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Models of Acquisition: How to Acquire Stress*

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0. Introduction

Current models of acquisition have largely focused on the *logical problem of acquisition* (cf. Dresher & Kaye 1990, Tesar & Smolensky 1993): how is a grammar acquired from the data given UG? This problem is sketched in (1):

(1) *The logical problem of language acquisition*

Learning Theory
DATA <-----> UG <----> GRAMMAR

One of the most explicit models in *phonology* is the parametric stress learning model proposed by Dresher & Kaye (1990). It shows that a machine equipped with metrical theory is able to set the parameters correctly on the basis of cues in the data, and does this in a specific order. Although this model shows that, in principle, a parametric theory of stress is learnable, it oversimplifies the real acquisition problem. To propose a more explanatory model the *developmental problem of acquisition* also has to be considered: how does the acquisition process take place in real time? However, developmental studies in the area of stress (cf. Klein 1984, Hochberg 1988a, b) have so far not provided clear patterns of development in the data. They have mainly focused on two questions: (i) whether children learn stress lexically or by rule (Klein 1984, Hochberg

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1987, 1988b), and (ii) whether or not children have a bias towards a particular foot type (Allen & Hawkins 1978, 1980, Hochberg 1987, 1988a). However, the evidence adduced in these studies is confusing and often contradictory. Moreover, they have not focused specifically on development.

In this paper I give a detailed account of how acquisition of stress proceeds and relate it to the parametric learning model proposed by Dresher & Kaye. This account demonstrates that a close study of child data not only reveals the principled and systematic nature of development, but also has consequences for learnability and phonological theory. The study is based on spontaneous longitudinal data from 12 children acquiring Dutch. The children, aged between 1;0 and 1;11 years at the start of a one-year period of data-collection, were recorded at two-week intervals. Although the main focus is on Dutch data, the account makes interesting predictions for the acquisition of prosodic structure in general.

The outline of the paper is as follows: I first briefly describe the assumptions underlying the Dresher & Kaye model and provide a metrical analysis of the Dutch stress system. The main part of the paper, however, will be devoted to the description and explanation of the acquisition data on stress.

1. Assumptions underlying Dresher & Kaye's stress learning model

Dresher & Kaye's approach follows the 'principles and parameters' model of Chomsky (1981a, b). In such a model the learning process consists of fixing the parameters that underlie stress systems on the basis of the input received. The question is how? To formalise a deterministic learning system each parameter comes with a default value and a description of a cue to detect the marked value. The default value is the value for which no positive evidence is available; the marked value that for which positive evidence is most available. The learner's task is to look for cues in the data that trigger the setting of a parameter from the default value to the marked value. If no such cue is found, the parameter is kept in the default value; i.e. nothing happens. Otherwise the parameter is set to the marked value. However, once a parameter has the marked value, it cannot be changed again, since the learner in the model is deterministic.

This means that the choice of the initial unmarked parameter values is crucial. Furthermore, it is important to ensure that parameters are fixed correctly from the start, since fixing a parameter in the wrong setting is fatal. The learner should be prevented from fixing a parameter on the basis of exceptional data. Therefore a buffer to detect exceptions (based on frequencies) is built into the model. The learner should also be prevented from fixing parameters that are dependent on other parameter values prior to the parameters on which they are dependent, because this may also lead to crucial errors from which the learner cannot retreat. One way to overcome this problem is to assume that parameters are fixed in a specific order. We will see shortly that parameters seem to be fixed in a specific order, both by the machine learner and children, although the order differs.

Dresher & Kaye adopt as a model of UG a particular parametrised version of a tree-only metrical theory. Stress patterns are expressed by metrical tree structures that are built on rhyme projections. Metrical tree structures have the form of labelled trees, where, in any group of sister nodes, one node is labelled strong (s) and the others are labelled weak (w). The various possibilities of metrical tree construction are expressed in terms of a set of (binary) parameters. The parameters assumed in Dresher & Kaye (1990) are given in (2). The numbers behind the parameters refer to the order in which the parameters are set by Dresher & Kaye's machine learner. The values in the first column

are the default values assumed by Dresher & Kaye. The second column gives the default values based on the present study. I suggest default values for some of the parameters that Dresher & Kaye did not give default values for; and in the case of the iterativity parameter I have assumed a different default value. The third column gives the values required for Dutch, largely based on analyses of Trommelen & Zonneveld (1989, 1990). This is the grammar that the children in this study eventually need to learn.

(2)	<i>Parameters of metrical theory</i>	<i>D&K</i>	<i>Fikkert</i>	<i>Dutch</i>
a.	WORD TREE DOMINANCE PARAMETERS			
	• <i>Main Stress Parameter</i> ¹ (7) The word-tree is strong on the	—	Right	Right
b.	FOOT-SHAPE PARAMETERS			
	• <i>Bound/Unbound (BU) Parameter</i> ² (6) Feet are	Binary	Binary	Binary
	• <i>Headedness Parameter</i> ³ (8-ii) Feet are strong on the	—	Left	Left
	• <i>Quantity-Sensitivity (QS) Parameter</i> ⁴ (1) Feet are	QI	QI	QS
	• <i>Weight Parameter</i> ⁵ (2) Feet are QS to the	Rhyme?	?	Rhyme?
c.	PARAMETERS OF FOOT CONSTRUCTION			
	• <i>Directionality Parameter</i> (8-i) Feet are built from the	—	Right	Right
	• <i>Extrametricity (EM) Parameter</i> ⁶ (4) There is an extrametrical syllable	No	No	Yes
	• <i>Edge of Extrametricality (EoE) Parameter</i> (5) It is extrametrical on the	—	?	Right
	• <i>Iterativity Parameter</i> ⁷ (3) Feet are iterative	Yes	No	Yes

¹ Dresher & Kaye do not assume a default value for this parameter. The learner simply has to check a foot-sized window at the edges to determine the location of main stress. This requires that the learner already knows what kind of feet the language has. Therefore, this parameter is set relatively late.

² QI languages allow only binary feet and therefore have the value [Binary] for the B/U parameter. However, for QS languages Dresher & Kaye assume the default value [Unbounded], because a positive cue exists for binary feet, but not for unbounded feet: namely, the existence of a light stressed non-peripheral syllable in a word or stress on both the rightmost and leftmost light syllable. Since the value for the B/U parameter is dependent on the value for the QS parameter, Dresher & Kaye have to assume that the B/U parameter may follow a path from [Binary] to [Unbounded] and back to [Binary]. I will show that this problem of retreating from marked values simply does not arise in Dutch child language, giving support to the claim that unbounded feet do not exist (Prince 1986, 1990, Prince & Smolensky 1993).

³ Dresher & Kaye do not assume default values for the directionality parameter and the headedness parameter. The four possible configurations that these parameters generate have to be tested simultaneously until the learner finds a consistent fit.

⁴ The existence of words with the same number of syllables but different stress patterns is a positive cue for detecting QS. Therefore, the value [QI] is assumed to be the default value.

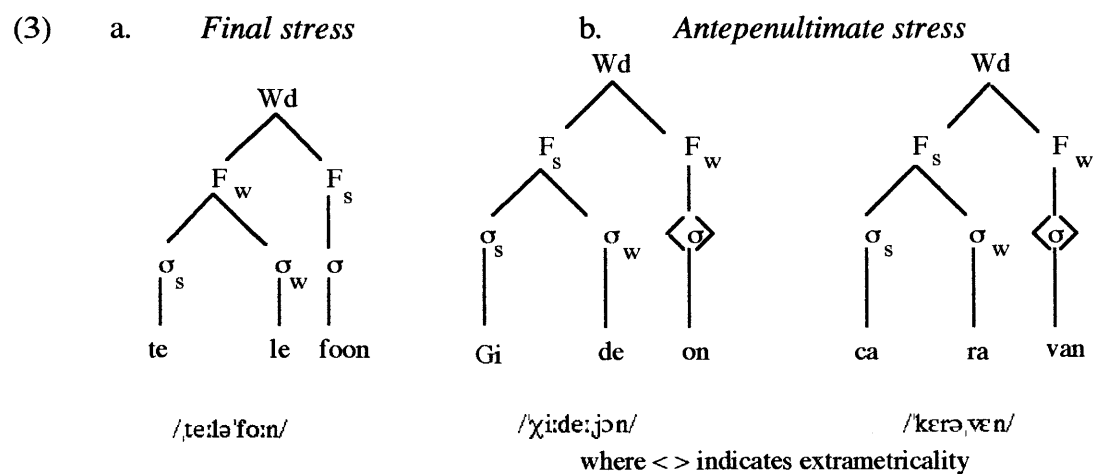
⁵ There is no positive cue for either value; the learner simply checks the possibilities in this order. However, there is no principled reason behind this ordering.

⁶ There is no positive cue to detect extrametricality; stress at both edges of the word, however, is an indication for no extrametricality. Nevertheless, Dresher & Kaye assume that no extrametricality is the default case. Dutch exhibits a special case of extrametricality, which, I will argue, is better accounted for by assuming the Obligatory Branchingness parameter: A foot receiving main stress must be branching.

⁷ The cue for the marked value [No] is the absence of secondary stress; however, one could also argue that the presence of secondary stress is a positive cue for the value [Yes], and therefore assume the default value [No]. I will provide evidence for this from child language.

2. A metrical analysis of Dutch stress

Dutch has binary left-headed feet parsed exhaustively from right to left. Then a word-tree is constructed on the feet. Main stress in a word is controlled by an unbounded word-tree in which the rightmost node is labelled 'strong'. Since feet are left-headed and main stress falls on the rightmost foot the result is penultimate stress. However, final and antepenultimate syllables are also eligible for main stress assignment. In order for stress to fall on these syllables the parameters referring to quantity-sensitivity and extrametricality become relevant. Dutch is a quantity-sensitive language. Although Dutch has a vowel length distinction long vowels do not count as heavy; -VV rhymes are light, -VC rhymes are heavy, and -VVC and -VCC rhymes are superheavy. Heavy and superheavy syllables form a foot on their own, as shown in (3). According to Trommelen & Zonneveld (1989, 1990) Dutch requires the setting [Yes] for the EM parameter. They assume that every word-final syllable is extrametrical, except the 'superheavy' ones.⁸ Furthermore, Dutch has the idiosyncratic property that final syllables are made extrametrical *after* foot formation. This is referred to as 'late extrametricality' (Lahiri & Koreman 1988, Kager 1989, Trommelen & Zonneveld 1989, 1990).⁹ It therefore only affects the location of main stress, which can be placed on the second foot from the right edge of a word, as in the examples in (3b):



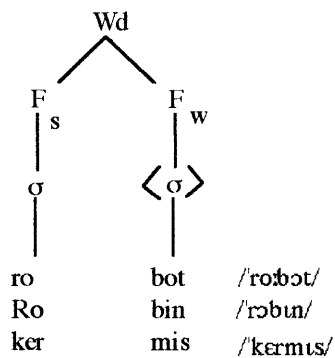
The parameters discussed so far describe the basic stress pattern of Dutch, but there are many exceptions to this pattern.

The analysis presented here has the consequence that disyllabic words with a closed final syllable are analyzed with an extrametrical final syllable, and therefore stress is on the penultimate syllable, as in (4a). Disyllabic words with a closed final syllable and final stress are exceptional in that they do not have a final extrametrical syllable (4b). Thus, the words in (4a) are considered regular, and those in (4b) exceptional. However, we will see that the child language data seem to suggest the opposite. Moreover, we will see that the extrametricality properties of Dutch pose learnability problems and can better be captured by assuming the Obligatory Branchingness Parameter, given in (5).

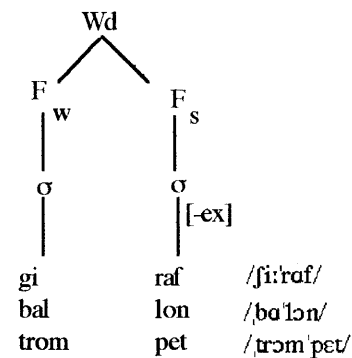
⁸ Superheavy syllables only occur at word edges. Word-internal rhymes are maximally two-positional (-VV or -VC). Therefore, superheavy syllables could be considered as disyllabic: a bipositional rhyme followed by the onset of a degenerate syllable. This would explain why they always receive main stress and are not subject to the extrametricality rule.

⁹ In earlier literature this phenomenon was not captured by (late) extrametricality, but by the Lexical Category Prominence Rule (LCPR): "Label the right/left node strong iff it branches" (Hayes 1981, van der Hulst 1984, among others).

(4) a. *Regular*



b. *Exceptional*



(5) *Obligatory Branchingness (OB) Parameter:*

The foot receiving main stress must be branching [Yes/No].

3. **Dresher & Kaye's parametric stress learning model**

Before turning to child language acquisition I first describe the machine learner in Dresher & Kaye's model. The learner is equipped with the set of parameters and their associated cues described in (2). On the basis of cues in the input data the learner determines the parameter values. These parameter values form the learner's hypothesis about the grammar of the language. To test the hypothesis the learner builds metrical trees on the plain input forms, i.e. on strings of segments without stress markings. The resulting output forms are compared with the original input forms (the forms with stress markings). If the correct parameter values have been determined by the learner, there will be a complete match between the derived output forms and the input forms. The learner has been successful. If input and output forms do not match, the learner has failed, and the forms are passed on to a non-deterministic learner, called the cranker, which simply checks all other possible combinations of parameter settings, until it finds a consistent fit. It is clear that ideally the model would not have to make use of this non-deterministic cranker.

If the model also works as a model of child language acquisition, it predicts that errors in child language are based on parameter values not yet fixed, and crucially, not *wrongly* fixed parameter values. Moreover, the model predicts that children start out assuming quantity-insensitive binary feet. Children acquiring Dutch must at some point change the default into the marked setting and arrive at quantity-sensitive feet. Let us now turn to the child language data.

4. **Child language acquisition data**

One of the most intriguing results in the study of the acquisition process is how fast and systematic it really is. Although the Dutch stress system is quite complex, children manage to acquire the most important aspects of it before age 3. Moreover, they do it in a very systematic fashion. We will first look at children's productions of disyllabic target words, and subsequently focus on the longer ones.

Most children do not produce disyllabic words from the earliest stages. Preceding the stage at which disyllabic words appear, they have a stage at which they exclusively produce monosyllabic words. However, disyllabic words enter their active vocabularies

relatively early. Disyllabic targets with initial stress are produced correctly insofar as stress and the number of syllables are concerned from a very early stage (6a), whereas disyllabic targets with final stress show a clear pattern of development, as shown in (6b):

(6)	<i>Adult target</i>	<i>Stage 1</i>	<i>Stage 2</i>	<i>Stage 3</i>	<i>Stage 4</i>
a.	baby 'baby' /'be:bi:/	['be:bi:]	['be:bi:]	['be:bi:]	['be:bi:]
	auto 'car' /'o:to:/	['to:to:]	['o:to:]	['o:to:]	['o:to:]
b.	gitaar 'guitar' /χi:'ta:r/	['ta:]	['si:ta:]	['hi:'ta:ɹ]	['hi:'ta:ɹ]
	giraf 'giraffe' /ji:'raf/	['haf]	['fi:af]	['si:'a:f]	['si:'ra:f]

The generalisation with regard to the final stressed target words, which form more than one foot in the adult grammar, is that only the final foot is produced at the first stage. At the second stage the other syllable of the target word is also produced. However, the child's production form has a trochaic stress pattern. At stage 1 and 2 the child's forms seem to consist of exactly one foot. At the third stage each syllable forms a foot on its own, resulting in two feet, which are produced with an equal amount of stress. Finally, at the fourth stage, the target forms are produced correctly, as far as the number of syllables and stress is concerned.

One important observation is that the stressed syllable in the target word is always produced; however, it need not be produced as stressed by the child, which is particularly clear in the data from stage 2. This shows that the adult foot structure is not copied along with the segmental material, and that stress and segmental structure are largely independent.

If we look at the child's production of trisyllabic adult words, the patterns in (7) arise. The forms in (7a), with penultimate stress, behave similar to the forms in (6a): at the first two stages one trochaic foot is produced. At the third stage a second foot is produced, where both feet receive an equal amount of stress. The words in (7b) and (7c), which differ in the location of main stress in the adult forms, show a similar developmental pattern. At the first stage, the rightmost foot is produced *independent of the stress level in the adult word*. It is not the main stressed foot, but the rightmost foot that is produced. At stage 2, the initial syllable of the target word is adjoined to the form of stage 1, and the resulting string of segments is produced as a trochee. At stage 3 two feet are produced, both with an equal amount of stress. At stage 4 main stress is assigned not to the rightmost foot, but to the rightmost *branching* foot. For the data in (7b) there is a fifth stage in which the stress pattern is as in the adult words: final main stress, and antepenultimate secondary stress.

(7)	<i>Adult target</i>	<i>Stage 1</i>	<i>Stage 2</i>	<i>Stage 3</i>	<i>Stage 4</i>
a.	pantoffel 'slipper' /pan'tɔfəl/	['tɔfhi:]	['tɔfɔ]	['pan'tɔfɔ]	[.pan'tɔfɔ]
	spaghetti 'spaghetti' /spa:'χeti:/	['heta]	['heta]	['pa:'heta]	[.pa:'heta]
b.	telefoon 'telephone' /te:lə'fo:n/	['fɔm]	['tɪfo:m]	['te:nə'fɔn]	['te:lə'fo:m]
	krokodil 'crocodile' /kro:ko:'dɪl/	['di:rw]	['ko:rwɪ]	['keke'kɪw]	['ko:kə'dɪw]
c.	olifant 'elephant' /'ɔli:fant/	['fan]	['ɔfan]	['ɔfi:'fan]	['ɔfi:'fant]
	kangoeroe 'kangaroo' /'kæŋgəru:/	['kau]	['ka:ku:]	['ka:kə'ru:ŋ]	['kaku:ju:ŋ]

How can we explain the developmental patterns? What triggers the transition from one stage to the next? I claim that the transitions from one stage to the next can be understood as (i) the setting of one or more parameters from the default (unmarked) value to the marked; and/or (ii) the extension of the child's template.

4.1. The transition from stage 0 to stage 1

Prior to stage 1 the child only produces monosyllabic forms. At that stage none of the stress parameters needs to be set, since they are simply irrelevant. Only when disyllabic words enter the child's system do stress parameters become relevant (stage 1). Not all disyllabic target words are produced as disyllabic by the child, as we saw in (6b), but if the child produces disyllabic words, stress is invariably initial. We further saw that all forms of stage 1 are maximally disyllabic and consist maximally of one foot. That is, the data argue for a bounded, rather than an unbounded foot. The data in (8) confirm this claim:

(8)	<i>Trisyllabic target words with initial stress only</i>		
	tekenen 'to draw' /te:kənə(n)/	→	['ka:kə] Elke (1;8.13)
		→	['kɛki:], ['kɑkɑ:] Elke (1;8.31)
		→	['kɛikɛi] Elke (1;9.24)
	andere 'other' /'andərə/	→	['a:nə] Elke (2;0.25)

The fact that all output forms are at most one foot, although the input forms can contain more than one foot, is taken to be evidence for the default value [No] for the iterativity parameter. Thus, at stage 1 the child's template is extended from a monosyllabic to a disyllabic template, however, it consists of exactly one foot. Since the input contains both trochaic ($\sigma_s \sigma_w$)_{Wd} words (*baby*) and iambic ($\sigma_w \sigma_s$)_{Wd} words (*giraf*), the child has to make a decision about the headedness of feet and the direction of parsing, since not both types of disyllabic target words can be one foot: one has to be more than one foot. The different settings for the directionality and headedness parameters predict different results, as is illustrated in (9):

(9)	<i>Target words:</i>	$(\sigma_s \sigma_w)$ _{Wd}	['be:bi:]	$(\sigma_w \sigma_s)$ _{Wd}	[ʃi:'raf]
a.	D:LR, H:L	$(\sigma_s \sigma_w)$	['be:bi:]	(σ_w)	[ʃi:]
b.	D:RL, H:L	$(\sigma_s \sigma_w)$	['be:bi:]	(σ_s)	[raf]
c.	D:RL, H:R	(σ_w)	['bi:]	$(\sigma_w \sigma_s)$	[ʃi:'raf]
d.	D:LR, H:R	(σ_s)	['be:]	$(\sigma_w \sigma_s)$	[ʃi:'raf]

Where D = Directionality, and H = Headedness, L = Left, R = Right

Only the settings of (9b) explain the observed pattern characterising stage 1 in child language. The child seems to have left-headed feet parsed from the right, or from the word *ending*. Biases towards word endings are commonly found in the literature on child language (cf. Slobin 1973, Echols 1987). They are often viewed as performance properties, but I hypothesise that they reflect a universal default value, [Right-to-left], for the directionality parameter. The child language literature also often refers to biases to attend to stressed syllables (cf. Echols 1987, 1988, among others). These two biases together seem to guide the child in discovering the basic foot type of the language, as can be seen in (10). (10a) shows the results on the assumption that the first stressed syllable from a word edge and the word edge itself form the properties on the basis of which the cue for the directionality parameter has to be defined. Not only does it make the right predictions, this analysis does not need to make reference to 'skipping', as in (10b), or

It is important to note that, although the cue for QS is available at stage 1, quantity does not seem to play a role yet. This illustrates that the child is an incremental mode learner: although the relevant cues are available quite early, the cues are only used to determine parameter values when the child is 'ready' to use the cues. This becomes particularly clear, if we compare the child learner with the machine learner. Suppose that the child builds metrical trees on the segmental strings of the input forms to test the current settings of the parameters. If the child acts like the machine learner we expect that disyllabic target words with final stress will be realised as disyllabic words with initial stress, given the default values of the parameters. Although there is a stage at which this prediction is borne out, this is not the first stage in the development. Rather, the first stage is the stage at which these words are typically reduced to the stressed (monosyllabic) foot of the adult target. Only when metrical trees are not built on the whole string of segments of the adult target with final stress, but on the segments in the final foot of the adult word, do we expect the forms typical of stage 1. In other words, not the whole adult input form is considered, but only part of it, a crucial difference with the machine learner. If only the final foot is considered as input to the learning system, then the output forms created on the basis of the parameter settings match the input forms, and thus, the child will not change any parameters, since there is no evidence for the marked settings. The relevant parameters (all still in the default value) are given in (11):

(11) **Relevant parameters still in the default value at stage 1**

<i>Directionality parameter</i>	Feet are built from the	[Right]
<i>Headedness parameter</i>	Feet are strong on the	[Left]
<i>QS parameter</i>	Feet are QS	[No]
<i>EM parameter</i>	There is an extrametrical syllable	[No]
<i>B/U parameter</i>	Feet are	[Binary]
<i>Iterativity parameter</i>	Feet are built iteratively	[No]

I have not included all parameters, since not all of them are relevant at this stage. As long as the input forms to the learner consist of maximally one foot, the main stress parameter is simply not relevant. Since the default value for the QS parameter is [QI], the Weight parameter is irrelevant; and since the default value for the EM parameter is that there is no extrametrical syllable, the EoE parameter is not relevant either.

4.2. The transition from stage 1 to stage 2

Although no stress errors are detected at stage 1, the child may, however, discover, by comparing the target forms with the output forms, that the output forms and the target forms do not match in the number of syllables. To solve this mismatch between input and output, the next step in the development is to produce an extra syllable in words that have one syllable in the output form, and two (or more) in the adult target form (stage 2). When metrical structures are built on the resulting disyllabic forms the output forms will have QI left-headed binary feet, because, so far, there has been no evidence that any of the stress parameters are inappropriately set. Therefore, the parameter values at stage 2 are the same as at stage 1, i.e. those given in (11).

4.3. The transition from stage 2 to stage 3

When the output forms of stage 2 are compared with the target forms, the child may detect two things: (i) disyllabic and trisyllabic targets with final (main or secondary) stress are produced with the wrong stress pattern at stage 2; and/or (ii) the number of syllables in the output forms is not identical to number of syllables in the trisyllabic target forms. If the child focuses on the number of syllables first, the prediction is that all trisyllabic forms are produced as trisyllabic forms with stress on the penultimate and

antepenultimate syllables, i.e. $(\sigma_s)_F(\sigma_s \sigma_w)_F$, at stage 3. However, this is not the case. Children first focus on stress, and only later on the number of syllables. Additional evidence comes from trisyllabic target words that are produced by the child as disyllabic words, consisting of two feet, which receive equal stress, as in (12):

(12) *Stage 3*a. *Trisyllabic targets with initial main stress*

caravan 'caravan' /'kɛrə,vɛn/	→	['kɛ:vʌn]	Robin (2;2.27)
kangoeroe 'kangaroo' /'kɔngəru:/	→	['kɑ:kʊ:ŋ]	Tom (1;6.11)
olifant 'elephant' /'ɔ:li:fɔnt/	→	['ɔ:fɔn]	Tom (1;7.23)
olifant 'elephant' /'ɔ:li:fɔnt/	→	['ɔ:fɔnt]	Eva (1;9.8)

b. *Trisyllabic targets with final main stress*

pelikaan 'pelican' / pe:li:'kɑ:n/	→	['ke:'kɑ:m]	Tom (1;7.9)
parachute 'parachute' / pɑ:rɑ:'fyt/	→	['pɑ:plʌt]	Tom (1;7.9)
muzikant 'musician' /,my:zi:'kɔnt/	→	['ti:k'tʌnt]	Tirza (1;11.19)
boerderij 'farm' /'bʊrdə'rei/	→	['py:'hɑ:j]	Tirza (2;0.18)

In the forms in (12) the segmental material of the child's form is the same as at stage 2; however, at stage 3 the prosodic structure has changed: from one left-headed QI foot to two QS feet.

At stage 3 the child makes use of the cue associated with the quantity-sensitivity parameter: the existence of words with an equal number of syllables but a different stress pattern. The child has detected disyllabic words with initial *and* final stress. Therefore, the child now is able to set the QS parameter to the marked setting [QS]. However, the child also has to determine what counts as a heavy syllable. Is the language QS on rhymes or on nuclei? Children seem to regard any closed syllable as heavy, independently of the length of the vowel and independently of the nature of the final consonant(s),¹² since all closed syllables, whether heavy or superheavy, are now stressed in the child's output forms.

This has interesting consequences for the production of disyllabic words with initial stress which have a final closed syllable: they are now produced with the wrong stress pattern. Robin's data show this nicely. (13a) illustrates that these target words were produced correctly by the child during the previous stages. However, at stage 3, when the QS parameter is set to [QS], these words are produced with level stress, as shown in (13b). The data in (13c) show that the child eventually learns to produce them correctly. On the assumption that learning is deterministic, the child cannot retreat from the value QS, once it is set. Therefore, the target words in (13) have to be marked as exceptions contrary to the standard analysis of Dutch stress, which argues that final-stressed disyllables are the exception, as we saw in (4), because they do not have extrametricality, whereas in the unmarked case final syllables are extrametrical in Dutch. However, so far there has been no evidence for the learner to assume extrametricality: final syllables do not systematically lack stress. I will come back to this point when I discuss the setting of the main stress parameter(s).

¹² Fikkert (1994a, b) deals in detail with the acquisition of syllable structure. It is shown that vowel length distinctions are acquired very late. Also the difference between heavy (closed) syllables and superheavy syllables is acquired very late. The latter property was generally not acquired at the end of the period of data-collection. This means that certain aspects of both syllable structure and stress are acquired after age 3.

(13)a. STAGES 1/2

Robin *name* /'rɒbɪn/ → [ɔ̃pɪn], [nɔ̃mɪ] Robin (1;10.7)

b. STAGE 3

Robin *name* /'rɒbɪn/ → [hɔ̃'pɪn] Robin (2;1.26)

David *name* /'dɑ:vɪt/ → [tɑ'fʊ:n] Robin (2;1.26)

tractor 'tractor' /'trɛktɔ̃r/ → [tɑk'tɔ̃] Robin (2;2.27)

penguin 'penguin' /'pɪŋɡʊ:n/ → [pɪ'wɪŋ] Robin (2;3.10)

c. *Robin*: STAGE 4

botsing 'collision' /'bɔ̃tsɪŋ/ → [bɔ̃χɪɪŋ] Robin (2;4.29)

circus 'circus' /'sɪrkʊ:s/ → [sɪkʊ:s] Robin (2;4.29)

robot 'robot' /'rɔ:bɔt/ → [hɔ:pɔs] Robin (2;4.29)

Besides setting the QS parameter to the marked value the child also has to make a decision about the value of the iterativity parameter at this stage, since s/he now knows that some target words consist of more than one foot. Moreover, the produced forms at stage 3 can contain two feet, whereas previously the child's production forms all consisted of exactly one foot. It seems that the iterativity parameter is set to its marked value [Iterative] at stage 3. Although now the main stress parameter could be relevant, it is still not set. The fact that the child produces forms with two feet where both feet receive an equal amount of stress indicates that the parameter is simply not considered yet.

Dresher & Kaye predict that, once children have decided that the language they are learning is QS, the unmarked value for the B/U parameter, 'feet are [Binary/Unbounded]', is set to the default value [Unbounded]. However, the data do not give evidence for a stage at which the child assumes that the language has unbounded feet. Rather, it seems that children still only allow maximally binary feet, parsed exhaustively from right to left.¹³

To summarise, at stage 3 the child has set the parameters in (14a) from the default to the marked values. The B/U parameter, however, remains in the default value [Binary]. I hypothesise that the parameters in (14b), which had the default value at stages 1 and 2, now become fixed in the default value. They are no longer subject to change.

(14)a. **Parameters set at stage 3**

<i>QS parameter:</i>	Feet are QS	[Yes]
<i>Weight parameter:</i>	Closed syllables are heavy	[Yes]
<i>Iterativity parameter:</i>	Feet are iterative	[Yes]
<i>B/U parameter:</i>	Feet are	[Binary]

b. **Parameters that now have the default value fixed**

<i>Directionality parameter:</i>	Feet are built from the	[Right]
<i>Headedness parameter:</i>	Feet are strong on the	[Left]
<i>EM parameter:</i>	There is an extrametrical syllable	[No]

Thus, all foot-shape parameters and all parameters of foot construction have now been set. Only the word-tree dominance parameter(s) still have to be fixed. The assumption that the EM parameter is now fixed in the default value [No] has

¹³ Since Dutch has binary, rather than unbounded feet, it might, however, be the case that children have already received evidence for binary feet.

consequences for the standard analysis of Dutch stress. However, since extrametricality in Dutch plays a role *after* foot formation ('late extrametricality') it is not surprising that it is set at the same stage as the main stress parameter. This will be the focus of the next section.

4.4. The transition from stage 3 to stage 4

When the level stress forms of stage 3 are compared with the target forms, the child may discover that there is a difference between main stress and secondary stress in the adult forms; therefore s/he may focus on the location of main stress. Since the disyllabic target words with final stress are now produced correctly, we could conclude that children have learned that main stress is assigned to the rightmost foot. However, we would expect to find main stress on the rightmost foot in longer words too. This prediction is not borne out by the data, as shown in (7). Rather, it looks as if the children have discovered that the first *branching* foot from the right receives main stress. That is, main stress is assigned to the right. However, in addition to the main stress parameter there seem to be an Obligatory Branchingness (OB) parameter: 'A foot receiving main stress must be branching'.

In principle, children could have assigned main stress to the leftmost foot. However, in that case we would have expected that the disyllabic target words with final main stress would be produced with main stress on their leftmost foot, which is never the case. One could argue that in most cases this leftmost foot consists of a light syllable only, and is therefore not eligible to receive main stress. Crucial evidence against the hypothesis that main stress is assigned to the leftmost foot comes from longer words whose leftmost foot is a complete foot. Some data are given in (15):

- (15) Target words with two complete feet
- | | | | |
|---|---|-----------------|-----------------|
| macaroni 'macaroni' / ,ma:ka:'ro:ni:/ | → | [,ma:ki:'o:ni:] | Robin (2;3.22) |
| limonade 'lemonade' / ,li:mə:'na:də/ | → | [,mi:mə:'mɑ:tə] | Noortje (2;8.1) |
| televisie 'television' / ,te:lə'vi:si:/ | → | [,te:lə'fi:zi:] | Leon (2;1.7) |

These data point out that main stress is assigned to the first branching foot from the right. I therefore assume the OB parameter. This parameter makes the late extrametricality parameter no longer necessary: a final monosyllabic foot will not receive main stress, unless there is no branching foot in the word.¹⁴ The questions that remain to be answered are: 'Are there default values for these parameters, and, if so, what are they?' and 'What triggers the setting of the OB parameter and the main stress parameter?'

I hypothesize that the default value for the main stress parameter is that main stress is assigned at the same edge as where the foot-building procedure starts. Since the default value for the directionality parameter is [Right-to-left], the default value for the main stress parameter is that main stress is assigned to the rightmost foot.

¹⁴ It should be noted that descriptively the late extrametricality parameter and the obligatory branchingness parameter are equivalent. I prefer to use the latter, though, since it directly expresses the relation with main stress location. The late extrametricality parameter which marks a syllable extrametrical after foot formation does not seem to be appropriate, since it does not directly express the relationship between late extrametricality and the location of main stress. It would be better to mark a monosyllabic foot as extrametrical (see Lahiri & Koreman 1988). However, the obligatory branchingness parameter is more general. Furthermore, the location of main stress on the final syllable of disyllabic words consisting of two feet follows without further stipulations. Moreover, the EoE parameter is no longer necessary.

It is unclear, however, what the default value for the OB parameter is. The child language data in (7) seem to suggest that by default main stress feet have to be branching, i.e. disyllabic. The cue for the marked value [No] would then be the existence of final stress on a monosyllabic foot in the presence of a disyllabic foot, i.e. words as in (7b). However, the data from Leon, given in (16) seem to suggest the opposite.

(16) *Leon's data arguing for the default value [No] for the OB parameter*

a.	ooievaar 'stork' / 'o:jəvɑ:r/	→	[o:fa:'fa:ɹ]	Leon (1;10.1)
	krokodil 'crocodile' / ,kro:ko:'dɪl/	→	[ti:ty:'ty:ɪ]	Leon (1;10.15)
	pelikaan 'pelican' / ,pe:li:'ka:n/	→	[,me:ka:'ka:n]	Leon (1;10.15)
b.	olifant 'elephant' / 'o:li:fɑnt/	→	['o:nəfɑnt]	Leon (1;11.12)
	ooievaar 'stork' / 'o:jəvɑ:r/	→	['o:fi:'fa:ɹ]	Leon (1;11.12)
c.	krokodil 'crocodile' / ,kro:ko:'dɪl/	→	['kro:ku:dɪ]	Leon (2;2.4)
		→	['ko:kɔ:dɪ]	Leon (2;2.4)
	Amsterdam <i>idem</i> / ,ɑmstə'r'dɑm/	→	['ɑmstə'dɑm]	Leon (2;3.18)
d.	krokodil 'crocodile' / ,kro:ko:'dɪl/	→	[,kro:ro:'dɪw]	Leon (2;4.15)
	papegaai 'parrot' / ,pɑ:pə'χɑ:j/	→	[,pɑpə'χɛij]	Leon (2;4.15)
	apparaat 'machine' / ,ɑ:pɑ:'rɑ:t/	→	[ɑpɑ'rɑ:t]	Leon (2;8.5)

Leon's data in (16a) seem to indicate that the default value for the OB parameter is [No], and main stress is therefore assigned to the final foot of the word. When he discovers the cue for the marked value of this parameter, the existence of main stress on the antepenultimate syllable, all forms are subject to change. However, the words in (16c) are now incorrectly produced with antepenultimate stress. When these forms are checked against the input data, a mismatch is discovered. However, since the parameter is already set to the marked value, there is no way to resolve this mismatch. Therefore, the forms in (16c) are marked as exceptions. Since most trisyllabic forms with final main stress end in a superheavy syllable, this may lead to the discovery of the difference between heavy and superheavy syllables. Words like *krokodil*, however, have to be marked as exceptions to the OB parameter. This issue needs further investigation, especially with older children, since the concept of superheavy syllables was still not acquired by most children in this study at the end of the recording period.

To conclude, at stage 4 the remaining parameters are set. In other words, the child has more or less mastered the stress pattern of the language, since all parameters now have the value as indicated in (2). They are set in the following order:

(16) **Parameters set at stage 4**

• <i>Directionality Parameter:</i>	Feet are built from the	[Right]
• <i>Headedness Parameter:</i>	Feet are strong on the	[Left]
• <i>EM Parameter:</i>	There is an extrametrical syllable	[No]
• <i>QS Parameter:</i>	Feet are QS	[Yes]
• <i>Weight Parameter:</i>	Closed syllables are heavy	[Yes]
• <i>Iterativity Parameter:</i>	Feet are iterative	[Yes]
• <i>B/U Parameter:</i>	Feet are	[Binary]
• <i>Main stress Parameter:</i>	The word-tree is strong on the	[Right]
• <i>Obligatory branchingness Parameter (OB parameter)</i>	A foot receiving main stress must be branching	[Yes]

5. Summary and conclusions

To summarise, I have shown that the stress system children arrive at differs in some crucial ways from the standard analysis of Dutch stress. First, I argued that the *late* extrametricality parameter is best replaced by assuming that the set of word-tree dominance parameters contains an Obligatory Branchingness (OB) parameter, whose default value is [No]. This has several advantages. First, the close relationship between late extrametricality and the location of main stress is expressed more directly. Moreover, if superheavy syllables are reanalysed as underlyingly disyllabic (i.e. as a syllable with a regular bipositional rhyme followed by an degenerate syllable, consisting of an onset only), it follows that they receive main stress. Second, disyllabic words ending in a final closed (-VC) syllable with final stress (*giráf*) are treated as regular by the children, rather than irregular, as assumed in the standard analysis of Dutch, whereas those with initial stress (i.e. words like *Róbin*) are considered exceptional and not regular as in an analysis assuming late extrametricality. Since these words do not have a disyllabic foot, main stress is on the rightmost syllable in these words in the unmarked case. The initial stressed words have to be marked as exceptional. Third, 'late extrametricality' seems to be an idiosyncratic property of Dutch.

Furthermore, I have argued on the basis of the developmental patterns in child language for default values for parameters for Dresher & Kaye could not define defaults. Moreover, a different default value was suggested for the iterativity parameter.

Finally, it has been shown that the model proposed by Dresher & Kaye is not only successful as a model for machine learning; it also sheds more light on child language acquisition. On the assumption that learning is deterministic, and that UG contains, beside a set of principles and parameters, a set of cues associated with the parameters, the child is able to set the parameters to the values required by the language s/he is learning on the basis of simple data.

However, also important differences between the machine learner and children came to light. (i) Children are incremental learners contrary to the machine learner which is a batch-mode learner; the incremental learning property can be implemented in the model by making the learning module recursive. (ii) There was no need for the non-deterministic 'cranker' in the Dresher & Kaye model. This is a desirable result, since the cranker is an unintelligent brute force learner which simply checks all possible combinations of parameter values. Such a learner is computationally costly. (iii) There are important differences between the *input* to the machine learning system and that to the child's learning system. Children may use only part of the adult input forms. The machine lacks this kind of creativity. Furthermore, the input to the machine learner is fully segmented, syllabified and coded for stress levels. This is not necessarily the case for the input to the child's learning system: it may not be fully segmentalised and syllabified; rather stress and syllable structure are acquired simultaneously. Moreover, there is no evidence that children at the initial stages make a distinction between main and secondary stress, or between heavy and superheavy syllables. Finally, another important difference between the input to the child's learning system and that to the machine learner is that children, unlike the machine learner, are able to fix the parameters on the basis of fairly short words. Like the machine, children are able to fix all the stress parameters correctly, and they do so before the age of 3.

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