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Vihman, Marilyn orcid.org/0000-0001-8912-4840 and Croft, William (2007) Phonological development : toward a "radical" templatic phonology. Linguistics. pp. 683-725. ISSN 0024-3949

https://doi.org/10.1515/LING.2007.021

Phonological development: toward a "radical" templatic phonology*

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Abstract

"Radical" templatic phonology is a template-based approach to segmental phonological representation. The central hypothesis is that the segmental phonological structure of words is represented as language-specific phonotactic templates, in the sense used in the developmental literature. Template-based organization of the early lexicon has been identified in children acquiring several different languages. It is the result of a usage-based abstracting or "induction" process based on both babbling practice (phonetic production) and input experience with specific adult phonological patterns. The resulting templates thus constitute patterns that reconcile (or "adapt") the model provided by target words with the child's own phonetic repertoire of syllables or word shapes — typically extending or building on the forms initially "selected" for first word production, in which adult and child forms show a close match. In adult phonology segment categories — natural classes, or features — are best defined in terms of their occurrence in positions in the templates in individual languages, not as independent universal categories. After reviewing the status of segment categories and their phonetic basis in contemporary phonological theory we present crosslinguistic evidence of pervasive variation in both phonetic realization and phonological distribution patterns, evidence that supports the template construct.

1. Introduction

In this article we argue for a template-based approach to segmental phonological representation. Our central theoretical hypothesis is that the segmental phonological structure of words is represented as language-specific phonotactic TEMPLATES (the latter including syllable structure and other higher-order structures such as metrical structure).[1] We present

Linguistics 45–4 (2007), 683–725
DOI 10.1515/LING.2007.021
0024–3949/07/0045–0683

crosslinguistic evidence from phonological development that supports a template-based approach to phonological representation. We argue, however, that the template-based approach is equally suited to the analysis of adult phonology. Research in more phonetically-oriented approaches towards phonological categories, and in usage-based or exemplar models of the representation of phonological knowledge, also supports a template-based approach to the representation of the phonological structure of words. We take this research (and ours) to its logical conclusion, arguing that it applies to more abstract phonological categories and adult phonologies as well. Before turning to this evidence, we briefly discuss three general issues that have led us to this approach to phonological representation.

The first issue is the relationship between language structure and language function, namely, communication for the purposes of social interaction (see Clark 1996; Keller 1994). The hypothesis that we propose, following many others, is that the starting point for the analysis of linguistic structure should be the sound-meaning link that defines linguistic signs or symbols. This hypothesis does not rule out the possibility that generalizations about linguistic structure, including phonological structure, may be separated from generalizations about their function. Indeed, there is much arbitrariness in language, most notably the arbitrariness of the association of a phonological form with a particular meaning in a particular language. Also, as is well known, the phonological organization of a word into syllables often fails to match the morphological composition of a word. But we will argue below that the basic phonological unit is a word template, specifically defined on a phonological unit that is also a fundamental symbolic unit.[2] We will argue that starting from words can solve certain theoretical and empirical problems that arise for reasons not directly connected to language function and, furthermore, that this reflects the developmental learning sequence.

The second issue is the empirical range of a linguistic theory. A central fact about linguistic data is the pervasiveness of variation: variation across languages, across dialects, across speakers, across utterances by an individual speaker, and also variation in the behavior of linguistic units across linguistic contexts. We do not believe it is appropriate to abstract away from empirical variation, or to attempt to explain it away (e.g. by positing separate invariable grammars; see, e.g., Croft 2000: 51–53). Instead, we seek a model of grammatical representation that will accommodate this variation. The need to accommodate the full range of variation observed within and across languages will play a central role in our arguments for a template-based approach to segmental phonology.

The third issue is the relationship between a linguistic theory and psychological plausibility. In many linguistic theories, it is common to separate grammatical competence from performance, and to evaluate competence theories on the basis of principles of simplicity and generality, leaving aside performance or even the precise psychological implementation of the competence module. But simplicity and generality are a priori formal criteria, not psychological ones. Moreover, separating competence from performance makes it impossible to subject competence models to empirical psycholinguistic evaluation.

We consider it to be preferable (other things being equal) to posit a unified model of grammatical representation that does not separate a competence module from its psychological implementation, or from actual language processing (compare Bybee 2001: 8). In particular, psycholinguistic evidence should be relevant to the evaluation of theories of grammatical representation. In this paper, we focus on the representation of the phonological structure of linguistic units. We draw on another type of psycholinguistic evidence, namely, that afforded by language development, to support a template-based approach to phonological representation.

The developmental data that we bring to bear on the question of word templates in phonology raises a final general issue: the relationship between child language data and data derived from adult linguistic behavior. Only the latter is normally used as a basis for theories of linguistic representation. Such theories are then applied to first language acquisition data. Often there are substantial discrepancies between the hypothesized adult system and the developing child system. In this situation, two opposing proposals are typically made.

The DISCONTINUITY HYPOTHESIS maintains that the process by which language is learned and the representations developed by the child are different from those that are found in the adult system and must therefore somehow be replaced by the adult system at a later stage of development. The discontinuity hypothesis is unattractive because it seems to make little or no connection between what the child knows and does and what the adult knows. It also appears to insulate the theory of the adult system from any potentially disconfirming data from child language development.

The CONTINUITY HYPOTHESIS maintains that the child already knows the adult system (because many aspects of it are innately specified). The inability of the child to exhibit adult linguistic behavior is taken to be due to performance and other limitations (or in one variant, to the need for innate capacities to mature over time). The continuity hypothesis is also unattractive in that it too appears to insulate the competence model of the adult from any potentially disconfirming developmental data.

We suggest that it is preferable to develop a theory of linguistic representation that draws on developmental as well as adult data from the outset. Such a theory will view the development of knowledge of linguistic structure as a gradual process, assuming neither full adult competence from the beginning nor a discontinuity between developmental stages and adult outcome. The template-based approach to segmental phonology constitutes such a theory. It proposes that a limited number of specific, actual word shapes are the first steps in phonological learning. The child gradually develops first one or a small number of phonological templates, then a wider variety of them, while at the same time inducing a range of other phonological categories and structures from the known word shapes. The result of differentiating and generalizing knowledge of the phonological structure of words in the course of language acquisition is an adult template-based model of phonological representation, with neither discontinuity nor an assumption of pre-specified adult competence.

2. Word templates in early phonological development

2.1. *A brief history*

For over thirty years child phonologists have been claiming that the earliest phonological structure is whole-word based. Perhaps the simplest expression of the idea is that of Francescato (1968: 148) (who makes reference to Reichling 1935): "Children never learn sounds: They only learn words, and the sounds are learned through words." At the time that the idea was first seriously put forward, infant speech perception had not yet begun to be investigated and there were few, if any, acoustic studies of children's word production. Nevertheless, the pioneering studies in child phonology made some fundamental observations, while later, more detailed studies have provided further support for the basic idea of whole-word phonological development.

In 1971 two diary studies, one American (Menn), one British (Waterson, whose work is rooted in the Firthian tradition; see also Menn 1983; Waterson 1987), provided empirical data that seemed to point to the idea that the whole word was at the core of a child's early phonology. Concluding a close analysis of her son Daniel's first words, Menn (1971) suggested that "the facts that simplifying is principally by assimilation embracing the whole monosyllable, all simplifying is done within word boundaries, [and] ... there is no conditioning across word boundaries indicate that *the word is an entity, stored and accessed as a block*" (Menn 1971: 247, emphasis ours). Daniel's "assimilation embracing the whole

Table 1. *Mean length in syllables for early word targets in seven languages*[3] *(ordered by proportion of monosyllables)*

Language (N children)	1-SYL.	2-SYLS.	3+-SYLS.	Mean words per child
English (5)	.59	.35	.06	120
Swedish (5)	.44	.52	.04	106
Welsh (5)	.36	.54	.10	53
Estonian (3)	.33	.58	.09	48
French (5)	.28	.68	.04	114
Finnish (10)	.18	.79	.03	133
Italian (25)	.17	.58	.26	22
Mean	.34	.58	.09	

monosyllable" generally involved velar harmony (e.g., at 22 months, when systematic forms began to appear: [gæk] *cracker,* [gʌg] *bug,* [gʌk] *truck*).

It has since become clear, partly through Menn's own later work, that a number of qualifications have to be made to this summary of "the facts". We now know that conditioning can also occur across word boundaries, for example (see Donahue 1986; Stemberger 1988; Matthei 1989; Menn and Matthei 1992). Furthermore, there is no reason to equate the word with the monosyllable, outside of an English language context. Disyllables dominate the early lexicon of children acquiring most of the other languages in which early word phonology has been extensively investigated, through either diary or observational studies (Estonian, Finnish, French, Greek, Hebrew, Hindi, Italian, Japanese, Spanish, Swedish, Welsh). The Germanic languages generally may constitute exceptions, as monosyllables appear to be the most common early word form in Dutch (e.g., Elbers and Ton 1985) and German (Leopold 1939; Elsen 1996) as well as English; for Swedish our data show that mono- and disyllabic early word forms are in close balance. Table 1 indicates proportions of word targets of differing lengths in a crosslinguistic sample of early word data, with 3–25 children represented in each language group. However, it remains the case that the fundamental intuition — that whole words are at the core of early phonology — was convincingly illustrated in Menn 1971 and Waterson 1971 for the first time.

Table 2 illustrates the type of phenomenon with which Waterson 1971 was concerned, drawing on data from her son P.

This child's forms are less closely related to their adult targets than were those that Menn reported for Daniel. Perhaps for this reason Waterson draws more radical conclusions in attempting to account for her findings:

Table 2. *P's early word templates: "nasal structure" (age 1;6) ⟨ɲVɲV⟩*

Child form	Adult target
[ɲaɲa]	another
[ɲeːɲeː], [ɲɪːɲɪ]	finger
[ɲaɲø]	Randall
[ɲeːɲeː]	window

(Adapted from Waterson 1971)

> It [...] seems reasonable to consider that a child perceives some sort of schema in words or utterances through the recognition of a particular selection of phonetic features ... which go into the composition of the forms of the words or groups of words, and this recognition of a schema results in his producing words of the same type of structure for such adult forms. (Waterson 1971: 206)

Unfortunately Waterson's insistence on perception as the source of her son's early word schemas was never convincingly supported by direct evidence (see Waterson 1987 for some attempts to provide such evidence, however), and the idea that the child's patterns derive from what is salient in the target words, although plausible, remains only an idea, since the evidence so far inheres primarily in the production data themselves — a problematic circularity.

Ferguson, Peizer and Weeks (1973) were sufficiently impressed by their data, drawn from a case study of Weeks' granddaughter (see also Weeks 1974), to assert that "for the adult we may assume that the predominant [phonological] unit is the phoneme ... [whereas] for many children the earliest domain seems to be the entire lexical unit ..." (p. 57). Two years later, basing themselves primarily on their analysis of longitudinal first word data from three children (including those of the English-German bilingual child Hildegard, as documented by her father, Leopold 1939), Ferguson and Farwell (1975) published the classic statement of the whole word position, which they extended to adult phonology as well:

> The data and analysis of this study suggest a model of phonological development and hence of phonology which is very different from those in vogue among linguists. The model would de-emphasize the separation of phonetic and phonemic development [i.e., contra Jakobson 1941/68], but would maintain in some way the notion of "contrast" ... It would emphasize individual variation ... but would incorporate the notion of "universal phonetic tendencies" ... It would emphasize the primacy of lexical items ... but provide for a complex array of phonological elements and relations .... (Ferguson and Farwell 1975: 437)

This position has been cited repeatedly but has only recently begun to receive empirical investigation. Studies with adults over the last five years or so have shown that phonotactic familiarity effects, based on relative frequency of occurrence of segments and segmental sequences, facilitate (speed up) the processing of nonwords, although competitive effects deriving from known lexical items (similarity neighborhoods) tend to slow processing of real words in dense neighborhoods (see Vitevich, Luce, Charles-Luce and Kemmerer 1997; Vitevich and Luce 1998, 1999). Similarly, Beckman and Edwards (2000a) found that familiarity with particular phonemic sequences resulted in more accurate repetition of nonwords by three- to four-year-olds (see also Edwards et al. 2004).

The idea of whole word phonology was further extended and more tightly defined by Macken (1979), who summed up her analysis of the early phonology of a Spanish-speaking child by noting that "[a number of] unusual substitutions can be accounted for by the overgeneralization of [...] preferred word patterns [...] Prosodic similarity between certain adult words provides a plausible explanation for the similar treatment of some words" (p. 29). Macken alludes to word templates here ("preferred word patterns") and appears to be agreeing with Waterson in finding a probable source for the child's patterns in the "prosodic similarity" of words in the adult language. Based on her detailed longitudinal case study, she goes on to adumbrate her findings for the early word learning period: "... all words had a consistent word pattern form; ... new patterns resulted from the expansion of previously acquired word patterns; some words changed patterns over time as new word patterns were learned (Macken 1979: 34).

We will see that this description fits the data for any number of other children for whom detailed phonetic lists of early words have been provided in the intervening years. Macken (1996) indicates further that she sees word templates as being identifiable through "the typical overgeneralization and conspiratorial effects of the several rules that operate to produce [a particular] output — e.g., metathesis (plus harmony) ..., consonant epenthesis ..., unusual deletion of the input medial stressed V ..." (p. 169).

How solid, and how crosslinguistically valid, is the empirical basis for the "whole word phonology" idea in language development? The three arguments that have been primarily used to support the concept are as follows:

1. *Variability of segment production*: A child may produce the same sounds differently in different words, and some words may be more variable than others. This suggests that the child has knowledge of particular words but has not yet developed abstract categories of sounds for production (Ferguson and Farwell 1975).

2. *Relationship of child word to adult target*: The relation of early child words to their adult models is often found to be difficult to account for on a segment-by-segment basis. Instead, the child seems to be targeting a whole gestalt (Waterson 1971). The resulting patterns have been described as "whole word processes", sometimes characterized as either HARMONY (assimilation of noncontiguous vowels or consonants) or MELODY (patterning in the sequencing of noncontiguous vowels or consonants) (Grunwell 1982; Macken 1992, 1995; Vihman 1996).
3. *Relationship between child words*: The interrelation between the child's own words may be more evident than the relation to the adult models (Macken 1979). This is due to the child's eventual reliance on one or more word templates, specific phonological patterns which fit many of the words that the child attempts (these words are said to be SELECTED), but which are also extended to words that are less close to the template (these words are then ADAPTED to fit the template [Vihman and Velleman 2000]).

An additional argument can be proposed, with reference to the apparent basis for developmental patterning that is distinct from the phonology of the adult language:

4. *Source of child patterns*: The dominant child patterns of the early word production period are responses to challenges posed by adult target words, primarily, the challenge of producing distinct consonants or distinct vowels, or both, in different syllables or different word positions (i.e., initial and final consonants in a monosyllable, as in Daniel Menn's forms, cited above).

We will provide no specific developmental evidence here in relation to (1), the variability in production of the same segment in different words, but such evidence can be obtained from the more detailed of the various single-case or small group studies cited (see also Section 3.1 below). The evidence to be provided in Section 2.2 (as well as in Table 2 above), based on data from individual children, will serve to illustrate the remaining arguments, which are complementary. Finally, we will indicate some of the differential effects of ambient language rhythmic patterning on the shapes of early child templates in Section 2.3, where we provide cross-linguistic data based on three to ten children per language group.

The nature of the challenge that early word production poses to children has yet to be satisfactorily established. Some have argued that the challenge is primarily representational (memory difficulties: see Vihman 1978; Macken 1979; among others) or articulatory (production difficulties: Labov and Labov 1978; Studdert-Kennedy and Goodell 1995; among others); both speech planning (Chiat 1979) and speech processing (Berg and Schade 2000) have also been identified as plausible bases for children's problems. Although infants are known to have remarkable capacities for perceptual processing (specifically, for segmental discrimination) from the earliest months, so that perceptual problems per se might seem an unlikely source of difficulty[4], it has become increasingly clear that the deployment of these capacities in relation to the discrimination of minimally distinct word forms requires additional attentional resources, at the very least, and constitutes a novel task for one-year-olds (Stager and Werker 1997; Werker et al. 2002). Thus some combination of attentional or representational factors may be involved, although differences in motor control and practice must also affect differences in production (McCune and Vihman 2001).

2.2. *Evidence for word templates in early phonological development*

In the earliest period of acquisition the idea of structure emerging from known holistic phonological units can be demonstrated in its simplest, most direct form. Menn 1971 observed that early phonological patterning "is partly determined by the shapes of the first handful of words attempted" (p. 246). Later studies have made it clear that, contrary to Jakobson's (1941/1968) well-known "discontinuity" view, the source of the shapes of the first words is often to be found in prelinguistic vocal practice, or babbling (Stoel-Gammon and Cooper 1984; Vihman et al. 1985; Vihman and Miller 1988; Elbers and Wijnen 1992; Vihman 1992; McCune and Vihman 2001), with some effects of the ambient language on vocal production being identifiable even before first word production (Boysson-Bardies et al. 1989; Boysson-Bardies and Vihman 1991; for comparable effects in the semantic domain, see Bowerman and Choi 2001).

The earliest word forms are thus typically closely related to the individual child's babbling patterns (Vihman et al. 1985) as well as being relatively accurate (Ferguson and Farwell 1975), and they may show strong selection constraints (Ferguson et al. 1973; Schwartz 1988). That is, it is often apparent that only a small range of the many possible adult word patterns are attempted, with certain phonetically accessible forms characterizing most of the first words produced. Such forms include particular phonotactic shapes or prosodies (CVCV, VCV, or in some cases CVC); forms with a limited range of onset consonant types (stops, nasals, glottals and glides); forms with only a single consonant type; forms including only low or front vowels, especially in the first syllable; and forms involving associated CV sequences, such as labial + a or schwa, alveolar + front vowel, velar + back vowel (Davis and MacNeilage 1990, 1995, 2000, 2002).

Although direct experimental evidence remains limited (but see Vihman and Nakai 2003; DePaolis 2006), there is reason to believe that the earliest word forms are the product of implicit infant matching of own vocal patterns to input patterning (Vihman 1993, 2002b). This would account for the findings of relative accuracy and of phonologically constrained selection. A first lexicon of some five to ten identifiable, spontaneously produced adult-based words would be the result of that match. As a result, the earliest word forms of children acquiring different languages are broadly similar (with limited phonotactic shapes and consonant and vowel patterns, as indicated above), being rooted in the physiological constraints that govern vocal production in the babbling and first word period (Locke 1983; Locke and Pearson 1992; Davis and MacNeilage 1990, 1995, 2000; Kent and Bauer 1985; Kent 1992; see Appendix B, Vihman 1996, which presents the first few words of 27 children acquiring seven different languages; as well as Tables 6a, 7a, 8a, and 9a below, which also sample the first word forms of children acquiring different ambient languages).

Within these biologically given limits, however, the ambient language shapes the first phonological patterns or templates, which emerge out of the first words as the child begins to target new word forms beyond his or her existing range, sometimes selecting minimally new adult patterns to attempt, sometimes adapting more distant adult patterns by imposing an existing pattern on them (Vihman and Velleman 2000). Whereas the first words are individual by child but broadly similar crosslinguistically, the templates that are then induced from them, signaling the first phonological organization, reflect language-particular differences to a limited extent, as we will illustrate below.

Individual synchronic patterns from children learning a wide range of languages have provided evidence of word templates, with or without making reference to whole word phonology (for examples, see Berman 1977 [Hebrew/English]; Macken 1978, 1979 [Spanish]; Vihman 1993 [French], Vihman and Velleman 1989, Vihman et al. 1994b [English], Vihman and Velleman 2000 [Finnish], in addition to the children whose data are presented here). Tables 3–5 add to the sample in Table 2 with examples from Vihman's son Raivo, acquiring both English and Estonian, Waterson's son P., and another Estonian-learning child, Madli; note the similarity of the Estonian data in Tables 3 and 5 to Waterson's data (Tables 2 and 4).

Table 3. *Raivo's early word templates: "nasal structure" (Estonian; age 1;3.18–1;3.24) ⟨nəN⟩ (N = any nasal)*

Child form	Adult target
[in(+)], [næ(+)] (im.); [nɪŋ]	lind 'bird'
[nənən], [nən]	rind 'breast' (nursing)
[næniŋ], [næŋ], [nɪŋ], [nɪn]	king 'shoe'
[niŋ], [ninin], [niŋ]	kinni 'closed'

'+' indicates several repetitions of the syllable in production; 'im.' = imitation
(Adapted from Vihman 1981)

Table 4. *P's early word templates: "sibilant structure" (age 1;6) ⟨(stop)Vʃ⟩*

Child form	Adult target
[byʃ]	brush
[dɪʃ]	dish
[ɪʃ]	fetch
[ɪʃ], [ʊʃ]	fish
[ʊʃ]	vest

(Adapted from Waterson 1971)

Table 5. *Madli's early word templates (Estonian; age 1;8) ⟨(p, t)Vs⟩*

Child form	Adult target
[is:]	isa, issi 'daddy'
[as:]	kass 'cat'
[pis:]	piss 'pee'
[us:]	suss 'slipper'
[tis:]	tiss 'teat'
[us:]	uss 'snake'

(Adapted from Kõrgvee 2001)

No segmental substitution account could do justice to these data — or capture the systematicity apparent here. This was the point that Waterson was making in 1971; the "little word groups" or schemas that she identified when her son P had roughly 150 words turn out to roughly characterize Madli's and Raivo's Estonian early word patterns as well.

Three types of clues are generally used to identify a child's word template(s):

a) Consistency of patterning in a substantial number of the child forms for words produced in one or more recording sessions or over a period of some weeks or months;

b) The occurrence of unusual phonological correspondences between adult and child forms (i.e., rules or processes or "repairs" to target word violations of child constraints), under the influence of a dominating pattern or template;
c) Frequently, a sharp increase in words attempted that either fit or can be fitted into the pattern.

Given these criteria, it is clear that such patterns are most reliably identified on the basis of longitudinal data from the same child, as Macken (1996) emphasized. The systematicity in a child's early word production tends to be evident only after the child has produced some critical number of word forms. The number of forms will vary from one child to the next, since the emergence of a systematic word production plan or template depends on the child inducing this structure from the words s/he is able to say. For example, Menn 1971 observed,

> using hindsight, only 3 of [Daniel's first] 30 words fail to satisfy the constraints reflected by the first set of phonotactic rules, those which govern stage 2 ... One is led to the opinion that, while phonotactic rules have not yet crystallized in stage 1, something vaguely systematic, from which the rules will develop, is at work. (Menn 1971: 231f.)

A developmental progression can thus characteristically be tracked in longitudinal studies of individual infants, from relatively accurate (but highly constrained) earliest word forms to systematically adapted (and thus sometimes less accurate but wider ranging) later forms. To illustrate this progression Table 6 presents data from a case study of a child acquiring German in a monolingual context (Elsen 1996). Here and in what follows we will distinguish the first words, which we term "selected" (these are the early words in which "something vaguely systematic ... is at work"), and the later words, which may be either "adapted" (e.g., the velar harmony words produced by Daniel as his phonotactic "rules" began to operate) or "selected", in cases in which the adult word targeted already fits the child's existing phonotactic constraints or word template.

We have organized the words according to their patterning, primarily their phonotactic patterns. In the first months of word production we find simple monosyllabic ⟨Ca⟩ patterns (with initial stop: *da, Buch*), ⟨VV⟩ and ⟨CVVC⟩ (with the rising diphthong [aɪ]: *ei!, Ei, nein*), ⟨CVCV⟩ (with both consonants and vowels agreeing across the two syllables: *Mama, Papa, pieppiep, Teddy, das da*), and a single ⟨$C_1V_1C_2V_2$⟩ pattern, with a labial – alveolar sequence *(bitte)*. The child's forms are closely related to their adult targets; in Ferguson and Farwell's

Table 6. *Developmental progression in first words (Annalena: German). ⟨CV(C1V1)⟩; ⟨Vi⟩; ⟨labial – alveolar⟩ as phonological patterns, first fifty words (data from Elsen 1996)*

a. Select only (8–10 mos.)

Child form	Adult target	Characteristic pattern (based on later template)
[da]	da 'there'	CV
[ba]	Buch 'book'	CV
[aɪ]	ei! (fondling expression)	Vi
[aɪ]	Ei 'egg'	Vi
[naɪn]	nein 'no'	Vi
[mama]	Mama 'mama'	CVCV: CH + VH
[baba]	Papa 'papa'	CVCV: CH + VH
[pɪpɪ]	pieppiep 'mouse'	CVCV: CH + VH
[dɛdɛ]	Teddy	CVCV: CH + VH
[data]	das da 'that one there'	CVCV: CH + VH
[bɪta]	bitte 'please'	lab C . . . alv C

CH = consonant harmony; VH = vowel harmony; MET = metathesis, RED = reduplication; TRUNC = truncation

b. Select + adapt (10–12 months)

Select			*Adapt*		
Child form	Adult target	Template	Child form	Adult target	Template
[ja]	ja 'yes'	CV	[ba]	Wasser 'water'	CV
[bɪ]	Bild 'picture'	CV			
[de:]	Tee 'tea'	CV			
[dɛ]	Zeh 'toe'	CV	[baɪ]	Wasser 'water'	CV + Vɪ
[haɪ]	heiss 'hot'	Vɪ	[oɪ]	oh!	Vɪ
[baʊ]	Baum 'tree'	Vʊ	[aɪl]	Öl 'oil'	Vɪ + Vɪ
			[aɪl]	Eule 'owl'	Vɪ, Vl
[pœ:p]	tööt 'toot' (blow nose)	CVC: CH	[mom]	Baum 'tree'	CVC: CH [*note regression*]
			[mom]	bong!	CVC: CH
[ki:ki:]	kikeriki 'cock-a-doodle-do'	CVCV: CH + VH	[nana]	Zahn(bürste) 'tooth(brush)'	CVCV: CH MET + RED
[pipi:]	Pipi 'peepee'	CVCV: CH + VH	[nana]	Annalena	CVCV: CH TRUNC + MET
[nanə]	Banane 'banana'	CVCV: CH + VH	[dada]	Tag '(good)day'	CVCV: RED
[bebi]	Baby	CVCV: CH	[vava]	wauwau 'bowwow'	CVCV: CH
[babi:[d]]	Papier 'paper'	CVCV: CH	[baba]	Bauch 'belly'	CVCV: RED
			[gɪŋgɛ]	trinken 'to drink'	CVCV: CH

Table 6 (*Continued*)

Select			*Adapt*		
Child form	Adult target	Template	Child form	Adult target	Template
[ata], [ada]	ada 'bye'	VCV	[aðða]	essen 'to eat'	VCV
[man]	Mann! 'oh boy!'	CVC: lab ... alv	[bal]	Lampe 'lamp'	CVC: lab ... alv MET
[man]	Mann 'man'	CVC: lab ... alv	[bələ]	Brille 'glasses'	CVC: lab ... alv
[bal]	Ball 'ball'	CVC: lab ... alv			

CH = consonant harmony; VH = vowel harmony; MET = metathesis, RED = reduplication; TRUNC = truncation

terms, they are fairly "accurate", although we find some omission of syllable-final consonants and two instances of vowel change ([ba] for *buch*, [dɛdɛ] for *Teddy*).[5]

In the following two months, as the pace of word learning quickens considerably (some 40 new words are added), we find (under "select") all of the same patterns represented, with some loosening of the constraints apparent in the earlier words. The ⟨CV⟩ patterns include new vowels and an initial glide; the diphthong [aʊ] occurs as well as [aɪ]; new syllables occur in harmonizing disyllabic words. In addition, there are two new phonotactic shapes for words — ⟨VCV⟩ and ⟨CVC⟩. It is notable that the CVC syllables, the only word forms with differing C_1 vs. C_2, either show consonant harmony or retain the previously represented sequence labial – alveolar. Under "adapt", moreover, we find essentially the same word shapes and sequential constraints but with more radical departures from the adult model.

One way of conceptualizing the child's adapted forms is to see them as the result of the child (implicitly) imposing one or more preexisting templates, or familiar phonological patterns, on an adult form that is sufficiently similar to those patterns to serve as a "hook". From this perspective, we can see the effects of the child's "practice" or motoric familiarity with reduplicated patterns (resulting in [nana] for *Zahnbürste* and [baba] for *Bauch*, for example) and with the diphthong [aɪ], which now appears unexpectedly in adult words that lack it (e.g., *Wasser, oh!, öl*). Note that the child has consistently produced only C1–C2 sequences involving labials followed by alveolars (see *bitte* among her first words, *Mann, Ball, Brille* among her later words), this also being the presumed motoric-plan basis for the metathesis of *Lampe* to [bal]. Thus, from a usage-based perspective, the child's adoption of the pattern [bal] (identical to her production of *Ball*) for *Lampe* is not surprising, despite the fact that it involved both (1) omission of the final vowel and medial nasal and (2) rearrangement of the syllable-onset consonants.

In these data, then, we can see evidence of a shift from the exclusive production of words that deviate very little from the adult model to words that may deviate quite markedly, and in different ways for different words, with the result that certain patterns are heavily overrepresented in the child's surface forms. In general, the child's changes affect whole word forms, not individual segments, and a number of word templates or well-practiced patterns can be identified, some of them acting jointly in certain cases (⟨CVC⟩ + ⟨labial – alveolar⟩, for example).

In Table 7 we see the first words of a child (Virve) acquiring Estonian but with some exposure to English as well (Vihman 1976).

Table 7. *Developmental progression in first words (Virve: Estonian [and English]) (Vihman 1976). ⟨a... i⟩ or $V_1 \ldots V_2$ = ⟨low – non-low⟩*

a. Select only (10–12 months)

Child form	Adult target	Characteristic pattern (as identified in later template)
[hai]	hi	CVV: Vi
[pai]	pai 'nice'	CVV: Vi
[aita], [aida]	aitäh /ai'tæh/ 'thanks'	VV(CV): Vi
[ao]	allo 'hello (into telephone)'	VV: Vo
[se]	see 'this'	CV
[te], [teðe], [tete]	tere 'hello'	CV(CV)

Adult Estonian words have initial stress unless otherwise noted.
CH = consonant harmony; MET = metathesis; VH = vowel harmony

b. Select + adapt (14–15 months)

Select			*Adapt*		
Child form	Adult target	Template	Child form	Adult target	Template
[titːɪː]	kikeri'kii 'cock-a-doodle-do'	CVCV: CH, VH	[asi]	isa 'father'	VCV: $V_1 \ldots V_2$ (i) MET
[apə]	habe 'beard'	VCV	[ami] [ani]	ema 'mother'	VCV: $V_1 \ldots V_2$ (i) MET
[kɔ̥kɔ̥]	cookie, cracker	CVCV: CH, VH	[ati]	liha 'meat'	VCV: $V_1 \ldots V_2$ (i) MET

Table 7 (*Continued*)

Select			*Adapt*		
Child form	Adult target	Template	Child form	Adult target	Template
[tin]	kinni 'closed'	C_1VC_2	[ta | ti]	lahti 'open'	CVCV: $V_1 \ldots V_2$ (i) CH
[tata], [tai]	tädi /tæti/ 'auntie'	CV(CV): CH, Vi	[tati]	kallikalli 'hug'	CVCV: $V_1 \ldots V_2$ (i) CH
[pe:bi]	beebi 'baby'	CVCV: CH, $V_1 \ldots V_2$ (i)	[papu]	bravo	CVCV: $V_1 \ldots V_2$ (high V) CH
[ap:i]	appidu 'uppy-do' (jump)	VCV: $V_1 \ldots V_2$ (i)			
[pai]	*bye*	CV: Vi			
[ta | si]	tantsi 'dance'	CVCV: $V_1 \ldots V_2$ (i)			
[atsi(h)]	ɑt'sih 'achoo'	VCV: $V_1 \ldots V_2$ (i)			
[man:i]	Manni (name)	CVCV: $V_1 \ldots V_2$ (i)			
[pawawei]	papagoi 'parrot'	CVCVCV: Vi			

Adult Estonian words have initial stress unless otherwise noted.
CH = consonant harmony; MET = metathesis; VH = vowel harmony

This child began talking early, although not as precociously as Annalena. Her early word production suggests tightly constrained phonological selection, in that words attempted as well as word forms produced were restricted to (1) a limited segmental inventory (labial and alveolar stops, [s], glides and glottals), (2) constrained word shapes such that only a single consonant type could occur anywhere in the word ([tete] for *tere*), and (3) constrained vowel sequencing as well (lower vowel first, higher vowel second). Note that three of Virve's first six recorded words include the diphthong [aɪ], the same diphthong favored by Annalena.

In the following two months of rapid lexical advance Virve loosened constraints on possible word forms step by step, as illustrated in Table 7b. First manner ([tin] for *kinni*),[6] then place (*Manni*) were allowed to vary, but not both. Within the vowel sequences, similarly, we see a consistent tendency to produce either harmonizing forms or ⟨V(...)i/u⟩ patterns, these word forms being supported by the adult models listed under "select" but imposed on the models listed under "adapt".

Although the final /i/ pattern is also commonly found in English (e.g., Molly, in Vihman and Velleman 1989; Alice, in Vihman et al. 1994a; and the subject of Davis and MacNeilage 1990) and can plausibly be related to the high input frequency of diminutives such as *baby, doggie, kitty,*

Table 8. *Developmental progression in first words (Eeriku: Estonian) (Salo 1993) From vowel harmony (VH) constraint to sequential constraint $V_1 \ldots V_2 = \langle low - non\text{-}low \rangle$ (SEQ) or front/back harmony (F/B)*
First 50 words: 1;5–2;5: All (non-onomatopoeic) multisyllabic target words are listed below, along with the child's word form. Numbers in parentheses refer to the order of first production of these forms.

a. No vowel sequences allowed

Select (target vowels fit pattern)			*Adapt (target vowels violate pattern)*		
Child form	Adult target	Template	Child form	Adult target	Adaptation
[pæpa]	päkapikk 'elf' (3)	CVCV: RED	[tit]	tita 'child' (4)	TRUNC
[paba]	paber 'paper' (5)	CVCV: RED	[en:]	onu 'uncle' (6)	TRUNC
[ana]	vanaema 'grandmother' (9)	VCV: VH	[æ:]	väike 'little' (8)	TRUNC

MET = metathesis, RED = reduplication; TRUNC = truncation

b. Vowel sequences admitted (but low – non-low preferred)

Select (target vowels fit pattern)			*Adapt (target vowels violate pattern)*		
Child form	Adult target	*Relation of target to template*	Child form	Adult Target	Adaptation *Relation of target to template*
[isa]	isa 'daddy' (12)	*Violates SEQ and F/B*	[tr:u], [tr:d]	toru, torud 'pipe, pipes' (14, 15)	[produce r]
[a:u]	halloo! (24)		[mum:]	muna 'egg' (16)	TRUNC *Violates SEQ*
[pa:p:a]	papagoi 'parrot' (30)	VH	[ame]	ema 'mother' (17)	MET *Violates SEQ and F/B*
[aitæh]	aitäh 'thanks' (33)	*Violates F/B*	[pop:]	potsataja 'fairy tale animal' (18)	TRUNC *Violates SEQ*

Table 8 (*Continued*)

Select (target vowels fit pattern)			*Adapt (target vowels violate pattern)*		
Child form	Adult target	*Relation of target to template*	Child form	Adult Target	Adaptation *Relation of target to template*
[istu]	istu 'sit!' (37)	*Violates F/B*	[amo]	homme 'tomorrow' (19)	MET *Violates SEQ and F/B*
[arstæd]	arsti(-)tädi 'doctor-auntie' (38)	*Violates F/B*	[aut]	auto 'car' (20)	TRUNC *Violates SEQ*
[priv]	prillid 'glasses' (40)	TRUNC (despite VH in target)	[trar]	traktor 'tractor' (21)	TRUNC [produce r]
[æbi]	käbi 'pinecone' (41)		[o:ro]	koori 'peel' (23)	VH *Violates F/B*
[sin:a]	sinna 'to there' (45)	*Violates SEQ and F/B*	[trr]	terita- 'sharpen (pencils)'	TRUNC [produce r]
[sis:e]	sisse 'to inside' (46)	*Violates SEQ*	[o:t]	oota 'wait' (32)	TRUNC *Violates SEQ*
[pæe]	päike 'sun' (47)		[or:]	orav 'squirrel' (36)	TRUNC *Violates SEQ* [produce r]
			[eeriur]	hiireurg 'mousehole'	MET (1st two syllables) *Violates SEQ*
			[ara]	hari 'brush' (42)	VH *Violates F/B*
			[pe]	pea 'head' (43)	TRUNC *Violates SEQ*
			[avr]	Aivar (44)	TRUNC [produce r]
			[todo]	Tota-tädi 'Auntie Tota' (49)	VH *Violates SEQ*

MET = metathesis, RED = reduplication; TRUNC = truncation

nappy, etc., it is not necessary to invoke English influence as a source of Virve's patterns. Table 8 presents all the disyllabic words attempted among the first 50 words of a monolingual Estonian-learning child, Eeriku (Salo 1993).

Like Virve, Eeriku generally avoided the vowel sequence non-low — low (that is, he observed a sequential constraint on vowel height, which we term SEQ) as well as nonharmonizing front-back vowel sequences (F/B), adapting words which fail to meet those constraints by the use of truncation (TRUNC) and metathesis (MET) as well as vowel harmony (VH). As can be seen in Table 8a, the first few longer words that Eeriku attempted had low vowels only or were truncated to eliminate the second vowel. Word (12), *isa* 'daddy', is the only word that violates SEQ until the very last few words produced in this period, which covered a full year in Eeriku's case. Eeriku showed a highly unusual affinity for the difficult Estonian consonant (trilled) /r/. Of his first 50 words 13 include an /r/; in several cases he appears to truncate specifically in order to produce a syllabic or coda /r/. Otherwise, the adaptations of adult targets included in Table 8b all seem to conspire to achieve a vowel sequence that violates neither SEQ nor F/B (for each word we have indicated the violation avoided in italics).

Finally, in Table 9 we see the same developmental progression that was illustrated in Tables 6–8, this time based on data from a child acquiring English, though with some exposure to Spanish (Alice: Jaeger 1997), and starting on her first word production at 18 months, several months later than the two children discussed in some detail so far.

Alice again shows only minor changes from the adult model in most of her first words ("select only"). The child forms for *food, bottle,* and *doggie* constitute an exception: Jaeger notes that these unusual phonetic forms, which were produced with a strongly nasal release of the medial obstruent, correspond to one of this child's frequent prelinguistic babbling patterns.

However, by five months later, when Alice had acquired a lexicon of some 100 words, she had developed a striking word-form constraint or template, restricting unlike consonants to a front-before-back sequence. This led to extensive changes to some adult words ("adapted"), while other words showed only minor consonant or vowel substitutions ("selected"). The constraint was prefigured by six (out of a total of 22) earlier words, *bottle, mine, doggie, this* and, at 20–21 months, *block, stocking*). At 23 months the only exceptions to the constraint were the words *dummy, jump* and *tum* — one of only two exceptions to the constraint among Alice's first words. It seems likely that the exceptional status of all three words at the later stage stems from entrenchment due to the frequent use Alice made of this form in a period of great lexical expansion. While living temporarily with her grandparents, from 1;9.15 on, she called both of them [tʌmʌ] for a few days.

Table 9. *Developmental progression in first words (Alice: English) (data from Jaeger 1997). ⟨C1 – C1⟩ or fronting constraint: ⟨labial – alveopalatal⟩, ⟨labial – velar⟩, ⟨alveopalatal – velar⟩*

a. Select only (18–19 months)

Child form	Adult target	Child form	Adult target
[mama]	mommy	[haɪ], [ʔaɪ]	hi
[tata]	daddy	[ʔa:w]	out
[nana]	Anna	[(pə)pa:ɪ]	byebye
[peipi]	baby	[tʌm]	‘music’: tum(te-tum)?
[kʌta:]	look at that	[maɪn]	mine
[kakŋ]	‘food’: cracker/cookie?	[tiç]	this
[papm:]	bottle	[ʔmʔm]	‘no’: mm-mm
[takŋ]	doggie	[ʔʌʔoʊ]	uh-oh

b. Select + adapt (23 months)

Child form	Adult target	Child form	Adult target
[pʌtu] lab – alv	butter	[pita] MET alv – lab → lab – alv	David
[tik^h] alv – vel	cheek	[taɪk] MET vel – alv → alv – vel	kite
[pak^h] lab – vel	frog	[piç] MET pal – lab → lab – pal	sheep
[pʌpi] lab – lab	puppy	[puç] MET alv – lab → lab – alv	soup
[tiç] alv – pal	teeth	[piti] MET alv – lab → lab – alv	TV
Exceptions (based on entrenchment of [tʌm]?)			
[tʌm] dummy			
[tʌmp] jump			
[tʌmi] tum ‘music’			

MET = metathesis

2.3. *Prosodic/segmental interactions and ambient language influence*

So far we have looked at longitudinal data from three children, each acquiring a different language, as well as at sample word patterns from a few additional children acquiring English and Estonian. We have seen that some patterns occur crosslinguistically and that the early segmental types children produce tend to be similar regardless of the language to which the child is exposed. Some patterns do differ by ambient language, however. In this section we illustrate the effect of the ambient language on early child word patterns by considering NO ONSET, or child omission of word-initial consonants. This pattern is disfavored by “markedness

Table 10. *Initial consonant omission in five languages*[7]

Language (N children)	% select	Language (N children)	% adapt
Finnish (11)	23.9	French	16.4
Estonian (3)	22	Welsh	16
French (5)	15.4	Finnish	14.9
Welsh (5)	13	Estonian	14
English (6)	11.8	English	4.3
Mean	17.04		13.12

constraints": CV is the most widely occurring syllable pattern, universally, and is also the first adultlike syllable infants produce (at about 6–8 months [Oller 1980, 2000]). However, as we shall see, the accentual pattern of the adult language renders some segmental positions more salient than others, so that although the omission of initial consonants occurs only rarely in English child words, it is far more common in other languages. We will summarize some evidence to this effect and will then consider how differences in adult language accentual patterning might result in this difference in early child word patterns.

In a study of Finnish children acquiring geminate consonants Vihman and Velleman (2000) were surprised to find that the second most common child phonological pattern (after consonant harmony) was "no onset" (31%, both selected and adapted) — a pattern considered to be a mark of deviant phonology in English (see also Savinainen-Makkonen 2000). Subsequent analyses of data from children learning other languages suggest that it is the ABSENCE of any such pattern in data from English-speaking children that is unusual. Table 10 shows the proportion of initial consonant omission in selected and adapted word forms for each of five languages.

The column labeled "% select" shows the mean proportion of the children's forms that are based on adult words (or phrases) that fall into the "no onset" pattern. Although Finnish has the highest proportion, the languages are roughly evenly distributed across the range, from 12 to 24%. The column labeled "% adapted" shows the incidence of child forms in which an initial consonant of the adult form has been omitted (a pattern seen in some earlier tables as well).[8] Here we see that four of the five languages cluster closely together, with incidence of initial target consonant omission ranging from 14% to 16%. Only English, in accordance with what has generally been taken to be the universal norm, shows a very low incidence of initial consonant omission (4%); see Figure 1.

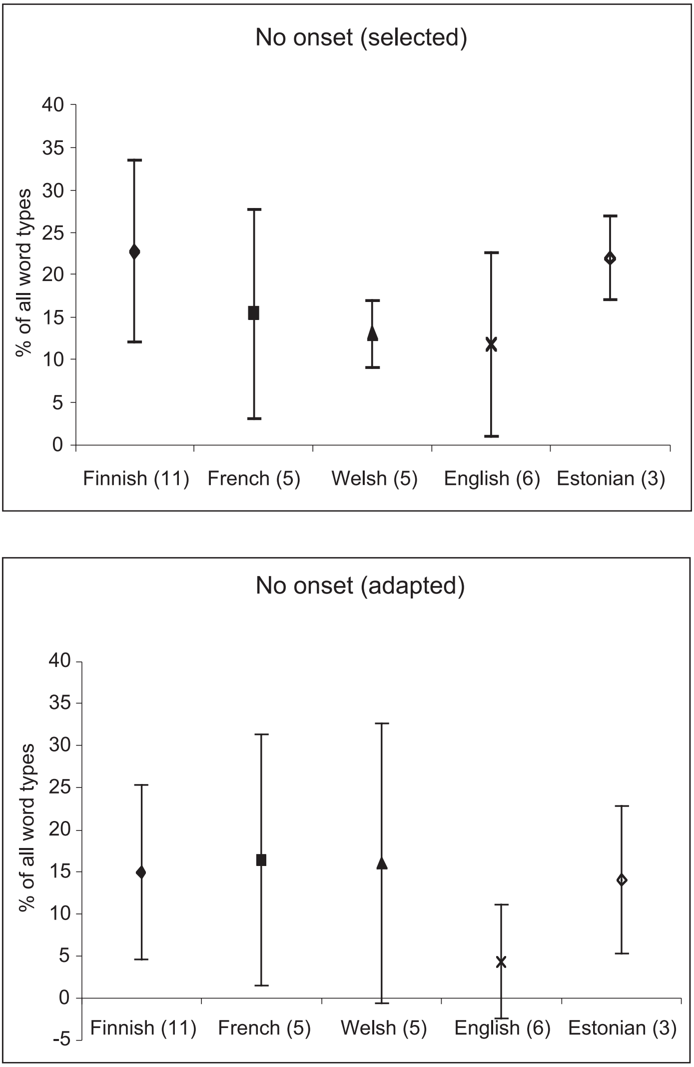

Figure 1. *No onset (selected vs. adapted) in five languages*

Thus, a similar proportion of target words and phrases lack an onset consonant in all five languages (based on words selected), but the children are less likely to adapt target words by omitting an onset consonant in English than in any of the other languages. We must look beyond the basic segmental structure of the language to account for this.

The languages differ in their accentual patterns, especially their rhythmic patterns. In English the dominant trochaic pattern is manifested, phonetically, in a longer and louder first syllable (which may also be higher in pitch) and a reduced second syllable (Vihman et al. 1998; Vihman et al. 2006). In none of the other languages do these factors jointly affect the first syllable, despite the fact that in our sample all but one of the languages is primarily or exclusively trochaic. In French the dominant pattern is iambic, with lengthening of the final syllable as the primary accentual marker. In Welsh, although the first syllable of a disyllable is normally stressed, this is manifested by a short first-syllable vowel followed by a lengthened medial consonant and a long second vowel (see Vihman et al. 2006 for documentation of both adult and child production). Finnish, although strictly and exclusively trochaic, has another highly salient rhythmic characteristic — frequently occurring medial geminates — which can deflect infant attention away from the initial consonant. Indeed, the presence of medial geminates appears to be a powerful attractor for infant attention, since children target a disproportionate number (49%, compared to an incidence in mothers' content words of 37%) (Vihman and Velleman 2000). In the children's own productions, 55% have long medial consonants, again suggesting attention to and overextension of this rhythmic property.

Here then we see group results analyzed in the same way as the longitudinal data presented in Tables 6–9 above. A similar proportion of VCV patterns occurs in the input in all five languages (mean of 17%), based on child selection of words to attempt that lack an initial consonant (e.g., English *uh-oh*, Table 9). In the case of all of the languages except English the children extend the pattern to assimilate word targets falling outside it in the adult language. In some cases the omitted consonant itself poses a problem for the child (see Table 4, in which P, learning English, systematically omits initial fricatives). In most cases, however, omission of the initial consonant appears to be a way to arrive at a pronounceable form despite the difficulty posed by a word-internal noncontiguous consonant sequence. This is a striking demonstration of the effect of the whole-word (disyllabic) pattern on learning, since it is the lengthening of a medial consonant or final vowel, or both, which appears to draw the child's attention away from the initial segment, typically considered most critical to word learning in English.

As further evidence for the hypothesized role of geminates in supporting a "no onset" template, Table 11 summarizes the phonological patterning in the complete lexicon of a child V, aged 1;7, who is bilingual in Hindi and English (with a few words from other Indian languages).

Table 11. *Consonant harmony and "no onset" in a bilingual child, V (1;7)*

Phonological pattern	English		Hindi (+ a few Bengali and Malayalam words)		Total word types
	Select	Adapt	Select	Adapt	
CV(V)	7 *no*	1 *ball* [bɔ:]	4 /tʃa:/ 'tea'	1 /phu:l/ 'flower' [pu:]	13
V(V)(C)	1 *eye*	0	4 /a:g/ 'fire'	0	5
C_1VC_1 (or place agreement only)	3 *cake*	12 *dog* [kɔg]	0	1 /na:k/ 'nose' [ka:k]	16
C_1VC_2	10 *bus*	0	2 /ka:n/ 'ears'	1 /gəram/ 'hot' [gəm]	13
C_1VC_1V	2 *dirty*	0	6 /ba:ba/ 'grandpa'	0	8
C_1VC_2V	1 *bowwow*	0	3 /kʰãta/ 'thorn'	0	4
VCV	0	3 *cover*	5 /a:pa/ 'aunt'	7 /pa:ni/ 'water' [a:ni]	15
VCCV	—	—	6 /ənda/ 'egg'	13 /kəŋghi/ 'comb' [əŋghi]	19
$C_1VC_1C_1V$	—	—	1 /ʈəʈʈi/ 'excrement'	0	1
C_1VC_1 C_1VC_1	—	—	2 /ti:tti:t/ 'sweet'	0	2
C_1VC_2 C_1VC_2	1 *ticktick*	—	2 /pətpət/ 'beating'	0	3
Total	25	16	35	23	99

(Based on Bhaya Nair 1991)
One example of each occurring pattern is provided; numbers in each cell indicate the total child word form types conforming to the pattern (T = 198 words).

This child primarily produces monosyllables in English (83% — far exceeding the mean seen in other children acquiring English as well; see Table 1) but disyllables in the Indic language words he knows (78%). Indeed, the author/diarist sees the child's differential attention to English monosyllables vs. Hindi disyllables as V's way of keeping the languages apart in a setting in which several languages are current and code mixing is the rule. V's English words also tend to show consonant harmony (15/41, or 37%) while his Hindi words tend to show "no onset" instead (35/58, or 60%). Interestingly, three of his English words also show initial consonant omission: [ʌbə] *cover*, [ʌŋki] *monkey*, [ɔtə] *water* — a probable sign of interaction with the Hindi pattern, since such a pattern seems highly unusual for English words whose initial consonants are a stop, a nasal and a glide.

Of the initial consonants omitted in non-English words, 6/20 are affricates or /ʃ/ or /r/, segments the child does not yet produce or produces only rarely. (Four English, three Hindi and one Bengali word are produced with initial affricates; none have initial /ʃ/ or /r/.) Yet segmental difficulties are not the sole or primary basis for "no onset" since in three cases the omitted consonant is a stop or nasal that agrees in full or in place only with the medial consonant. Of the child words that differ from their targets by virtue of initial consonant omission, 13 out of 20 (65%) have a medial consonant cluster; 8 of these (40%) are geminates. Thus, the medial long consonants are as plausible a rhythmic source of the "no onset: adapt" pattern here as in Finnish.

2.4. *Universals of early phonological development — or inductive generalizations from the lexicon?*

We have considered the emergence of word templates in the course of first word production as recorded in several diary studies. The templates cannot be innate, since they are not always present from the first words, nor can they be universal, since they differ from one child to the next and also differ to some extent by ambient language.

Rather, we take them to be the emergent product of three sources of phonological knowledge for the child: (1) familiarity with the segmental patterns typical of the adult language, which advances steadily over the last few months of the first year (see Jusczyk 1992, 1997); (2) developing motoric control and familiarity with a subset of adultlike phonological patterns due to production practice (babbling); and (3) increasing familiarity with the structure implicit in the children's own first lexicon. The child's early word forms can be taken to reflect sensitivity to matches between his or her emergent production patterns and frequently used adult words. The wide interchild variability in early phonological patterning that we see even within the limits of a single ambient language does not derive from the adult input, however, but from the individual "filter" that each child brings to the word learning process. This is evident from the fact that while the phonological patterns found by sampling input from five mothers are strikingly similar, those of their five children are widely different (see Vihman et al. [1994a], which replicates the finding in three languages, English, French, and Swedish).

We take the fact that crosslinguistic differences shape word templates to be a natural consequence of the induction process, since the target lexicon necessarily shapes the patterns implicit in the child's first fifty words or so. We note that English, Estonian and German data often show a concentration of CVC shapes (see also Vihman and Velleman 1989). In contrast, French data do not normally show CVC forms as early as the first 50–100 words (Vihman 1993, 1996), although the English-French bilingual early words reported by Brulard and Carr (2003) do include such forms, and they dominated the English lexicon of the child V, as indicated in Table 11. These diary studies provide some insight into the construction of templates under conditions of bilingual input (Vihman 2002a).

In short, we see the earliest phonological organization as constituting an inductive generalization based on the child's first repertoire of phonetic patterns and their interaction with the phonological structure implicit in the words of the ambient language that the child is attempting to reproduce. The phonological organization itself inheres in whole word patterns or word templates, as can be seen from the adapted patterns illustrated above. Phonological categories will gradually emerge later, in different ways for different children. The developmental pattern is like that found in recent studies of early syntax, in which "verb islands" are found in lieu of abstract grammar, with productive use of subcategories emerging only slowly, in different ways for different children (e.g., Tomasello 1992; Lieven et al. 2000).

3. From child to adult: toward a "radical" templatic phonology

In Section 2, we argued for a templatic approach to phonological development in the child. In this section, we argue that a templatic approach is equally suited to the analysis of adult phonology. This argument derives much from phonetically oriented, exemplar and usage-based approaches to phonology and from a related approach to syntax, Radical Construction Grammar (Croft 2001).

3.1. *Variation and phonological categories*

One of the initial arguments for a templatic approach to child phonological development is the variability of segment production. Such variability is pervasive in adult phonological categories as well. Ohala writes, "One of the major discoveries of phonetics for the past century is the tremendous variability that exists in what we regard as the "same" event in speech, whether this sameness be phones, syllables, or words" (Ohala 1993: 239). Ladefoged and Maddieson's (1996) survey of segments across languages documents this variability on virtually every page. Pierrehumbert, in a paper advocating an approach to phonology that is quite similar to ours, also begins by demonstrating the high degree of variation found not just in segments but also in prosodic structures (Pierrehumbert 2003a: 120–127; see also Pierrehumbert et al. 2000).

This variability occurs at all levels, from individual usage events to languages (that is, crosslinguistic variation). For example, vowel productions are standardly mapped onto a two-dimensional F1–F2 space, and scatter plots illustrate variation in production in usage events within and across individuals (e.g., Pierrehumbert 2003b), leading to sociolinguistic variation (e.g., Labov 1994). Ladefoged and Maddieson (1996) document this variation as it eventually manifests itself as divergence across dialects and across languages. For example, at the dialect level, Californian English speakers use true interdentals in a word such as [θ̟ɪŋk] whereas British English speakers use a dental fricative [θɪŋk] (p. 20). Crosslinguistically, many languages distinguish dental and alveolar stops, particularly in India, Australia and the Americas. Most such languages contrast a laminal dental [t̻] vs. an apical alveolar [t̠] as in Toda [pot̻] 'ten' vs. [pɑːt] 'cockroach', but Temne contrasts an apical dental vs. a laminal alveolar (Ladefoged and Maddieson 1996). Most such languages also have greater affrication of apical alveolars than laminal dentals, as in Isako, but Dahalo has greater affrication of the laminal dentals (p. 25).

Variation is so pervasive that an adequate theory of phonology cannot ignore it or properly abstract away from it (see Section 1). Pierrehumbert (2003a) argues for an approach to phonological categories based on mathematical psychology that accommodates variation:

> A category is a mental construct which relates two levels of representation, a discrete level and a parametric level. Specifically, a category defines a density distribution over the parametric level, and a category system defines a set of such distributions. Using the density distributions for categories in a category system, incoming signals may be recognized, identified, and discriminated through statistical choice rules. This understanding of categories has been generally adopted in experimental phonetics and sociolinguistics. (Pierrehumbert 2003a: 119)

We believe that this approach to categories can and should be adopted in phonology as well.

One result of this approach to categorization is that the segment categories that can be formed from the actual input are not phonemes but positional variants of phonemes (Pierrehumbert 2003a: 129–30). For example, tokens of initial and final /s/ in English differ from each other significantly. Within each position, /s/ and /z/ are reasonably well differentiated, but across positions, there is substantial overlap between /s/ and /z/ tokens. Pierrehumbert (2003a: 140) concludes that "the engine of adult speech perception appears to be positional segmental variants." Pierrehumbert's conclusion is exactly that of our templatic approach: segmental phonological categories are defined in terms of their position in a larger structure (the word template; see Section 3.2). The evidence that Pierrehumbert amasses supports this view for adult phonology as well.

Pierrehumbert restricts her attention to the identification of individual segments, that is, positionally defined allophones. She notes that phonemes, as categories of allophones in different positions, play little if any role in adult speech perception (Pierrehumbert 2003a: 129). But contemporary generative phonological theory does not refer much to phonemes either; for example, phonemes are hardly mentioned in a recent survey of theories of phonological representation (Ewen and van der Hulst 2002). Instead, a more abstract or general category is used for phonological representation, namely features. A feature is a more general category that subsumes multiple segments — namely, all the segments that possess that feature.

Yet features as a more general category are problematic. For example, Ewen and van der Hulst (2002) argue that the same vowels are categorized in different ways depending on the relevant phonological process/phonotactic pattern (pp. 15–21, 102–5). The vowels in (1), for example, are grouped according to the category/feature of tenseness:

(1)	[+tense]	*i*	*e*	*a*	*u*	*o*
	[−tense]	*ɪ*	*ɛ*	*ə*	*ʊ*	*ɔ*

Ewen and van der Hulst argue that this categorization of vowels is needed to describe a constraint on final stressed vowels in English (e.g., [+tense] /biː/ vs. [−tense] */bɪ/).

A different categorization of the same vowels, given in (2), is necessary for representing the constraint on possible vowels in a single word (vowel harmony) in some languages. Vowel harmony in languages such as the Asante dialect of Akan is governed by the feature of advanced/retracted tongue root (±ATR; Ewen and van der Hulst 2002: 19–20):

(2) [+ATR] *i e ə u o*
[−ATR] *ɪ ɛ a ʊ ɔ*

Finally, Ewen and van der Hulst (2002) argue that the categorization of vowels in terms of the traditional feature of height is also necessary in order to describe, for example, the stepwise shifts in vowel height of the English Vowel Shift and also a diphthongization process in Skane Swedish (pp. 20–21; we have used a multivalued height feature here but most feature theories use various devices to avoid multivalued features):

(3) [high] *i u y*
[high-mid] *e o ø*
[low-mid] *ɛ ɔ œ*
[low] *a*

Ewen and van der Hulst (2002) introduce three different features for grouping the same sounds in the three different ways in (1)–(3) (they use the single-valued features ATR [advanced tongue root] and @ [for laxness] and some combination of features for height: pp. 102–105). That is, they have proposed a distinct vowel feature for each of the three phonological phenomena they describe. They write,

> The range of processes surveyed in this section suggest that vowel systems can be organized along different phonetic and phonological parameters, and hence that our feature system must be rich enough to be able to describe all of the parameters found to play a role in the organization of vowel systems. (Ewen and van der Hulst 2002: 21)

We agree with this statement but we raise the question, where does it stop? For example, Ewen and van der Hulst (2002) observe in a footnote that with respect to another English phonotactic phenomenon, occurrence before *ŋ*, the category of [−tense] vowels must exclude *ə*, and in other respects *ə* acts as a separate class (p. 18, fn 16). In other words, occurrence before *ŋ* defines a different natural class from that in (3), namely {*ɪ ɛ ʊ ɔ*}. In principle a new feature should be posited for that class. Otherwise one is in effect choosing the distribution pattern defined by final stressed vowels over that defined by occurrence before *ŋ* — but there is no a priori reason to do so.

The logical conclusion to this process would be the positing of a different feature for each category defined by each phonotactic constraint. This is in fact what we are basically arguing for: even the more abstract categories familiar to us from phonological theory are defined in terms of their position in phonotactic templates. That is, phonological categories are defined in terms of their distribution in templatic patterns. In other words, the phonotactic templates are basic, and phonological categories are derivative (we return to this point in Section 3.2).

A templatic approach to adult phonology is supported by the widespread and well known fact that the most general and abstract categories of sounds (those usually described by features) actually differ in different word or syllable positions. For example, Bybee (2001) suggests that consonants in initial and final position are quite different in phonetic realization (compare Pierrehumbert 2003a above), that "consonant" as a category may not be valid: "onsets and codas may not be unified into a single set of consonants" (Bybee 2001: 88). She adds, "This proposal would predict that a language could have a completely mutually exclusive set of syllable onsets and syllable codas" (p. 88).

Although we are not familiar with such a language, some languages have quite distinct sets of initial and final consonants with only partial overlap. Sedang exhibits this pattern for stressed syllables and in addition has a third series of consonants for initial consonants in an unstressed syllable preceding the stressed syllable, called a "presyllable" (Smith 1979: 22, 26, 37):

Table 12. *Sedang consonant inventories by position*

Initial stops	*p*	*t*	*c*	*k*	*ʔ*		
	ᵐb	*ⁿd*	*ᶮj*	*ᵑg*			
	m	*n*	*ɲ*	*ŋ*			
	pʰ	*tʰ*	*cʰ*	*kʰ*			
	'b	*'d*					
	'm	*'n*	*'ɲ*	*'ŋ*			
	m̥	*n̥*	*ɲ̥*	*ŋ̊*			
Final stops	*p*	*t*		*k*	*ʔ*		
	m	*n*		*ŋ*			
Presyllabic stops	*p*	*t*		*k*	*ʔ*		
	b						
	m						
Initial continuants	*s*	*ʂ*					
	β	*l*	*r*		*j*		*h*
	'β	*'l*	*'r*				
	β̥	*l̥*	*r̥*		*j̊*		
Final continuants		*l~r*	*w*	*j*	*jʰ*	*jˤ*	*h*
Presyllabic continuants		*s*					
		l	*r*	*j*			*h*

In addition, there are consonant clusters with stops followed by *l* or *r*. The total count of initial vs. final consonants in Sedang is as given below (clusters and the presyllabic consonants are excluded from this comparison):[9]

(4) Initial: 41 consonants, 30 unique to initial position
Final: 14 consonants, 3 unique to final position
Overlap: 11 consonants

Smith writes, "The dissimilarity of the final consonant inventory from the initial single consonant inventory ... recommends the establishment of a separate consonantal system for each consonantal position of the phonological word" (Smith 1979: 37). Moreover, the relationship between the syllable nucleus and the final consonant is also complex: final zero and glides allow for register and oral-nasal distinctions in the nucleus, final nasals allow for register distinctions only, and other finals allow only oral-nasal distinctions (Smith 1979: 42–44). This example demonstrates not only that one must distinguish between syllable-initial and syllable-final "consonants" as distinct phonological categories, but "presyllable" consonants are a distinct category as well. All three categories of "consonants" are defined by their position in the Sedang word template, as Smith recommends.

The closest example to mutually exclusive positional categories of a highly general feature that we are aware of is found with the "vowels" of the 19th century Tremjugan dialect of Khanty (Abondolo 1998: 362). The set of word-initial (stressed) vowels of Khanty (called V_1 below) is not the same as the set of noninitial vowels (V_2; *ï* and *ë* are back unrounded vowels, *ä* is a front low unrounded vowel and *å* a back low rounded vowel; *ə* and *ə̂* are front and back central vowels, respectively):

(5)

Initial vowels:	*ii*	*ee*	*ää*	*ïï*		*uu*	*oo*	*åå*
		e	*ä*	*ö*	*œ*		*o*	*a*
Noninitial vowels:	*ii*	*ee*	*ää*	*ïï*	*ëë*			*aa*
		ə	*ə̂*					

V_1: 13 vowels, 9 unique to initial position
V_2: 8 vowels, 4 unique to noninitial position
Overlap: 4 vowels

This analysis of Khanty vowels treats long vowels as a separate category (or set of phonemes) from short vowels. There is good reason to do so; the qualities of short and long vowels are quite different:

(6)

Long (full) vowels:	*ii*	*ee*	*ää*	*ïï*	*ëë*	*uu*	*oo*	*åå*	*aa*
Short (reduced) vowels:		*e*	*ä*	*ö*	*œ*	*ə*	*ə̂*	*o*	*a*

VV: 9 vowels, 5 qualities unique to long vowels
V: 8 vowels, 4 qualities unique to short vowels
Overlap: 4 vowels

This is a particularly sharp case where a highly abstract phonological category differs quite substantially depending on the position of the phones in the template. But it is a common phenomenon, particularly in comparing stressed and unstressed vowels or long and short vowels (which are themselves often phonotactically restricted) and also vowels occurring in more narrowly defined positions in a word template, such as final syllables.

In fact, "consonant" and "vowel", to the extent that they are empirically valid phonological categories, are themselves defined in terms of their position in the syllable, characterized most broadly as periphery and nucleus respectively. In this approach, then, what basically differentiates "semivowels" from "vowels" and "syllabic consonants" from (ordinary) "consonants" is their position in the syllable. Of course, the nature of the articulatory gestures is what allows the sounds to function as either syllable nuclei or syllable peripheries. But that is merely part of an ultimately phonetic explanation of the phonological patterns (that is, which sounds occur in which syllable positions).

3.2. *Words and templates as the basic units of phonology*

All of the examples discussed in Section 3.1 imply that the empirically supported phonological categories found at all levels of generalization from the most concrete (tokens of the same segment) to the most abstract (consonant and vowel) are defined particular to a position in a phonological template, generally a word template. If categories of segmental phonological units are defined positionally relative to a word template, then the word template must be the primary unit of phonological representation, and the individual segment category is derived from it. This is exactly the approach that emerges from the crosslinguistic developmental data examined in Section 2. Although Pierrehumbert does not take this position explicitly, she does assume that the lexicon is a central part of the cognitive architecture that is the target of phonological acquisition (Pierrehumbert 2003a: 116) and she recognizes that the ability to perceive what she calls "prosodic structure", which is basically our notion of template, must be (and is) acquired very early (Pierrehumbert 2003a: 140). Bybee explicitly takes the position that the word is the basic unit of phonological representation (Bybee 2001: 29–31) and that segment categories are "emergent" (Bybee 2001: 85).

The child begins with words, and templates are generalizations over the phonological structure of words (compare Bybee 2001: 89–95). The templates determine the phonological categories of a language, from the most concrete to the most abstract. The arguments presented in this section imply that as the child matures to become an adult speaker of her language, the phonological representations of individual words and the phonological relations between words do not change in any essential respect. Adult phonological representations constitute a continuation of child representations. In the words of Ferguson and Farwell (1975: 437), "we assume that a *phonic core of remembered lexical items* and articulations which produce them is the foundation of an individual's phonology ... Thus we assume the primacy of lexical learning in phonological development ..." [emphasis ours]; (see also Beckman and Edwards 2000b). The adult templates are both more general and more varied than those of the child, but this is a difference in degree, not kind.

The exemplar and usage-based models propose that individual usage events play a role in adult phonological representation. Exemplar approaches to word recognition appear to provide a plausible model for the implicit emergence of phonological structure from repeated memory traces (Goldinger 1996, 1998; Pierrehumbert 2001). The basic idea is that memory traces of new experiences, including speech input, are laid down with each exposure. These traces retain detail (e.g., regarding speaker's voice characteristics and also context) over a period of time; retention is longer in tasks drawing on implicit memory than in explicit recall. As children listen to adult words in the period of first word production, the input sequences represented in the greatest detail should be those that automatically activate similar motor plans from the child's own vocal production repertoire. These sequences may also be retained as traces of often repeated babbling in the child's own voice. Note that the effects of existing patterns will necessarily be strongest at the outset of identifiable word production. Computer modeling shows that abstraction is the automatic consequence of aggregate activation of high-frequency tokens, with regression toward central tendencies as numbers of highly similar exemplars accumulate: "the single voice advantage diminishes as word frequencies increase. Old High Frequency words inspire 'abstract' echoes, obscuring context and voice elements of the study trace" (Goldinger 1998: 255). The appropriate size of the phonological exemplar is a word, because a word is "a unit of usage that is both phonologically and pragmatically appropriate in isolation" (Bybee 2001: 30) — that is, the smallest linguistic unit encountered in language use.

Frequency plays a significant role in the representation of phonological knowledge of adults as well as children learning language. Experimental work with adults, using nonword stimuli, has shown that language users are highly sensitive to the phonotactic regularities implicit in the lexicon

(Vitevich et al. 1997; Vitevich and Luce 1998, 1999; Frisch 2000; Frisch et al. 2000; Frisch and Zawaydeh 2001; Treiman et al. 2000; Bailey and Hahn 2001; see also Pierrehumbert 2003b). Bybee (2001) surveys diachronic and typological as well as experimental evidence demonstrating the role of token and type frequency in phonological organization and processes. Edwards et al. (2004) have demonstrated such lexical frequency effects in children, the strength of existing patterns being inversely correlated with vocabulary size. They argue that children develop an implicit "phonological grammar" out of the words they learn holistically (p. 422). The phonological grammar so derived permits access to sublexical patterns in both perception and production. Those patterns include both typical acoustic fragments and abstract phonological categories (phoneme sequences), and access is facilitated by both auditory and articulatory experience with words.

It should be noted that much current research in phonological theory, as surveyed in Ewen and van der Hulst (2002), goes in the opposite direction to the approach discussed here, by attempting to simplify and further generalize abstract phonological structures. But the reality of the complex variation in phonological patterns leads to a proliferation of theoretical constructs to deal with violations of the constraints imposed by the highly general and simple structures. The set of phonological features has been simplified through the postulation of such principles as binarity, underspecification and single-valued features (Ewen and van der Hulst 2002: 54, 63–85). But theorists have consequently been required to posit constructs such as redundancy constraints, default rules, the Redundancy Rule Ordering Constraint, dependency and particles (Ewen and van der Hulst 2002: 66–68, 75–77, 91–92, 102–105). The inventory of syllable structures has been simplified through the postulation of the sonority sequencing generalization and the hypothesis that all syllable structures are binary branching (Ewen and van der Hulst 2002: 136, 175). Again, this has required the positing of constructs such as syllable prependices and appendices, extrasyllabic segments, empty syllable positions, and licensing and government relations between segments in syllables (Ewen and van der Hulst 2002: 136–139, 147–150, 165, 174–193). Finally, the inventory of metrical feet has been simplified by various principles, in particular the principle that all feet are binary (Ewen and van der Hulst 2002: 226). Again, this has required the positing of constructs such as monosyllabic feet, degenerate feet, weak local parsing, extrametricality and footless languages (Ewen and van der Hulst 2002: 226, 228–237). In our view, these additional theoretical constructs are ad hoc, and their proliferation strongly suggests that this sort of simplification in representation does not lead to natural empirical generalizations. In contrast, the only phonological categories posited by a templatic approach to phonology are (i) words; (ii) word templates of varying degrees of schematicity, and (iii) syllable and segment categories as subparts of those phonological templates, defined in terms of their occurrence in particular template positions. This is a formally simple model, utilizing a minimum of theoretical constructs.

The templatic approach to phonology is further supported by nonlinear representations (van der Hulst and Smith 1982; Goldsmith 1990). Phonological properties or features are not specifically bound to particular segment positions in a word: they can be restricted to a single segment position or extended over multiple positions (which may be limited to consonantal slots only or vocalic slots only). This hypothesis about the mapping of phonological properties onto skeletal positions has been formalized by representing each feature on its own tier (Ewen and van der Hulst 2002: 41–44). Articulatory phonology (Browman and Goldstein 1989, 1991, 1992; see also Bybee 2001: 69–77) takes this trend to its logical conclusion. Articulatory phonology is a directly phonetically based nonlinear model, in which the articulatory gestures are the basic phonological "features", and the nonlinear mapping of gestures is the result of the complex motor coordination of the gestures to produce a word. The execution and coordination of articulatory gestures are the source of most phonological processes. Nonlinear models take inspiration from Firth's (1957) prosodic approach to phonology. Firth uses the metaphor of a musical score to describe his prosodic representations (p. 137–38), very similar to the tiers of contemporary nonlinear models and specifically the "articulatory score" of Browman and Goldstein.

Firth emphasizes a further point about nonlinear models which links them to a templatic approach to phonology. If features are not simply mapped onto segment positions, then the basic unit of phonological structure is the domain of the complex mapping of features, i.e., the word, or even a larger unit (Firth 1957: 121). A nonlinear model must represent a larger unit than a single segment, because the mapping between tiers spreads across segments. In fact, the domain of the mapping is more basic than the individual segments in the skeleton of a word, because the assignment of features to a segmental position in the skeleton is determined by the mapping. Thus nonlinear phonology has already moved away from segments to larger units as the basic units of analysis. A templatic phonology brings this tendency to its logical conclusion by treating the word as the basic unit of phonological representation.

Our templatic approach to phonological representation is centrally concerned with a redefinition of phonological categories of segments in words according to their phonotactic position as defined by syllable and word structure. This mirrors a constructional approach to syntactic representation, in particular Radical Construction Grammar (Croft 2001). Croft argues that the variation in syntactic category membership and definition within and across languages requires that they be defined ultimately in terms of their "position" or role in the syntactic constructions used to define them. It is described as "radical" in order to emphasize that the constructions are basic and the syntactic categories of particular units are derived from the constructions. In this respect our templatic approach to phonology is also "radical". Radical Construction Grammar also adopts the definition of categories used by Pierrehumbert, as a level of discrete categories mapped onto a density distribution of individual functions or meanings, the conceptual space parallel to the space defined by phonetic parameters. This model of categories is known as the semantic map model in typological theory (Haspelmath 2003; Croft 2003; Croft and Poole forthcoming). In this respect the radical templatic model of phonological representation is conceptually the same as the radical constructional model of syntactic representation.

We conclude by responding to an objection to an exemplar-based model such as that advocated here. It appears that an exemplar-based model presupposes the very categories that it defines by its exemplars. How does the speaker know that the various exemplars of *p* or *æ* in different words are instances of the same phonological category, and not exemplars of phonetically neighboring categories in the phonetic parameter space? For example, Labov's research on a single individual's productions of vowel tokens (Labov 1994, inter alia) demonstrates that individual exemplars of one phoneme will be included in the phonetic range of another phoneme: for example, some exemplars of /æ/ will occur in the range of exemplars of /ɛ/. How does a speaker know that those tokens are exemplars of /æ/ and not /ɛ/? This question cannot be answered in a purely segment-based approach to phonological representation. If one begins with segments, one must have a definition of those segments that is either ultimately phonetic, or else purely arbitrary (i.e., a particular exemplar is stipulated to be an exemplar of /æ/ even if its actual realization is [ɛ] in purely phonetic terms).

On the other hand, if one begins with words as phonological units, then the question can be answered and the paradox is solved. The phonetically outlying token is an exemplar of /æ/ because it is part of a specific word, and other occurrences of that word contain exemplars that cluster around the central phonetic tendency for /æ/. How is the word identified as the same word? The word is of course identified as the same by its meaning in the context of use, linked to prior occurrences of the word with that meaning in similar contexts of use. In other words, we return to the starting point of our perspective on phonology: phonology, like other aspects of language, must begin from the sound-meaning link that is central to the symbolic nature of language.

Received 21 January 2003
Revised version received
30 March 2005

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1. The term "template" has been used in generative phonology in reference to analyses in which fixed prosodic structures (syllabic and metrical) have been posited to account for patterns in which segmental material appears to be matched or fitted into such templates (see, for example, the analyses summarized in Kenstowicz [1994: 270–274, 622–625]; see also McCarthy and Prince [1988, 1990]). Our use of the term follows the usage in phonological development: it is more general, in that it describes word-sized patterns at all levels of phonological organization, and is not restricted to template-matching or template-fitting processes.
2. Larger structures, namely constructions, are also symbolic units. Constructions may have distinctive phonological properties, specifically prosodic properties. However, these are beyond the scope of this article, which limits itself to segmental phonological representations.
3. For additional detail regarding the data summarized here, see Vihman (1996) (English and French), Vihman et al. (1994a) (Swedish), Vihman and DePaolis (2000), Vihman et al. (2006) (Welsh), Kõrgvee (2001), Salo (1993) and Vihman (1976) (Estonian), Kunnari (2000) (Finnish), and D'Odorico et al. (2001) (Italian).
4. See Vihman (1996) for a review of the long-standing debate regarding the role of perception in word production errors.
5. Note that we disregard changes in voicing in all of the developmental analyses: voicing is not generally thought to be under voluntary control at this age, nor is transcription of voicing in child production reliable without acoustic verification. See Macken (1980) for an overview of the acquisition of voicing contrasts.
6. The velar stop /k/ was produced as [k] only before the (whispered) back vowel [ɔ] at this stage; it was fronted to [t] before front vowels (see Vihman 1976).
7. Data from the case study of Sini, a child acquiring Finnish (Savinainen-Makkonen 2001), and from Andrew, a child acquiring British English (French 1989), have been added to the data cited in Note 3.
8. Note that we are disregarding initial glottal stop, which is notoriously difficult to transcribe reliably (Vihman et al. 1985). Examples of "no onset" can be found in Tables 4 (P: initial fricatives omitted), 5 (Madli: initial /k/ and /s/) and 8 (Eeriku: initial /k/, /h/ and /v/).
9. *l* and *r* are treated as distinct in initial position but as variants in final position; Smith does not describe the nature of the final liquid variation. We treat both *l* and *r* as occurring in both initial and final position.

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