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PART III

Discovering units

From first words to segments

A case study in phonological development*

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The emergence and later fading of two phonological templates – a 'palatal' template and consonant harmony – are investigated in the first 500 words produced by a child acquiring Estonian and English. Throughout the period the child's use of palatal forms, in particular, considerably exceeds their frequency in Estonian, the child's dominant language. Regression in accuracy is also traced, both overall and in individual word forms. Changes in frequency of use of the template patterns are related to growth in the size of the lexicon, the consonant inventory, and the length in syllables of words attempted. Articulatory difficulty is found to play at best a minor role in motivating pattern use, which is ascribed instead to the challenges of planning and recall.

Keywords: Phonological development; Estonian; template

1. Introduction

Children's very first words typically target adult words of simple prosodic structure and segmental make-up – that is, one- or two-syllable word forms with open syllables, no clusters, core consonants (stops, nasals, glottals and glides) and little (if any) consonant or vowel variegation across the word. Accordingly, the first words tend to be 'surprisingly accurate' (Ferguson & Farwell 1975), with some errors of omission but rarely substitutions and still less often (if ever) reordering of sequences. Furthermore, contrary to the formulation of Jakobson (1941/68), these early word forms are largely based on what has already become familiar through babbling practice (Vihman et al. 1985). This can be accounted for by assuming that infants respond with heightened attention to adult words that provide an approximate match to their own vocal forms (Vihman 1991, 1993, 1996; for experimental

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evidence of such 'filtering' of the adult input through the child's own production patterns, see DePaolis, Vihman & Keren-Portnoy in press). This model goes some way toward explaining the further surprising fact that the forms of the first words differ considerably across individual children even within a single language group, despite the fact that adult input samples show remarkably uniformity (see Vihman et al. 1994, for an analysis of the input to one-year-olds of five mothers in each of three language groups, English, French and Swedish).

Once identifiable first words have begun to be produced, it has been documented in both diary studies and observational studies based on home recordings that most (if not all) children pass through a period of regression in accuracy, in which the child's words are more readily analyzed as matching adult word targets as a whole than in terms of a segment-by-segment match (see especially Menn 1971; Waterson 1971; Ferguson & Farwell 1975; Macken 1979; Menn 1983; more recent studies that support the idea of early words being rooted in holistic representations include Vihman & Croft 2007 and Fikkert & Levelt 2008). According to this model, which has been termed 'whole-word phonology', the period of 'accurate' item learning is followed by an extension of these well-practiced early word forms to targets that are less similar to the pattern, allowing for an advance in word learning even while production constraints – on word length in syllables, changes in consonants across the form, etc. – remain unchanged. For example, at 10 months the French child Laurent produced the relatively accurate forms [hailo], [ailo] for *allo* 'hello', [də], [dlə] for *donne-le* 'give it' and [ljoljo] for *lolo* 'bottle' (baby-talk [BT] form) (Vihman 1993; Vihman & Kunnari 2006). Five months later his word forms tended to fit an l-medial template, as can be clearly seen in such forms as [kɔla] for *canard* 'duck', [bɔlo] for *chapeau* 'hat', [bəla] for *la brosse* 'the brush' and [kola] for *la cuillère* 'the spoon', none of which has a medial /l/ in the target. At the same time Laurent produced more accurate forms for target words that conformed to his preferred pattern: [alo] for *allo* 'hello', [dəlo] for *dans l'eau, de l'eau* 'in/some water', [palɔ] for *ballon* 'big ball' and [pala] for *pas là* 'not there, all gone'.

'Whole-word phonology' can be taken to reflect the child's extraction of implicit word patterns through distributional learning over his or her first word forms, which themselves reflect a filtering of the adult input through the child's own output constraints (Kager, Pater & Zonneveld 2004). The result of this implicit learning is an internal representation or 'template' that consists of one or more systematic structures involving set prosodic positions to be filled from a limited segmental repertoire. In these templatic structures some aspects of target words, such as unstressed syllables or codas, may be represented in a way that has little relation to the adult form, supporting the suggestion that children are drawing on whole-word-based internal representations – at least for production, which poses

a serious challenge to memory as well as to planning and articulation – alongside their more detailed and variable (exemplar-based) memory of specific tokens, as heard in both the input and the child's own output.

Despite the long-standing evidence of templates based on production studies, however, only two studies to date have tracked a child's progress from the use of templates to a more segmentally oriented phonology: Macken's (1979) case study of a child acquiring Spanish, and Oliveira Guimarães (2008), which follows four children acquiring Brazilian Portuguese.[1] Here we describe the use of templates by one child, Maarja, (a pseudonym) in the simultaneous acquisition of Estonian and English. The goals here are, first, to sketch changes in the use of two phonological templates from the first fifty words (age 12–16 months) to a production vocabulary, across the two languages, of 500 words (by 22 months), well beyond the single-word period. Second, we attempt to relate those changes to changes in the size of the representational units that underlie the child's productions – whole word forms, initially, but something more like adult sequences of segments by the end of the period in question.

2. Methods

Participant. Maarja is being raised bilingually with Estonian and American English as home languages. Estonian is spoken by her father and the community as well as being the primary language spoken between the two parents; English is spoken by Maarja's mother, with additional input from occasional visits to English-language communities and visits from friends of the family. Estonian rapidly became the dominant language after Maarja began attending full-time daycare from the age of 17 months, although she continued to produce new English words and to show good comprehension of English.[2] The data reported on here come from diary records kept by the child's mother, a trained linguist, who was the primary caregiver until Maarja was 17 months old. Each new form

1. See also Priestly (1977) for a fully documented case study of the evolution of a child's CVjVC template, from first uses at 22 months (e.g. *berries* [bajas], *chocolate* [kajak], *flannel* [fajan], *tiger* [tajak]) to segmentally faithful 'ordinary replacement forms' at 26 months.

2. The fact that the data come from a child exposed to two languages from the start is given no particular consideration here, although the source language for all forms is clearly marked. Note that, as demonstrated for three other bilingual children in an earlier study (Vihman 2002), the child's templatic patterns are applied irrespective of the particular language source.

was noted as it was heard and later collated into a list of new word forms and combinations.

Analysis. What are Maarja's templates and how might they have contributed to her word learning? To address these questions we first identify and trace the rise and fall of template use and then weigh the relative importance of other factors that might have influenced the nature and rate of vocabulary growth and the accuracy of word production. These include changes in both (i) the length in syllables of words attempted and produced and (ii) the child's consonant inventory.

In order to carry out these analyses we consider separately 50-word additions to the set of new word types produced (referred to as 'samples'), until the point when 500 different words have been recorded; the set of words considered in each sample includes (unnumbered) new variants of old words added in as they were recorded, for a total word list of 564 words. These 50-word samples are not 'stages' in any sense but are merely an analytic convenience, to allow comparison over time and to map the sources of change against lexical growth. We take as our starting point the period in which the first fifty different word types were attempted in some recognizable way (Sample I: age 12–16 months). For our initial purpose of observing lexical growth in relation to template use, however, we divide the period of the study into eight one-month periods (combining the words produced at 12, 13 and 14 months as the first age-point).

We note, finally, that words that first occurred in combinations are also included in the new-word-forms count; combinations began at 15 months but reached a total of over five recorded new types per month only at 18 months (20 combinations). We give no separate attention to words used in combinations here, however.

3. Results

Figure 1 shows the child's cumulative vocabulary growth over the period of the study. We note that after the initial slow start – one word at 12, three more at 13 months – an early 'lexical spurt' resulted in 18 new word forms attempted at 14 months (for a total of 22 word forms recorded) and a further 33 at 15 months (for a total of 55 word forms).

3.1 The palatal template

If we consider the forms of the child's first 50 words we find a striking reliance on a particular phonological melody, which we call 'the palatal template'. We define this

pattern broadly, to include all words in which at least one syllable has as its nucleus a front-rising diphthong <VI> or the tense vowel [i]; a few of the later child forms take the expanded palatal shape CoVi/jV,[3] where intervocalic [i] represents a long palatal glide. Disregarding the question of fidelity to the target form, we include in Figure 1 all child forms that match any of those criteria in tracing use of the palatal template over the entire period of the study.

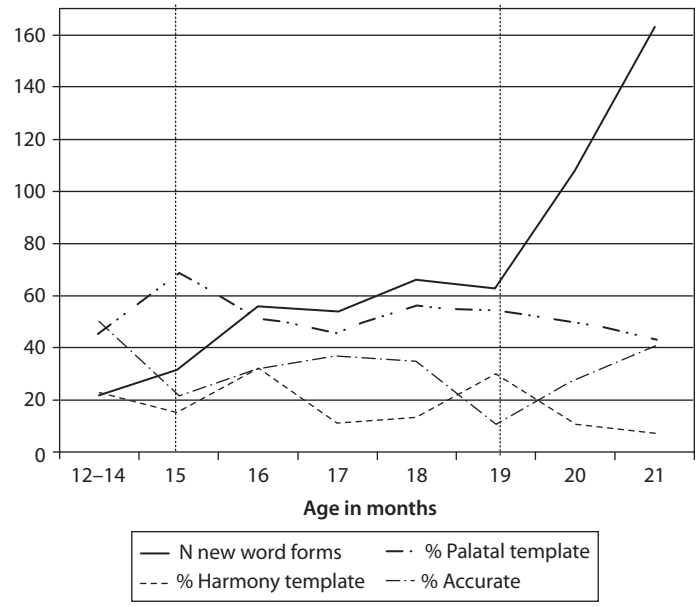

Figure 1. Lexical growth and template use. Number of new word forms recorded per month, ages 12–14 through 21 months (collapsing 12–14 months for first point); proportion of template patterns and accurate word shapes produced

Table 1 shows the 31 different words that include any such palatal variants in Sample I (out of the 50 word types targeted), together with all the recorded forms. Out of a total of 111 word forms recorded within this first lexically defined sample (age 1;0.10–1;4.7), including all variant tokens that meet the criteria, 59 tokens – or 53% – can be termed 'palatal' (see the child word forms in bold face in the table).

3. Co means that the onset consonant is optional.

Table 1. Palatal word patterns in child forms: First 50 words (Sample I)[4]
English word targets are in *italics*, palatal tokens in bold face. For boxed rows, see text.

New words	Child age	Child form	Target	Target phonetic form	Gloss
1	1;0.10	[ɑɪːˈtæʰ], [tæʰ]	aitäh	[ɑɪˈtæh]	thanks
2	1;1.23; 1;1.29	[**ʔaɪ**], [**daɪ**]	pai	[paɪ]	nice; patting sound
3	1;2.3	[**mʏmːi**], [**mɑmːi**] [**ɑmːi**]	mõmmi	[ˈmʏmːi]	teddy
4	1;2.5	[**dæ | iː**] [**əpˈtih**],	*daddy*	[ˈdædi]	
5	1;2.5	[**əpˈsih**], [**əpˈsiː**]	hopsti	[ˈhopsti]	up, jump (BT)
6	1;2.10	[**mʌmːiː**]	*mommy*	[ˈmɑmi]	
7	1;2.15	[**inːi**], [**ʏnːi**]	kinni	[ˈkɪnːi]	closed
8	1;2.21	[**bɛˈbeɪ**], [**bəˈbeɪ**]	beebi/*baby*	[ˈpeːbi], [ˈbeɪbi]	baby
9	1;2.21	[**ʔaɪ**], [**paɪ**], [**baɪ**]	pall, *ball*	[paʌ́ː], [bɑl]	ball
10	1;2.26	[**ʔʏɪ**]	kõll	[kʏʌ́ː]	clink (glasses)
	1;3.0	[**kʏɪ**]	kõll	[kʏʌ́ː]	clink
11	1;3.4	[əˈ**bi(ː)**], [**bʏi**], [əˈ**bʏi**]	*belly(button)*	[ˈbɛlibʌʔn̩]	
12	1;3.4	[**kʏi**] [**pʏiː**],	kalli-kalli	[ˈkalːikalːi]	hug, cuddle
13	1;3.6	[**pʏiː | uː**]]	*peek-a-boo*	[ˈpikəbu]	
	1;3.8	[**kai**]	kalli-kalli	[ˈkalːikalːi]	hug, cuddle
	1;3.9	[**kʏɪ**]; [kʏn]	kinni	[ˈkɪnːi]	closed
14	1;3.15	[**bei**],	*bib* (im.)	[bɪb]	
		[**biː**], [bɪ]			

(Continued)

4. Stress in Estonian is normally on the initial syllable, as it is in most English disyllabic words addressed to children. We mark stress here on adult target words but note it on child forms only when it perceptibly affects the non-initial syllable.

Table 1. (Continued)

New words	Child age	Child form	Target	Target phonetic form	Gloss
15	1;3.15	['kʌpə], **[kʌpi], [kupi]**	*cup*	[kʌp]	
	1;3.15-16	**[pʌpːi]**	*cup*	[kʌp]	
16	1;3.16	**[siː]**	siin	[siːn]	here
17	1;3.16	**[wiː]**	*whee*	[wiː]	
18	1;3.18	**[meɪ]**	*melon,* melon	['mɛlən], ['mɛlon]	
19	1;3.18	**[bɑɪ]**	*bye*	[bɑɪ]	
20	1;3.19	**[tsis], [sis], [ʃis]**	*cheese*	[tʃiːz]	
21	1;3.19	['banə], **[baɪ], [baiə]**	*banana*	[bə'nænə]	
	1;3.19	**[biː]**	beebi/*baby*	['peːbi], ['beɪbi]	
22	1;3.20	**[bʏiː], [ə'bʏi], [bʏiə]**	*apple*	['apl̩]	
23	1;3.21	**[biː]**	*bee*	[biː]	
24	1;3.25	**[iː], [iːə]**	*ear*	[iəɾ]	
25	1;3.29	**[piː]**	*peepee*	['pipi]	
26	1;3.29	**[paɪ]**	*spider*	['spaɪdə̯]	
	1;3.29	**[mɛɪu]**	*melon,* melon	['mɛlən], ['mɛlon]	
27	1;4.0	**[ɑsːi]**	kass(i)	['kasːi]	cat
	1;4.0	**[iː]**	*cheese*	[tʃiːz]	
28	1;4.1	**[tita]**	tita	['tita]	baby (BT)
29	1;4.2	**[paɪ]**	padi	['padi]	pillow

(Continued)

Table 1. (Continued) Palatal word patterns in child forms: First 50 words (Sample I) English word targets are in *italics*, palatal tokens in bold face. For boxed rows, see text.

New words	Child age	Child form	Target	Target phonetic form	Gloss
30	1;4.2	**[paɪ]**	*potty*	[ˈpɑɾi]	
31	1;4.7	**[baɪ]**, **[baɪs]**	*bath*	[bæθ]	

From Table 1 it is evident that the first forms produced were relatively accurate or 'selected' (Vihman & Velleman 2000). This suggests that the child has identified in the input some easily matched word forms that were also sufficiently frequently occurring and situationally interesting to have left a trace in her memory – specifically, a 'motor trace' that could support the form-meaning link that is the primary challenge for early word learning (Stager & Werker 1997; Keren-Portnoy et al. 2010).

A horizontal line divides the table into two separate steps in the formation of the palatal template. Above the line are 10 words whose target forms include either /Vɪ/ or /i/ or, in the case of the last two forms (at age 1;2.21 and 1;2.26), a palatal lateral, which a child could be expected to produce (and perhaps also perceive) as a front glide. These forms can be considered to have been selected (at least in part) for their phonological form, which lends itself to production by a child who has been focusing much of her vocal output on words whose nuclei end in /i/; note that the child's errors – generally of omission, as expected for the earliest period – tend here to affect the onset consonant (e.g. *pai, mõmmi, kinni, pall, kõll*). It is worth observing too that only ten more words had been attempted up to this point, four of them onomatopoeia (*aua* 'woof', *uu-uu* 'hoot' (owl sound), *moo, baa*), the remaining words being produced with the simple shape Cɑ (4) or VCV (2).

Below the line, in the second step of template formation, we see forms that include an /i/-nucleus (*bellybutton, kalli-kalli*, *peek-a-boo*) or a palatal lateral (*kõll*), but also forms that do not (here indicated by outlining or 'boxing': *cup, melon, banana, apple* and *bath*). In these latter cases we say that the child has 'adapted' the target to fit her preferred template. Here, then, we have a mix of 'selected' and 'adapted' word forms. In fact, although the majority of words that Maarja produces in Sample I with palatal nuclei do have some phonetic basis for the pattern in their target form (tokens of these five words are the only clear exceptions), it is apparent from Table 1 that many rather similar forms are being produced at very short intervals (generally every day or two) from about 15 months on. Furthermore, in Sample II several more adapted palatal forms appear (Table 2).

Table 2. Palatal word patterns in child forms: 50–100 words (Sample II)[5]
English word targets are in *italics*, palatal tokens in bold face; clearly adapted forms are boxed.

New words	Child age	Child form	Target	Target phonetic form	Gloss
1	1;4.7	**[baɪ], [bʊ̯i]**	*bunny*	[ˈbʌni]	
2	1;4.16	**[anəˈsiː]**	anna siia	[ˈanːaˈsiːa]	give (it) here
3	1;4.17	**[daɪ]**	*dancing*	[ˈdænsɪŋ]	
	1;4.17	**[taida]**, [tata], [dada]	aidaa, tadaa	[aɪˈdaː], [taˈdaː]	byebye
	1;4.21	[ˈdædi]	*daddy*	[ˈdædi]	
4	1;4.21	**[meɪ]**, [ˈmelo], **[meɪjo]**	Meelo	[ˈmeːlo]	(proper name)
5	1;4.21	**[koti]**	kot(t)i	[kot(ː)i]	bag, purse (sG, sP)
6	1;4.22	**[eɪjoː]**, **[aioː]**, **[ɑljo]**, **[ɑjo]**	*hello*, hallo	[ˈhɛlo], [ˈhalːoː]	
7	1;4.22	**[haɪ]**	*hi*	[haɪ]	
8	1;4.22	[kʊ̯ti]	võti	[ˈvʊ̯ti]	key
	1;4.22	**[kiːz]**	*cheese*	[tʃiːz]	
9	1;4.24	**[ʃɪv]**, **[sipɑ]**	*slipper*	[ˈslɪpə]	
10	1;4.24	**[ʃiu]**, [kəˈsu]	kiisu	[ˈkiːzu]	kitty
11	1;4.25	**[tiː]**	*birdie*	[ˈbə̆di]	
12	1;4.25	**[nɪn]**, [nʌnd], [nʌnt], [ˈ**ninə**]	lind	[lind]	bird
13	1;4.25	**[tatsi]**	tantsi	[ˈtantsi]	dance
14	1;4.27	**[ɑmpti]**	ampsti	[ˈampsti]	a bite (BT)
15	1;4.27	**[piː]**	*pea*	[pi]	
16	1;4.27	**[bʊ̯ɪ]**	*button*	[ˈbʌʔn̩], [ˈbʌtn̩]	
17	1;4.27	**[kati]**	katki	[ˈkatki]	broken

(Continued)

5. Abbreviation used in this and later tables: s 'singular', G 'genitive', P 'partitive', N 'noun'; BT 'baby talk'.

Table 2. (Continued) Palatal word patterns in child forms: 50–100 words (Sample II) English word targets are in *italics*, palatal tokens in bold face; clearly adapted forms are boxed.

New words	Child age	Child form	Target	Target phonetic form	Gloss
18	1;4;28	**[bɑɪ]**	*book*	[bʊk]	
19	1;4;28	**[ʃəbaɪ], [baɪ],** [bat], [bats]	*butterfly*	[ˈbʌɾəflaɪ]	
20	1;4;29	[ˈ**nina**], [næn:]	nina	[ˈnina]	nose
21	1;4.30	**[kɑjə]**	küünal/ *candle*	[ˈky:nɑl, [ˈkændl̩]	candle
22	1;5.0	**[dɪŋ], [diŋ]**	*ding (dong)*	[ˈdɪŋ dɑŋ]	
23	1;5.2	**[maɪ]**	*mitten*	[ˈmɪʔn̩]	
24	1;5;2	**[kɑja]**	kala	[kɑlɑ]	fish
25	1;5;5	[ti:]	*tree*	[tɹi:]	

In the next sample, Sample III (17–18 mos., words 101–150), we find only a few adapted palatal patterns. At 1;5.7 *guy* provides a good model for a 'selected' diphthongal palatal form, for example, while *koala* is produced on that same day as [kɑ] or [kala]. However, a few weeks later (1;6.20) *koala* is produced both as [kwalə] and as [kwajə]. The last two examples of new words adapted to fit the diphthongal palatal template are [sui:] for *swim* at 1;6.11 and [koi] for *koolis* 'at school' at 1;7.2, although words appropriately produced as palatal forms continue to appear throughout the period, as either English or Estonian targets allow (e.g. *side, bless you, ai-ai* 'ouch, ow', *välja* 'to-outside').

Can we infer that the child was first selecting, then adapting target words to fit a 'whole word pattern', the production of which became increasingly well-practiced and familiar – rather than simply responding to input frequency? The overall profile of use of the palatal pattern that we have described gives plausible support to the idea. In the first months of word production, when accurate production of salient word forms prevailed, we find 45% palatal patterns. This is followed by a very high concentration of palatal forms in the next month, reaching 69%. What then follows is a steady, somewhat lower level of use (about 50%) for five more months. Finally, in the last month of the study (age 21 months.), which is marked by particularly rapid lexical growth, occurrence of the palatal pattern again drops to about the level of the first words (44%). Might this proportion reflect the maximum typical input frequency of words with i-nuclei, diphthongal or not, medial /j/ and/or word-final /i/?

To obtain more direct information as to the input frequency of palatal patterns in Estonian input in the absence of transcribed recordings for this child, we made use of an earlier study of a monolingual first-born child whose one-hour recordings made by the parents in the home began at age two (for more detail, see Vihman & Vija 2006).[6] We analysed all child-directed speech, by either parent, over the course of the first such recording, counting as 'palatal pattern' all words including one or more instances of /j/ or /(V)i/, in any word position, and dividing that count by total words produced.

Out of 1723 words produced in a total of 381 maternal utterances directed to the child (MLU 4.5), 758 were palatal forms (44%). Out of the 225 words produced in 56 paternal utterances directed to the child (MLU 4.0), 103 were palatal forms (46%). Combining the parents' data, the mean incidence of palatal forms for this Estonian input is 45% – which is also the level of Maarja's use in the periods of highest accuracy (her first and final months). This input analysis included onset /j/, however, which is common in Estonian but which did not feature as part of Maarja's template. If we exclude onset /j/, the overall use of palatal forms in the combined parental data falls to 36%, which indicates that Maarja's palatal pattern is most likely supported but not determined by its level of input use.

We also lack data for Maarja's English input. Note, however, that at least one other American child has been reported as having a palatal pattern, including both Vi diphthongs, especially in monosyllables, and medial palatalized consonants (Vihman, Velleman & McCune 1994), and high occurrence of final /i/ in English has also been reported previously (Davis & MacNeilage 1990). Nevertheless, use of a palatal pattern is by no means universal among English-speaking children (see Vihman 2010). Maarja's profile of palatal pattern use, then, together with our analysis of input to another Estonian child, gives good reason to think that Maarja was, for the entire period of the study, responding with a degree of enhanced (implicit) attention to palatal patterns at least as much as to the sheer overall frequency of occurrence of the pattern in the two input languages.

A second question we may ask is whether recurrent use of the pattern is primarily a response to articulatory difficulty, or whether memory also plays a role. Note that the first palatal forms produced involve the syllable nucleus [aɪ], which appears to be articulatorily congenial to Maarja, and that in general the palatal pattern affects syllable nuclei, not onsets. This focus on syllable nuclei may account for the omission, in so many of the first few words, of the onset consonant, the least salient aspect of these words if matching to an internal

6. The data are at ⟨http://childes.psy.cmu.edu/data/Other/Estonian/vija⟩.

palatal-nucleus template was operative from early on.[7] As was the case in earlier studies such as Waterson (1971), we take these forms to be whole-word-based because no segment-by-segment alignment with their adult models would yield an interpretable phonological analysis: see, for example, *peek-a-boo* [pʧiː], *kinni* [kʧɪ], *banana, book, bath,* all produced as [bɑɪ]. This interpretation is supported by the fact that some of these words were first produced more accurately and only later replaced by a palatal pattern. For example, *kinni* 'closed' first appears at 1;2.15 as [inːi] and [ʧnːi], and only almost a month later, at 1;3.9, as [kʧɪ]. The last such example in this data set is *pasta,* first produced in a nearly accurate form at 1;5.17 as [patə], but recorded a month later, at 1;6.9, as [pɑjə]. We return to the question of the role of articulation, planning and memory as sources of templatic representations in the Discussion.

We take such late-appearing expressions of the template to be based not so much on incomplete *perception* of the adult form (or a 'vague representation': Swingley 2005) as on a mnemonic 'short-cut' or on-the-fly phonological categorization of a heard word form as an exponent of the by now well-established templatic pattern (cf. the imitation of *bib* as [biːˑ], [bɪ], [bei]). The phenomenon of misremembering (a kind of miscategorization, not misperception) based on more familiar names or words can also be seen in adult errors: cf. *Chase* for *Chafe* or *spasmodic* for *sporadic* (the latter noted several times on BBC radio 4 in the 1990s, suggesting a meaning shift in progress, supported by phonological similarity as well as misremembering); the literature on malapropisms (e.g. Fay & Cutler 1977) provides many more instances.

3.2 Consonant harmony

Consonant harmony is the most widely occurring 'whole-word' phonological pattern in development – but (*contra* Smith 1973) it is not a 'universal' but varies widely from one child to the next (see Vihman 1978, where the three English children included in the study ranged in harmony use – counting 'adapted' forms only – from 5 to 32%, the two Estonian children from 9 to 25%). In Maarja's case it accounts for a third of all forms produced at its highest period of use (16 months:

7. Note that although omission of the onset consonant is unusual in English, in languages with medial geminates (including Estonian) or phrase-final lengthening (like French) it is far more common (Vihman & Croft 2007). The focus on nuclear palatal patterns provides yet another basis for demoting the importance of the onset in a child's early word form representations.

see Figure 1) but only 18%, on average, over the entire time of the study (as compared with 52% in the case of the palatal template), and with only 6% of all the word forms produced being adapted to arrive at a harmony form.

The use of harmony is seen as a dynamic force for the first time at 1;3.16, when *cup* is produced as [pʌpːi] (note the addition of the diminutive *-ie/y,* not used with this lexical item in the input speech, which creates a form that fits the palatal template as well as showing consonant harmony); the few previous forms counted as showing harmony had a single consonant across syllables or word positions in the target as well as in the child form (i.e. they were selected for harmony, not adapted to it). Note that although in Table 1 eight target words show harmony in their adult form (as well as most of them having a palatal form, as we define it) – *mõmmi* 'teddy'*, daddy, mommy, baby* (twice)*, bib, peepee* and *tita* 'baby' – only four are actually produced as harmony forms by the child ([mɤ̃mːi], [mʌmːiː], [bɛˈbeɪ], [tita]). It is only the latter that we count as harmony use by the child (whether selected or adapted). Even the period of highest use of harmony includes only a few adapted forms (Sample II: see Table 3).

Table 3. Harmony word patterns in child forms: 51–100 words (Sample II). English word targets are in *italics*, harmony tokens in bold face. Only adapted forms are included here.

New words	Child age	Child form	Target	Target phonetic form	Gloss
	1;4.17	**[gʊk]**	*book*	[bʊk]	
1	1;4.17	**[nunu];** 1;4.19 **[nononos]**	notsu	[ˈnotsu]	piggie
2	1;4.19	**[saʊs]**	*house*	[haʊs]	
3	1;4.25	**[nɪn], [nʌnd], [nʌnt],** **[ˈninə]**	lind	[lind]	bird
4	1;4.26	**[wɑwɑ],** [wɑ]	*water*	[ˈwɑɾə]	
5	1;4.30	[puː], **[puːm], [muːn]**	*spoon*	[spuːn]	

In the following months long words have a particular tendency to show 'active harmony' in this sense (10 of the 24 forms, or 42%, target words of more than two syllables [Table 4] – whereas the overall incidence of long words, even in this period of higher use, reaches only 11%). It is notable, as well, that harmony tends to affect the unstressed portions of words in both languages, especially in child word forms of more than two syllables (cf. *Helena, mängida, muusikat, väike seen, vanaema, otsivad, põrandale* – all stressed on the initial syllable).

Table 4. Adapted harmony word patterns in child forms in Samples III–X: 101–500 words. English word targets are in *italics*, harmony tokens in bold face. Only adapted forms are listed here.

New words	Child age	Child form	Target	Target phonetic form	Gloss
1	1;5.23	[dɑg], **[dɑdi]**, [dɑgi]	*dog(gie)*	['dɑgi]	
2	1;6.15	**[ænənə]**	Helena	['hɛlɛnɑ]	
3	1;6.19	[sɑpɑt], **[pɑpɑt]**, **[pɑput]**	saapad (papud?)	['sa:pad] (['papud])	boots (slippers/ booties)
4	1;6.30, 1;8.23	**[nɑn:ut]**; **[mɑn:ut]**	raamat	['rɑ:mɑt]	book
5	1;7.0	**[nin:ut]**, **[nind]**	lennuk	['len:uk]	airplane
6	1;7.1	**[miʔdidɑ]**, **[mædidɑ]**	mängida	['mæŋgidɑ]	play
7	1;7.5	**[musitat]**	muusikat	['mu:zikat]	music, sP (object case)
8	1;7.5	**[bibɑts]**	liblikas	['liblikɑs]	butterfly
9	1;7.17	**[tidu]**	tigu	['tigu]	snail
10	1;7.23	**[nɑm:ɑs]**, rarely **[mɑn:ɑs]**	lammas	['lɑm:ɑs]	lamb
11	1;8.5	[mu: bæk], [mu: ɑ bæk], **[bu: bæk]**	*move on back*	['mu:vɑn'bæk]	(< song)
12	1;8.6	**[bɛsɛsɛd]**	väike seen	['væike'se:n]	little mushroom (< song)
13	1;8.6	**[bibibæk]**	*sleeping bag*	['sli:pɪŋ'bæg]	
14	1;8.11	**[ɑnɑnɑ]**	vanaema	['vɑnɑɛmɑ]	grand-mother
15	1;8.26	[pɑlun], **[pɑnun]**	palun	['pɑlun]	please
16	1;9.3	**[dʏn:ib]**	kõnnib	['kʏn:ib]	walks
17	1;9.4	**[tɪkuk]**, **[tykuk]**, **[tukuk]**	tüdruk	['tydruk]	girl

(Continued)

Table 4. (Continued)

New words	Child age	Child form	Target	Target phonetic form	Gloss
18	1;9;8	**[bɪpsi ˈɪtsi]**	*itsy bitsy*	[ˈɪtsiˈbɪtsi]	
19	1;9;15	**[tɛdɛ],** [tɛː], [tɛlɛ], [tɛðɛ], [tɛrɛ]	tere	[ˈtɛrɛ]	hello
20	1;9;16	**[nɑɪnɛ]**	laine	[ˈlɑɪnɛ]	wave (N)
21	1;9;18	**[dæʔdɛ], [dædɛ]**	*blanket*	[ˈblænŋkɛt]	
22	1;9;23	**[bɑbaʊn],** [ɛbaʊn]	*fell-down*	[fɛlˈdaʊn]	
23	1;9;23	**[otsibɑp]**	otsivad	[ˈotsivɑd]	they are looking for
24	1;9;26	[pˌvlɛ], **[pvlale]**	põrandale	[ˈpʏrandale]	onto floor

The use of consonant harmony to support the long-word production required by Estonian semi-agglutinative morphology is illustrated in the month following the 500-word point by two forms that extend the Estonian verb form *otsivad* seen at 1;9: *keerutab* 's/he is twirling' [kɛːdɑbɑb], *joonistavad* 'they are drawing' [jonsibɑb]. These forms give the impression of a filler syllable, [-bap/b], being used to complete verb forms without the child having any clear understanding of the meaning or function of the morphemes it replaces (compare the use of a final sibilant in English before the functions of plural/possessive/3sg present tense have been understood: Peters & Menn 1993).

3.3 The move to segmental representation

1. *'Accurate' word form production.* Figure 1 shows the overall increase in new word forms produced, month by month, over the period of the first 500 words, culminating in a dramatic rise in the last two months, at the time when the harmony template again declines in use. In addition, Figure 1 also shows the fluctuations in the proportion of 'accurate' word forms produced over the 10-month period. The term 'accurate', applied consistently over the entire period, needs some qualification. Since the child's forms were recorded in a diary format, on-line rather than with repeated listening and/or acoustic analysis to support transcription, the reliability

of errors affecting voicing and either vowel or consonant length could not be independently established (although, impressionistically, relatively few errors in length were noted); we disregarded those errors as well as some minor vowel errors, such as production of [ʌ] for [ɑ], for the same reason. (To illustrate our use of the term, we consider only seven of the child forms given in Table 1 to count as fully 'accurate': *aitäh* [ɑɪˈtæh], *mõmmi* [mɤmːi], *mommy* [mʌmːiː], *whee* [wiː], *bye* [baɪ], *bee* [biː] and *tita* [tita].)

Here we see that the child's forms were at their most accurate in the first period of word production (50% of the 22 words produced at 12–14 months). Thereafter, accuracy falls to half that level and then rises again, to close to the overall mean of 33%, where it remains for most of the period studied, with the exception of a sharp dip, to 11%, at 19 months. Recall that at 15 months the palatal template had its strongest influence (67%, against the overall average of 52%), which could help to account for the initial dip in accuracy, while the continued relatively low level of accuracy throughout most of this period could reflect the use of whole-word patterning more generally. However, there is no increase in template use that might explain the second, more dramatic dip at 19 months. What other factors could be responsible? To understand the child's advances beyond the early period of template use we will consider two additional measures: word length in syllables (in both targets and child word forms) and the child's consonant inventory.

2. *Word length in syllables*. Might a shift in the kinds of words attempted be responsible for the 19-month dip in accuracy that we see in Figure 1? To evaluate this hypothesis, we chart in Figure 2 changes in word length in syllables for both target and child forms (including more than one variant only where length in syllables differs), across the period of the first 500 words (based on percentage occurrence).

It is immediately clear that one- and two-syllable forms dominate the entire period. Longer words are first attempted in Samples III and IV (17–18 months) but reach over 20% of word forms produced only in the last sample (21.5–22 months). For the first four 50-word samples, monosyllables dominate the child's production while target words are fairly equally divided between the two types; from Sample V (19 months) on, however, disyllables come to dominate both words attempted and words produced while monosyllables fall below 30%. At about the same time, at Sample IV and then consistently from Sample VI on, longer words make up about 15% or more of words attempted while they are *produced* at that level only from Sample VI on. This shift to disyllable dominance along with emergent long-word use corresponds to the second dip in accuracy noted on Figure 1.

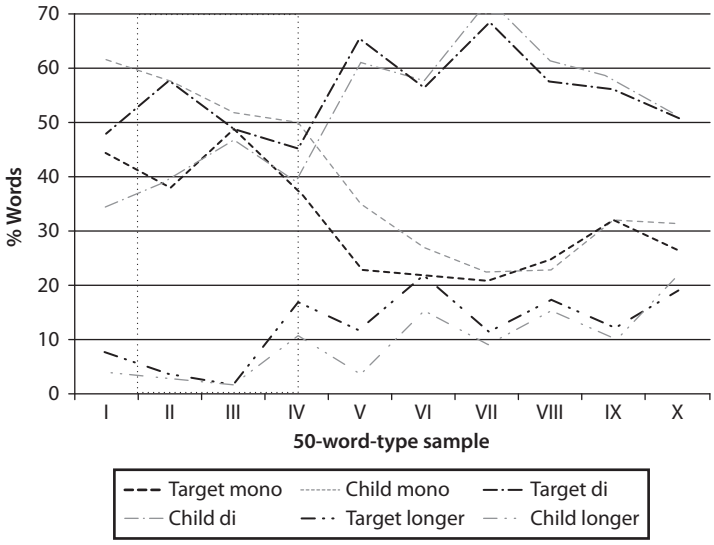

Figure 2. Percent word length in syllables, plotted by 50-word-type samples. The vertical dotted lines correspond to the lines in Figure 1, indicating dips in accuracy

3. *Consonant inventory changes over time*. We consider changes in the inventory of consonants only here, rather than in all segments, as this has proved the best predictor of later phonological advance in earlier studies of typically developing children acquiring English (Vihman & Greenlee 1987; Stoel-Gammon 1992) as well as in a large study of both typically developing children and late talkers (Vihman et al. in revision). Criteria for inclusion in the inventory – namely, occurrence in at least two child forms, for distinct word targets – have to be met independently in each sample (i.e., no credit is given for use in earlier samples). Match to target form is not a consideration; that is, consonant substitutions are given full credit, in order to obtain as full a picture as possible of the vocal resources the child is able to draw on for production (although uses as substitutes for the target consonant are so marked). Onsets and codas are considered separately, based on position in the syllable, not the word (although most codas, especially in the early samples, are word-final, not internal). Single uses of consonants are also noted but are not included in the total inventory counts. The total inventory for each sample is shown in Table 5 and in Figure 3; totals are based on uses in two different word types in a sample, regardless of syllable position.

Table 5. Consonant use by 50-word-type samples. Segments occurring in only one word type in a given sample are in parentheses; segments occurring only incorrectly, in substitution for the correct target sound, are in square brackets. After Sample I, consonants are indicated in bold face when they first appear in two word types in a single sample, taking onsets and codas separately and disregarding target language.

Sample (N wds)	Onset C	Coda C	Total
I (0–50)	p t ([ts]) k b d ([g]) s ʃ m n w j	p (k) s m n	11
II (51–100)	p t k b d [g] s [ʃ] (h) m n (w) **l** [j]	p **t** [**ts**] (k) (d) s (v) **z** m n (ŋ)	14
III (101–150)	p t ([ts]) k b d **g** s **ʃ** m n l (j)	p t k (g) s ([v]) m n ŋ	12
IV (151–200)	p t k b d (g) s ([v])([z]) m n (w) j	(ps) t **ts** k (d) (dz) (f) s n (l)	10
V (201–250)	p t (ts) k b d s (h) **v** m n	p t ts (tʃ) (d) (g) s n (l)	10

(Continued)

Table 5. (Continued)

Sample (N wds)	Onset C	Coda C	Total
VI (251–300)	p t k b d g s **h** v (z) m n (w) (l) (j)	p (ts) k (dʒ) (f) s ([h]) (z) (m) n (ŋ)	12
VII (301–350)	p t k b d (f) s (ʃ) h (v) **z** m n (l) j	(p) t k d (g) s (m) (ŋ)	11
VIII (351–400)	p t (ts) k b d ([g]) (f)(θ) s h (z) m n l j	(p) t k **b** d z (m) n ŋ	13
IX (401–450)	p t k b d (g) (f) s h v m n **w** l j	p t (k) (b) (d) s (h) z n (ŋ) **l**	14
X (451–500)	p t k b d g (f) s h v m n (w) l (j)	[p] t k b d (f) s (h) z (m) n ŋ l ɹ	16

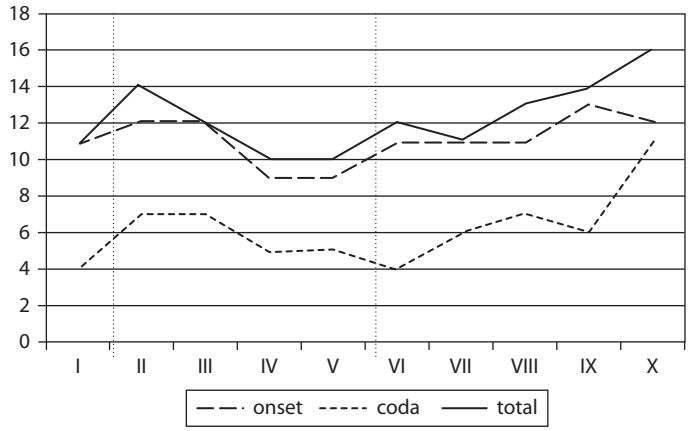

Figure 3. Size of consonant inventory, plotted by 50-word-type samples

Maarja shows substantial diversity of consonant types already by the end of Sample I: 11 consonants altogether, all of them occurring at word onset but only [p], [s] and the nasals [m] and [n] also in coda position. The inventory of onsets includes five stops, both voiced and voiceless, but with [g] occurring only once (for target /k/: *sock* [gɑ]). Both [s] and [ʃ] occur twice, although one use of the palatal [ʃ] occurs in lieu of the affricate onset to *cheese.* The two anterior nasals and the glides [w] and [j] complete this extensive core inventory.

In Sample II we see a rise in both onset and coda use. This is the most diverse inventory expressed in a single sample until the penultimate sample, when Maarja has begun to produce inflectional endings in both her languages; these morphological markers include the voiced (or, more precisely, lenis voiceless) stops /-b/ and /-d/ (3rd and 2nd person markers on verbs, resp., and noun plural) in Estonian and /-z/ (noun plural) in English. Frequency in one or the other of Maarja's two languages affects her usage: The palatal sibilant [ʃ], which occurs only in loan words in Estonian, is used twice per sample only in the first three (up to 18 mos.), before she begins full-time attendance at Estonian daycare. Onset [v], far more frequent in Estonian than in English adult speech, and coda [z] occur in words from both languages. Estonian [h], first fully included in the inventory only in Sample VI (20 mos.), is established at onset and is also used appropriately in coda position in Samples VIII–X, both word-internally and finally: *kahvel* 'fork', *päh* 'yuck'. The only addition to the inventory in the final sample is the English approximant /ɹ/, used in coda position (*tractor, hair).*

Neither Estonian tap /r/ nor trilled /r:/ had yet been produced by the end of the study. In Figure 3, the overall pattern is one of rapid increase in inventory in the second sample followed by a decline in consonant use in new forms in both

onsets and codas until Sample VI, when onsets begin to increase, followed by an increase in coda use at Sample VII. We note that the low point in coda use corresponds to the onset of longer word production. Thus the dip in accuracy seen at 19 months is best accounted for by the change in the length of words targeted (in Sample V) and then produced (in Sample VI); the changes in consonant use simply reflect that development.

4. Discussion and conclusion

The data presented here support the idea that the early word forms are based on a mix of perception (of ambient language input, the child's own output, and matches between the two) and, after the earliest period of production, phonological (template-based) categorization of whole-word patterns in the input, resulting in what we hypothesize to be whole-word representations. We cannot identify the specific origin of Maarja's favored palatal template with any confidence, although (like Priestly 1977) we note that some target words produced relatively accurately by the child early on could have been an important source or prototype for the template (cf. *aitäh, pai, pall* and *kõll*: Table 1). A still earlier possible influence is the child's own real name: It has a medial /l/, which the child produced as [j] in her early words (for experimental evidence that the child's name may be the first word to be recognized without specific training, see Mandel, Juszcyk, & Pisoni 1995; Bortfeld et al. 2005).

What we have documented is the child's remarkable perseverance in her use of the palatal template throughout the period of the study. In the early months of word production we see her apparent reliance on the front-rising diphthong, in particular, as a kind of 'bootstrap' into word use: This provided the child with the possibility of repeatedly using minor variants on the highly familiar motor routine [VI] as a basis for first remembering and then planning and articulating an increasing number of new words. The support offered by words including palatal vowels, diphthongs or glides declines somewhat in importance only in the final month of the study (samples VII–X). In that same month, when the child was producing many combinations as well as a more substantial number of words of more than two syllables, harmony came to be used to support long word production in particular, although this did not affect a major proportion of the child's words at that point.[8]

8. The combinations, based on daily notes rather than transcribed recordings, indicate a dominance of two-word combinations in this month, with some three-word combinations and only very rarely longer utterances.

To address the broader question of units of representation, can we say that at some particular point Maarja shifted from 'whole-word' to 'segmental' phonology? It is unclear just what evidence would be sufficient to make the claim – nor is it beyond dispute that even adults are entirely 'segment oriented' in their phonology (Ferguson & Farwell 1975; Beckman & Edwards 2000). However, by tracing the growth in word length in syllables we have been able to make some guesses at the likely constraints, both articulatory and mnemonic, that underlay (i) the child's narrow focus on palatal patterns in the second month of the study and (ii) her renewed departure from accurate production as late as 19 months, when her 'ambition' to produce longer words (notably, her new sensitivity to morphological marking) apparently exceeded either her planning or her representational capacities, or both.

Alongside the nonlinearity apparent in the profile traced here for Maarja's accuracy in reproducing adult models we also find nonlinearity in the diversity of consonants she produces in a given sample. Recall that accuracy is actually *highest* in the first month of regular word use (14 mos.: 9/18, or 50%), with a return to as much as 40% accuracy only in the last month covered here (19 mos.: 65/163). Yet in Sample II (15–16 mos.) Maarja produced 14 different consonants to criterion and succeeded in producing in close to their adult form even such challenging words as English *clap* [kɑp], *slipper* [sipɑ] and *toes* [toːz], Estonian *ampsti* 'a bite' [ɑmpti], *kala* 'fish' [kalə], *konn* 'frog' [konː], [kunː], *kott* 'bag' [kot], [kət] and *tantsi* 'dance' [tatsi]. (Each of these includes consonants that differ in place or manner, or both, yet only the clusters fail to be accurately matched.) This makes it unlikely that articulatory ability *per se* was a major factor in Maarja's failure to match target words in that and subsequent samples.

Instead, we take template use to serve as unconscious support for word learning as regards both the long-term representation and the planning needed for production; accordingly, we assume that as word knowledge grows, the need to rely on such support will decline. Experimental work is required to test the role of templates in word learning. (Such a study is underway with two-year-olds, most of whom show some trace of template use: Bidgood et al. 2010.) It is unlikely to be possible, especially in a diary study, to pinpoint a specific moment at which a shift to segmental representation is completed; however, the decline in use of the two templates identified here over the course of learning the first 500 words strongly suggests at least the beginning of such a shift.

Does word production, supported by template formation, help the child to learn segments? The answer, again, is not altogether straightforward. Based on consonant use alone, in samples equated for numbers of new words attempted, the child makes little progress over the course of the 10 months covered here: She quickly moves from an inventory of 11 consonants in Sample I to 14 in

Sample II, but then regresses to lower levels of use (at least in new word forms) right up until the penultimate sample, when she resumes use of (not quite the same) 14 consonants. At the same time, however, she has moved from predominantly monosyllabic production to a dominant use of disyllables alongside nearly equal use of monosyllables and words of 3–5 syllables. And her overall level of accuracy, after an initial decline over the first few months of word use, has returned to something closer to the initial level – despite the far more difficult words now being attempted, the added complexity of emergent morphological marking in both languages and the planning needed to produce word forms in combination. Finally, we find, in the last samples, very few instances of child forms adapted to a whole-word template; that is, at this point the child forms can generally be aligned with the target forms, leaving specific segmental substitutions as the only errors. Thus phonological knowledge must necessarily have increased over the period of the study and, more specifically, there is evidence of emergent segmental knowledge. Just how best to characterize the child's phonological knowledge will differ according to one's understanding of adult phonology (for whole-word and usage-based approaches, see Ferguson & Farwell 1975; Beckman & Edwards 2000; Bybee 2001; Pierrehumbert 2003). It seems clear, however, that the emergence and decline in template use that we have traced here provide an insight into phonological advance that could not be obtained from direct measures of consonant inventory or overall phonological process use alone.

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