Clinical Forum

Whole-Word Phonology and Templates: Trap, Bootstrap, or Some of Each?

Shelley L. Velleman
University of Massachusetts at Amherst
Marilyn M. Vihman
University of Wales at Bangor

ABSTRACT: Advances in psycholinguistics have identified cognitive mechanisms that may account for the phenomena of whole-word phonology and phonological templates in normally developing children. Deficits in these same mechanisms may also account for certain types of disordered phonologies. In this paper, these cognitive mechanisms are described, strategies for identifying whole-word phonological patterns in normal and disordered phonologies are proposed, and intervention strategies that draw on these same mechanisms as a way to overcome their inappropriate persistence are recommended.

KEY WORDS: whole-word phonology, template, regression, implicit learning, mirror neuron

Language learning is pattern learning. In any given language, only certain patterns are permissible. For example, only a limited number of combinations of nouns with verbs, affixes with stems, or phonological place of articulation features with manner features will occur. Patterns occur at various levels of abstraction, from macro levels, such as the strong English preference for subject-verb-object word order, to micro levels, such as the specific distribution patterns of certain verbs (e.g., in English, *Give the church the money* is permissible, whereas *Donate the church the money* is not).

There is reason to believe that children enter language at what might be called, from a linguistic point of view, the middle level of abstraction, relative to the construction in syntax, the "basic level" word in semantics, and the whole-word form in phonology. In each case, middle-level entry means lexical—or word-and-phrase—learning, which can be taken to be at the heart of syntactic, semantic, and phonological development (Beckman & Edwards, 2000a, 2000b). Thus, the child is seen as entering into the complexities of syntax by first learning "verb islands," or particular verbs together with the satellite words with which they typically occur in the input (Tomasello, 1992). Or more generally, the child is found to make use of whole phrases (such as *more juice, that way, what's this?)* as "frozen" multiword units (Lieven, Pine, & Baldwin, 1997; Pine & Lieven, 1993) or as partially productive frames with variable slots (*it's* [modifier word], *I wanna* [action word], *where's my* [object word]: Lieven, Behrens, Speares, & Tomasello, 2001). Only later, and construction by construction, does the child begin to decompose and creatively reconstruct such units, as evidenced by the very slow and gradual emergence of productivity, or the consistent use of specific forms for the expression of particular meanings across a wide range of different lexical contexts (e.g., the use of English *–ed* to mark past tense on a wide range of verb stems, or the use of an auxiliary verb such as *be* with different subjects (*he's…, we are…*) and in different constructions (declarative, interrogative, etc.) (Lieven, Theakston, Pine, & Rowland, 2000). The emergence of a productive (and relatively "abstract") linguistic system is evidenced most clearly by errors of overgeneralization, because overgeneralization results from the

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application of a productive linguistic pattern to new instances that do not happen to follow that pattern in the adult language.

For semantic development, "middle-level entry" refers to the finding that the child begins with basic level words (*apple, chair)* rather than either superordinates (*fruit, furniture*) or more particular word choices (*Golden Delicious, Pippin; highchair, rocker:* Brown, 1958; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Adults instinctively tend to provide these basic-level words in the input to children to begin with (Anglin, 1976; Brown, 1977). In short, children begin with what they hear in the input speech stream, picking out the subparts identified either by intonational salience and prosodic groupings (Brown, 1973; Croft, 1995; Gleitman & Wanner, 1982; Mandel, Jusczyk, & Kemler Nelson, 1994) or by frequent occurrence as isolated utterance units, or both (Morgan & Demuth, 1996). Paradoxically, the choice of a small holistic unit with which to begin building a syntactic, semantic, or phonological system may be facilitated by the child's initially limited memory for language (Newport, 1991).

The view that phonological development begins with whole-word learning has been very gradually gaining support ever since it was first suggested in the 1970s (Ferguson & Farwell, 1975; Macken, 1979; Waterson, 1971). The idea grew largely out of close attention to child data. For example, Waterson noted that "some of [her son] *P*'s early forms seemed so different from the corresponding adult forms as to appear to have no relationship to them at all, but they are known to be the same by their function in context.... Examined segmentally such child's forms show very little congruence with the adult forms" (Waterson, 1971, p. 179). For example, *P* produced four forms that began with the palatal nasal, even though this phone does not occur in adult English (except as the cluster [nj], as in *canyon*): *finger* produced as ['ñẽːñẽ], ['ñiːñi]; *window* as ['ñẽːñẽ]; *another* as ['ñaña]; and *Randall* as ['ñañø]. When compared segment by segment with the adult forms, the child's forms seem not to correspond to the adults' in any systematic way. Considered as phonetic patterns on their own, the forms clearly constitute a simple reduplicated production routine in which an approximation of the stressed syllable is copied as the second syllable, discarding other portions of the word:

$$'\sigma_1\sigma_2 \rightarrow \ '\sigma_1\sigma_1$$

The use of palatal [ñ] may have had its source in an articulation the child developed in babbling. Although there is no close linear correspondence with the apparent adult targets, the relationship is not random but merely holistic. That is, the child used the disyllabic "nasal structure" (as Waterson terms it) in response to multisyllabic adult words that feature a nasal anywhere in the stressed syllable—hence the term "whole-word" phonology.

According to the middle-level entry account, then, knowledge of language is not built up brick by brick from the atoms of form or meaning—that is, the child does not first learn as individual units, roots and affixes, or semantic features such as "round shape" or "four-legged," or phonetic segments or features, and then assemble them into words. Rather, the learner begins at the word (or phrase) level of each component (syntax, semantics, phonology). The assumption that the child begins at the middle level, which is immediately available in the speech the child hears, eliminates the need to posit the universal stock of linguistic units, segments, features, principles, rules, or word-learning constraints that some assume to be innately available (Chomsky, 1995). From our perspective, lexically based learning makes it possible for the child, beginning only with the biological resources and social context that are naturally available in infancy and using only general learning processes, to derive from input speech the abstract, complex, hierarchical structures of language (Croft, 2001; Langacker, 1987). The second goal of this paper is to explore ways in which this perspective might shed light on developmental disorders in the area of phonology, and on their treatment. Before direct consideration of disorders, however, more thought must be given to the kind of learning that underlies phonological development in general.

EXPLICIT VERSUS IMPLICIT LEARNING

The argument to be made here is that the child embarks on "the construction of a phonology" via two separate but ultimately mutually supportive routes. *Explicit learning* refers here to learning with attention. Often, it involves the intentional goal to replicate adult verbal behavior in given situations by matching their sound patterns with vocal productions of a comparable kind, that is, to deliberately attempt to produce a word or phrase. It begins not with the minimal units of phonetics or phonology (Ingram, 1992; Jakobson, 1941/1968), but with the lexicon. Words are the units "given" by the input speech. They constitute whole prosodically marked units available to be matched. As the child begins to remember and reproduce increasing numbers of adult word forms (under situationally appropriate conditions), he or she is launched on language acquisition. The sound system of the adult language or languages will necessarily begin to crystallize out of this lexical learning, however approximate or inadequate the child's first word attempts may be.

The second route into language, which has begun to be demonstrated empirically only recently, is that of *implicit learning* (Ellis, 1994). Implicit learning happens "incidentally" or unintentionally, through mere exposure to the patterns of a language (i.e., even in the absence of attention to language). It refers to the development of expectations about the frequencies of occurrence, or probabilities, of various linguistic events (such as the production of particular syllable types) in the language(s) the child hears—or overhears. Experimental testing has sometimes focused on patterns to which the participant is only incidentally exposed while attending to a completely different task (e.g., Saffran, Newport, Aslin, Tunick, & Barrueco, 1997). Subjects have been shown to learn linguistic patterns even under these conditions. Other studies have demonstrated implicit learning for segmentation of the speech stream and for learning syntax, first in studies of adults exposed to artificial languages (Reber, 1967, 1993; Saffran, Newport, & Aslin, 1996), then with infants exposed to sequences of syllables (Saffran, Aslin, & Newport, 1996).

Specifically, in the Saffran et al. (1996) studies, infants as well as adults listened to monotone strings (the "artificial language") consisting of six trisyllabic synthesized "words" (*babupu, dutaba,* etc.) concatenated without pauses. After a total of 21 minutes of exposure to the strings, the adults were asked to identify which of a set of test trisyllables had made up a part of the artificial language. Success on this test could only be achieved by computing the transitional probabilities from one trisyllabic sequence to the next. That is, the participants had to (subconsciously) keep track of which syllables occurred repeatedly in the same sequence, which provides an important cue to word status. This feat was achieved on 76% of the nonword test items. To put it differently, adults were able to develop a "feel" for what was "in" the artificial language, even on very brief exposure. Infants were exposed to the same stimuli for just 2 minutes, after which they were "tested" with repetitions of trisyllabic sequences. Some of these were "words" from the sample sequences they had heard. Others were trisyllabic "nonwords," misordered sequences of the same synthesized syllables. Infants responded by orienting longer toward nonwords, a statistically significant (consistent) "novelty" response. This response was taken to demonstrate that the infants, like the adults, had implicitly learned the transitional probabilities between pairs of syllables. That is, the infants responded not by orienting toward what they had heard before (the "familiarity response" that is typically found in the head-turn procedure). Rather, they oriented toward what was new to them, presumably because the monotone stimuli were relatively simple, compared to natural speech (for this interpretation, see Johnson and Jusczyk, 2001, who replicated the finding).

In this kind of study of probabilistic learning, participants can be understood to be gradually accumulating a sense of the input language "norm" as regards sequences at every level—segments, syllables, prosodic units, words, phrases, and clauses. As suggested by studies of implicit learning in adults, this kind of learning in infants may be assumed to occur in the absence of any specific attention to linguistic patterning or intent to learn particular words. Effects such as those shown in numerous perception studies by Jusczyk and his colleagues, revealing sensitivity to prosodic units (clauses, as early as 4.5 months, then phrases at 9 months, and finally words at 11 months), can be taken to be the result of implicit learning (Jusczyk, 1997). The effect of implicit perceptual learning on production can also be seen, for example, in the subtle ambient language effects on vowel production revealed by acoustic analyses of prelinguistic infants exposed to British English, French, Arabic or Cantonese (de Boysson-Bardies, Sagart, & Durand, 1984).[1]

Note that several empirical studies suggest that implicit learning, unlike explicit learning, is relatively free of age effects, so that infants, children of different ages, and aging adults all seem to experience implicit learning to roughly the same extent (Rovee-Collier, 1997; Saffran et al., 1997; Vinter & Perrochet, 2000; cf. also, for example, Treiman, Kessler, Knewasser, Tincoff, & Bowman, 2000). It must be assumed that such implicit learning indirectly supports the child's efforts to intentionally reproduce words from the ambient language (where such intentional efforts reflect explicit learning, or learning with attention). It is also likely that this implicit accommodation to the accents of the native language and dialect gradually leads to the very finely tuned phonetic production of 3-year-olds, who can already be variously recognized as speakers of English from New Jersey, Newcastle, or Stockport, for example (Dougherty & Foulkes, 2000; Lodge, 1983).

Implicit learning also results from motoric practice, however. It is generally necessary as well as natural for both adults and children to engage in repeated exercise of a new skill (e.g., writing, typing, bicycle riding, driving, playing golf or tennis) before it can be called on voluntarily in the service of a selected goal. At this point, the transformation of implicit into explicit knowledge has begun. Evidence for this kind of learning comes from studies of amnesic patients, for example, who have been shown to be capable of learning new skills despite their impaired ability to lay down new (explicit) memory traces. (They are sometimes unable to recognize the very training situation in which repeated exposure or practice has led to learning of the new skill [Poldrack & Cohen, 1994].) Thus, for language development, implicit learning in production must also be factored in. The gradual increase in motoric skills, and therefore in the range of vocal motor schemes (VMS; consonants or other phonetic patterns that the child can produce at will), depends in part on practice, that is, on recurrent production of the same schemes (McCune & Vihman, 2001). By the second year of life, many infants have developed a range of VMS. These early vocal patterns differ from one child to the next, but clearly have a critical impact on early word learning. Children with a more diverse VMS repertoire learn more new words more quickly (McCune & Vihman, 2001). By the time a child has made use of some 50 different words, he or she is often found to have developed one or more word production routines or templates. From this perspective, these patterns reflect induction of a systematic, relatively abstract structure from the implicitly laid down initial perceptual and motoric traces (see also Karmiloff-Smith, 1992).

Individual children make their start on distinct individual paths. Cross-linguistic studies make it particularly evident that two or more children acquiring the same language show differences in patterning in their early word production, or in early semantic or syntactic patterning, that cannot be traced to the input. To demonstrate this with regard to phonological development, Vihman, Kay, de Boysson-Bardies, Durand, and Sundberg (1994) analyzed, for five mother-child pairs in each of three language groups (English, French, and Swedish), one sample of maternal input and longitudinal samples of early words from the

[1] Notice that children are influenced by the ambient language in semantic as well as in phonetic structuring even before they produce their first words (Bowerman & Choi, 2001; Choi & Bowerman, 1991).

same infants. The variability in patterning in the infant samples consistently proved to be far higher than that found in maternal speech, which was highly similar across the five mothers within each language group. In short, the individual differences reflected different starting points for the infants, based on their initial—necessarily limited—"take" on the patterns available in the input.

In cross-linguistic studies in which children are developmentally matched on the basis of the number of spontaneous word types they consistently produce in a half-hour recording session, the onset of word production is established as the first of at least two sessions in which four or more words are used (the 4-word point), whereas the first session in which approximately 25 or more words are used spontaneously is identified as a useful landmark later in the single-word period (de Boysson-Bardies & Vihman, 1991). These sessions correspond to a parental diary record of approximately twice as many words (Vihman & Miller, 1988), so that the 4-word point means a diary record of 8 to 10 words and the 25-word point means a record of 50 words or more. Such studies have shown that whereas at the outset of identifiable word production, children within the same language group differ as much as children in different language groups, by later in the single-word period, the language of the input has exerted a "channeling" effect. By this later point, there are greater differences between different language groups than within language groups in the phonetics of children's words (de Boysson-Bardies & Vihman, 1991). During this period, implicit learning continues while explicit learning is just beginning. This means that the child now develops an ability and a desire to match specific adult models. Both the level of sensitivity to phonological patterning of an individual child (implicit learning) and the aspects of language and communication on which the child focuses attention play important roles from this point on. This is where intentional, explicit lexical learning interacts with implicit matching of the child's own vocal practice to input patterning. In short, both implicit and explicit learning form an indispensable part of normal phonological development and they occur in parallel once motoric and cognitive capacities have reached the necessary threshold levels.

Development in the First Year: Response to Prosodic Versus Segmental Patterns

In order to set the stage for first word production, this section briefly presents infant development in perception and production in the first year, when an initial sensitivity to the prosodic patterns that are familiar from the womb and an intuitive affective response to a small number of distinct prosodic patterns form the foundation for the later construction of the first sound-meaning correspondences (for more extensive reviews, see Fernald, 1991; Jusczyk, 1997; Vihman, 1996). To summarize the basic developmental pattern, infants appear to progress from familiarity with the prosodic patterns of the ambient language (i.e., intonation, stress, etc.), which can be demonstrated as early as 4 months (Kemler Nelson, Hirsh-Pasek, Jusczyk, & Wright Cassidy, 1989), to familiarity with recurrent segmental patterns (i.e., the distribution of specific consonants and vowels within words), which can generally be shown only later, after age 7 or 8 months (Jusczyk & Aslin, 1995). At the same time, studies of vocal production in the first year have shown that between approximately 6 and 8 months, a maturationally timed motoric advance leads to the emergence of "canonical babbling" (i.e., the rhythmic production of CV (consonant-vowel) syllables that makes it possible for caretakers to identify the first word-like patterning: Oller, 1980; see also Koopmans-van Beinum & Van der Stelt, 1986; Stark, 1980). Whether the babbling of truly speech-like CV syllables heightens infants' attention to segments or, conversely, attention to segments reinforces infants' tendency to babble at this age, or both, this coincidence in timing between emergent response to familiar segmental patterns and the first adult-like vocal production can be taken as "circumstantial evidence" of a relationship between (implicit) perceptual learning of input patterns and emergent production capacities.

To model this interaction, Vihman (1993) proposed an "articulatory filter" as the mechanism linking perception and production, a mechanism that would come into play at the time of emergence of adult-like productive ability (ca. 6–8 months). The recent discovery of "mirror neurons" in both monkey and human brains lends plausible neurological support to that construction. In the course of making single-cell recordings of the premotor cortex in monkeys, di Pellegrino, Fadiga, Fogassi, Gallese, and Rizzolatti (1992) discovered that "when the monkey observes a motor action that is present in its natural movement repertoire, this action is automatically covertly retrieved" (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995, p. 2608). That is, some of the neurons that would typically be activated to initiate a particular motor action are activated in response to simply observing it. Fadiga et al. (1995) provided indirect neurological evidence that "in humans [too] there is a neural system matching action observation and execution…. The observation of an action automatically recruits neurons that would normally be active when the subject executes that action" (p. 2609). Although it has not yet been possible to study the activation of motor neurons for speech directly, the studies performed to date hint at the possibility that practice in performing a particular motor speech routine (e.g., producing CV syllables) may lay the groundwork for the activation of the same motor neurons when similar routines are produced by others (e.g., when the infant hears adult word forms similar to his or her own babbling patterns). If this were the case, then once an infant had begun to produce speech-like syllables, he or she would also begin to experience an automatic motoric response to similar patterns in the input, mediated by mirror neurons (Vihman, in press). Such a response would provide the child with the first direct neuronal connection between the segmentally specified perception of a word shape and its execution. Hypothetically, the internal motoric response would heighten infant attention to those input patterns that constitute a rough match to the child's own frequent vocal patterns. Under these conditions, the infant might attend more to reduplicated series of open CV syllables, for example, than to more complex adult sequences (Davis & MacNeilage, 2000).

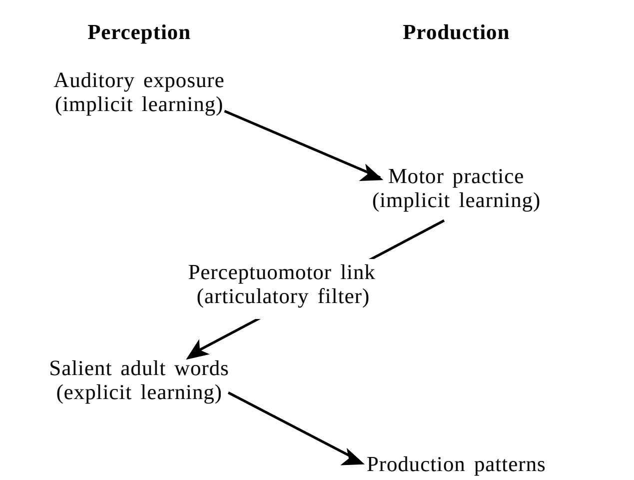
Notice that implicit learning of the patterning of the ambient language itself influences early vocal production. Cross-linguistic studies (e.g., Levitt, 1993) have revealed ambient language effects even before first word production, within the physiologically limited repertoire of early infant production capacities. Figure 1 illustrates the spiral of input influences mediating between the adult model and the child's early words. First, input speech is experienced by the young infant, from birth (auditory exposure, implicit perceptual learning). Then, vocal production begins, in the middle of the first year, permitting motor practice (implicit learning of a different kind). This, in turn, leads to the child hearing adult language through the "filter" of his or her own well-known articulatory patterns (perceptuomotor link). As a result of that filtering, certain adult words become particularly salient for a child, who notices the word's occurrence in situations of interest and remembers them accordingly (explicit learning). Once a number of such words have been retained, an abstract pattern or template crystallizes out of the combination of word shapes that the child has practiced motorically and those words that he or she has noticed. This results in relatively consistent child word shapes (recall the nasal structure produced by Waterson's son *P*, as described above). For vocally expressive children, the match of their own vocal patterns to selected frequent input lexical forms (words or phrases) would serve as the first bootstrap to word learning. Such children often produce situationally appropriate (context limited) word forms by 10 or 12 months.

Early phonology.

First word production and selected patterns. Studies of contemporaneous babble and first word production have clearly established the relevance of babbling practice for first word production (in sign language [Cheek, Cormier, Repp, & Meier, 2001] as well as in oral language [Vihman, Macken, Miller, Simmons, & Miller, 1985]). The first words are highly similar in form to the child's concurrent babble. Although both first words and babble are limited in their range of phonetic forms, the individual child's word forms can be seen to emerge out of his or her particular set of vocal patterns. Identification of first words is all the more difficult because of this close relationship. Attention to both form and context of use is necessary to distinguish early word forms from babble (Vihman & McCune, 1994). In general, the findings of Ferguson and Farwell (1975), that first words are surprisingly variable, accurate, and apparently "selected" at least partly on phonological grounds, have held up well over the intervening 25 years. This is naturally explained under the assumption that it is not so much conscious intent to avoid difficult phonetic forms as the unconscious experience of a match to the forms that are particularly accessible to a given child that underlies first word production (see Figure 1). That is, the child is not avoiding difficult forms, but is selecting accessible ones. The vocally expressive child can be seen to produce more or less automatically, in a recurrent, familiar situational context, an appropriate phonetic pattern that is taken from his or her vocal repertoire.

Templates and adapted as well as selected patterns. Analysis of longitudinal data from 20 children acquiring English (McCune & Vihman, 2001; Vihman & McCune, 1994), as well as comparable data from 10 children acquiring Finnish (Vihman & Velleman, 2000) and 5 children each acquiring French, Japanese, Swedish, and Welsh (Velleman & Vihman, 2001), suggests that an important change can be identified between the two word points characterized above. The first word forms are very similar to concurrent babble forms. They are also relatively accurate in the sense that substitution errors are rare, as are sequencing mismatches between child form and target word (though omission errors are not uncommon). In contrast, by the 25-word point, the child appears to be attending less closely—or responding less directly—to adult word forms. Accuracy is typically less in evidence, even for words that were once pronounced in an adult-like fashion. Whereas formerly the child's words were relatively close to adult targets and at the same time hard to distinguish from babble, these later words show a new characteristic, namely, similarity in form among themselves. For some children, this means several small groups of closely related words. For others, a single typical word form emerges, a "frame-and-slot" type of pattern in which the child appears to settle on a word production routine and then use that routine to "collect" adult words that are similar enough to that form to lend themselves to production within its constraints. As indicated above, for example, Waterson's son *P* had a frame that consisted of two syllables. The frame was further specified, or constrained, to include stress on the initial syllable and a nasal consonant at the onset of each syllable. The open slots, or less fully specified portions of the pattern, were constrained to be filled by two identical vowels. *P* collected words with nasals in them and fit the vowel from the stressed syllable of the target word into both of the vowel slots. This kind

Figure 1. Model of the interaction of perception and production.



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of a word production routine has been termed a template or “word recipe” (see Macken, 1979, 1992; Menn, 1983, also used the term “canonical form”).

Working Definition of Word Templates

A template is an abstract or schematic phonetic production pattern that integrates salient adult word or phrase targets and the child’s own most common vocal patterns. It can be taken to emerge from target words that are frequently attempted by the child on the basis of the child’s existing phonetic forms (VMS) and from adaptation of less narrowly selected target words to fit the pattern (McCune & Vihman, 2001). Within the limited range of expected productions for 1-year-olds, templates move children toward the adult realization of sound-meaning correspondence by divergent paths. In some cases, templates specific to individual children’s phonological development have been traceable to the child’s preverbal vocal motor schemes (Vihman, Velleman, & McCune, 1994). Operationally, evidence of a template involves consistency in phonetic and/or phonotactic patterning across word tokens with regard to the following: (a) child forms, (b) selection of words from the adult model for production, and (c) adaptations of the adult model to the child’s template.

Consonant harmony has proved to be the basis for many children’s early word patterns (Lleó, 1990; Macken, 1978; Menn, 1971; Stoel-Gammon & Cooper, 1984; Vihman, 1976), reflecting the difficulty posed by changes in place or manner of consonant across the word. However, some children show fixed sequential patterns instead (see Velleman, 1996). Some of these templates dictate the order of features in the word, such as Macken’s (1979) report of an initial labial/medial alveolar <CVCV> pattern (e.g., [pwæta] for Spanish *sopa soup*). Other templates dictate the placement of a default consonant, often in medial position, as in the <CVjVC> pattern (e.g., [bajak] for *basket* and *blanket*, [tajak] for *tiger* and *turkey*) identified by Priestly (1977). Table 1 provides a typology of templates that have been identified so far (with examples drawn from English except where English examples could not be found).

The emergence of templates in a child’s phonology is of fundamental significance. The child appears to have turned inward, or to be moving away from reliance on the early matches between his or her own vocal patterns and adult forms. Now the child experiences, in addition, (implicit) comparison across word forms, resulting in a kind of consolidation and emergent systematization. Over the first year, the child will have begun accumulating implicit perceptual knowledge of distributional patterns in the input language, and from the time of first canonical babbling, he or she will have been developing VMS. These patterns will have given rise to the first identifiable word productions (item learning). But now, the familiar patterns begin to cluster into voluntarily accessible categories of word forms, resulting in one or more word templates (such as consonant harmony, sequential patterns, or default consonants). The child’s word form patterns will now have gone beyond an unrelated set of one-to-one matches between perceived form and production routine. Perceived forms that are similar to one another in some way (e.g., by inclusion of a nasal, in the case of Waterson’s *P*) are now actively treated similarly in production as well. Specifically, they are produced as a (partially) shared production routine (e.g., reduplicated nasal syllables). Words that had previously been produced relatively accurately may now show regression as extension of an articulatory routine (word pattern) takes precedence over item learning.

An example from a child named Alice is provided by Jaeger (1997). Alice’s first word forms, at 18 months, mostly demonstrated reduplication (e.g., [mɑmɑ] for *mommy*) or consonant harmony (e.g., *byebye* produced as [(pə)pɑː^{j}]). The few words that included two different consonant places of articulation demonstrated no particular order preference. For example, *mine* was accurately produced in a front-to-back pattern, with a labial consonant followed by an alveolar [mɑ^{j}n], whereas *look at that* was produced in a back-to-front pattern, with alveolars following velars—which accurately replicates the word-final consonants of the target phrase [kʌtɑː], [kʌtæː]. By 23 months, when the child had produced more than 100 words, a clear overriding pattern had developed in which front consonants were produced early in the word, followed by consonants produced farther back in the mouth, regardless of their order of occurrence in the adult target word. For example, *sheep* was produced as [piç] (in which [ç] is a voiceless palatal fricative), *kite* as [tɑ^{j}k], and *t.v.* as [piti] (with substitution of labial [p] for adult labiodental /v/). The advance to a more systematic phonology at 23 months is reflected in the child’s forms by the overgeneralization of the child’s sequencing pattern to words structured differently in the adult language. That is, the child has sacrificed the close match to the adult forms in favor of consistency among her own production routines.

Both vocal motor schemes (implicit production learning) and the phonological patterns reflected in the adult words that the child has attempted (implicit perceptual learning) contribute to the development of one or more templates. Once a template has been established, the child selects matching words from the ambient language that can be produced accurately within the restrictions of the template, or goes beyond a match to adapt partially known adult forms to fit the production pattern (Vihman & Velleman, 2000). With a growing repertoire of phonetically related forms, the child is capable of expressing a growing array of meanings. The repertoire reflects ease of production (based on familiarity or experience with production) for the individual child (Menn, 1983), although the increase in word types produced typically has as its trade-off a decrease in production accuracy.

Longitudinal analysis revealed the early phonetic sources of a template identified for one child followed from 9 months through the end of the single word period (Molly: Vihman & Velleman, 1989). Molly appeared to focus on final consonants in her early words. This focus evolved into a pattern of selecting words with final consonants and producing stops with a strong release and nasals with a following [i] or schwa. Eventually, this pattern was applied to other words as well. Vihman and Velleman (1989) documented this process, identifying words such as *cheese*

Table 1. Templates: A typology.

Basis for template (adaptation)	*Child form and gloss* *Selected*	*Child form and gloss* *Adapted*	*Source (language, if not ENGLISH)*
Consonants			
Consonant harmony		[gʊg] *dog*	Daniel: Menn, 1971
VCV (omit initial C)	[içi] /isi/ *father*	[ala] /kala/ *fish*	Atte: Kunnari, 2000 (Finnish)
CVC (omit final vowel)	[tʌk] *duck*	[dʒak] *cracker*	Sean: Vihman, in press
"Front-to-back" sequencing			
1. labial – alveolar (reverse Cs)	[maʲn] *mine*	[piç] *sheep*	Alice: Jaeger, 1997
2. alveolar – velar (reverse Cs)	[tikʰ] *cheek*	[dæge] *alligator*	Alice: Jaeger, 1997; Philip: Ingram, 1974
3. labial – velar (reverse Cs)	[pakʰ] *frog*	[miŋ] *cream*	Alice: Jaeger, 1997; Philip: Ingram, 1974
Other feature-by-position patterns			
velar – labial (reverse Cs)	[kova] /kova/ *hat*	[kami] *monkey*	Shelli: Berman, 1977 (Hebrew/English bilingual)
velar or alveolar – labial (reverse Cs)	[gɪbːiː] *good boy*	[ʔənɪmːiː] *Simon*	Timmy: Vihman et al., 1994; Vihman, 1996, Appendix C
medial [j] (reverse Cs)	[lajən] *lion*	[rajap] *rabbit*	Christopher: Priestly, 1977
medial [l] (substitute C)	[palõ] /palõ/ *balloon*	[kɔla] /kanaʀ/ *duck*	Laurent: Vihman, 1993 (French)
final velar (omit initial C)		[ak] (alt. w/ [gak]) *clock, sock, rock, quack*	Daniel: Stoel-Gammon & Cooper, 1984
final fricative (omit final V)	[məs] /müts/ *hat*	[məs] /musi/ *kiss*	Raivo: Vihman, 1981 (Estonian/English bilingual)
Vowels			
Vowel harmony (substitute V)		[hæʰmæ] *hammer*	Jacob: Menn, 1978
"Low-to-high" sequencing			
a…i (reverse vowels)	[pai] /pai/ *nice; pat (kitty)*	[asi] /isa/ *daddy*	Virve: Vihman, 1976 (Estonian)
a…u (reverse vowels)		[akːu] /kukka/ *flower*	Saini: Kunnari, 2000; Vihman & Velleman, 2000
final i (add vowel)	[pipi] *baby*	[panːi] *Brian*	Molly: Vihman & Velleman, 1989
Consonant-vowel affiliation			
alveolar C + high front vowel (substitute V)		[didi] *baby*	Daniel: Stoel-Gammon, 1983
velar C + back vowel (substitute V)		[kɔkɔ] *cookie*	Virve: Vihman, 1976

produced as [ɑɪtʃ] or *Nicky* as ['ɪnːi] as forms "adapted" to fit the template. Although this template reflected Molly's advance to systematic phonology, her mother reported that, in the process, Molly had become more difficult to understand. For example, once the child began producing all nasal-final words with a final vowel, words that had previously been easy to distinguish now all sounded the same. Specifically, *button, balloon, banana*, and *bunny* had been pronounced differently but were now all produced as ['bʌnːə] or ['bɑnːə]. Homonymy—an evident consequence of overuse of a single template and a clear source of decreased intelligibility as the number of different words attempted increases—may be one of the primary factors leading to the eventual dissolution of templates. Although some young children are tolerant of fairly high levels of homonymy for short periods of time (e.g., Velten, 1943; Vihman, 1981), communicative efficacy eventually requires that the template be abandoned in favor of a more flexible set of production patterns (with a return to relatively greater accuracy).

One mechanism for the transformation from item-by-item learning to a productive, generalizable word template would be the laying down of memory traces of each word heard, whether produced by the child or by others. As similar traces (tokens of the same word) accumulate, the details could be expected to blur or fade, so that a more abstract pattern or word-form type would emerge (Goldinger, 1996, 1998). This abstract patterning should gradually become increasingly flexible and diverse. Because each child arrives at his or her own unique synthesis of heard and self-produced patterns, the templates differ from one child to the next. Nevertheless, analyses of children learning different languages suggest that templates share certain characteristics with the ambient language, resulting in a common "look" to the templates of a given language group. For example, 5 out of 10 children learning Finnish showed consonant harmony in more than half of their word forms (Vihman & Velleman, 2000), but in a large sample of published reports, only one-third of children learning English showed this pattern (Vihman, 2001). On the other hand, 2 out of 5 English-learning children had templates based on final consonants by the 25-word point, while no French children did (Vihman & de Boysson-Bardies, 1994).

IMPLICATIONS FOR DISORDERED PHONOLOGY

Implicit Versus Explicit Learning

It is clear from our earlier discussion that children with severely impoverished input (i.e., those to whom an inadequate amount of speech is addressed or received, e.g., due to hearing loss) within a meaningful context will be at a disadvantage with respect to both implicit and explicit learning (see, for example, Culp et al., 1991; Sachs, Bard, & Johnson, 1981). With respect to implicit learning, the relative probabilities of various speech sounds and sound sequences can be registered only if there is consistent and sufficient exposure to input speech (whether child-directed or not). Similarly, a child cannot learn to pronounce particular words (explicit learning) unless he or she is exposed to them. The levels of exposure that are required for each type of learning are unknown, but clearly there is a minimum (no learning will occur without some level of exposure). But what about children with a typical amount of exposure to speech and a typical level of peripheral hearing of speech who nonetheless:

- fail to produce the expected quantity and/or quality of prelinguistic vocalizations, and/or
- fail to produce words at the expected time, and/or
- produce speech that is unintelligible due to a restricted phonetic and/or phonotactic repertoire or due to excessive homonymy or variability?

The possible implication of mirror neurons in motor-planning-based phonological disorders (i.e., childhood dyspraxia) so far remains highly speculative. Children with a diagnosis of dyspraxia typically have histories of producing far fewer and far less mature prelinguistic vocalizations than infants whose speech develops on course (Velleman & Strand, 1994). In addition, difficulty with elicited imitation is often reported to be a symptom of childhood dyspraxia. Many children with this diagnosis are best able to produce speech in highly automatic contexts such as singing or repeating well-known rhymes. This suggests that the firing of mirror motor neurons in immediate response to the perception of spoken forms within one's own repertoire, which is presumed to occur in normally developing children, may be lacking in such children. Such a lack could be attributable either to the fact that the original motor pattern does not occur (because the child rarely vocalizes) and is therefore unavailable to be recalled, or, hypothetically, due to some deficit in the mirror neuron system itself. Either way, the lack of prelinguistic motoric practice, the lost opportunity to make production-perception linkages, and the subsequent failure to develop vocal motor schemes deprive the child of these likely bootstraps into the word-production process. Some phonologically delayed children begin to babble or use jargon after an initial period of speech therapy. This should not be regarded as a negative. Rather, it shows that therapy has activated the system, and that the child is now getting some of the motor practice that he or she missed out on before. Therefore, such non-meaningful vocalizations should be strongly encouraged. In addition, the speech-language pathologist should listen carefully for preferred production patterns (VMS) and should target motivating, functional, meaningful words that match the child's phonetic and phonotactic predilections to the greatest extent possible.

Another possible source of phonological/language delay could be a reduced ability to learn probabilistically from input without explicit focus on linguistic patterning. One significant benefit of implicit learning, as shown by studies of speech perception by infants aged 8–10 months and older, is the knowledge of which aspects of the speech stream can be ignored. There are many fine phonetic details that are irrelevant to the comprehension of a particular language. Months before they begin producing words, most infants are no longer attentive to such nonnative contrasts. Without the ability to focus specifically on just those aspects of the speech stream that signal meaning differences in the ambient language, a hypothetical child with impaired implicit learning may be overwhelmed by innumerable phonetic cues and so be unable to learn to associate particular word forms with particular meanings. In addition, the child's prelinguistic production would be unaffected by the tendencies of the ambient language, reducing the likelihood of relevant motor attunement. Although no such case has been documented, the first author has encountered clinical cases in which a child appears to focus on aspects of the speech stream that are not relevant to English. For example, one child used tones contrastively, as if he were learning Chinese or some other tone language. Similar patterns have also been reported for one child with otitis media (Donahue, 1993) and one who was developing normally (Jaeger, 1997).

Stackhouse and Wells (1997), citing Parker and Rose (1990), suggested that a lack of auditory experience is the source of "speech patterns which are characterized by 'exotic' vocalic and consonantal articulations, i.e., ones which are not found in the ambient language" (p. 196) in children who are profoundly deaf. In the absence of an awareness of language appropriateness, the child may select sounds for production that provide salient tactile feedback. Some children with phonological disorders also produce speech sounds that are not appropriate for the language they are learning, such as the velar fricative [x] in English (as in the German word *ach*). However, non-ambient sounds are also sometimes produced by normally developing children (cf. Waterson's *P*, discussed above), so this characteristic cannot be considered diagnostic. Alternatively, a child with little sense of language-specific phonetic appropriateness may simply adhere to a small set of easily produced phones (such as labial and alveolar stops, nasals, and glides) and fail to engage in the expected expansion of this repertoire as time goes on.

Deficits in Implicit Learning?

Many approaches to language and phonological therapy emphasize the importance of focused listening to particular linguistic patterns (e.g., modeling and expansion of selected targets in language; auditory bombardment of selected sounds or sequences in phonology). These strategies may work specifically to increase the child's implicit knowledge of ambient language patterns. The effects of implicit learning on production may be seen in children who temporarily overgeneralize new sounds to inappropriate contexts, such as a child once evaluated by the first author, who reported that he liked to go to [spitʃkʰ θɛrapikʰ]—*speechkuh therapykuh.* Clearly, his therapy had recently focused on word-final velar stops.

In some cases, the primary goal of therapy may be implicit learning. As Vinter and Perrochet (2000) put it,

> Implicit learning shapes the perceptions a participant develops of a situation through the direct and continuous tuning of the processes devoted to the treatment of incoming information. These processes...thus provoke changes in the way information is encoded. (p. 1238)

It is encouraging for speech-language pathologists to know that implicit learning is available to human beings throughout their life span, and especially that it can facilitate the development of a native-like fluency in a foreign language at least up to the age of 7 years (Johnson & Newport, 1989; Oyama, 1976). Thus, a child who seems to be lacking an awareness of the structural or segmental probabilities of what should be his or her native language—such as a child exposed to English who fails to produce fricatives or final consonants—may benefit from intensive exposure to the structure or the sound class that is absent from his or her system. Intermittent exposure to such forms, in the stream of daily speech, may be inadequate for such children. This is one of the motivations for Hodson and Paden's (1991) recommendation to use auditory bombardment of target words via headphones with slight amplification. Alternatively, there may be specific aspects of the acoustic signal to which the child is failing to attend. Fast ForWord, a highly controversial computer-based auditory training system (Gillam, Frome-Loeb, & Friel-Patti, 2001), is intended to address this possibility. In any case, when such a child produces, for example, a fricative in any position or a final consonant in any word, this may be seen as progress toward an important goal—whether these productions represent a match to the actual target word or not.

Explicit Learning Deficit Despite Implicit Knowledge

Other children may learn implicitly and reflect this in their appropriate phonetic and phonotactic repertoires, yet still demonstrate a phonological disorder. Most speech-language pathologists have had the experience of evaluating a child and finding that he or she is indeed capable of producing all of the expected phones in all of the relevant positions. The student may even be barred from receiving speech therapy in the schools because his or her phonetic repertoire is seen to be age-appropriate. Yet the child is unintelligible because these phones substitute for each other in what may seem to be a random fashion. Process analyses may yield contradictory results, such as backing of alveolars to velar in some words or on some occasions and fronting of velars to alveolar in others.

Variability of this type is often a major factor contributing to the child's poor intelligibility. Excessive use of certain processes is certainly a problem, but at least listeners can become attuned to a consistent child's speech patterns and gradually improve their ability to decipher the child's message. Children with excessive variability, on the other hand, are difficult to interpret even by those who know them best. They are often found to adhere to the phonetic structure of English. That is, they do not tend to substitute non-English sounds such as [x] for English phonemes, and sounds with limited distribution, such as [ŋ], do not tend to appear in inappropriate places (e.g., initial position in the case of [ŋ]). They do seem to be speaking a language that is phonetically and phonotactically very similar to English, yet is unintelligible. These children simply have not yet attained the explicit knowledge of which sounds belong in which specific words.

An example of this kind of apparent randomness was reported by Velleman (1998). Ellen, at age 4;0 (years;months), produced several English fricatives and affricates in at least one position, at least once each: [f, v, ð, s, ʃ, h, tʃ, dʒ]. Only one non-English fricative, the voiced bilabial [β] (as in Spanish *la**b**io* [Eng. – *lip*]), was produced, and it was produced only once. Yet, the following phonological processes applied to fricatives and affricates in her speech:

- omission (e.g., [nɑɪ] for *nice*, [pʰun] for *spoon),*
- stopping to nearest place of articulation (e.g., [beɪs] for *vase*),
- substitution of a velar stop (e.g., [ʃug] for *shoes),*
- gliding (e.g., [wæntə] for *Santa),*
- epenthesis of [w] (e.g., [fwɪk] for *fish),*
- palatalization (e.g., [ʃɑʊwʊ] for *flower),*
- affrication (e.g., [brʌtʃ] for *brush),*
- cluster coalescence (e.g., [fɛdɚ] for *sweater),*
- nasal emission for sn- clusters (e.g. [s̃eɪk] for *snake),* and
- glottalization (e.g., [hi] for *see).*

Thus, the same phone was sometimes substituted and at other times was itself the target of substitution. Clusters were sometimes inappropriately created from singletons (via epenthesis of [w]) and at other times inappropriately reduced to singletons. Percentages of occurrence of these processes ranged from 10% to 100%, depending on the target phoneme and the phonetic context. Despite many attempts at analysis, no clear pattern of occurrence could be identified in Ellen's speech that might indicate a motoric or perceptual basis for these processes. Such unpredictable variability in the production of a large functional class of English sounds had a significant impact on Ellen's intelligibility and both she and her mother (who was herself a speech-language pathologist, and therefore experienced in deciphering disordered phonologies) were very frustrated. Clearly, Ellen had a sense of which fricatives and affricates occur in English (implicit knowledge), and was not having difficulty producing specific speech sounds per se (motor ability). What she seemed to be lacking was the explicit knowledge of which of these sounds occur in which words in adult English. Because her productions were highly variable, it seemed more likely that her underlying representations (mental lexical entries) for these words were incomplete or in flux, not complete but inaccurate (Barlow, 1996; Velleman, 1988).

In a case such as this, fricatives and affricates should be targeted specifically in therapy, one place of articulation at a time. This would be more efficient than targeting the entire class as a whole, as the child's knowledge of fricatives/affricates as a class was not in question. Auditory bombardment and speech discrimination activities should be included to heighten the child's implicit awareness of the distribution and explicit awareness of the contrastive value of these sounds in the lexicon of English. Care should be taken to minimize overgeneralization by clearly temporally separating focus on one fricative or affricate from focus on the next.

Templates: An Interaction of Explicit and Implicit Learning

As with children whose phonologies are developing normally, the interaction between implicit and explicit learning may lead to the development of phonological templates in children with disordered phonologies as well. Like the occurrence of morphological overgeneralizations (e.g., *sitted* for *sat*), the emergence of a template is a positive sign, indicating that the child is systematizing his or her phonology. Patterns are fundamental to language. The ability to register and generalize them is vital for language learning. A child's advance from apparently unsystematic phonology to the emergence of consistent patterns is an indication of progress. However, there are associated dangers. Most concerning is the possibility that a child with a phonological disorder may become "stuck" in a template, adapting all words to fit that particular pattern for an inappropriately long time or to an inappropriate extent. A child's adherence to a template despite growing unintelligibility (as the child's productive lexicon and communicative intentions continue to grow) is a problem that the first author has often faced in the phonology clinic. Such a situation may occur when phonological therapy is delayed in favor of intensive language therapy. The child's mean length of utterance and vocabulary grow, and he or she begins to attempt to express a much broader range of more abstract meanings, but effective communication remains blocked by the child's limited repertoire of productive word shapes.

Let us consider Cora, a child aged 2;5 who was referred to early intervention due to unintelligibility. The speech-language pathologist assigned to the case suspected that a template might be interfering with Cora's communicative effectiveness. How should the speech-language pathologist go about identifying such patterns in the child's speech? There are certain aspects of the speech sample that can be focused in on in order to more quickly identify possible templates and other sources of unintelligibility.

The first thing to look at is homonymy—different intended words that the child pronounces in the same way. Cora had many of these, as shown in Table 2. What most of these homonyms shared was the lack of an initial consonant. Several also demonstrated the substitution of [ʌ] for other vowels. The patterns are V, VC, and VCV. The two exceptions to this pattern (*boat/poop* and *bug/ball*) shared a different word shape, bV(b).

The second easily accessible source of information about templates is variability. When the child produces the same word in several different ways, what are the commonalities among the various pronunciations? Cora's variable word forms are listed in Table 3. Again, two primary patterns emerged. The most frequent one was again a vowel-initial word shape. *Candy*, for example, was produced in four different ways, none of which included the target initial consonant. The second pattern was one in which the initial consonant was produced, but harmonized with the second (medial or final) consonant in the word, as in [boʊb] for *broke*, [dɑdə] for *daddy* and, most surprisingly, [bub] for *two*. The vast majority of these consonants were labial. Consonants in CV word forms also tended to be labial.

The findings about Cora so far, then, can be summarized using two templates:

- V(C)(V): vowel-initial forms, in which the vowel is often [ʌ] and the consonant is often labial
- C_1VC_1(V): one or two syllable forms with consonant harmony; the consonants are often labial, and the vowels are often [ʌ]

Looking at the remainder of Cora's word forms verifies the predominance of these patterns. Many of these words

Table 2. Cora's homonyms.

Target words	*Pronunciation*
apple, aball[a], spider, playdough	[ʌbʌʰ]
boat, poop	[boʊp]
bug, ball	[bʌ]
cat, light, bed, out, cut	[ʌt]
eyes, I, hi	[ɑɪ]
icecream[1], alldone[1], tractor	[ʌdʌʰ]
Marina, Justine	[inə]
no, Idon'tknow[1], close	[oʊ]
Oscar, sticker, horsie	[ʌgʌ]
roll, water	[ɔʊwə]
up, keep	[ʌp]

[a] Note that phrases that were judged to be produced as whole words by the child are written without a space between the words.

Table 3. Cora's variable forms.

Target words	*Pronunciation*
apple	[ʌp, ʌpʌʰ]
baby	[bibi, beɪbi]
blue	[buwəʰ, lu]
broke/broken	[bwoʊp, boʊ, boʊb]
candy	[ʌdi, æni, ʌmi, ʌndi]
daddy	[dodɑ, dʌdə, dɑdə]
eat	[ɑɪt, it, i]
Grandma	[nʌjʌ, ʌmə]
happy	[æpi, æbi]
help	[oʊp, ʌp, ɛoʊp]
juice	[ui, u, us]
little	[ɪtʌʰ, itʌʰ]
more	[mʌ, mʌnʰ]
no	[noʊ, moʊ]
open	[oʊbəʰ, oʊb, oʊp, ʌbi, oʊp, oʊbə]
out	[ɑʊ, æt]
Pooh	[bu, bui]
purple	[ʌpʌʰ, pʌtʌʰ]
shoe	[u, uʰ]
sock	[ɔk, wɔ]
two	[duwʌʰ, bub]

seem to have been selected because they already fit the patterns in their adult form:

- V(C)(V) template: *a lot, egg, Ellie, ouch*
- C_1VC_1(V) template: *booboo, mama, lolli(pop), puppy*

Other words are adapted:

- V(C)(V) template: *car* as [ʌ], *clean* as [i], *cock-a-doodle-doo* as [ɪdɪdu], *done* as [ʌn], *flower* as [ʌwʌ], *paper* as [ʌpwʌ], and many more
- C1VC1(V) template: *balloon* as [mum], *banana* as [nʌnʌ]

In process analysis terms, Cora was using initial consonant deletion and consonant harmony to fit the targets into her templates. Her two productions of *sock* reflected her two different templates. In one case, she omitted the initial consonant but produced the second ([ɔk]). In the other, the final consonant was omitted. The initial consonant was preserved structurally but was substituted with a labial glide ([wɔ]). In addition, Cora substituted [ʌ] for other vowels (as well as exhibiting some other vowel deviations) and labialized consonants.

Interestingly, a few of Cora's productions fit neither template. In particular, *airplane* ([tɪkʊm]) and *kitty cat* ([kɪdigæʰ]) were her most sophisticated word forms, boasting changes in place of articulation within the word. These may have been progressive idioms—early learned, accurate word forms that did not change when the templates took hold. Or they may have been advance signs that Cora was beginning to break free from her templates.

What would be the appropriate therapy goals for such a child? As stated earlier, for many children, templates are, at least initially, a successful functional means of increasing vocabulary despite a limited phonetic or phonotactic repertoire. As fluency therapists are well aware, it is often not easy to convince a person to abandon a once-successful strategy, even if it has since become a liability. Therefore, "make her stop it" is a gradual process of shifting reliance on a primary template to another minor or emerging template, or of expanding the parameters of the template to more closely resemble the (very general) phonological template(s) of the language being learned. Furthermore, it is often easier to introduce new words with the target pattern than to change the "frozen" form of a well-rehearsed word. As always, new word targets should be as motivating and functional for the child as possible.

In this case, the factor that was having the most negative effect on Cora's intelligibility was the omission of initial consonants. In such cases, the first therapy goal should be to reduce the frequency of application of the most interfering template. The secondary template (consonant harmony) could be used as a route out of the vowel-initial template. That is, the child should be encouraged to produce words that are currently being produced without an initial consonant with a harmonized initial consonant instead. Words like *purple* that include two labial consonants in the adult form anyway could serve as the initial targets. Words with two target consonants from the same non-labial place of articulation, such as *done*, would follow. For some children, this type of target is easier if the two consonants are structurally parallel (e.g., both syllable-initial in a CVCV word form). Others may be better able to produce two consonants in a word if the two consonants play two different structural roles (e.g., one syllable-initial and one syllable-final in a CVC word form).

As initial consonant deletion decreases—that is, the VCV template assumes a lesser role in the child's phonology—the focus of intervention could shift to the harmony template. Words with two different consonant places of articulation could be targeted. Again, this must be done gradually and carefully. For example, the vast majority of Cora's consonants were bilabial and alveolar, but she had a strong tendency for labial harmony. Therefore, there were two possible routes to follow, depending on her response:

- *Target words with one labial and one alveolar consonant.* Try both orders of occurrence (labial then alveolar, alveolar then labial) to see which is most successful. There are some indications that a labial-alveolar pattern might work, given that she does already produce such forms sometimes, such as [mʌnʰ] for *more* and [pʌtʌʰ] for *purple*. Also, a labial-alveolar order preference appears to be more common among children who are developing normally (Davis & MacNeilage, 2000; Ingram, 1974; Jaeger, 1997; Macken, 1979; Studdert-Kennedy & Goodell, 1995). Of course, there is also the possibility that neither will be successful—that the labials in most such words will exert their influence and cause the alveolars to harmonize, no matter what the order of occurrence may be.

- *Additional words with some combination of alveolar, velar, and/or palatal consonants.* The majority of the few non-harmonized forms that Cora produced during the initial sample included velar or palatal consonants:
  - *kittycat* produced as [kɪdigæʰ],

– *Grandma* produced as [nʌjʌ],
– *airplane* produced as [tɪkʊm].

Thus, targeting additional words that would be far less likely to be subject to labial harmony because there is no labial in the target word might be successful.

An additional parallel goal could be to increase the variety of manners of articulation within a word. Cora did occasionally produce a combination of stop or nasal plus glide, but the two consonants within her words more often shared the same manner of articulation. The production of words with a stop plus a nasal (in either order), from the same place of articulation at first, would be an appropriate goal.

In addition to homonyms and variability, looking at the word shapes of unintelligible productions is another way to identify children's templates. Velleman (1998) illustrated this strategy with respect to Ellen (whose fricatives were discussed above) at an earlier point in her phonological development, at age 2;4. Ellen's intelligible utterances—words and phrases—revealed a strong pattern of consonant harmony whenever two or more consonants were present in the same word or phrase. Examples included [gʌk] for *duck,* [dʌt] for *gum,* [bubu] for *spoon,* [ɑdədʌdʌ] for *happy birthday,* [dɑdə] for *thank you,* [bu bubu] for *dog boo-boo,* and even [bɑ bɑbɑ] for *not bottle* (with a negative head shake).

Her unintelligible utterances confirmed this harmony pattern and revealed another, labial-alveolar consonant alternation template as well:

Consonant harmony template: [bububu], [ɔdɔtʰ], [ʌdʌbɑbɑɪ], [ʌbububibu]

Labial-alveolar template: [bʊdɪvʊ], [bʌdə], [bidə], [bʌdəbʌbʌdə], [bʊdæ], [bʌdʊ], [bʌnəmɑʊ], [bʌdʌmbʌ], [bʌdʌ]

Once the latter had been identified, a look back through the utterances with known meanings highlighted her use of this pattern in some of those words as well (e.g., the selected target word *panda* produced as [bɑdə], and the adapted words *kitty*—[bʌdə]—and *blow it*—[bʌdʌɪʔ]). Ellen was young and might have outgrown these templates without intervention. However, high frustration levels of all family members led to a decision to try therapy.

Again, in a case like this, success in decreasing the predominant template—harmony—is likely if the initial target words have the pattern of the secondary template—labial-alveolar alternation. Once that first step has been achieved, that template should be expanded gradually to include slightly different forms, such as alveolar-labial alternations, or perhaps combinations of places of articulation that begin with labial (e.g., labial-palatal or labial-velar) or end with alveolar (e.g., palatal-alveolar or velar-alveolar). Again, the key is to expand the parameters of the template gradually to more closely resemble those of the language being learned.

It is also important to note that a template may recur later as a temporary solution for the production of a new, difficult structure or sound segment in children with phonological disorders, just as templates may recur in children who are developing normally. For example, John, at 8;4, after many years in therapy, was at last attempting multisyllabic words and words with less common English phonemes (such as [ʒ] and [dʒ]). His first productions of these difficult words exhibited a recurrence of consonant harmony and velar-last patterns:

Consonant harmony pattern: *aluminum foil* as [alumɪmə fɔɪjə], *hippopotamus* as [hipopamənɪs], *refrigerator* as [rifɪdʒədʒɛʔɚ], *beige* as [beɪv]

Velar-last pattern: *plastic* as [plæsɪk] (selected), *basket* as [bæsɪk], *message* as [mɛʃɪg], *package* as [pætʃɪg]

This appeared to be a regression, but it was not really a bad sign. It indicated that John was drawing on his available phonological resources—including past templates—to cope with new challenges, just as normally developing children do. In fact, Ellen's history of consonant harmony at 2;4 was the motive for using just such a strategy to decrease her stopping, gliding, and glottalization of fricatives at 4;0. Words with fricative consonant harmony were targeted (although there are unfortunately only a few of them, such as *fife, sheesh, sis,* and *zoos*). (For discussion and illustration of consonant harmony in normally developing children dealing with long words beyond the earliest stages of word learning, see Vihman, 1996, Ch. 9).

CONCLUSION

Implicit perceptual learning guides the normally developing child to become sensitive to those phonotactic and phonetic features of the input that recur most frequently, that is, to those that are the most typical of the ambient language. Implicit motor learning, possibly facilitated by an automatic neurophysiological response to within-repertoire motor models, further hones the child's attention, marking as especially salient those aspects of the input that match his or her own output capabilities and practice. Thus, the child enters the explicit (word learning) phase of phonological development with specific skills and expectations. As in syntax and semantics, the child's efforts focus on learning words as wholes, and this is reflected in early productions. As the number of types and tokens heard and spoken increases, a sense for pattern leads the child to systematize. In this process, the implicit and explicit forces often conspire to yield a phonological template. The template is a simplification pattern, usually based on earlier word preferences (selection), which is now applied to a variety of adult words through a process of adaptation. In many children's early phonologies, templates serve as a stepping stone in the direction of the adult system, despite the decrease in accuracy that may temporarily result.

There are several possible points of origin for phonological disorders within this developmental progression. Implicit learning, explicit learning, and ongoing systematization in response to new learning of both types are all critical to the smooth and successful development of a functional phonological system. If any of these types of learning fails to occur to an appropriate extent, or the system becomes trapped in a particular set of templates, phonological delay or disorder will result. Intervention may focus on the implicit learning of patterns, explicit learning of specific word targets, expansion of frozen templates to more closely approximate the patterns of the adult language, or all of these at different times, in response to somewhat different problems.

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Contact author: Shelley Velleman, Department of Communication Disorders, Arnold House, University of Massachusetts, Amherst, MA 01003-0410. E-mail: velleman@comdis.umass.edu