whether tree structures tend grow in depth to the left or to the right) prior to assigning a full semantics to their input. Thus, early sensitivity to larger, clause-level prosodic cues may provide infants with an initial pass at organizing complex sentences into hierarchical structures. Once the Branching Direction parameter is set, additional phonologically encoded information can be harnessed.

Jusczyk and Kemler Nelson note that, in addition to evidence for the existence of phonological correlates of syntactic structure in input, Phonological Bootstrapping accounts require evidence that infants can detect the relevant phonological properties and make use of these properties in organizing their representations of input. Jusczyk and Kemler

Nelson review results of preference studies showing that, beginning at 4½ months, infants display sensitivity to the sets of prosodic cues that have been implicated in signaling clause- and utterance-final boundaries. By 9 months, infants are sensitive to the subtler prosodic cues that have been implicated in signaling phrase-final boundaries. Moreover, as early as 2 months, infants appear to exploit prosody in representing speech: 2-month-olds are more likely to detect segmental changes in strings of words spoken with sentential prosody than in identical strings spoken with list prosody. Nevertheless, echoing a view expressed in several other chapters, Jusczyk and Kemler Nelson caution against a naive version of Phonological Bootstrapping in which prosody transparently reveals syntactic structure. Rather, prosodic cues are only one of several types of probabilistic information in input speech that learners may use in beginning to unravel the syntactic structure of their language.

In sum, the chapters in Part IV point to the potential use of global prosodic cues to phrase structure as a first pass at organizing syntactic units. They also point to the necessity of including other types of acoustic, distributional, and segmental information for conducting utterance-internal analyses. On this view, analyses of phonology-syntax relations in infant-directed speech have not yet succeeded in capturing all of the information potentially available to language learners. First, cues to phrase groupings do not occur in isolation, but rather in correlation with one another. Most analyses to date have examined single cues, whereas the predictiveness of sets of cues may be substantially greater (see Morgan et al., this volume). Second, infants do not hear words in isolation, but rather in connected discourse. Most analyses to date have relied on absolute measures of phonological properties of words, but analyses that take into account effects of both segmental and suprasegmental context would be more likely to reflect the sorts of information on which infants must rely. Third, infants are not engaged in the single task of discovering phonology–phrase structure relations, but are rather engaged in analyses at a variety of linguistic levels. Tentative results of some of these other analyses (for example, identification of words as function words or content words) may help to inform infants' analyses of relations between phonology and syntax. The chapters in Part V consider how acquisition of words, grammatical categories, and phrases, and the uses of phonological, semantic, and syntactic sources of information, might be interrelated

PART V: SPEECH AND THE ACQUISITION OF LANGUAGE

Gerken discusses how learners come to be able to locate words and phrases in continuous speech, identify category memberships of words and phrases, and discover hierarchical structure of input utterances. She suggests that these processes exploit different forms of information: Segmentation of words and phrases makes particular use of prosody,

labeling words as members of lexical categories depends on recognition of function morphemes, and hierarchical structuring of utterances requires attention to distributional patterns across sentences and sentence fragments. Gerken characterizes word- and phrase-level segmentation, acquisition of grammatical categories, and apprehension of clause-level syntactic structure as "potentially distinct problems" for language learners. Indeed, from an analytic perspective, it is probably useful to initially consider these problems independently.

Nevertheless, it seems likely that acquisition of these different levels of syntactic structure must be intertwined. Consider, for example, how speech rhythm may assist in word-level segmentation: For English in particular, as Cutler (this volume) has argued, strong–weak pairs of syllables are sequences likely to be words. However, this generalization holds only if the weak syllable is *not* a function word syllable. Strong monosyllabic content words are often followed by weak function words, and segmenting such sequences as words would be misleading at best. Hence, efficient application of metrical strategies in word-level segmentation requires some knowledge of category memberships of words. Conversely, one partial predictor of the category memberships of words is the number of syllables they contain (Kelly, this volume), so that assignment of words to grammatical categories is partly dependent on successful word-level segmentation. Knowledge of category membership may assist in bracketing input (Morgan et al., this volume), whereas knowledge that a phrase boundary occurs between a strong syllable and a weak one should inhibit consideration of this pair of syllables as a word. The manner in which acquisition of words, grammatical categories, and phrase structure interact with one another is an important topic for further research.

Gerken notes that early acquisition of syntax doubtless proceeds contemporaneous with acquisition of native language phonology (and may indeed inform acquisition of some aspects of phonology). As emphasized here, learners will not only need some knowledge of native language phonology but will also need to be able to integrate diverse forms of phonological and other linguistic information to bootstrap into grammar. In their chapter, Werker, Lloyd, Pegg, and Polka review findings on the attunement of infant speech perception capacities to properties of the native language. In accordance with the model proposed by Mehler et al. (this volume), these accommodations appear first in relation to gross prosodic properties and vocalic categories of the native language and later spread to consonantal categories. Werker et al. note that there are domain-general, age-related changes in infants' abilities for remembering and exploiting environmental regularities and propose that certain reorganizations in infant speech perception occur in concert with such domain-general changes. They note evidence that inhibition of discrimination for nonnative consonantal contrasts is correlated with ability to form visual categories based on arbitrarily correlated features; both changes occur around 10 months. In light of this

and other evidence, Werker et al. urge that theories of early acquisition be cognizant of the changing cognitive nature of the language learner, putting the baby in the bootstraps, as it were.

The concluding chapter by Hirsh-Pasek, Tucker, and Golinkoff observes that infants are engaged in a variety of developmental tasks, linguistic and nonlinguistic, while immersed in an ocean of information available over a variety of channels. Noting that proposals for Phonological (or prosodic) Bootstrapping have intended to account for how infants formulate representations of input to which syntactic and semantic analyses can be suitably applied, Hirsh-Pasek et al. propose that phonological and other forms of information are used in combination across development. This view is elaborated from the perspective of dynamic systems theory. Hirsh-Pasek et al. suggest a non-linear model of language learning in which different forms of input information, rather than being cast in a rigid ranking of importance, assume differing weights as acquisition proceeds. They note that systems theory suggests a specific set of empirical approaches and provides a framework for integrating future research across disciplinary boundaries, research of the sort needed to explain the child's acquisition of language.

On our view, the contents of this volume offer an emerging picture of how and what infant's perception and representation of phonetic, phonotactic, prosodic, and stochastic patterns manifest in input speech contribute to the acquisition of language. Acquisition must begin with analysis of speech (or signing), for it is these *signals* that constitute the linguistic environment for the learner. Although analyses of speech will not carry acquisition to its completion, such analyses are essential. A Phonological Bootstrapping account of language development may be envisioned in which primitive linguistic representations based on perceptual analyses of input phonology suffice for making rudimentary syntactic inductions. The deductive consequences of these inductions allow infants to exploit new forms of information (semantic, syntactic, or pragmatic) for linguistic purposes and may also allow infants to use aspects of input phonology that were once indecipherable. Access to these new forms of information paves the way for the development of more detailed linguistic representations, which then serve as bases for making more complex linguistic inductions. In this upward spiraling of linguistic abilities, input phonology may assume a progressively less important role. At the root, however, it is the signal that conveys words, phrases, sentences, indeed grammars to each new generation.

REFERENCES

Abney, S. (1987). *The English noun phrase in its sentential aspect*. Unpublished doctoral dissertation, MIT, Cambridge, MA.

Abrahamsen, A. H. (1987). Bridging boundaries versus breaking boundaries: Psycholinguistics in perspective. *Synthese, 72*, 355–388.

Baltin, M. (1982). A landing site theory of movement rules. *Linguistic Inquiry, 13*, 1–38.

Brown, R. (1973). *A first language*. Cambridge, MA: Harvard University Press.
Chomsky, N. (1965). *Aspects of the theory of syntax*. Cambridge, MA: MIT Press.
Chomsky, N. (1986). *Barriers*. Cambridge, MA: MIT Press.
Cooper, R. P., & Aslin, R. N. (1994) Developmental differences in infant attention to the spectral properties of infant-directed speech. *Child Development, 65*, 1663–1677.
Cooper, W. E., & Paccia-Cooper, J. (1980). *Syntax and speech*. Cambridge, MA: Harvard University Press.
Darwin, C. (1877). A biographical sketch of an infant. *Mind, 2*, 285–294.
DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*, 1174–1176.
Demuth, K. (1992). Accessing functional categories in Sesotho: Interactions at the morpho-syntax interface. In J. Meisel (Ed.), *The acquisition of verb placement: Functional categories and V2 phenomena in language development* (pp. 83-107). Dordrecht: Kluwer Academic Publishers.
Demuth, K. (1994). On the 'underspecification' of functional categories in early grammars. In B. Lust, M. Suñer, & J. Whitman (Eds.), *Syntactic theory and first language acquisition: Cross-linguistic perspectives*. (pp. 119-134). Hillsdale, NJ: Lawrence Erlbaum Associates.
Dewey, J. (1894). The psychology of infant language. *Psychological* Review, 1, 63–66.
Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental Psychology, 27*, 209-221.
Fernald, A., Taeschner, T., Dunn, J., Papousek, M., Boysson-Bardies, B., & Fukui, I. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language, 16*, 477–501.
Fletcher, P., & MacWhinney, B. (1995). *Handbook of language acquisition*. Oxford: Blackwell.
Garnica, O. K. (1977). Some prosodic and paralinguistic features of speech to young children. In C. E. Snow and C. A. Ferguson (Eds.), *Talking to children* (pp. 63–88). Cambridge: Cambridge University Press.
Gleitman, L. R., & Wanner, E. (1982). Language acquisition: The state of the state of the art. In E. Wanner & L. R. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 3–48). Cambridge, England: Cambridge University Press.
Hirsh-Pasek, K., Kemler Nelson, D. G., Jusczyk, P. W., Wright Cassidy, K., Druss, B., & Kennedy, L. (1987). Clauses are perceptual units for young infants. *Cognition, 26*, 269-286.
Hockett, C. F. (1966). The problem of universals in language. In J. H. Greenberg (Ed.), *Universals of Language*, 2nd edition (pp. 1-29). Cambridge, MA: MIT Press.
Inkelas, S., & Zec, D. (Eds.) (1990). *The syntax/phonology connection*. Chicago: University of Chicago Press.
Jusczyk, P. W., Cutler, A., & Redanz, L. (1993). Infants' sensitivity to predominant stress patterns in English. *Child Development, 64*, 675–687.
Jusczyk, P. W., Hirsh-Pasek, K., Kemler Nelson, D. G., Kennedy, L. J., Woodward, A., & Piwoz, J. (1992). Perception of acoustic correlates of major phrasal units by young infants. *Cognitive Psychology, 24*, 252–293.
Kelly, M. H. (1992). Using sound to solve syntactic problems: The role of phonology in grammatical category assignments. *Psychological Review, 99*, 349–364.
Lewis, M. M. (1936). *Infant speech: A study of the beginnings of language*. New York: Harcourt Brace.
Liberman, A. M., Cooper, F. S., Shankweiler, D. P., & Studdert-Kennedy, M. (1967). Perception of the speech code. *Psychological Review, 74*, 431–461.
Liberman, A. M., Delattre, P. C., & Cooper, F. S. (1952). The role of selected stimulus variables in the perception of unvoiced stop consonants. *American Journal of Psychology, 65*, 497–516.
Lust, B., Suñer, M., & Whitman, J. (Eds.) (1994). *Syntactic theory and first language acquisition: Cross-linguistic perspectives*.. Hillsdale, NJ: Lawrence Erlbaum Associates.
Markey, K. L. (1994). *The sensorimotor foundations of phonology: A computational model of early childhood articulatory and phonetic development*. Unpublished doctoral dissertation, University of Colorado, Boulder.

McCarthy, J., & Prince, A. (in press). *Prosodic morphology: I. Constraint interaction & satisfaction*. Cambridge, MA: MIT Press.

Mehler, J., Jusczyk, P. W., Lambertz, G., Halsted, G., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition, 29*, 143–178.

Meisel, J. (Ed.) (1992). *The acquisition of verb placement: Functional categories and V2 phenomena in language development*. Dordrecht: Kluwer Academic Publishers.

Morgan, J. L. (1986) *From simple input to complex grammar*. Cambridge, MA: MIT Press.

Morgan, J. L. (in press). A rhythmic bias in preverbal speech segmentation. *Journal of Memory and Language*.

Morgan, J. L., & Newport, E. L. (1981). The role of constituent structure in the induction of an artificial language. *Journal of Verbal Learning and Verbal Behavior, 20*, 67-85.

Newport, E. L. (1977). Motherese: The speech of mothers to young children. In N. Castellan, D. B. Pisoni, & G. Potts (Eds.), *Cognitive theory* (Vol. 2, pp. 177-217). Hillsdale, NJ: Lawrence Erlbaum Associates.

Peters, A. M. (1983). *The units of language acquisition*. New York: Cambridge University Press.

Pinker, S. (1984). *Language learnability and language development*. Cambridge, MA: Harvard University Press.

Prince, A., & Smolensky, P. (in press). *Optimality theory: Constraint interaction in generative grammar*, Cambridge, MA: MIT Press.

Saussure, F. de (1916/1959). *Course in general linguistics*. New York: Philosophical Library.

Slobin, D. I. (1982). Universal and particular in the acquisition of language. In E, Wanner & L. Gleitman (Eds.), *Language acquisition: The state of the art* (pp. 128-170). Cambridge: Cambridge University Press.

Snow, C. E. (1972). Mothers' speech to children learning language. *Child Development, 43*, 549-565.

Streeter, L. A. (1978). Acoustic determinants of phrase boundary perception. *Journal of the Acoustical Society of America, 64*, 1582-1592.

Velten, H. V. (1943). The growth of phonemic and lexical patterns in infant language. *Language, 19*, 281–292.

Wexler, K., & Culicover, P. W. (1980). *Formal principles of language acquisition*. Cambridge, MA: MIT Press.