

## *Phonological Development*

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In learning to talk, children must gain knowledge of the phonological forms of words and phrases of their native language and must learn the articulatory and phonatory movements needed to produce these words and phrases in an adult-like manner. Thus, phonological acquisition has two basic components: a cognitive–linguistic component associated with learning the phonological system of the ambient language and the development of speech–motor skills needed for adult-like productions. A full understanding of phonological development, then, must be broad-based, including an understanding of the motor and auditory skills underlying speech production and of processes of memory and pattern recognition associated with storage and retrieval of words in a child’s lexicon. This chapter addresses these issues by providing a summary of phonological development in typically developing children, a discussion of the relationship between phonological and lexical acquisition, and a summary of theoretical approaches to the study of child phonology.

In the discussion of phonological development in children, descriptions of some speech sounds contain terms with which readers may not be familiar. The following provides brief definitions of some of these terms. In the field of phonetics and phonology, consonants are often grouped together into classes on the basis of “features” denoting *place* of articulation (where in the mouth the sound is produced) and *manner* of articulation (how the sound is produced). The places of articulation frequently referred to in the following discussion of phonological development are *labial*, that is, consonants produced with the lips (e.g., [p,b,m]), *alveolar*, that is, consonants produced with the front of the tongue (e.g., [d,n,s]), and *velar*, that is, consonants produced with the back of the tongue (e.g., [k,g]). The manners of articulation referred to in the following sections are *stop*, that is, consonants produced with full blockage of the airstream (e.g., [p,b,t,d]), *fricative*, that is, consonants produced with friction of the airstream (e.g., [f,s,z]), *nasal*, that is, consonants produced with the airstream passing through the

nasal cavity (e.g., [m,n]), *liquid*, that is, consonants produced with little blockage of the airstream (e.g., [l,r]), and *glide*, that is, “vowel-like” consonants produced with no blockage of the airstream (e.g., [w,j]; the consonant [j] is the first sound of the word “you”). More complete phonetic descriptions of the *segments* of English (i.e., the consonants and vowels) are available in texts by Chomsky and Halle (1968), Stoel-Gammon and Dunn (1985), and Bernhardt and Stemberger (1998).

## Typical Phonological Development

### *Prelinguistic development*

Prior to the onset of meaningful speech, infants produce a wide range of utterance types. In the first month of life, the output is not very “speech-like”: common utterance types include cries, coughs, burps, or wheezes. Around 2 to 3 months of age, however, vowel-like vocalizations occur, and by 6 to 7 months, most infants produce consonant–vowel (CV) syllables that, although non-meaningful, resemble syllables, or words, of adult languages. The repertoire of speech sounds changes dramatically during the first year of life. In the first 6 months, vowel articulations tend to predominate and most consonantal sounds are produced in the back of the mouth. With the onset of CV babbling (also referred to as canonical babbling), consonants produced in the front of the mouth, articulated with the lips or front of the tongue, are frequent, particularly [m], [b], and [d]. Thus babies produce many one- and two-syllable utterances like [baba] or [di]. Between 6 and 12 months, the consonantal repertoire expands considerably, but claims that babies produce all the sounds of all languages of the world have not been substantiated (see the discussion of Jakobson, 1968, below). In fact, a limited set of consonants, primarily stops, nasals, and glides, accounts for the great majority of consonant productions (Locke, 1983). Although some language-specific features are present in late babble (10–12 months), analyses of prelinguistic vocalizations from infants raised in many different linguistic communities have shown a predominance of these consonant classes in all infants (Locke, 1983).

During the prelinguistic period, babies are exposed to adult input and begin to form representations that will allow them to understand and produce words of their language. In addition, they hear their own babbled productions, which serve as the basis for linking their own articulatory movements with the resulting acoustic signal (Vihman, 1996). This link is important for the production of words: The baby who repeatedly produces the non-meaningful syllable [ma] at 7 months becomes aware of the tactual and kinesthetic sensations associated with this syllable and hears the acoustic output associated with the production, creating an articulatory–auditory “feedback loop” that is fundamental to speech production throughout life (Fry, 1966; Stoel-Gammon, 1998a). Furthermore, in the case of a word-like form such as [ma], the match between the babble [ma] and the real word [mama] means that the child’s non-meaningful vocalization can be transformed into meaningful speech with relative ease (Locke, 1993).

*From babble to words*

Babies typically produce the first words around their first birthday, and words and babble co-exist for several months thereafter. The phonetic properties of babble and early words are highly similar, with the same consonants and syllable types occurring in both (Stoel-Gammon, 1998a). Developmentally, babble productions serve as the building blocks for the articulation of adult-based words. Comprehension and production of words require the presence of “underlying representations” and thus add an important element to the child’s developing phonological system. Although the precise nature of underlying representations is not well understood, even in adult speech, it is generally agreed that these “stored” representations contain information that allows a speaker to understand and produce words. It is particularly difficult to determine the form of underlying representations for children in the early stages of acquisition. On the one hand, it is possible that their representations are very similar to those of adults; on the other, because of their limited lexicon, their representations may contain much less detail than those of an adult. In addition, it is possible that a child’s mispronunciation of a word influences the underlying representation for that word.

Longitudinal studies of babbling and early words show that individual production patterns in terms of sounds, syllable shapes, and vocalization length are often “carried forward” to a child’s first words (Stoel-Gammon & Cooper, 1984; Vihman, 1996; Vihman, Elbert, & Ferguson, 1987). Experimental evidence of this type of continuity comes from a study of the acquisition of nonsense words. Messick (1984) exposed children in the very early stages of word learning to nonsense words that were either phonetically similar or dissimilar to their own babbles; she found that the children produced a significantly greater number of words that were phonetically similar to their own babbled productions, but that they showed no differences in their ability to understand the two types of nonsense forms.

Although children vary extensively in the age of onset of meaningful speech and in the rate at which they add new words to their developing lexicon, common tendencies in the phonological patterns of first word productions are quite striking. The period from the onset of meaningful speech to acquisition of a 50-word vocabulary is characterized by a “phonetic inventory” of simple syllabic structures and a small repertoire of consonants and vowels. (The term “phonetic inventory” is used here to describe the elements occurring in a child’s productions and does not take into account accuracy of production.) In English, syllable types predominating in the first-word period include CV (consonant–vowel) as in *go*, CVC as in *sit*, and CVCV as in *baby*; in terms of consonantal repertoire, productions are composed primarily of stops, nasals, and glides. Consonants missing from the inventories of young children tend to be those that occur infrequently in the language, such as [v], and/or require more articulatory precision, such as the initial consonants of the words *chew*, *shy*, *red*, *juice*, *think*, *they* (note that two letters in written forms, e.g., *ch*, represent a single sound in the spoken form).

Research on first word production in languages other than English reveals the same general properties in terms of sound types and syllable structure: in all languages, CV syllables tend to predominate, and stops, nasals, and glides occur frequently. Language-

specific influences are apparent, however, in the frequency of occurrence of particular sound classes, syllable types, and stress patterns. For example, children acquiring English produce many CVC words (e.g., *ball*, *book*) and disyllables with stress on the first syllable (e.g., *mommy*, *bottle*, *cracker*); French-learning children, by comparison, produce a greater proportion of two-syllable words, more words with stress on the last syllable, and more nasal consonants, all features of the French language (de Boysson-Bardies et al., 1992).

### *Phonological development beyond the first-word stage*

The end of the first-word stage, around 18 months, is signaled by a rapid increase in vocabulary size, an expansion of the repertoire of segments and syllable shapes, and the onset of two-word utterances. By 24 months, the typically developing child learning English has acquired a productive vocabulary of 250 to 350 words and can produce multiword sentences. At this period, a child's phonological system can be described in two ways: through an "independent" analysis, with a focus on the child's productions without reference to the adult model, or via a "relational" analysis, comparing the child's production to the adult model. Each type of analysis provides important information. An independent analysis includes a summary of the child's phonetic inventory, that is, a list of segments, sound classes, syllable and word structures, and suprasegmental patterns in the child's speech. A relational analysis, in contrast, focuses on similarities and differences between the child's pronunciation of a word and the adult form.

*Phonetic inventories.* Independent analyses of the speech of 2-year-old children without reference to the adult model show that the basic elements of the adult system are present, although the child's system is not complete; the phonetic inventory (i.e., the sounds and syllable structures produced) of a typically developing 2-year-old child includes stops (as in *pie*, *bee*, *toe*, *doe*, *key*, *go*), labial and alveolar nasals (as in *me* and *no*), and glides (as in *we* and *you*) (Stoel-Gammon, 1985). In terms of syllable structures, the repertoire includes CV and CVC syllables that can combine to form disyllabic words. In addition, the average 2-year-old can produce some words with consonant clusters (i.e., two adjacent consonants) as in *twin* or *milk*. The vowel repertoire is more complete than the consonantal system (Stoel-Gammon & Herrington, 1990). By age 36 months, the typical phonetic inventory has expanded to include consonants from nearly all place and manner classes of English as well as a range of syllable and word types.

*Adult-child comparisons.* Relational analyses of children's productions are based on a comparison of the adult form and the child's production and are used to examine accuracy of production and to determine the types of errors that occur. Such analyses reveal that accuracy of consonantal production improves markedly between 24 and 36 months, as a majority of children acquiring English can accurately produce all stops, nasals, and glides, as well as some fricatives, during this period. By 42 months, the repertoire of accurate segments, at least in some word positions, has increased to include liquids, fricatives, and affricates as in *church* and *judge*.

Study of the differences between the adult target and the child's production show that, in some cases, the two forms differ to such an extent that it is impossible to determine what the child was trying to say; in this case, the child's form is classified as "unintelligible." At the age of 2 years, about half of a child's utterances are intelligible (i.e., can be understood by an adult who is not familiar with the child). By the age of 3 years, the level of intelligibility increases to 75% and by age 4, it is 100% (Coplan & Gleason, 1988). This does not mean that the child's productions are fully adult-like by age 4, rather that the errors do not interfere with intelligibility.

Comparisons of adult targets and child productions of intelligible words reveal that differences in the two forms are quite systematic; these differences have been described in terms of phonological "processes" (Stampe, 1969) that modify the target by omitting sounds or syllables, or by substituting one sound class for another. In terms of omissions, children often simplify a word by omitting the final consonant, producing a CV rather than a CVC syllable (e.g., omitting the [r] of *car*), or by producing a single consonant rather than a sequence of consonants (e.g., omitting the [l] of *blue*). Both of these patterns yield CV syllables, the basic syllable type from the babble period. Stress patterns within a word also play a role in children's omissions: unstressed syllables are often omitted from the child's form. Thus the first syllable in *spaghetti* or *banana* may be omitted (or the second syllable in *telephone* or *crocodile*).

Errors involving substitutions can also be related to patterns of late babble. In particular, fricatives and affricates in the target word, which are rare in babble, may be produced as stops; thus *very* is produced with an initial [b]; *shoe* and *sip* with initial [t], and *Joe* and *zoo* with initial [d]. Other common substitution patterns include velar stops (/k/ and /g/) produced as alveolar stops ([t] and [d]), as in the word *go* produced with a [d], and target liquids (/l/ and /r/) produced as glides ([w] and [j]), as in *red* and *light* produced with initial [w]. Works by Ingram (1976), Grunwell (1981), and Stoel-Gammon and Dunn (1985), among others, include more complete descriptions of common error patterns in children's speech.

This summary has provided a brief description of phonological development from birth to 3 years, with emphasis on production and examples primarily from English. Basic production patterns that first appear in the prelinguistic period, that is, CV syllable structures with stop, nasal, and glide consonants, tend to predominate in the first-word period. With increasing age and an expanding vocabulary, children begin to move beyond the basic repertoire and learn to produce a wider range of features of the target language. The following section explores the relationships between phonology and acquisition of the lexicon.

## The Relationship between Phonological and Lexical Development

### *Lexical selection in early words*

As noted above, the individual sound pattern preferences in babble have been found to carry over into meaningful speech, forming the building blocks for the child's early lexical items. Research focusing on phonology and the lexicon shows that individual

children exhibit patterns of lexical selection and avoidance based on their own phonological abilities and preferences. Ferguson and Farwell (1975), for example, described a child who showed a marked preference for words with sibilant consonants (e.g., *ice, shoes*). Another child, described by Stoel-Gammon and Cooper (1984), had a preference for words ending with a velar stop; his very early vocabulary included many velar-final words such as *milk, clock, talk, walk, frog, block, quack, whack, sock, and yuk*, all pronounced as [gak]. These findings indicate that the specific words in a child's early vocabulary are determined not only by semantic and pragmatic influences, but also by a child's productive phonological ability.

Experimental evidence for the phenomenon of lexical selection and avoidance comes from a set of studies of novel word learning by Leonard and colleagues (Leonard, Schwartz, Morris, & Chapman, 1981; Schwartz & Leonard, 1982). The studies show that young children are more likely to produce novel words whose phonological characteristics are consistent with their own phonologies (IN words) than words with phonological features not present in the children's phonologies (OUT words). These studies provide additional evidence of the influence of phonology on lexical acquisition during the period of the first 50 to 100 words.

### *Lexical–phonological patterns beyond the early-word period*

The relationship between phonology and lexical development continues to exist beyond the first 50-word period. Stoel-Gammon (1998b) investigated the phonological characteristics of earlier- and later-acquired words based on age-of-acquisition data taken from the MacArthur Communicative Development Inventory, a parental checklist of receptive and productive vocabulary for infants and toddlers up to 30 months of age. Words acquired between 11 and 19 months of age showed considerable effects of lexical selection; in initial position, words with stops and bilabial consonants (e.g., /p,b,m/) were predominant; in contrast, words acquired between 20 and 30 months displayed a greater variety of phonetic characteristics, indicating reduced phonological influence on the selection of new words.

The relationship between lexical and phonological development is not unique to English. Using normative data from a Cantonese version of the Communicative Development Inventory, Fletcher and colleagues (Fletcher et al., 2004) compared the phonological characteristics of words acquired between 16 and 22 months with characteristics of words acquired between 23 and 30 months. The results of this study were very similar to those found by Stoel-Gammon (1998b): target words with initial bilabials, nasals, glides, and stops are highly preferred for the early-acquired words in Cantonese. The authors conclude that lexical selection based on the initial consonant of the target word was evident for early-acquired words, but that this effect weakened for the later-acquired words. The authors note that their results indicate a pattern of lexical selection beyond the first 50-word stage because the average productive vocabulary size of the younger group was 98 words.

As the child acquires a larger vocabulary, the influence of lexical selection appears to decline; the relationship between phonological and lexical acquisition does not disappear, but takes on a different form. Beyond the first 50 words, a strong relationship between

the number of words in the child's productive vocabulary and the complexity of the child's phonological inventory is observed; children with larger vocabularies tend to have larger inventories of speech sounds and syllable structures than children who produce fewer words (Stoel-Gammon, 1998a). At this point of development, it appears that the increasing size of the lexicon becomes a driving force in the acquisition of phonology, a view supported by the work of Lindblom (1992) and Walley (1993), among others.

Thus far, this chapter has focused on the "what" of phonological development, including the ages and stages of typical development; the sounds and syllable structures acquired; the types of errors that occur; the nature of individual differences; and the relationship between phonological and lexical acquisition. The following section explores the "why" of phonological development, by providing a summary of theoretical accounts that have been proposed to account for this aspect of language learning.

## **Theoretical Approaches to Phonological Development**

This section presents a brief outline of the field of developmental phonology and a more detailed discussion of some of the most influential theories and of the major works that reflect each theoretical framework. The dividing line between theories is not always easy to determine, as many of the most influential works reflect the dynamic nature of the field, with individuals borrowing one feature of a theory and incorporating it into another, as the knowledge of the facts of phonological development evolves over time. The description of each theory includes a summary of its strengths and weaknesses.

### *Developing a theory*

Menn (1980) stated that there are, in general, three stages that unfold when an existing "central" theory is extended to encompass a new, related area. In this case, the existing theory is that of adult phonology and the related area is the study of child phonology. The first phase is the extension phase, during which time the existing theory is simply applied, without modification, to the new area of study. The second phase is the comparison phase, when researchers use new data to test the existing theories and begin to discover the pitfalls and problems of a simple extension of the existing theory. The final stage consists of the creation of a new theory, either specialized for the new area or a modification of the existing general theory to encompass the related field.

In child phonology, the extension phase began with Jakobson's (1941) monograph *Child language, aphasia and phonological universals* (translated from German in 1968), as he applied unmodified, structuralist phonological principles to the process of phonological acquisition. The extension phase continued with the generative accounts of phonological development, most notably Neil Smith's (1973) description of his son's development, and to a lesser extent with David Stampe's natural phonology (Donegan & Stampe, 1979). As more information regarding the facts of phonological acquisition became available in the 1970s, people began to test the ideas of the earlier theorists



against the growing body of data. During this period, work of Charles Ferguson and his colleagues and students introduced new child-centered theories of phonological development. Since then, we continue to be in Menn's third stage of the development of a theory, the creation of a new theory, and numerous potential theories have been proposed. The following sections summarize the requirements of a theory and describe major theories that have been proposed.

The field of phonology has traditionally been distinguished from phonetics, with phonology describing the abstract, linguistically meaningful properties of the sound system and phonetics describing the concrete, redundant, and physical characteristics of speech production and perception. Approaches to the study of speech development are often divided along these same lines: Phonological approaches tend to analyze development in terms of its relationship to the endpoint (a mature, symbolic linguistic system), while phonetic approaches address the acquisition of speech from the initial state, a motorically and cognitively immature organism.

### *Requirements of a theory of phonological development*

Three different publications (Bernhardt & Stemberger, 1998; Ferguson & Garnica, 1975; Stoel-Gammon & Dunn, 1985), spanning a period of more than 20 years, offer remarkably similar descriptions of what a theory of phonological development must account for. A combined summary of the necessary components reveals the following: A theory must: (1) account for the facts of adult phonology; (2) account for the facts of child phonology, including: (a) general patterns of development, including common error patterns as noted in the first section of this chapter; (b) individual differences in patterns of acquisition; (c) within-child variability in the production of individual sounds and words; (d) continuity between prelinguistic and linguistic development; and (e) the fact that child productions change over time; (3) be able to explain the role of input; (4) be able to account for the discrepancy between perception and production; (5) account for both phonetic (i.e., articulatory) and phonological learning; (6) be compatible with other theories of linguistic and non-linguistic learning; and (7) must make testable predictions regarding patterns of acquisition and error types. It is clear from the descriptions below that some of these "requirements" were not considered at all in some theories; at the same time, fundamental constructs of a particular theory may not have been included in the list above.

### *Structuralist theories*

Roman Jakobson's (1941) monograph is probably the best-known and most influential account of phonological development, and is grounded in the framework of structural linguistics, which was dominant at the time. Structuralism is rooted in the empiricist tradition, with an emphasis on establishing structural grammatical laws based on analysis of spoken language. The proposals put forth by Jakobson were the motivation for dozens of researchers who set out to test the theories against a growing body of child data.



Eventually, many of Jakobson's proposals would be discredited, paving the way for the development of new theories that would better account for the facts of child phonology.

One of Jakobson's major claims is that there is a discontinuity between prelinguistic and linguistic vocal development. He describes the babbling period as a "purposeless egocentric soliloquy" and a "biologically oriented period of 'tongue-delirium'" (1968, p. 24), and states that babies produce a wide variety of different speech sounds, representing all conceivable sounds of the languages of the world. Given the strong relationships between babbling and speech cited in the earlier sections, this view is no longer tenable.

The emergence of phonological development, according to Jakobson, represents the beginnings of true speech. During this period, the "phonetic abundance" of the babbling period (i.e., the large number of different sounds) is replaced by the "phonemic poverty" of early word productions (i.e., the small number of different sounds); acquisition of phonemic contrasts is said to adhere to a universal order, subject to laws of "irreversible solidarity" that dictate the relative order of acquisition of individual phonemic contrasts in all children and all languages. The order is based on structural principles and implicational hierarchies regarding the nature of phonemic inventories in adult languages. For example, the presence of fricatives (e.g., /f,s/) in a language implies the presence of the more "basic" stops (e.g., /p,t/), just as the acquisition of fricatives by the child implies that stops have been acquired.

Jakobson did not gather developmental data, but rather relied on a few published diary accounts and anecdotal claims. Given his interest in linguistic universals and the minimal data the conclusions are based on, the strengths of this theory lie in its ability to explain the general patterns of the appearance of individual sounds that are often observed in children. The widely observed pattern of consonants produced with the lips or front of the tongue (e.g., [b,d]) appearing before consonants produced with the back of the tongue (e.g., [k,g]), for example, is readily accounted for by Jakobson's rules of "irreversible solidarity." While we know now that there is an enormous amount of individual variability, Jakobson's universal order of acquisition is still considered important, especially in the field of speech language pathology for the diagnosis and treatment of phonological disorders. Children are identified as disordered or delayed based on these principles, and treatment is typically grounded in the notion of a universal order (and timetable) of acquisition.

While some of Jakobson's conclusions are still accepted, numerous criticisms of his theory have been cited. The major criticisms, as presented by Ferguson and Garnica (1975), focus on the inability to account for many of the facts of child phonology. For example, inter- and intra-child variability, now well documented, is ignored, and the strict discontinuity between babble and speech has been found to be false, as noted in the description of development provided above.

### *Rule- and constraint-based theories*

*Generative phonology.* While the structuralist tradition emphasized the importance of analyzing overt speech to identify structural laws and linguistic universals, linguists

within the generative tradition took a position that stressed the difference between what speakers produce and what they actually know about their language, thus distinguishing performance from competence, and taking competence as the focus of study. Noting the structural similarities among the languages of the world, Chomsky (1972) proposed the existence of a Universal Grammar, a set of restrictions on the possible structure of language based on an innate, hard-wired language device. The ability to acquire language, according to his view, involves “an innate mental endowment” that allows children to discover the structure of their language with relatively little data from the adult language. The primary generative influence for both adult and child phonology comes from a seminal work by Chomsky and Halle (1968), *The sound pattern of English*. In this work, underlying phonological representations are taken to be abstract, encompassing only that information that is not predictable from the system of phonological and phonetic rules that operate on-line in the generation of spoken words. Thus, phonology consists of an abstract underlying representation together with a system of ordered rules that transform the representation into the surface form we actually say.

In 1973, Neil Smith published a detailed account of his son Amahl’s language development, rooted in the generative tradition. Smith provided a complete formal description of the phonological rules active at each stage of Amahl’s speech development, using data obtained between the ages of 2;2 and 4;0. Smith assumes (1) that the child’s underlying representations are adult-like; (2) that there is a set of strictly ordered, obligatory realization rules that produce the child’s phonological form; and (3) that the phonological form is then subject to phonetic rules that create the child’s output. According to Smith, phonological development can be described as a process of rule modification applied to stable, adult-like representations, and there is no evidence for an independent, child-based phonological system. His basic argument for adult-like mental representations is the assertion that sound change is an “across-the-board” phenomenon, by which a newly acquired sound is immediately used in all relevant words. Interestingly, Smith’s data provide multiple examples of change that is not, in fact, across-the-board. In the longitudinal description, many, if not most, of the rules are described as becoming optional before disappearing.

A major strength of all rule-based theories of child phonology is the ability to account for the regular correspondences between adult targets and child productions. If final consonants are never present, then a rule deleting consonants in final position can capture this pattern. Furthermore, the central role of features (subunits of phonemes) in generative theory allows for these generalizations to be stated parsimoniously; it is a fact of child language that certain types of speech sounds tend to pattern together (e.g., fricatives are produced as stops). Another fact of child phonology, however, is that development includes variability, non-linearities, and exceptions, especially in the earliest stages. Generative theory, however, does not have an adequate mechanism for accounting for these now well-known facts. Smith’s study of his son’s development does not start until 26 months of age; an attempt to use a set of realization rules to describe the productions of a younger child in the very earliest stages of language acquisition would not be an easy task. Just how phonological representations come to exist is not specified, and the assumption that perceptual abilities are fully developed at the onset of linguistic production is problematic. The question of continuity between prelinguistic and

linguistic development is an interesting one for generative theory. While the assumption of innate, hard-wired language structures implies at least implicit continuity, there is no treatment of the role of prelinguistic vocalizations in the major generative works. Lastly, not only does the theory not account for the role of input in acquisition, it downplays the importance of language input, making it difficult to account for the early appearance of language-specific phonological patterns in child speech. According to generative theory, language, by definition, is not learnable so must therefore be innate.

*Natural phonology.* Another important work within the rule-based approaches to child phonology, Stampe's theory of natural phonology (Stampe, 1969), shares a number of important characteristics with traditional generative theory. First, the child is assumed to be operating with adult-like representations from the very earliest stages of language acquisition; in addition, a certain amount of linguistic knowledge is presumed to be innate. In the case of natural phonology, the child is born with a predetermined, universal set of phonological processes that dictate the form of his productions. The basic thesis of natural phonology is that "the living sound patterns of language, in their development in each individual as well as in their evolution over the centuries, are governed by forces implicit in human vocalization and perception" (Donegan & Stampe, 1979, p. 126). According to Donegan and Stampe, every child is born with the same set of innate processes, and the act of acquiring a language-specific phonology consists of learning the constraints a language imposes on these natural processes. Children must learn to suppress, limit, and reorder the processes in accordance with the phonology of their native language.

Natural phonology has some advantages over traditional generative theory: it specifies clearly what is considered to be innate, and by positing the universal existence of these natural processes accounts for the structuralist observations of the congruencies between child processes and phonological patterns in adults. The processes, by definition, may apply variably, accounting for variability in the production of individual sounds within a child. Input is granted a somewhat more important role in the process of learning, and the fact that the processes are assumed to be grounded in the physical attributes of the child's speech mechanism begins to provide some explanation for the nature of child productions. The most enduring influence of Stampe's theory, however, is probably the role that phonological processes continue to play in the description of the systematic errors that occur both in typical development and in children with phonological disorders (see the section *Typical Phonological Development* above for examples of these processes). As with previous theories, however, no attention is given to the role of prelinguistic vocal development or to individual differences across children.

*Constraint-based approaches.* Stampe modified generative phonology to incorporate the notion of natural processes; he did not, however, completely reject the generative notion of rules that transform underlying representations into surface (i.e., spoken) forms, but distinguished between innate processes and learned rules. Another approach to both child and adult phonology is a constraint-based approach referred to as "optimality theory" (Prince & Smolensky, 1997). Constraint-based approaches to child phonology, as outlined by Bernhardt and Stemberger (1998), maintain many of the fundamental

characteristics of generative phonology; the feature (a subunit of the phoneme) is maintained as the basic unit of phonological representation and underlying representations are thought to consist only of unpredictable phonological information, with redundant and predictable information stored in the child's grammar. Instead of strictly ordered rules, however, output is governed by a set of constraints that are ranked and determine the optimal production of a word. The two basic types of constraints are faithfulness constraints, which dictate that the output should be as similar to the adult form as possible, and output constraints, which are based on articulatory and perceptual abilities. Constraints, unlike rules, can be violated, and output forms are generated by constraints and violations of constraints. Phonological acquisition is a process of re-ranking constraints so that the output matches the adult form. The initial state of the system, however, is not clearly specified and the question of the origin of the individual constraints is left unanswered.

A constraint-based system has many similarities with traditional generative theory in its description of child phonology. Underlying representations remain the same; however, ordered rules are replaced by ranked constraints. Because they are more recent, however, constraint-based theories do not ignore many of the facts of child phonology that are now known. Thus, the concept of prelinguistic to linguistic continuity is accommodated by positing constraints that operate during the babbling period and are then carried over to the beginning of meaningful speech, accounting for the similarities between babble and early word productions. Furthermore, individual differences are ascribed to a certain amount of randomness in the initial ranking of constraints; while some constraints may be universally ranked high or low, others are random and ranked differently by individual children. Other applications of constraint-based approaches to phonological developmental can be found in the works of Dinnsen and colleagues (e.g., Dinnsen & O'Connor, 2001) and Gierut and colleagues (e.g., Gierut, 2001; Gierut, Morrisette, & Champion, 1999).

### *Child-centered theories*

Child-centered theories reflect the beginnings of the third phase in the development of a theory of child phonology with the realization that the facts of child phonology, having been tested against the existing theories, necessitate a more radical departure from adult theory than had previously been attempted. According to these theories, child phonology must be addressed on its own terms, rather than in relation to the adult system.

*Prosodic theory.* Waterson's (1971) prosodic approach to phonological development differed dramatically from traditional structuralist and generative accounts. In particular, it questioned the idea that the phoneme or the feature was the basic unit of representation for the child, as it was assumed to be for the adult. Furthermore, the role of perception and the specific nature of the input were elevated to primary status in the theory. According to Waterson, perception develops gradually in conjunction with production. Underlying representations are not assumed to be adult-like, since perception is not adult-like in the earliest stages. In the analysis of the speech of her young son, P, she

used a non-segmental approach, incorporating articulatory features as well as suprasegmental features such as syllable structure and stress patterns, and established five different structure types to describe P's productions. According to Waterson, the child perceives a schema for a set of words with a particular structure and then reproduces the salient characteristics in his own output. Thus, the words *fish*, *fetch*, *brush*, and *dish* form a "sibilant" schema in that the final consonant of each of these words is a sibilant consonant in the adult form; P's productions of these words also contained a sibilant consonant. The features that appear in the child's spoken form are determined by the child's perception, by the child's own output system, and by the "strength" and "salience" of articulation in the adult form.

Obviously, not all children base their early productions on these same schemas, a fact accounted for by the role Waterson gives to the input: Each child hears a different set of words with enough frequency for them to be recorded, and extracts schemas from this input. The strengths of this theory include the explicit treatment of the role of perception and input in phonological development, the recognition of individual patterns of development (in the form of different schemas), and the variable stability of sounds in different contexts. It is, however, quite limited in scope as it is based on a small dataset from one young child, and does not address the systematic error patterns that occur or the typical order of acquisition of individual sounds.

*Cognitive theory.* One of the basic principles of the cognitive theory of phonological development is that children play an active role in acquiring the phonology of their language; they choose words to say based on their own articulatory abilities, and then formulate, test, and revise hypotheses regarding phonology based on linguistic experience. Because of this, a major strength of the theory is its attention to the phenomenon of individual patterns of acquisition. It is, by definition, designed to account for observed phenomena such as lexical selection, regression, and the use of phonological strategies, which are generally characteristic of the very earliest stages of development. It does not, however, have much to say about the systematic correspondences observed between adult forms and child productions that appear later in development.

Ferguson and Farwell (1975) provide a detailed account of the longitudinal development of initial consonant categories in three children, a paper now considered a seminal work illustrating the cognitive theory of phonological development. One important observation from this study is the frequent occurrence of intra-word variability, that is, the fact that some words are pronounced in different ways by the same child at the same point in time. Ferguson and Farwell claim that this variability "makes it difficult to make statements about either phonological contrasts or unique underlying forms and systematic rules" (1975, p. 425). Other observations include the presence of regressive and progressive phonological idioms (words that are either more or less advanced than the current phonological system would suggest) and the selectivity of the child in choosing individual words to try to produce. The authors highlight the importance of the lexicon in phonological acquisition (as described in a previous section); phonological development is not just a matter of change in the system (rules), but may take place on a word-by-word basis, reflecting the individual experiences and preferences of the child.

Ferguson and Farwell (1975) offered an outline of the essential characteristics for any phonological theory, based on their observations. The model should: (1) de-emphasize the separation of phonetic and phonemic development; (2) emphasize individual variation, but incorporate the notion of “universal phonetic tendencies”; (3) emphasize the importance of lexical items in phonological development; and (4) allow for the gradual development of a phonological system, based on generalizations from the child’s own “phonic core” of words and the articulations needed to produce them.

### *Biological theories*

Biological models for the development of early speech (e.g., Kent, 1992) are based on an approach that emphasizes the importance of general principles of developmental biology and the role of anatomical and motor development in the development of a phonological system. In Kent’s model for early phonological acquisition (1992), audition and speech motor function are viewed as genetically determined. Early productions are limited by motor ability, especially by jaw-tongue synergy and by the inability to move the tongue in a precise manner. Universal patterns in terms of order of acquisition are described in relation to the development of specific motor capacities. Little attention is given to the role of perception in the acquisition of phonology; however, other biological theorists have suggested that substitution errors in child speech are at least partly predicted by acoustic similarity, and Thelen (1991) highlights the importance of multimodal mapping (including acoustic, sensory, and visual) in the production of canonical babble and later speech.

Kent described the production of early words as holistic “motor scores” that become more reliable as coordination improves. These motor scores may be compared to the vocal motor schemes described by Vihman (1992) and to Browman and Goldstein’s (1992) “gestural phonology.” In this view, segmental consistency is rooted in the developing precision of motor performance. Phonemic organization emerges through global mapping between sensory and motor routines. A fundamental difference between this view and the approaches described above is that in the biological approach, “development is a process in which the child progressively applies available resources in attempting to emulate the mature behavior” as opposed to the view that development is “a process in which the child simplifies a fully comprehended version of the mature behavior” (Kent, 1992, p. 85).

The strengths of this approach include the emphasis on continuity between phonetic and phonological learning and prelinguistic and linguistic production as well as the integration with other types of non-linguistic learning and development. Variability in production can also be accounted for in terms of the use of motor scores and the gradual increase in coordinative ability. Furthermore, this approach allows for the simultaneous development of production and perception skills, by not attributing adult-like phonemic representations to young children. Although not specified completely, systematic correspondences between child and adult forms are potentially accounted for by motoric and perceptual limitations. One criticism of biological models that has been noted, however, is that the infant is often portrayed as a passive learner, rather than an active participant



in the acquisition process, and that little attention is given to individual patterns of development.

### *Usage-based phonology*

A relatively new linguistic theory, “usage-based linguistics” (Kemmer & Barlow, 2000), assumes a close relationship between language use and language structure, with structure seen as both a generator and a product of language use. With specific reference to phonology, a usage-based account emphasizes the role that language use plays in shaping a linguistic sound system (Bybee, 2001), while a usage-based approach to phonological acquisition highlights the important role of language input and use in the instantiation and ongoing modification of the child’s phonological system. From this perspective, phonology is not acquired independently of other aspects of grammar, but is intimately linked to the individual words that are present in the lexicon and the characteristics of use of those words. Thus, a usage-based account predicts that lexical effects will be detected in children’s productions of non-words. Two lexical characteristics that have been investigated are word frequency and neighborhood density of individual words.

It is well documented that word frequency influences adults’ speech. In particular, high frequency words display an advantage in both perception and production tasks (summary in Ellis, 2002); in addition, word frequency has also been shown to have an important effect on processes of historical sound change. It is reasonable, then, to suspect that word frequency plays a role in the development of a linguistic sound system. A few researchers have investigated this hypothesis, with mixed results. For example, studies by Leonard and Ritterman (1971) and Tyler and Edwards (1993) showed facilitative effects of word frequency on accuracy of children’s productions. By contrast, Velten (1943) observed that his daughter’s high frequency words were the last to change when a new contrast entered her phonological system.

Effects of “neighborhood density,” which refers to the phonological relationships between words in an individual’s lexicon, are also well known in the adult perception and production literature. Phonological “neighbors” are defined as words that differ from one another by a one phoneme addition, deletion, or substitution (Luce & Pisoni, 1998); for example, the words *bat*, *mat*, *pit*, *pet*, *past*, *spat*, *at*, among others, would be neighbors of the word *pat*. For children acquiring language, neighborhood density may influence the ongoing reorganization of phonological representations during development. For instance, words that reside in dense neighborhoods (i.e., have many neighbors) may need more detailed phonological representations due to potential confusability with other similar sounding words. Charles-Luce and Luce (1990) conducted a computational analysis of the lexicons of children aged 5;0 and 7;0 and found that they are less dense than adult lexicons, suggesting that children may be able to function with less detailed phonological representations. In an experimental test of this hypothesis, Metsala (1997) found effects of both word frequency and neighborhood density on the ability of children in first grade to recognize spoken words in a gating task, a task in which successively more acoustic–phonetic information is provided to the listener until the word is identi-



fied. The children performed best on high frequency, high density words, suggesting that these words may be more specified phonetically.

The role of neighborhood density has also been investigated in relation to children's production abilities. Gierut and Storkel (2002) and Morrisette (1999) found mixed results of the effect of neighborhood density on accurate production of fricatives. In a study of imitative productions of non-words by typically developing 2-year-olds, Zamuner, Gerken, and Hammond (2004) found that high phonotactic probability (which was correlated with high neighborhood density) consistently facilitated accurate production of coda consonants. Beckman and Edwards (2000) found similar results with somewhat older children.

While the research that exists regarding the role of lexical factors in phonological development sometimes presents conflicting results, there is substantial evidence that young children are sensitive to many of the same lexical factors as adults and that these lexical characteristics may play an important role in the acquisition of phonology. Future research will let us know if this is indeed a promising framework for contributing to our understanding of critical parameters of phonological development.

### *Summary: Theories of phonological development*

This section has provided a historical overview of the various linguistic theories that have been used in the description of the acquisition of a phonological system. Each theory was shown to have its individual strengths and weaknesses in terms of the ability to account for what were presented as the basic requirements for any theory of child phonology. Notable differences were found in views of underlying representations and in the amount of attention given to the phonological–cognitive aspects of development compared with the phonetic–biological aspects. No single theory was able to account for all phenomena that have been documented in studies of phonological acquisition, yet each was good at accounting for particular aspects of the data. The most recent theory, a “usage-based” approach, lacks sufficient child data from children under the age of 4 years to be fully evaluated at this point.

## **Conclusion**

This chapter has provided a review of three interrelated aspects of the study of phonological development. In the first section, a brief outline of patterns of development was presented, beginning with the prelinguistic period and continuing to the age of 42 months. Similarities between babble and early speech were highlighted and cross-linguistic patterns were discussed. The second section focused on the link between phonological and lexical development in young children. Research in this area makes it clear that phonological acquisition affects, and is affected by, the acquisition of words. The third section provided a historical overview and evaluation of theories of phonological development. A complete theory should account for a wide range of phenomena

related to development, including the links between perception and production, the presence of both common patterns and individual differences, the formation of underlying representations, and the mechanisms underlying change in a child's phonology from first words to adult-like productions. At present, no single theory accounts for all of these; however, as the body of research in this field increases, we should be able to formulate new theories, or modify existing ones, to reach a goal of a full understanding of this area of study.

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