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Alignment, Stress, and Parsing in Early Phonological Words*

Katherine Demuth
Brown University

1. Introduction

Researchers have long noted that children omit syllables from early words. Echols & Newport (1993) and Echols (1993) report that children tend to retain both stressed and final syllables in their output forms. Yet stressed and final syllables do not, in and of themselves, constitute a 'phonological unit.' In fact, Echols & Newport (1993) and Echols (1993) provide not a phonological, but a 'perceptual' explanation for the fact that stressed and final syllables tend to be those that surface in children's early words. The purpose of this paper is to demonstrate how these facts can also be accounted for from a phonological perspective, where children's early word shapes are the result of competing phonological constraints.

Previous 'phonologically' based accounts of early word structure have proposed that English-speaking children's early words are trochaic feet, and that this might be universal (Allen & Hawkins 1978, 1980). In a longitudinal study of the acquisition of stress in early Dutch, Fikkert (1994) shows that trochaic feet play an important role in determining the shape of children's early multisyllabic words. In particular, she shows that early feet in Dutch are quantity insensitive trochaic feet. That is, before Dutch-speaking children begin to acquire the distinction between heavy and light syllables and the role of weight in stress assignment, they appear to have quantity insensitive feet, which by their very nature are trochaic (cf. Hayes 1995). This may, in fact, be the basis for Allen & Hawkins' (1978, 1980) proposal that children's first feet are universally trochaic (though see Demuth (1996a) and below for discussion).

Given the prevalence of (trochaic) feet in children's early productions, Fikkert (1994), Gerken (1991, 1994), and others have proposed that children's early words conform to a trochaic 'template.' However, Demuth & Fee (1995) show that a trochaic 'template' approach is too rigid to account for children's earliest words, and provides no explanation for how children move beyond this point. Rather than treating children's words as 'truncated templatic forms,' they show that early words are prosodically constrained, resulting in a Minimal Word or binary foot (see also Ingram this volume). Critically, however, the construction of these feet is 'flexible.' That is, segments and syllables of a target word (or 'input form') are mapped into children's word productions (or 'output form') not on the basis of the surface string itself, as Gerken (1991, 1994) and Archibald (1995) suggest, but by treating the entire 'word' as a higher level prosodic entity, only part of which is mapped into children's actual productions. For example, the onset consonant of an unstressed

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syllable in the target word sometimes appears as the onset to a different syllable in the child's output (e.g. English /bənænə/ > [bænə] *banana* - Smith 1973, Dutch /bɑ'lòn/ > [ˈbòmə] *ballon* - Fikkert 1994). In other words, it is not *only* stressed and final syllables that appear in children's early words, especially before the age of 2 (Demuth & Fee 1995). Demuth (1995) illustrates how such early word forms can be understood from an optimality theoretic perspective (Prince & Smolensky 1993), where words are initially 'phonologically constrained,' and gradually come to approximate appropriate target forms as constraints are reranked over time (i.e. the language particular phonology is learned). Paradis (1995) and Pater & Paradis (1996) extend this approach to account for the early appearance of Minimal Words including stressed and final syllables in English and German.

In this chapter I illustrate how a similar constraint-based approach can account for the appearance of stressed syllables and prosodic word shapes in early Dutch. In section 2 I review findings on the acquisition of prosodic words. In section 3 I introduce some of the basics of Optimality Theory, and demonstrate how a constraint-based approach to the acquisition of prosodic words can handle otherwise difficult phenomena. I provide a constraint-based analysis of stress and prosodic word shape in Dutch in section 4, and conclude in section 5.

2. The Acquisition of Phonological Words

Fudge (1969) and Waterson (1971) were some of the earliest researchers to note that prosodic processes play an important role in the acquisition of language. Ferguson & Farwell (1975) and others after them (e.g. Macken 1979, Menn 1983, Vihman et al. 1985) noted that the word was (apparently) the domain in which much of the acquisition of (segmental) phonology took place. New theoretical developments in Prosodic Phonology (Selkirk 1984, Nespor & Vogel 1986), the structure of the syllable (Clements & Keyser 1983), stress systems (Hayes 1995), and Prosodic Morphology (McCarthy & Prince 1986) now provide the tools needed to explore several aspects of children's phonological development in the prosodic domain.

Demuth & Fee (1995) develop a prosodic approach to early phonological word development, showing how children gradually learn to exploit units of the Prosodic Hierarchy (e.g. the mora, syllable, foot, and phonological word). They show that children's early words in English and Dutch can be characterized as Minimal Words, or binary feet, even before stress-feet (i.e. quantity sensitive feet) begin to appear. They identify 4 major stages of prosodic word development, as outlined below:

(1) Stages in the Development of Phonological Words (Demuth & Fee 1995)

Stage I	Core (CV) Syllables
Stage II	Minimal Words
Stage III	1 Stress-Foot
Stage IV	2 Stress-Feet

Whereas the focus of Demuth & Fee (1995) is on Stage II - the Minimal Word Stage, the focus of this paper is on Stage III - where early words may be more than just a Minimal Word, but are still only a foot, or Stress-Foot, and Stage IV - where phonological words finally begin to contain two feet. At these later stages of development there are still constraints on the shape of phonological words, but stress begins to play an increasingly important role in the shape that these words take.

One of the best recent sources of data for addressing the acquisition of stress and interactions with prosodic word structures comes from Fikkert's (1994) longitudinal, cross-sectional study of the acquisition of the Dutch stress system in eight children between the ages of 1;0 and 2;9. Fikkert (1994) identifies four major stages of development in the acquisition of the Dutch stress system. These correspond roughly to Demuth & Fee's (1995) stages in the development of phonological words as follows:

(2)

Phonological Words Demuth & Fee (1995)	Development of Stress Fikkert (1994)
Stage III 1 Stress Foot	Stage 1 Final stressed syllable, optional epenthetic vowel: S (<w>) Stage 2 Sw output - stress shift if necessary
Stage IV 2 Stress Feet	Stage 3 2 stress feet per word optional epenthetic vowel: S(<w>)Sw Stage 4 1 main stress per word (on branching foot) 1 main stress per word (on first heavy syllable from right)

The term 'stages' of acquisition is used loosely here: As Fikkert (1994), Demuth & Fee (1995) and many others have noted, the transition between stages is a gradual one with a certain amount of overlap from one stage to the next (cf. Brown 1973). Importantly, however, the sequence of development seems to be the same. For example, Fikkert (1994) finds that all the Dutch children in her study pass through each of the four stages outlined above, though the process of reaching each stage is a

gradual one. Demuth & Fee (1995) find the same, though they also allow for certain steps to be skipped along the way, especially when not relevant to the language being learned. It is precisely this type of 'gradual' and 'flexible' acquisition process that has been difficult to capture from a theoretical perspective. Fikkert (1994) proposes a parameter-setting analysis of these forms, where children must learn about the language particular instantiations of foot construction, quantity sensitivity, and extrametricality - or defooting. In particular she shows that issues of quantity sensitivity are not learned until stages 3 and 4 when children's words begin to contain more than one foot. However, certain problems for prosodic word development, such as when and why certain syllables are added or deleted, remain unresolved. After a brief introduction to Optimality Theory in the following section, I show how a constraint-based account of Dutch-speaking children's prosodic words can account for the prevalence of stressed syllables in children's early speech.

3. A Constraint-based Account of Phonological Words

Optimality Theory (Prince & Smolensky 1993) is a theoretical framework based on the notion that grammars are composed not of ordered rules, but of a set of universally available grammatical 'constraints.' These constraints are hierarchically ranked with respect to each other, with the highest ranked constraints having the greatest effect on output form. Highly ranked constraints are generally not violated, but more lowly ranked constraints may be violated. The most 'optimal' output form violates the fewest highly ranked constraints. Grammars (or languages) then differ from each other in the ranking of constraints: In the hypothetical Grammar #1 below, with grammatical constraints A, B, and C, candidate 'y' is 'optimal' because it does not violate the highest ranked constraint A. However, if constraint B is ranked more highly than constraint A, as in Grammar #2, candidate 'x' will be the 'optimal' candidate, even though it also violates constraint C.

(3) *Grammar #1*

Candidates	Constraints				
	A	>>	B	>>	C
x	*				*
☞ y			*		

(4) *Grammar #2*

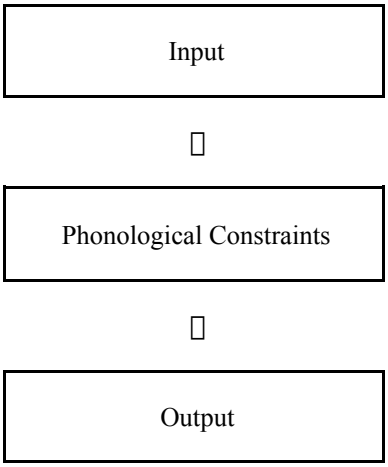
Candidates	Constraints				
	B	>>	A	>>	C

☞ x		*	*
y	*		

Demuth (1995) demonstrates how an optimality-theoretic analysis of prosodic words, specifically Minimal Words, can handle problems of speaker variation as well as development over time. Paradis (1995) extends this analysis to account for early German and English Minimal Word structures produced by bilingual Hildegard (Leopold 1939-49). In particular, she shows that the prevalence of both stressed and final syllables in children's early words can be handled through constraint ranking (see also Pater & Paradis 1996).

Critical to this enterprise is the assumption that children's early lexical representations, or underlying representations of words, are well-formed entities. That is, even though a child may say [nænə] for *banana*, I assume that, in the majority of cases, the child 'knows' that /bənænə/ is the underlying lexical form.[1] I call this underlying lexical representation the 'input' form - that is, it is the input to the child's productive phonology. The form that the child produces I call the 'output' form. I assume that the child's grammar (in this case 'phonological constraints') mediate between the input and output forms as shown below:

(5)



Viewed in this way, one of the problems for the child is to learn how to map underlying lexical 'input' onto surface 'output' forms.

What do the constraints on early grammars look like? Given issues of learnability and continuity, children's grammars must contain the same types of constraints that occur in adult grammars. Prince & Smolensky (1993) show that constraints are of two types: *Structural Constraints* are wellformedness constraints on output form. For example, if a given underlying lexical item - say a loan word

from another language - contains consonant clusters which are not possible sequences of English, such a word would have to be modified by various Structural Constraints so that the output form is a 'possible word' of English. On the other hand, *Faithfulness Constraints* ensure that elements of the input form (e.g. segments, features) are all mapped into the output form. Demuth (1995) and Gnanadesikan (1995) show that Structural Constraints play an important role in children's early grammars, where constraints that permit 'unmarked' structures to emerge first are initially ranked highest, and Faithfulness Constraints are often violated. Faithfulness Constraints and more marked Structural Constraints then becoming more highly ranked over time.

The following Structural Constraints (all attested in adult language) are needed to account for the shape of early prosodic words and the early presence of stressed and final syllables (cf. McCarthy & Prince 1993, 1994).

(6) *Structural Constraints - Wellformedness of Output form*

ALIGNFT-LEFT	Align (Foot, L, PrWd, L) - The left edge of every foot coincides with the left edge of the head of a prosodic word
ALIGNSTEM-RT	Align (Stem, R, PrWd, R) - The right edge of the stem coincides with the right edge of the prosodic word
ALIGNSTRESS-FT	Align (Stress, head, Ft, head) Stress coincides with the head of a foot
ALIGNSTRESS-PW	Align (Stress, R, Ft, R) - Main stress coincides with the first heavy foot from the right edge of the prosodic word
FTBIN	Feet are binary on some level of analysis (,)
NO-CODA	No coda consonants permitted
FTQS	Feet are Quantity Sensitive

ALIGNFT-LEFT says that feet will be trochaic, and ALIGNSTRESS-FT insures that the head of a foot receives stress. ALIGNSTEM-RIGHT means that the final syllable of the target word coincides with the right edge of the output form. ALIGNSTRESS-PW entails that stress is assigned to the first heavy syllable from the right edge of the prosodic word. This means that only one primary stress is permitted per word, but

that secondary stress will still appear on the heads of other feet within a prosodic word. FTBIN means that feet are binary at the level of the syllable (disyllabic feet) or the mora (bimoraic feet). NO-CODA is a phonotactic constraint against coda consonants: In languages that permit codas this constraint must be ranked very low. However, Demuth (1995) and Gnanadesikan's (1995) show that for children learning languages like English and Dutch, this constraint is initially ranked very high. FTQS means that feet are quantity sensitive: In languages with quantity insensitive feet this constraint would be ranked extremely low, and would have no effect in the language, i.e. quantity sensitivity is a marked phenomena. If, as Fikkert (1994) suggests, children learn to set the quantity sensitivity (QS) parameter at a later stage of development, then the early 'optimal' foot will be a branching, bisyllabic foot - i.e. a quantity insensitive trochaic foot - the 'unmarked' case. This would be in keeping with Demuth's (1995) and Gnanadesikan's (1995) previous proposals for the emergence of unmarked structures in early acquisition (cf. Jakobson 1941).

The other constraints needed are the following Faithfulness Constraints:

(7) *Faithfulness Constraints - Mapping between Input and Output*

MAX-IO	Every element in the Input has a Correspondent in the Output (No Deletion)
FAITHSYL	Every syllable in the Input must Correspond to a syllable in the Output
FAITHSTRESS	A stress-bearing element in the Input has a Correspondent in the Output
IDENT[F]	Every feature in the Input has a Correspondent in the Output

FAITHSYL ensures that all syllabic material in the input will be mapped into the output, and FAITHSTRESS ensures that the same will be true of an element (nucleus, rhyme, syllable) bearing stress - even if stress does not appear on this element in the actual output. Note that this last constraint is not needed for adult grammars. Rather, adult lexical representations can probably be stored independent of stress marking per se, and possibly independently of syllable structure (cf. Levelt 1989). I suggest, however, that such a constraint is part of adult grammars, but that it is very lowly ranked, having an effect in cases of speech errors and foreign language learning. IDENT[F] means that every segment in the output will be faithfully represented with its appropriate features, such as voicing, place of articulation, etc.

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Many of the traditional 'parameters' needed for describing stress systems - e.g. quantity sensitivity, head direction for feet, and direction of stress assignment (e.g. Dresher & Kaye 1990, are all captured here by alignment and faithfulness constraints. It might therefore appear that a constraint-based approach to early phonological systems is merely a notational variant of a parameter-setting approach. However, I will show below that issues of stress interact with other segmental and phonotactic constraints which cannot normally be included in a theory of stress. In this way, a constraint-based approach to acquisition provides a comprehensive framework for examining interactions between different aspects of phonological structure (cf. Demuth 1996b).

4. Stress and the Acquisition of Dutch Phonolological Words

In her discussion of how children acquire the Dutch stress system, Fikkert (1994) examines the acquisition both disyllabic and trisyllabic words in detail, and notes that the acquisition of quadrasyllabic words follows a similar pattern. Interestingly, despite the nature of the target word (input form), children's output at each stage is prosodically constrained in similar ways. The characteristics of these forms are summarized in (8).

(8) Stages in the Development of Dutch Stress Fikkert (1994: 206-7)

Stage 1	Final stressed syllable, optional epenthetic vowel : S (<w>)
Stage 2	Sw output - stress shift if necessary
Stage 3	2 stress feet per word optional epenthetic vowels: S(<w>)S(<w>)
Stage 4	1 main stress per word (on branching foot): Sws
Stage 5	1 main stress per word (on first heavy syllable from right)

Illustrative examples of three different children's output forms from target words of three different shapes are given in (9). Note that any given target word may not occur at all stages, though Fikkert (1994) shows that other words of the same shape will take that form.

(9) Target Words: Number of Syllables and Stress Placement[2]

□ˈ□ (Noortje) □□ˈ□ (Tirza) ˈ□□□ (Tom)

/ˌkoːˈnɛin/ 'koːnijn' /ˌbuːrdəˈrɪɛɪ/'boerderij'/ˈoːliːˌfɑnt/'olifantˈ'

Stage 1	[ˈkɛi]		[hɑm]
Stage 2	[ˈpɔːtɛin]	[ˈpɔdɛɪ]	[ˈoːla]
Stage 3	[ˈtâːˈtɛinɑ]	[ˈbuːdɪˈRɛɪ]	[ˈɔfəˈsɑn]
Stage 4/5	[ˌtɔːˈtɛin]		

Due to space limitations I restrict the following discussion to disyllabic stress-final words like /bɑˈlɔn/ 'ballon' and /ʃiːˈraːf/'giraf' (see Fikkert 1994 chapter 6 for further detail). Similar constraints can handle both trisyllabic and quadrasyllabic words.

(10) Stages in Stress Placement in Stress-Final Disyllabic Words

	/bɑˈlɔn/ 'ballon' (Robin p. 202)		/ʃiːˈraːf/ 'giraf' (Tirza p 205)
Stage 1	['mɔmə]	[ˈlaːf]	
Stage 2	['buːɔn]		
Stage 3	['bɑnˈdɔn]		[ˈsiːˈaːf]
Stage 4/5	Adult-like stress	[siːˈRaːf]	

I now provide an optimality-theoretic analysis of early phonological words in Dutch, focusing specifically on issues of stress. The reader is referred to Demuth (1995) for an optimality treatment of early prosodic words in Dutch, where NO-CODA and certain IDENT[F] constraints play an active role in determining the shape of early words - especially with respect to the appearance of epenthetic vowels (though Fikkert (1994) argues differently). The challenge here is to determine which ranking of constraints can account for the placement of stress, and which syllables end up being preserved or deleted. Critically, some constraints will be hierarchically ranked with respect to one another, with the more highly ranked constraints having more of an effect on output forms.

In the following tableau constraints that are indeterminent with respect to ranking are separated by a dotted line, whereas those which are hierarchically ranked with respect to each other are separated by a solid line. These same distinctions are represented by a coma and '>>' respectively in the summary of constraint ranking above each tableau. The '*' indicates that a constraint has been violated, and an '!' indicates that this candidate is no longer a possible form. The '☞' indicates the most 'optimal' output form, given a grammar with this ranking of constraints.

In (11) I consider the constraints that would produce Stage 1' ['mɔmə] as an 'optimal' output form. The syllable that is stressed in the input (or at least the rhyme of that syllable) is mapped into the output form. Thus, FAITHSTRESS must be ranked relatively high. In the child's output form, stress is marked on the left edge of a disyllabic phonological word - i.e. the head of the word is stressed. Thus, ALIGNSTRESS-FT is also satisfied. The phonological word is only one foot, thus the foot coincides with the left edge of the prosodic word, so ALIGNFT-LEFT is satisfied. All these constraints would appear to be ranked relatively highly in the

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child's grammar at Stage 1', but are not necessarily ranked with respect to each other. In contrast, the first syllable of the word is not mapped into the output, nor is the right edge of the stem aligned with the right edge of the prosodic word. Thus, both of FAITHSYL and ALIGNSTEM-RT must be ranked lower than the other three constraints. The following partial constraint ranking can allow for the form in 1' to be 'good'; we must then see if it also rules out other possible forms to determine if it is actually 'optimal.'

(11) ALIGNFT-LEFT, ALIGNSTRESS-FT, FAITHSTRESS >>
FAITHSYL, ALIGNSTEM-RT, ALIGNSTRESS-PW

/bɑˈlɔn/	ALIGN FT-LEFT	ALIGN STRESS-FT	FAITH STRESS	FAITH SYL	ALIGN STEM-RT	ALIGN STRESS-PW
1. ☞ ['mɔmə]				*	*	
2. ['buːɔn]			*!			
3. ['bɑnˈdɔn]	*!					*
4. [bɑˈlɔn]	*!	*				

Here we see that the form in 1. is the 'optimal' form: 2. is ruled out because the stressed syllable in the input (the final syllable of the word) is not the stressed syllable in the output (where it is the initial syllable of the word). The forms in 3. and 4. both violate ALIGNFT-LEFT because they both contain two feet: By definition the second foot cannot coincide with the left edge of the prosodic word.

The form in 2. has encoded stress on the first syllable, even though this is not stressed it in the input. In contrast, the form in 1. has added an epenthetic vowel, whereas this is missing in the form in 2. The constraint-ranking for stage 2 must thus have FAITHSYL ranked higher than FAITHSTRESS. This is shown in (12).

(12) ALIGNFT-LEFT, ALIGNSTRESS-FT, FAITHSYL >>
FAITHSTRESS, ALIGNSTEM-RT, ALIGNSTRESS-PW

/bɑˈlɔn/	ALIGN FT-LEFT	ALIGN STRESS-FT	FAITH SYL	FAITH STRESS	ALIGN STEM-RT	ALIGN STRESS-PW
1. ['mɔmə]			*!		*	
2. ☞ ['buːɔn]				*!		
3. ['bɑnˈdɔn]	*!					*
4. [bɑˈlɔn]	*!	*				

Thus, it appears that FAITHSTRESS is already beginning to be demoted (take on less importance) in Dutch-speaking children's grammars at this point, whereas other Faithfulness constraints, such as parsing segments and syllables of the input form into the output form, begin to become more highly ranked. Stress shift is needed here to satisfy ALIGNSTRESS-FT.

At stage 3. ALIGNFT-LEFT has been demoted, permitting prosodic words with more than one foot. This then allows forms with two primary stresses to appear - each foot bearing stress.

(13) ALIGNSTRESS-FT, FAITHSYL >> FAITHSTRESS >>
ALIGNSTEM-RT, ALIGNSTRESS-PW, ALIGNFT-LEFT

/bɑˈlɔn/	ALIGN STRESS-FT	FAITH SYL	FAITH STRESS	ALIGN STEM-RT	ALIGN STRESS-PW	ALIGN FT-LEFT
1'. ['mɔmə]		*!		*		
2. ['bu:ɔn]			*!			
3. ☞['bɑnˈdɔn]					*	*
4. [bɑˈlɔn]	*!					*

Fikkert notes that children finally learn that feet in Dutch are quantity sensitive, and that only one primary stress is permitted per word. This falls out naturally through the demotion of ALIGNSTRESS-FT and by specifying that ALIGNSTRESS-PW is ranked more highly than the previously demoted constraints ALIGNFT-LEFT and ALIGNSTRESS-FT.

(14) FAITHSYL >> FAITHSTRESS >> ALIGNSTEM-RT, ALIGNSTRESS-PW >>
ALIGNFT-LEFT ALIGNSTRESS-FT

/bɑˈlɔn/	FAITH SYL	FAITH STRESS	ALIGN STEM-RT	ALIGN STRESS-PW	ALIGN FT-LEFT	ALIGN STRESS-FT
1'. ['mɔmə]	*!		*			
2. ['bu:ɔn]		*!				
3. ['bɑnˈdɔn]				*!	*	
4. ☞ [bɑˈlɔn]					*	*!

In sum, the shape of disyllabic stress-final prosodic words in Dutch-speaking children's early acquisition can be captured by a few phonological 'constraints.' Larger prosodic words will require a few more constraints, but these same basic constraints will be involved.

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5. Stress and Markedness in Early Words

The purpose of this paper was to demonstrate how the presence of stressed syllables in children's early output forms can be accounted for within a constraint-based approach to the acquisition of prosodic words. Other constraint-based approaches to acquisition have shown that children's early grammars contain constraints that allow for 'unmarked' structures to emerge first, and that Faithfulness constraints gradually become more highly ranked over time (Demuth 1995, Gnanadesikan 1995). The forms examined here show exactly the same phenomena: The early ranking of Alignment constraints allows for prosodic words of only one foot, and feet that are quantity insensitive are those which emerge first. Over time Faithfulness constraints such as FAITHSYL become more highly ranked as various Structural constraints are demoted.

There is, however, one exception to the early low ranking of Faithfulness constraints, and that is the early high ranking of FAITHSTRESS. Can this constraint be thought of as 'unmarked' in some sense? Presumably not: The very definition of 'markedness' presumes that unmarked structures are found in all languages, such as the presence of 'core' CV syllables, yet many languages have no lexical stress. Rather, I suggest that, for children learning languages with lexical stress, the 'unmarked case' is a lexical item with stress, and that this is learned extremely early - even prior to the onset of first words (cf. Demuth 1996a). Stress as the unmarked case may have its roots in perceptual saliency (cf. Morgan & Demuth (1996) for papers discussing infant perceptual abilities in this regard). Alternatively, given the perceptual salience of stress, and the fact that the majority of English and Dutch open class words begin with a stressed syllable (Cutler & Norris 1988), English and Dutch-speaking children may rank FAITHSTRESS extremely highly, just as we saw above in stage 1. Interestingly, this is what appears to happen in the early acquisition of lexical tone in Bantu language Sesotho, where verb roots are lexically specified for tone (realized as High tone), or are toneless (realized as Low tone): Toneless verb roots are initially assigned a lexical high tone - this appears to be the 'unmarked' case (Demuth 1993). Although it is not clear if stress is encoded in adults' lexical representations, the 'parsing' of stressed syllables into output forms certainly remains part of adults' linguistic competence, and is used as a segmentation strategy when faced with various linguistic tasks (Cutler, Mehler, Norris, & Segui 1992). Further research will be needed to determine why (at least parts of) stressed syllables appear in children's early output forms. The constraint-based analysis presented here is offered as a step in that direction.

Notes

* I thank the audience at the UBC conference, and especially Barbara Bernhardt, for comments and discussion.

[1] This is, of course, an empirical issue which needs further investigation; Fikkert (1994), Echols & Newport (1993) and others have taken different views.

2 The data cited here come from the following pages of Fikkert (1994): Noortje (p. 206), Tirza (p. 223), and Tom (p. 227).

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