Ternary rhythm in alignment theory

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1 Introduction

This paper addresses ternary rhythm from the constraint-based viewpoint of Optimality Theory (OT, Prince & Smolensky 1993). Ternary stress systems differ from binary stress systems by stressing every third syllable in a word, instead of every second. I will extend the constraint-based analysis of binary rhythm (McCarthy & Prince 1993a, b) to ternary rhythm, focussing on the complex stress pattern of Estonian. Estonian rhythm is optionally binary or ternary, rhythmic variability being restricted by factors such as word length, and a three-way distinction of syllable weight. I will show that constraint-based theory solves problems inherent to earlier rule-based analyses (Prince 1980, Hayes forthcoming), in particular that of restructuring rules whose only function is to avoid look-ahead power in foot parsing. The analysis of ternary rhythm has consequences for the form and functioning of parsing and alignment constraints which will be evaluated for ternarity in Cayuvava.

A constraint-based analysis of ternarity bears on representational issues which have been much debated in recent literature. On the one hand, it has been argued that the universal foot inventory should incorporate ternary feet (Halle & Vergnaud 1987, Dresher & Lahiri 1991, Rice 1992). On the other hand it has been argued that binary feet suffice to account for ternary rhythm (Hayes forthcoming, Hammond 1990, Kager 1993a). This issue of foot size is placed in a new perspective by constraint-based theory. We will see that arguments pro and contra either both analyses counter-balance one another fairly well. Therefore this paper will not reach a uniform conclusion with respect to foot representation, but it intends to presents the arguments itself.

1.1 Binary rhythm in rule-based theory

Many stress languages display a perfect rhythmic alternation of stressed and unstressed syllables. Rhythmic stress is always oriented with respect to a word edge, initial or final. Pintupi, for example, has initial main stress and secondary stresses on following syllables (Hansen & Hansen 1969), cf (1a). The reverse is found in Warao (1b), where the penult has main stress, and rhythm alternates on preceding syllables (Osborn 1966). Rule-based metrical theory (Hayes 1980, forthcoming, Halle & Vergnaud 1987) models rhythm as the iterative construction of metrical feet. Feet are minimal rhythm units organising pairs of syllables into strong-weak or weak-strong relationships. Both Pintupi and Warao have strong-weak feet (σ_s σ_w), henceforth *trochees*. Rhythmic orientation towards word edges is modeled as *directionality*. Foot construction starts at a designated edge of the word (lefthand in Pintupi, righthand in Warao) and proceeds towards the opposite edge:

(1) a. [(yú.ma).(ɻìŋ.ka).(mà.ra).(tʲà.ɻa).ka] 'because of mother-in-law'
b. [e.(nà.ho).(rò.a).(hà.ku).(tá.i)] 'the one who caused him to eat'

Iterative foot construction is subject to operational conditions that guarantee maximal rhythmic organisation. First, it is *exhaustive* in the sense that all syllables must be organised into feet. Second, wherever possible it must form feet of *maximal* size (disyllabic in Pintupi and Warao). In versions of theory which completely disallow degenerate feet by *Foot Binarity* (Prince 1980, Kager 1993a, Hayes forthcoming), exhaustivity cannot be met in words with an odd number of syllables. These have an unparsed syllable at the edge where iteration stops (the final syllable in Pintupi, initial in Warao).

1.2 Binary rhythm in constraint-based theory

Rule-based phonology has recently been challenged by *Optimality Theory* (OT, Prince & Smolensky 1993, McCarthy & Prince 1993a, b), a constraint-based theory which abandons all serial derivations and rewrite rules. Instead, it defines phonological patterns in terms of relative well-formedness of the output, evaluated by constraints. Grammars are language-particular rankings of universal constraints. Violation of higher-ranked constraints is avoided at the expense of violations of lower-ranked constraints. Out of a potentially infinite numbers of output candidates, ranked constraints select the optimal candidate, which is the one which has the fewest violations of the high-ranked constraints of the language.

In the domain of rhythmic stress patterns, Optimality Theory faces the challenge of capturing *output* foot parsings. This requires a representational counterpart of the derivational notion of *directionality*. McCarthy & Prince (1993b) present such an account elaborating an idea which they attribute to Robert Kirchner. It is based on a constraint requiring that 'any foot stands as near to the designated edge of the Prosodic Word as possible'. For example, the foot parsing of Pintupi tilts towards the *lefthand* edge of the PrWd, as can be inferred from the odd-syllabled forms in (2a, c):

(2) a. [$_{Wd}$ (ŋu.nʲi).tʲu] 'mother'
b. [$_{Wd}$ (má.la).(wà.na)] 'through (from) behind'
c. [$_{Wd}$ (pú.liŋ).(kà.la).tʲu] 'we (sat) on the hill'
d. [$_{Wd}$ (tʲá.mu).(lìm.pa).(tʲùŋ.ku)] 'our relation'

Orientation towards the lefthand PrWd edge is implemented by ALL-FT-L, a constraint stating the (surprisingly strong) requirement that every foot stands in initial position of the PrWd[1]:

(3) ALL-FT-L: Align (Foot, Left, PrWd, Left)
'The left edge of every foot coincides with the left edge of some PrWd'

Deriving the distribution of feet in (2) from ALL-FT-L involves two notions typical of Optimality Theory: *constraint interaction* and *minimal violation*. If ALL-FT-L were undominated by other constraints (i.e., if it were surface-true), then no output with multiple feet would ever be selected. This is because for every output with multiple feet, a more optimal output can be imagined which has a single initial foot. Clearly ALL-FT-L cannot have this high-ranked position in Pintupi since all feet except the initial one in every word violate it. Rather ALL-FT-L exerts its influence in a more subtle way by interaction with the two higher-ranked constraints in (4), FT-BIN and PARSE-SYLL (Prince & Smolensky 1993)[2]:

(4) a. FT-BIN: Feet must be binary under syllabic or moraic analysis.
b. PARSE-SYLL: All syllables must be parsed by feet.

The *tableau* in (5) displays this interaction. The two relevant constraints, FT-BIN and PARSE-SYLL, select (5a) as the optimal output candidate as it has the smallest number of unparsed syllables, without having non-binary feet. This candidate defeats (5c), which has no unparsed syllables but fatally violates undominated FT-BIN, as well as (5b), which has a larger number of unparsed syllables. Violations of constraints are indicated by asterisks (for FT-BIN) or by syllables (for PARSE-SYLL), with fatal violations being indicated with '!'.

(5) /pu.liŋ.ka.la.tʲu/	FT-BIN	PARSE-SYLL
a. ☞ [$_{Wd}$ (pú.liŋ).(kà.la).tʲu]		tʲu
b. [$_{Wd}$ (pú.liŋ).ka.la.tʲu]		ka.la!tʲu
c. [$_{Wd}$ (pú.liŋ).(kà.la).(tʲù)]	* !	

PARSE-SYLL thus enforces a maximal parse of PrWd in binary feet - an alternating pattern. Having established the mechanism for enforcing multiple feet per word, we now return to the directionality problem. Kirchner's insight is that under domination by PARSE-SYLL, the rôle of ALL-FT-L is restricted to selecting the output which *minimally violates* it. This is the output in which all feet are *as close as possible* to the designated PrWd edge. We have minimal (or gradual) violation rather than absolute violation.

Now consider tableau (6). Note that none of the output candidates violate FT-BIN, while all share the same number of violations of PARSE-SYLL. Selection is passed on to the next constraint, ALL-FT-L, which selects (6a) as the optimal output. For reasons which will become clear in ù 3, I propose that ALL-FT evaluates candidates on a foot-by-foot basis. That is, ALL-FT may be considered as split up into a ranked set of sub-constraints ALL-FT_1(E)...ALL-FT_n(E), each evaluating the distance of a single foot FT_1...FT_n from the designated PrWd edge *E*:

(6) /pu.liŋ.ka.la.tʲu/	PARSE-SYLL	ALL-FT_1-L	ALL-FT_2-L
a. ☞ [$_{Wd}$ (pú.liŋ).(kà.la).tʲu]	tʲu		pu.liŋ
b. [$_{Wd}$ (pú.liŋ).ka.(là.tʲu)]	ka		pu.liŋ.ka !
c. [$_{Wd}$ pu.(líŋ.ka).(là.tʲu)]	pu	pu !	pu.liŋ.ka

This produces the directionality effect. Summarising, languages with binary rhythm share the constraint configuration of (7):

(7) PARSE-SYLL » ALL-FT

In this paper, I will test this basic configuration in ternary stress languages.

1.3 Outline

The organisation of this paper is as follows. In §2 I will outline an analysis of binary rhythm in alignment theory. §§ 2-6 are devoted to the mixed binary-ternary stress system of Estonian. § 2 contains a binary foot analysis. § 3 re-evaluates the rôle of PARSE-SYLL in this analysis, while § 4 rules out alternative analyses. § 5 provides the analysis of words with overlong syllables. § 6 introduces an alternative ternary foot analysis of Estonian, and a comparison with the binary foot analysis. § 7 is devoted to Cayuvava, another ternary languages. § 8 contains conclusions.

2 A binary foot analysis of Estonian

Estonian (Hint 1973) is perhaps the best-known of all ternary stress languages, and its mixed binary-ternary stress pattern was metrically analysed as early as Prince (1980). Main stress is initial with a small number of exceptions in loanwords. However, the pattern of secondary stress is highly complex, variably binary and ternary, and depends on factors of word length and syllable weight. Estonian has a three-way distinction of syllable weight: light, heavy, and overlong. Here I focus on the former two categories, postponing discussion of words with overlong syllables to § 5. Estonian counts open syllables with short vowels (Cv) as light, and syllables with long vowels or diphthongs (Cvv), as well as closed syllables (CvC) as heavy. Word-final consonants are extrametrical, which can be inferred from the fact that in final position Cv<C> counts as light, while CvC<C> still counts as heavy. The secondary stress pattern is optionally ternary or binary, and quantity-sensitive to some extent.

In the binary rhythmic pattern secondary stresses fall on every second syllable after the main stress regardless of syllable weight. However, final light syllables are unstressed, and stresses on adjacent syllables never occur. A binary foot parsing of this pattern, the output of the analysis of Hayes (forthcoming), is given in (8). Note that syllables are maximally parsed into feet, with feet standing as close as possible to the lefthand word edge. Consonant extrametricality is marked by angled brackets[3].

(8)	a.	(pá.lat<t>)	'piece, part. sg.'
	b.	(pí.mes).ta<v>	'blinding'
	c.	(ká.va).(làt<t>)	'cunning, part. sg.'
	d.	(ré.te).(lì.le)	'ladder, all. sg.'
	e.	(té.ra).(và.mal<t>)	'more skillful, gen. sg.'
	f.	(pá.ri).(màt.tel<t>)	'the best, abl. pl.'
	g.	(pí.mes).(tà.va).le	'blinding, ill. sg.'
	h.	(pí.mes).(tà.vas).se	'blinding, ill. sg.'
	i.	(pí.mes).(tàt.tu).te	'the dazelled, gen.pl.'
	j.	(ú.lis).(tà.va).(mài<t>)	'...'
	k.	(ə́p.pet).(tà.jat).(tèk<s>)	'...'
	l.	(ó.sa).(và.ma).(lè.ki)	'also more skillful abl.sg.'
	m.	(hí.li).(sè.mat).(tè.le)	'later, all. pl.'
	n.	(vá.ra).(sèi.mat).(tè.le)	'earliest, all. pl.'
	o.	(ə́p.pet).(tùs.te).(lè.ki)	'lessons, too, all.pl.'
	p.	(ú.sal).(tàt.ta).(và.mat).(tèk<s>)	'...'

It is immediately apparent that the constraints of (9) are undominated.

(9) a. ALIGN-L: Align (PrWd, Left, Head, Left)
'Every PrWd begins with the main stress foot.'

b. TROCH-FT: Feet are trochaic.

Observe that no foot consists of a single light syllable. Monosyllabic feet must contain a heavy syllable, and only occur in final position (cf. 8c, j, k, p). (Actually heavy monosyllabic feet in such words are obligatory.) Feet are either disyllabic $[\sigma\ \sigma]_F$ or bimoraic $[\sigma_{\mu\mu}]_F$. Both Prince (1980) and Hayes (forthcoming) express this equivalence by a generalised binarity formula: 'a foot is two stress units - syllables or moras'. This matches FT-BIN[4] in a constraint-based theory, which must be undominated in Estonian. Below I will return to the observation that heavy syllables are allowed in both strong and weak positions of disyllabic feet.

Next consider the fact that monosyllabic feet are confined to word-final position. Non-final feet are all disyllabic. For the binary rhythmic pattern of (8), Hayes (forthcoming) assigns maximal trochees from left to right. This automatically confines monosyllabic heavy feet to final position. *Maximal* foot construction cannot be directly translated into constraint-based theory by the now-familiar configuration of PARSE-SYLL » ALL-FT-L, however. If both disyllabic and monosyllabic heavy feet are legitimate, both ALL-FT-L and PARSE-SYLL favour ungrammatical (10b).

(10) a. (pí.mes).(tàt.tu).te b. *(pí.mes).(tàt).(tù.te)

Actually, the ungrammatical pattern (10b) resorts under a powerful generalisation, mentioned already by Prince (1980: 533). That is, stress clashes are not allowed:

(11) a. *(pá.ri).(**màt**).(**tèl**<**t**>) c. *(vá.ra).(**sèi**).(**màt**).(**tè**.le)
b. *(pí.mes).(**tàt**).(**tù**.te) d. *(ú.sal).(**tàt**).(**tà**.va).(**màt**).(**tèk‹s›**)

Binary syllabic rhythm in Estonian is due to strict avoidance of clash[5]. Clash avoidance is implemented as an undominated constraint *CLASH, which subsumes the effects of maximality in a rule-based analysis:

(12) *CLASH: No adjacent strong beats on the grid.

Monosyllabic heavy feet are confined to final position, since this is the only position in which no other foot immediately follows - so that clash can be avoided[6]. We arrive at a preliminary ranking of the binary rhythmic pattern:

(13) FT-BIN » *CLASH » PARSE-SYLL » ALL-FT-L

In the optional ternary pattern secondaries fall on every third syllable after the main stress. The parsings in (14) are the output parsings of the binary foot analysis of Hayes (forthcoming), which has no ternary feet but instead maintains binary feet which are separated by unparsed syllables.

(14)
a. (té.ra).va.(màl<t>)
b. (pí.mes).ta.(và.le)
c. (pí.mes).ta.(vàs.se)
d. (ú.lis).ta.(và.mai<t>)
e. (əp.pet).ta.(jàt.tek<s>)
f. (ó.sa).va.(mà.le).ki
g. (hí.li).se.(màt.te).le

Interestingly ternary rhythm is suppressed in some contexts, which allow only a binary pattern. First, no sequences of three unstressed syllables occur. Words with four light syllables must have a secondary stress on the penult, at a binary (rather than a ternary) distance from the main stress (cf. 15a). Second, in a sequence of two unstressed syllables the second (left unparsed by a foot in 8 and 14) must be light, compare the unattested forms (15b-g).

(15)
a. *(ré.te).li.le
b. *(ká.va).lat<t>
c. *(pá.ri).mat.(tèl<t>)
d. *(pí.mes).tat.(tù.te)
e. *(vá.ra).sei.(màt.te).le
f. *(əp.pet).tus.(tè.le).ki
g. *(ú.sal).tat.(tà.va).mat.(tèk<s>)

I will first consider the issue of ternary rhythm in a constraint-based analysis, and return to the ungrammaticality of the forms in (15) below.

Hayes (forthcoming) implements ternary rhythm in his rule-based theory by a foot parsing locality parameter, which has two values. Binary rhythm is due to *strong local parsing*, and ternary rhythm to *weak local parsing*[7].

(16)
a. *Strong local parsing*: Feet must be constructed adjacently.
b. *Weak local parsing*: Feet are constructed separated from each other by a single mora (in effect, a single light syllable).

Estonian has both, selecting either strong or weak local parsing in footing.

Translating weak local parsing into a constraint, we obtain *FtFt:

(17) *FtFt: Feet must not be adjacent.

The difference between binary and ternary rhythm can now be attibuted to the relative ranking of All-Ft-L and *FtFt. In the ternary pattern priority is given to avoidance of adjacent feet, while in the binary pattern priority is given to placing all feet as near as possible to the lefthand PrWd edge:

(18) a. Binary pattern: All-Ft-L » *FtFt
b. Ternary pattern: *FtFt » All-Ft-L

Variability may be formally interpreted as an *equal ranking* of constraints. Estonian variable rhythm is due to an equal ranking of *FtFt and All-Ft-L. Let us now consider the ranking of All-Ft-L and *FtFt with respect to Parse-Syll. In the binary pattern, Parse-Syll must dominate All-Ft-L (and therefore *FtFt as well). But in the ternary pattern, where *FtFt » All-Ft-L, two rankings are possible, both based on *FtFt » All-Ft-L:

(19) a. Ft-Bin » *Clash » *FtFt » Parse-Syll » All-Ft-L
b. Ft-Bin » *Clash » Parse-Syll » *FtFt » All-Ft-L

We cannot base the choice between these rankings on the words of (20), for which both rankings produce the ternary pattern:

(20)		*FtFt » Parse-Syll	Parse-Syll » *FtFt
	a.	(í.lu).sa.(và.le)	(í.lu).sa.(và.le)
	b.	(pí.mes).ta.(và.le)	(pí.mes).ta.(và.le)
	c.	(pí.mes).ta.(vàs.se)	(pí.mes).ta.(vàs.se)

For the words of (21), only ranking *FtFt » Parse-Syll (19a) produces ternary rhythm; the reverse ranking produces binary rhythm:

(21)		*FtFt » Parse-Syll	Parse-Syll » *FtFt
	a.	(té.ra).va.(màl<t>)	(té.ra).(và.mal<t>)
	b.	(ú.lis).ta.(và.mai<t>)	(ú.lis).(tà.va).(mài<t>)
	c.	(ə́p.pet).ta.(jàt.tèk<s>)	(ə́p.pet).(tà.jat).(tèk<s>)
	d.	(ó.sa).va.(mà.le).ki	(ó.sa).(và.ma).(lè.ki)
	e.	(hí.li).se.(màt.te).le	(hí.li).(sè.mat).(tè.le)
	f.	(ú.sal).(tàt.ta).va.(màt.tek<s>)	(ú.sal).(tàt.ta).(và.mat).(tèk<s>)

However, this ranking *FtFt » Parse-Syll gives incorrect results in (22):

(22)		*FtFt » Parse-Syll	Parse-Syll » *FtFt
	a.	*(ré.te).li.le	(ré.te).(lì.le)
	b.	*(ká.va).latt	(ká.va).(làtt)
	c.	*(pá.ri).mat.(tèl<t>)	(pá.ri).(màt.tel<t>)
	d.	*(pí.mes).tat.(tù.te)	(pí.mes).(tàt.tu).te
	e.	*(vá.ra).sei.(màt.te)	(vá.ra).(sèi.mat).te
	f.	*(əp.pet).tus.(tè.le).ki	(əp.pet).(tùs.te).(lè.ki)
	g.	*(ú.sal).tat.(tà.va).mat.(tèk<s>)	(ú.sal).(tàt.ta).(và.mat).(tèk<s>)

In conclusion, we face a constraint ordering paradox: the same constraint ranking *FtFt » Parse-Syll which is essential to ternary rhythm in the class of words (21), produces ill-formed outputs in another class of words (22). Let us first see how a rule-based theory kills this paradox.

In the analysis of Hayes (forthcoming) the ill-formed patterns of (22) are trimmed back by two mechanisms. The first is *persistent footing*:

(23) *Persistent footing*: If two stray syllables are left over at the end of the initial parse, they are regrouped into a syllabic trochee.

This accounts for (*ré.ti*).(*lì.le*) (22a), which receives two feet either by strong local parsing, or by weak local parsing plus persistent footing. The second is a condition on weak local parsing, to the effect that *only light syllables* may be skipped (the *minimal prosodic distance*, or MPR). This rules out the parsings (22b-f) all of which contain heavy skipped syllables. Note that persistent footing cannot be generalised to include the effects of MPR. If heavy syllables could be skipped by weak local parsing, persistent footing would produce ill-formed clashing outputs in (22b-f), such as *(*pá.ri*).(*màt*).(*tèl<t>*). We find that a rule-based analysis fails to provide a unified account of the cases of (22a) vs. (22b-f).

However a single generalisation can be stated for all cases of (22). These have either a sequence of unparsed syllables, or an unparsed heavy syllable. Stated informally 'sequences of stress units that are parsable by a foot should be parsed by a foot'. The notion stress unit (syllable or mora) is identical to that in Ft-Bin[8] . Accordingly, I propose Parse-2:

(24) Parse-2: One of two adjacent stress units must be parsed by a foot.

Note the interesting mirror-image relationship between FT-BIN and PARSE-2:

(25) a. FT-BIN: ‘Every foot parses some pair of stress units’.
b. PARSE-2: ‘Every pair of stress units is parsed by some foot’.

A similar relationship holds between PARSE-SEGMENT (‘Every segment is parsed by some syllable’) and FILL (‘Every syllable parses some segment’) (Prince & Smolensky 1993). Here the categories are segment and syllable, rather than syllable and foot. It also holds for ALIGN-FT and ALIGN-WD (McCarthy & Prince 1993a), where the categories are foot and PrWd:

(26) a. ALIGN-FT: Every L/R foot edge matches some L/R PrWd edge.
b. ALIGN-WD: Every L/R PrWd edge matches some L/R foot edge.

Apparently constraints which relate (prosodic?) units *x*, *y* come in pairs. One has the shape '$\forall x, \exists y\ p(x, y)$', and the other '$\forall y, \exists x\ p(y, x)$'.

The rôle of PARSE-SYLL in Estonian stress becomes rather marginal, since PARSE-2 does most of its work already. I will discuss the consequences of this in § 3. Summarising the remaining active constraints, we arrive at:

(27) Undominated: FT-BIN, *CLASH, PARSE-2, TROCH-FT, ALIGN-L
Dominated: ALL-FT-L, *FTFT (ranked equally)

By making *CLASH and PARSE-2 undominated, we have characterised the range of parsings within which *both binary and ternary* patterns fall. (Variation itself is due to equal ranking of *FTFT and ALL-FT-L as will be shown below.) Parsings in tableaux (28-31) are determined exclusively by undominated constraints (all are shown except TROCH-FT and ALIGN-L):

(28) /kavalatt/	FT-BIN	*CLASH	PARSE-2
a. ☞ (ká.va).(làt<t>)			
b. (ká.va).lat<t>			* !

(29) /retelile/	FT-BIN	*CLASH	PARSE-2
a. ☞ (ré.te).(lì.le)			
b. (ré.te).li.le			* !
c. (ré.te).li.(lè)	* !		

By PARSE-2, the tableaux of *kávalàtt* and *rétilìle* become nearly identical.

(30) /parimattelt/	Ft-Bin	*Clash	Parse-2
a. ☞ (pá.ri).(màt.tel<t>)			
b. (pá.ri).mat.(tèl<t>)			* !
c. (pá.ri).(màt).(tèl<t>)		* !	

(31) /pimestattute/	Ft-Bin	*Clash	Parse-2
a. ☞ (pí.mes).(tàt.tu).te			
b. (pí.mes).tat.(tù.te)			* !
c. (pí.mes).(tàt).(tù.te)		* !	
d. (pí.mes).(tàt.tu).(tè)	* !		

The set of undominated constraints suffices to rule out all ungrammatical patterns, regardless of the ranking of *FtFt and All-Ft-L. In particular they rule out: (i) ternary rhythm across a heavy syllable (30b, 31b), (ii) sequences of three unstressed syllables (29b), (iii) syllable clash (30c, 31c), and (iv) final stress on light syllables (29c, 31d). They correctly leave open variable rhythm only in the words of (15).

The binary pattern is due to the sub-ranking All-Ft-L » *FtFt. In the tableaux below I do not consider violations of undominated constraints.

(32) /pimestavasse/	All-Ft$_1$-L	All-Ft$_2$-L	*FtFt
a. ☞ (pí.mes).(tà.vas).se	pi.mes		*
b. (pí.mes).ta.(vàs.se)	pi.mes.ta !		

(33) /teravamalt/	All-Ft$_1$-L	All-Ft$_2$-L	*FtFt
a. ☞ (té.ra).(và.mal<t>)	te.ra		*
b. (té.ra).va.(màl<t>)	te.ra.va !		

(34) /usaltattavamatteks/	All-Ft$_1$-L	All-Ft$_2$-L	*FtFt
a. ☞ (ú.sal).(tàt.ta).(và.mat).(tèk<s>)	u.sal	u.sal.tat.ta	***
b. (ú.sal).(tàt.ta).va.(màt.tek<s>)	u.sal	u.sal.tat.ta.va!	**

The ternary pattern is due to *FtFt » All-Ft-L:

(35) /pimestavasse/	*FtFt	All-Ft$_1$-L	All-Ft$_2$-L
a. ☞ (pí.mes).ta.(vàs.se)		pi.mes.ta	
b. (pí.mes).(tà.vas).se	* !	pi.mes	

(36) /teravamalt/	*FtFt	All-Ft$_1$-L	All-Ft$_2$-L
a. ☞ (té.ra).va.(màl<t>)		te.ra.va	
b. (té.ra).(và.mal<t>)	* !	te.ra	

(37) /usaltattavamatteks/	*FtFt	All-Ft$_1$-L	All-Ft$_2$-L
a. ☞ (ú.sal).(tàt.ta).va.(màt.tek<s>)	**	u.sal	u.sal.tat.ta.va
b. (ú.sal).(tàt.ta).(và.mat).(tèk<s>)	*** !	u.sal	u.sal.tat.ta

This concludes the basic binary foot analysis of Estonian rhythm. § 3 will be devoted to the rôle of Parse-Syll, while § 4 will both set up and rule out two alternative analyses. § 5 will address words with overlong syllables.

3 The rôle of Parse-Syll

An interesting consequence of this analysis is that Parse-Syll becomes a rather marginal constraint in Estonian, since Parse-2 takes over its function. Parse-Syll has no independent function in the analysis, as it does not produce any patterns which are not already produced by rankings of All-Ft-L and *FtFt (discussed above). Consider the pattern *téravàmalt*, which is produced both by All-Ft-L » *FtFt (cf. 33) and Parse-Syll » *FtFt:

(38) /teravamalt/	Parse-Syll	*FtFt	All-Ft$_2$-L
a. ☞ (té.ra).(và.mal<t>)		*	te.ra
b. (té.ra).va.(màl<t>)	* !		te.ra.va

An interesting possibility emerges. What if Parse-Syll were eliminated completely, and replaced by Parse-2 in *all* rhythmic languages, binary and ternary? All rhythmic systems have Parse-2 » All-Ft, while *FtFt can be ranked in three ways, which are all attested:

(39) A typology of rhythmic stress systems (all have Parse-2 » All-Ft):

- a. Parse-2 » All-Ft » *FtFt (Pintupi, § 1; Estonian binary, § 2)
- b. Parse-2 » *FtFt » All-Ft (Estonian ternary, § 2)
- c. *FtFt » Parse-2 » All-Ft (Cayuvava, to be shown in § 7)

A major consequence of the elimination of Parse-Syll is that All-Ft-L should evaluate the distance of each foot from the lefthand word edge on a foot-by-foot basis, rather than all-feet-at-once basis. Foot-by-foot evaluation is crucial in producing the binary pattern pattern of a word such as *hílisèmattèle* under the ranking All-Ft-L » *FtFt:

(40) /hilisemattele/	PARSE-2	ALL-FT$_2$-L	ALL-FT$_2$-L	*FTFT
a. ☞ (hí.li).(sè.mat).(tè.le)		hi.li	hi.li.se.mat	**
b. (hí.li).se.(màt.te).le		hi.li.se !		

Although the total number of violations of ALL-FT-L is greater in the binary candidate (40a) than in the ternary candidate (40b), the former is selected because of a smaller violation of ALL-FT$_2$-L. Once ALL-FT$_2$-L has made its selection, any violations of ALL-FT$_3$-L become irrelevant[9]. If ALL-FT-L were evaluated simultaneously for all feet, ternary (40b) would be selected instead. Selection of binary (40a) then requires PARSE-SYLL » ALL-FT-L » *FTFT. In sum, elimination of PARSE-SYLL implies foot-by-foot evaluation.

4 Two alternatives, and their refutation

4.1 WSP instead of PARSE-2

First I will show that is not possible to account for the obligatory parsing of heavy syllables in the ternary pattern by eliminating PARSE-2, putting the *Weight-to-Stress Principle* (WSP, Prince & Smolensky 1993) to work.

(41) WSP: Heavy syllables are prominent in foot structure and on the grid

WSP should outrank *FTFT since binary rhythm prevails in, e.g. *pímestàttute* (**pímestattùte*). Still, WSP should remain dominated by *CLASH, as transpires from **pímestàttùte*. This motivates *CLASH » WSP » *FTFT » ALL-FT-L in the ternary pattern, with correct results in (42):

(42) /pimestattute/	*CLASH	WSP	*FTFT	ALL-FT-L
a. ☞ (pí.mes).(tàt.tu).te		*	*	pi.mes
b. (pí.mes).tat.(tù.te)		** !		pi.mes.tat
c. (pí.mes).(tàt).(tù.te)	* !	*	**	pi.mes, pi.mes.tat

However, incorrect outputs arise in words which contain sequences of heavy syllables (cf. 43-44). Since one of these must be unstressed because of *CLASH, the decision is left to *FTFT, which selects the incorrect output:

(43) /parimattelt/	*CLASH	WSP	*FTFT	ALL-FT-L
a. ☞ *(pá.ri).mat.(tèl<t>)		*		pa.ri.mat
b. (pá.ri).(màt.tel<t>)		*	* !	pa.ri
c. (pá.ri).(màt).(tèl<t>)	* !		**	pa.ri, pa.ri.mat

Even worse, this analysis fails to generate the binary rhythmic pattern under a ranking WSP » ALL-FT-L » *FTFT in cases such as (44):

(44) /pimestavasse/	*CLASH	WSP	ALL-FT-L	*FTFT
a. ☞ (pí.mes).ta.(vàs.se)		*	pi.mes.ta	
b. (pí.mes).(tà.vas).se		** !	pi.mes	*

4.2 Foot maximality instead of *CLASH

A second alternative which I will consider (and rule out) is attributing the effects of *CLASH under a constraint that feet must be *maximal*, preferring disyllabic $[\sigma\ \sigma]_F$ over monosyllabic $[\sigma_{\mu\mu}]_F$. We must then split up FT-BIN:

(45) a. FT-BIN-μ: Feet are binary on moraic analysis.
b. FT-BIN-σ: Feet are binary on syllabic analysis.

I assume PARSE-2 » FT-BIN-σ, to rule out *(*ká.va*).*lat*<*t*> etc. Now consider tableau (46). The 'ternary parsing' (*ú.sal*).(*tàt.ta*).*va*.(*màt.teks*) results from FT-BIN-σ » ALL-FT-L:

(46) /usaltattavamatteks/	*FT-BIN-σ	ALL-FT_3-L	*FTFT
a. ☞ (ú.sal).(tàt.ta).va.(màt.tek<s>)		u.sal.tat.ta.va	*
b. (ú.sal).(tàt).(tà.va).(màt.tek<s>)	* !	u.sal.tat	***
c. (ú.sal).(tàt.ta).(và.mat).(tèk<s>)	* !	u.sal.tat.ta	***

However, the 'binary' parsing (*ú.sal*).(*tàt.ta*).(*và.mat*).(*tèks*) (46c) cannot be selected by any ranking of constraints. As compared to the ungrammatical clashing output candidate (46b), it has the same number of nonmaximal feet, as well as the same number of adjacent feet, producing ties w.r.t. FT-BIN-σ and *FTFT. Regardless of ranking, ALL-FT-L prefers (46b) over (46c).

5 Words with overlong syllables

A feature of special interest of Estonian prosody is that of *overlong* syllables. These are heavy syllables Cvv/CvC with an extra element of length added at the end, i.e. Cvv:, CvvC:, or CvCC:. The secondary stress pattern of words with overlong syllables is variable, as shown by the forms in (47). Overlong syllables may be immediately followed by a secondary stress, as in the lefthand column, or by an unstressed syllable, as in the righthand column of (47). (Foot parsings will be motivated by the analysis.)

(47)	a.	(káu:).(kè.le)	(káu:).ke.le	'far away'
	b.	(jál:).(kè.test)	(jál:).ke.(tèst)	'trick, ell.pl.'
	c.	(töös:).(tù.se).le	(töös:).tu.(sè.le)	'...'
	d.	(trúu:).(tù.se).(lè.ki)	(trúu:).tu.(sè.le).ki	'...'
	e.	(hái:).(kùs.test<t>)	(hái:).kus.(tèst<t>)	'deseases, ell.pl.'
	f.	(töös:).(tùs.tes).se	(töös:).tus.(tès.se)	'industry, ill.pl.'
	g.	(áu:).(sàt.te).le	(áu:).sat.(tè.le)	'honest, all.pl.'
	h.	(téot:).(tàt.tut).(tèl<t>)	(téot:).tat.(tùt.tel<t>)	'backer, abl.pl.'
	i.	(kínt:).(lùs.te).(lè.ki)	(kínt:).lus.(tè.le).ki	'...'
	j.	(káu:).(kèt.tes).(sè.ki)	(káu:).ket.(tès.se).ki	'...'

Of the two patterns, those in the lefthand column of (47) seem to violate *CLASH. This freedom can be attributed to the extra length of overlong syllables, which is sufficient to overcome clash. I follow the proposal of Prince (1983: 62) that overlong syllables occupy *two grid elements*, while other heavy syllables occupy only one[10]. Since *CLASH refers to strong grid elements rather than stressed syllables, words in the lefthand column of (47) have no clash. (It will be shown below that *syllable*-based clash-avoidance explains the pattern in the righthand column of 47).

Interestingly, *ternary* rhythmic alternation, where stress resumes on the third syllable following an overlong syllable, is ruled out:

(48) a. *(trúu:).tu.se.(lè.ki) b. *(kínt:).lus.te.(lè.ki)

Overlong syllables apparently block the option of ternary rhythm, in which respect they behave differently from ordinary syllables. Ungrammaticality of the patterns in (48) follows from PARSE-2, but only if overlong syllables obligatorily form monosyllabic feet on their own (cf. Prince 1980: 519). Accordingly I propose an undominated constraint *Grid-Binarity*:

(49) GR-BIN: The head foot has precisely two grid positions.

Note that GR-BIN cannot be reduced to FT-BIN since monosyllabic heavy feet occur under secondary stress. Reference to the head foot is motivated by word minimality in Estonian - monosyllables must be overlong. Also, recent loans words with final main stress (e.g. *avenûu*:) end in overlong syllables (Prince 1980: 535). Finally, GR-BIN governs the shape of the initial syllable in the Strong Grade in Estonian gradation (Prince 1980: 538).

Words beginning with overlong syllables are now formally treated on a par with words beginning with disyllabic feet. First, *CLASH does not block the resumption of stress after an overlong syllable (cf. 50a). Second, sequences of two unparsed syllables are ruled out by PARSE-2 (cf. 50b):

(50)	a.	*CLASH:	(jál:).(kè.tes<t>)	(té.ra).(và.mal<t>)
	b.	PARSE-2:	*(trúu:).tu.se.(lè.ki)	*(ó.sa).va.ma.(lè.ki)

Two types of patterns in the righthand column of (47) require a slight modification of the analysis. First, words whose second syllable is heavy, e.g. (*hái*:).*kus*.(*tèst*<*t*>). Second, (*káu:*).*ke.le*, which has two unparsed syllables. Both involve violations of PARSE-2, a constraint which was found to be undominated for the cases discussed in previous §§. To produce the relevant parsings, PARSE-2 must be (optionally) dominated by a clash-avoidance constraint that rules out sequences of stressed syllables:

(51) *CLASH-SYLL: No adjacent stressed syllables.

The double-faced behaviour of overlong syllables with respect to clash avoidance is explained by the fact that they are both (a) bipositional on the grid, escaping from *CLASH, and (b) stressed syllables, and as such measured by *CLASH-SYLL. Observe that *CLASH-SYLL cannot be reduced to *FTFT, because of *(*ré.ti*).*li.le*, *(*ká.va*).*lat*<*t*>.

I propose the rankings in (52)[11], where all dominated constraints are unordered w.r.t one another, except that a partial subranking holds: PARSE-2 dominates both ALL-FT-L and *FTFT.

(52) U: GRWD=PRWD, FT-BIN, GR-BIN, *CLASH, TROCH-FT, ALIGN-L
D: PARSE-2, *CLASH-SYLL, ALL-FT-L, *FTFT, PARSE-SYLL
Partial rankings: PARSE-2 » ALL-FT-L **and** PARSE-2 » *FTFT

Crucial rankings among the dominated constraints may be portrayed as in the diagram below. Here domination indicates constraint domination, while nodes which are sisters in the diagram are ranked equally:

```
(53)            /        \
     *CLASH-SYLL      PARSE-2
                       /       \
                ALL-FT-L      *FTFT
```

This tree abbreviates the relevant rankings of dominated constraints in (54):

(54) a. (*CLASH-SYLL = (PARSE-2 » (ALL-FT-L = *FTFT)))
b. (*CLASH-SYLL = (PARSE-2 » (*FTFT = ALL-FT-L)))
c. ((PARSE-2 » (ALL-FT-L = *FTFT)) = *CLASH-SYLL)
d. ((PARSE-2 » (*FTFT = ALL-FT-L)) = *CLASH-SYLL)

This modification does not affect the analysis of words which have no overlong syllables. When every syllable has one grid position, *CLASH-SYLL and *CLASH produce identical evaluations. Hence we may reduce (54) to (55), i.e. precisely the two subrankings motivated in the basic analysis:

(55) a. (*CLASH » (PARSE-2 » (ALL-FT-L = *FTFT)))
b. (*CLASH » (PARSE-2 » (*FTFT = ALL-FT-L)))

I now return to the pattern of words with overlong syllables in the righthand column of (47). These go by subranking *CLASH-SYLL » PARSE-2 (54a/b). (I do not consider constraints ranked below PARSE-2.)

(57) /truu:tuseleki/	GR-BIN	*CLASH-SYLL	PARSE-2
a. ☞ (trúu:).tu.(sè.le).ki			
b. (trúu:).tu.se.(lè.ki)			* !
c. (trúu:).(tù.se).(lè.ki)		* !	
d. (trúu:tu).(sè.le).ki	* !		

(56) /káu:kele/	GR-BIN	*CLASH-SYLL	PARSE-2
a. ☞ (káu:).ke.le			*
b. (káu:).(kè.le)		* !	
c. (káu:ke).le	* !		

(58) /hai:kustest/	GR-BIN	*CLASH-SYLL	PARSE-2
a. ☞ (hái:).kus.(tès<t>)			*
b. (hái:).(kùs.tes<t>)		* !	
c. (hái:kus).(tès<t>)	* !		

The subranking PARSE-2 » ALL-FT-L » rest (cf. 54c) produces the patterns of the lefthand column of (47) (I do not consider violations of GR-BIN here):

(59) /káu:kele/	PARSE-2	ALL-FT$_2$-L	ALL-FT$_3$-L
a. ☞ (káu:).(kè.le)		kau:	
b. (káu:).ke.le	* !		

(60) /truu:tuseleki/	PARSE-2	ALL-FT$_2$-L	ALL-FT$_3$-L
a. ☞ (trúu:).(tù.se).(lè.ki)		truu:	truu:tu.se
b. (trúu:).tu.(sè.le).ki		truu:tu!	
c. (trúu:).tu.se.(lè.ki)	* !	truu:tu.se	

(61) /hai:kustest/	PARSE-2	ALL-FT$_2$-L	ALL-FT$_3$-L
a. ☞ (hái:).(kùs.tes<t>)		hai:	
b. (hái:).kus.(tès<t>)	* !	hai:kus	

Finally, the ranking PARSE-2 » *FTFT » rest (54d), produces patterns which sometimes match those of (54a/b), and sometimes those of (54c):

(62)	*CLASH-SYLL	PARSE-2 » ALL-FT-L	PARSE-2 » *FTFT
a.	(káu:).ke.le	(káu:).(kè.le)	(káu:).(kè.le)
b.	(hái:).kus.(tès<t>)	(hái:).(kùs.tes<t>)	(hái:).(kùs.tes<t>)
c.	(trúu:).tu.(sè.le).ki	(trúu:).(tù.se).(lè.ki)	(truu:).tu.(sè.le).ki

At this point the real reason can be pointed out for why GR-BIN must be undominated. Suppose that PARSE-2 were undominated, while GR-BIN were dominated by *FTFT. Then the first two syllables of *kint:lusteleki* would form a foot, and *FTFT » ALL-FT-L would produce a ternary interval:

(63) /kint:lusteleki/	PARSE-2	*CLASH-SYLL	*FTFT	ALL-FT$_2$-L
a. ☞ (kínt:lus).te.(lè.ki)				kint:lus.te
b. (kínt:lus).(tè.le).ki			* !	kint:lus
c. (kínt:).(lùs.te).(lè.ki)		* !		kint
d. (kínt:).lus.(tè.le).ki	* !			kint:lus:

5.1 Some residual cases

The analysis does not yet account for the ungrammaticality of patterns in the righthand column of (64), which are produced by the subrankings (54a-b):

(64)	*CLASH-SYLL » rest	PARSE-2 » rest	
a.	*(vánk:).rit<t>	(vánk:).(rìt<t>)	'carriage, part.sg.'
b.	*(júl:).kes.se	(júl:).(kès.se)	'bold, ill.sg.'

A generalisation holds for both forms in (64): they must contain two feet. As is well-known from phonetics, relative durations of syllables decrease with the number of syllables in a word (Nooteboom 1972). That is, the shorter a word, the longer its syllables. I hypothesise that the longer duration of syllables in short words puts such syllables under pressure to form feet on their own. In (64) we witness a phonologisation of a durational tendency. This is formulated in the constraint *Word-Binarity* (65):

(65) WD-BIN: Words consist of two feet.

Obligatory bi-podal realisation of both forms in (64) suggests that WD-BIN ranks high, but the possible form *káukele* requires free ranking with respect to *FTFT. Note that obligatorily stressed syllables are heavy in both forms of (64). This points to interaction with WSP, but I will leave this issue open.

Finally, there is gap in the rhythmic variability of some words (cf. 66). All have four or more syllables of which the first is overlong, the second is light, and the third is heavy. These only have the pattern of the righthand column of (66), while my analysis predicts both:

(66)	PARSE-2 » ALL-FT-L	*CLASH-SYLL » rest	
a.	*(káht:).(lè.vai).le	(káht:).le.(vài.le)	'doubtful, all.pl.'
b.	*(kəhk:).(lè.jat).(tèk:<s>)	(kəhk:)le.(jàt.tek:<s>)	'hesitant, transl.pl.'
c.	*(kúlt:).(sè.mat).(tè.le)	(kúlt:).se.(màt.te).le	'more golden, all.pl'
d.	*(káu:).(kè.mat).(tès.se)	(káu:).ke.(màt.tes).se	'far away, ill.pl.'

Avoidance of the forms in the lefthand column may be related to a similar phenomenon in Finnish stress, i.e. avoidance of light-heavy trochees (Kager 1993b). In contrast to Finnish, Estonian does not avoid light-heavy trochees completely, e.g. (*hí.li*).(*sè.mat*).(*tè.le*). The fact that only words beginning with overlong syllables display the effect[12] suggests interaction with *CLASH-SYLL, but I will not go into this matter here[13].

5.2 A rule-based analysis of words with overlong syllables

The constraint-based analysis solves some problems which are inherent to rule-based accounts, as I will now show. Hayes (forthcoming) analyses words with overlong syllables by the following set of rules:

(67)
a. Form generalised trochees from left to right
b. Weak local parsing is optionally invoked.
c. A superheavy (i.e. /μμμ/) syllable may be treated as μμ + μ.
d. Reparse the contents of a foot, provided no stress clash is created.

Sample derivations are below for each combination of options (strong vs. weak local parsing, monosyllabic vs. disyllabic treatment of a superheavy):

(68)		/truu:tu.se.le.ki/	
a.	1σ, SLP	(trúu:tu).(sè.le).ki	
b.	1σ, WLP	(trúu:tu).se.(lè.ki)	=> (trúu:).(tù.se).(lè.ki)
c.	2σ, SLP	(trúu:).(tù.se).(lè.ki)	
d.	2σ, WLP	(trúu:).tu.(sè.le).ki	

(69)		/kint:lus.te.le.ki/	
a.	1σ, SLP	(kínt:lus).(tè.le).ki	*(kínt:).(lùs).(tè.le).ki, by clash
b.	1σ, WLP	(kínt:lus).te.(lè.ki)	=> (kínt:).(lùs.te).(lè.ki)
c.	2σ, SLP	(kínt:).(lùs.te).(lè.ki)	
d.	2σ, WLP	Blocked by minimal prosodic distance	

The rôle of Reparsing (67d) transpires from (68c-69c), where a disyllabic foot of an overlong syllable plus a normal syllable undergoes it. When such a sequence occurs before a stress, as in (69a), Reparsing would create a clash, and thus is blocked. Clash is does not block Reparsing in (68c-69c) since overlong syllables may be treated as disyllabic.

Reparsing and the analysis which it is part of are subject to the following criticisms. First, forms which undergo Reparsing have superheavies which are treated as monosyllabic, since they occur in disyllabic feet. Then why does the anti-clash condition on Reparsing treat the same superheavies as disyllabic? Second, if Reparsing is obligatory (as it should in 68-69), it incorrectly eliminates the contrast between (*káu:ke*).*le* and (*káu:*).(*kè.le*). Third, application of Reparsing is restricted to feet that have superheavies, to prevent that the 'ternary' output (*té.ra*).*va*.(*màl*<*t*>) is neutralised to 'binary' (*té.ra*).(*và.mal*<*t*>). Fourth, Reparsing must not apply to multiple feet, to preserve rhythmic variablity of (*trúu:tu*).(*sè.le*).*ki* and (*trúu:*).(*tù.se*).(*lè.ki*). The problem is not so much that these problems cannot be circumvented by judicious conditions on Reparsing - perhaps this is possible. But the result would be an excessively complex rule, one with full transformational power.

One might try to eliminate Reparsing and its problems, by treating all overlong syllables as disyllabic, much as in my constraint-based analysis. This would then pose the problem of how to effectuate the required skipping of a heavy syllable in forms such as (*kínt*:).*lus*.(*tè.le*).*ki*, or sequence of light syllables in (*káu:*).*ke.le*. There may be two ways to implement this idea. First, one might try a de-stressing rule which would optionally delete a foot immediately after an overlong syllable. This rule would optionally apply to (*káu:*).(*kè.le*), provided that its output (*káu*:).*ke.le* is not sent straight back to where it came by persistent footing. However, the destressing analysis fails in (*kínt*:).(*lùs.te*).(*lè.ki*), where a ternary interval would be produced which is beyond repair. I conclude that this solution is untenable. Second, iterative foot construction itself might be made sensitive to clash, skipping a single syllable of any weight immediately after an overlong syllable. This analysis may work, but at the costs of severe complications. Clash must be *optionally* invoked by overlong syllables, since skipping is not obligatory. *Persistent footing* must be made sensitive to the *same* conditions, since it should allow (*káu:*).*ke.le*. Again, this solution is highly unattractive.

In sum, Reparsing may be fixed by judicious conditions on its application, which would make it a transformational rule, or be dispensed with. In the latter case, there are no viable alternatives for it.

6 A ternary foot analysis of Estonian

6.1 On representing ternary feet

According to ternary foot theory, ternary alternation involves actual ternary feet. Some versions assume 'flat' ternary feet without internal structure (cf. Levin 1988, Halle & Vergnaud 1987). Other versions of ternary theory, which I will adopt here, embody a representation of the ternary foot as a constituent composed of a *binary head* and a *non-head*. This conception originates in work by Prince (1980) and Selkirk (1980), and has been revived in the form of the *resolved foot* of Dresher & Lahiri (1991), Rice (1992, 1993), and Hewitt (1992). As an example of a ternary foot, consider the maximal shapes of the ternary trochee in (70).

```
(70)   a.  Foot            b.  Foot
           |    \              |   \
           Head   \            Head  \
           |   \    \          |       \
           σμ   σμ   σμ        σμμ      σμ
```

Dresher & Lahiri call this foot *resolved trochee*, because it captures the metrical equivalence of a single heavy syllable [$\sigma_{\mu\mu}$] and two light syllables [σ_{μ} σ_{μ}] in the head position of the foot[14]. This equivalence is expressed in the rhythmic domain in the form of *resolution*, the assumption that the head occupies a single metrical position on the grid. See (71):

(71) a. ([*] .) b. ([*] .)

$\sigma_\mu\sigma_\mu\ \ \sigma_\mu$ $\sigma_{\mu\mu}\ \ \sigma_\mu$

Evidence comes from Old English verse, where 'a light stressed syllable followed by any unstressed syllable is considered equivalent to a single heavy stressed syllable' (Dresher & Lahiri 1991: 261). Another piece of evidence comes from Cayuvava rhythm, to be discussed in § 7.

Both foot and head are subject to parametric variation in their internal metrical prominence. The head has its light syllable adjunct on the lefthand or righthand side. If a righthand adjunct is selected (as in 70), the foot is left-dominant (or *trochaic*). Similarly, the head itself is either left-dominant (as in 70) or right-dominant. Varying dominance of heads and feet produces a foot typology of four resolved feet (Rice 1993).

(72)	*Maximal Foot*	*Foot*	*Head*
a.	([μ $_\mu$] σ_μ)	Left	Left
b.	([$_\mu$ μ] σ_μ)	Left	Right
c.	(σ_μ [μ $_\mu$])	Right	Left
d.	(σ_μ [$_\mu$ μ])	Right	Right

Dresher & Lahiri (1991) present strong evidence for (72a) in Germanic, based on stress distribution, as well as foot-based processes such as High Vowel Deletion and Sievers' Law. Rice (1992, 1993) argues for (72b) in Chugach Yupik, and for (72c) in Sentani.

Interestingly we observe a parallel between binary and ternary theory. What they have in common is an explanation of ternarity by representational means taken from the analysis of binary rhythm. Binary theory maintains binary feet, while ternary theory maintains binary alternation on the grid. Accordingly, binary theory adopts non-adjacency of feet, while ternary theory has non-adjacency of strong beats in a resolved representation.

6.2 Ternary feet in Estonian

The sample of the ternary foot parsing of Estonian in (73) is essentially the output of the rule-based analysis of Prince (1980), translated into the resolved foot notation.

(73)	a.	([pí.mes].ta<v>)	
	b.	([ká.va]).([làt<t>])	
	c.	([ré.te]).([lì.le])	
	d.	([té.ra]).([và.mal<t>])	([té.ra].va).([màl<t>])
	e.	([pá.ri]).([màt.tel<t>])	
	f.	([pí.mes]).([tà.va].le)	([pí.mes].ta).([và.le])
	g.	([pí.mes]).([tàt.tu].te)	
	h.	([əp.pet]).([tà.jat]).([tèks])	([əp.pet].ta).([jàt.tèks])
	i.	([hí.li]).([sè.mat]).([tè.le])	([hí.li].se).([màt.te].le)
	j.	([vánk:]).([rìtt])	
	k.	([káu:]).([kè.le])	([káu:ke].le)
	l.	([jál:]).([kè.tes<t>])	([jál:].ke).([tès<t>])
	m.	([töös:]).([tù.se].le)	([töös:].tu).([sè.le])
	n.	([trúu:]).([tù.se]).([lè.ki])	([trúu:].tu).([sè.le].ki)
	o.	([hái:]).([kùs.test<t>])	([hái:kus]).([tèst<t>])
	p.	([kínt:]).([lùs.te]).([lè.ki])	([kínt:lus]).([tè.le].ki)

The full set of foot templates required for these parsings is given in (74):

(74)	$([\sigma\ \sigma]\ \sigma_{\mu})$	or	$([\sigma\ \sigma])$	or	$([\sigma_{\mu\mu}])$
	$([\sigma{:}\ \sigma_{\mu}])$	or	$([\sigma{:}\ \sigma])$	or	$([\sigma{:}])$

Note that the template of the *resolved trochee* of (72a) forms a subset of this set. With respect to Germanic, Estonian has the additional freedom to place syllables of any weight appear in any position of the head, strong or weak.

6.2.1 *Prince (1980)*. Let us first discuss the analysis by Prince (1980). The core of his analysis is a set of rules which define foot well-formedness:

(75)
a. Foot -> u u (where u is σ, μ)
b. Foot -> Foot μ
c. $[_F\ \sigma_1]\ \sigma_2$ -> $[_F\ \sigma_1\ \sigma_2]$ / ___ Foot.
d. No Foot may end on more than two weak syllables.

Rule (75a) characterises the Head of a foot, the minimal sequence which may constitute a foot on its own. The recursive rule (75b) states that to any Head, a light syllable may be adjoined. If the Head is disyllabic, then a light syllable may be appended, as in ([*pí.mes*].*ta*<*v*>), but not two, since (75d) rules out quadrisyllabic feet, as in *([*ré.ti*].*li.le*). If the Head is monosyllabic (i.e. overlong), the adjunction of two light syllables is permitted, as in ([*káu*:].*ke*.*le*). A non-final heavy syllable may adjoin to a monosyllabic Head (overlong syllable) by rule (75c). This optionally gives ([*hái*:].*kus*).([*tèst*]) and ([*hái*:]).([*kùs*.*test*]), but rules out ([*vánk*:].*ritt*).

Since for a single word multiple well-formed parsings may be possible, this analysis captures rhythmic variability. Prince (1980: 560) emphasises that no iteration nor directionality of foot construction is required[15]. In this sense his analysis is actually an early version of a constraint-based analysis.

On the negative side, the nondirectional character of the analysis poses the problem of how to account for restrictions on the distribution of feet of variable size. The ternary foot is a very variable parsing unit, being one to three syllables in size, and most words have multiple parsings satisfying foot well-formedness conditions. Still the set of attested parsings is smaller than what is predicted by foot well-formedness on itself. In a discussion of ungrammatical *([*pí*.*mes*]).([*tàt*]).([*tù*.*te*]), Prince (1980: 532-533) suggests that a *maximality* principle of foot parsing might be at work, which functions to avoid stress clash. This correctly predicts ([*pí*.*mes*]).([*tàt*.*tu*].*te*). But maximality also rules out parsings such as ([*hí*.*li*]).([*sè*.*mat*]).([*tè*.*le*]) in favour of 'maximal' ([*hí*.*li*].*se*).([*màt*.*te*].*lè*) and similarly ([*káu*:]).([*kè*.*le*]) in favour of maximal ([*káu*:].*ke*.*le*). The reverse problem is that two possible parsings may both satisfy maximality, while only one of these is allowed. E.g. maximality cannot distinguish ungrammatical *([*trúu*:*tu*].*se*).([*lè*.*ki*]) from ([*trúu*:*tu*]).([*sè*.*le*].*ki*). Prince does not address this issue, but as we will see below the solution involves a degree of directionality (by ALL-FT-L) which his analysis radically but incorrectly eliminates. In sum Prince's analysis falls short of dealing with the problem of rhythmic variability.

6.2.2 *Undominated constraints*. Translating Prince's foot well-formedness conditions (75a-d) into constraints, we find four undominated constraints:

(76) a. HD-BIN: Heads must be binary under syllabic or moraic analysis.
b. TROCH-FT: Feet are trochaic.
c. TROCH-HD: Heads are trochaic.
d. L-ADJ: An adjunct is a single light syllable.

L-ADJ matches Prince's foot well-formedness conditions (75b, d) and Dresher & Lahiri's templatic condition (70). It is functionally related to PARSE-2 in the binary foot analysis as it rules out both a heavy syllable and a sequence of syllables in the adjunct.

Variable foot size is due to an interaction of two constraints. ALL-FT-L favours rhythmic binarity by pulling feet as close as possible to the lefthand word edge. The second is a still unidentified ternarity constraint ***T***. Suppose that ***T*** were to maximise foot size, in the spirit of Princean *foot maximality*, by penalising non-maximal feet. This would fail for the contrast between 'ternary' ([*pí.mes*].*ta*).([*và.le*]) and 'binary' ([*pí.mes*]).([*tà.va*].*le*), both of which have one maximal and one non-maximal foot. Consequently ***T*** should maximise the interstress interval, in the *clash-based* spirit of Dresher & Lahiri's analysis. I therefore adopt the non-adjacency constraint *HDHD, a restatement of *FTFT on the level of the head:

(77) *HDHD: Heads of feet must be non-adjacent.

We identify *HDHD as the basic force towards ternary rhythm, and ALL-FT as its binary counterforce.

Resolution has consequences for the formalisation of clash avoidance. When each head has a single metrical position, adjacency of heads violates both *CLASH and *HDHD, and *CLASH is functionally identical to *HDHD. *CLASH can no longer be undominated as in the binary foot analysis, as that would rule out any adjacency of heads, and with it the binary rhythmic pattern. If *CLASH cannot be undominated, then *CLASH-SYLL must be, as clash avoidance is essential to the analysis for reasons pointed out in § 4.2. Of course undominated *CLASH-SYLL has serious repercussions for words with overlong syllables, which will be discussed later.

6.2.3 *Variability*. Ternary rhythm differs from binary rhythm in the relative position of *HDHD with respect to ALL-FT, as in (78):

(78) a. Binary rhythm: ALL-FT » *HDHD
b. Ternary rhythm: *HDHD » ALL-FT

Obligatory binary rhythm in certain words is due to pressure to parse every syllable in a foot, as Prince (1980: 533) points out. The *non-ternarity* effect is due to undominated PARSE-SYLL and L-ADJ, see tableaux (79-80):

(79) /retelile/	PARSE-SYLL	L-ADJ
a. ☞ ([ré.te]).([lì.le])		
b. ([ré.te].li).le	* !	

(80) /kavalatt/	PARSE-SYLL	L-ADJ
a. ☞ ([ká.va]).([làt<t>])		
b. ([ká.va].lat<t>)		* !
c. ([ká.va]).lat<t>	* !	

Observe that LIGHT-ADJUNCT succesfully excludes ternary rhythm across a heavy syllable, and that *CLASH-SYLL blocks clash:

(81) /parimattele/	PARSE-SYLL	L-ADJ	*CLASH-SYLL
a. ☞ ([pá.ri]).([màt.te].le)			
b. ([pá.ri]).([màt]).([tè.le])			* !
c. ([pá.ri].mat).([tè.le])		* !	

A preliminary constraint ranking is given in (82). To account for variability, I assume that *HDHD and ALL-FT-L are ranked equally:

(82) **U**: HDBIN, TROCHFT, TROCHHD, PARSESYLL, *CLASHSYLL, L-ADJ
D: ALL-FT-L = *HDHD

The binary pattern is based on the ranking ALL-FT-L » *HDHD. The tableaux below do not contain candidates violating undominated constraints:

(83) /teravamalt/	ALL-FT$_2$-L	ALL-FT$_3$-L	*HDHD
a. ☞ ([té.ra]).([và.mal<t>])	te.ra		*
b. ([té.ra].va).([màl<t>])	te.ra.va !		

(84) /pimestavale/	ALL-FT$_2$-L	ALL-FT$_3$-L	*HDHD
a. ☞ ([pí.mes]).([tà.va].le)	pi.mes		*
b. ([pí.mes].ta).([và.le])	pi.mes.ta !		

(85) /hilisemattele/	ALL-FT$_2$-L	ALL-FT$_3$-L	*HDHD
a. ☞ ([hí.li]).([sè.mat]).([tè.le])	hi.li	hi.li.se.mat	**
b. ([hí.li].se).([màt.te].le)	hi.li.se !		

The ternary pattern has the reverse ranking *HDHD » ALL-FT-L.

(86)	/teravamalt/	*HDHD	ALL-FT$_2$-L	ALL-FT$_3$-L
a.	☞ ([té.ra].va).([màl<t>])		te.ra.va	
b.	([té.ra]).([và.mal<t>])	* !	te.ra	

(87)	/pimestavale/	*HDHD	ALL-FT$_2$-L	ALL-FT$_3$-L
a.	☞ ([pí.mes].ta).([và.le])		pi.mes.ta	
b.	([pí.mes]).([tà.va].le)	*!	pi.mes	

(88)	/hilisemattele/	*HDHD	ALL-FT$_2$-L	ALL-FT$_3$-L
a.	☞ ([hí.li].se).([màt.te].le)		hi.li.se	
b.	([hí.li]).([sè.mat]).([tè.le])	* ! *	hi.li	hi.li.se.mat

6.2.4 *Overlong syllables*. Recall from § 6.2.1 that the challenge with respect to overlong syllables is to allow ([= σ] σ_μ) as a foot in ([*káu*:*ke*].*le*), but to rule it out in *([*trúu*:*tu*].*se*).([*lè*.*ki*]), etc. The binary foot analysis captured the rhythmic behaviour of overlong syllables by endowing them with two grid positions, while ordinary syllables have only one. However, in resolved foot theory à la Dresher & Lahiri (1991), heads have a single grid position. Therefore if *CLASH-SYLL is undominated as argued above, all words with overlong syllables should follow the pattern of the righthand column in (73). The pattern in the lefthand column of (73) requires the constraint in (89):

(89) 3μ-FT: Align ($\sigma_{3\mu}$, R, Ft, R)

3μ-FT requires that the righthand edge of every overlong syllable coincides with the righthand edge of a foot. Because of PARSE-SYLL, the next foot must begin immediately after this foot. We find that undominated 3μ-FT makes secondary stress fall on the syllable directly following the overlong syllable, as in the lefthand column of (73j-p).

3μ-FT must be optionally dominated by *CLASH-SYLL because of the pattern in the righthand column of (73k-p). Partial ordering of *CLASH-SYLL above ALL-FT-L and *HDHD produces the set of rankings in (90):

(90) a. (3μ-FT = (*CLASH-SYLL » (ALL-FT-L = *HDHD)))
b. (3μ-FT = (*CLASH-SYLL » (*HDHD = ALL-FT-L)))
c. ((*CLASH-SYLL » (ALL-FT-L = *HDHD)) = 3μ-FT)
d. ((*CLASH-SYLL » (*HDHD = ALL-FT-L)) = 3μ-FT)

This does not affect words with ordinary syllables where 3μ-FT is irrelevant.

The pattern of words in the righthand column goes by ranking (90a-b), with 3μ-FT » *CLASH-SYLL » *HDHD/ALL-FT-L.

(91) /káu:kele/	3μ-FT	*CLASH-SYLL	*HDHD	ALL-FT-L
a. ☞ ([káu:]).([kè.le])		*	*	kau:
b. ([káu:ke].le)	* !			

(92) /hai:kustest/	3μ-FT	*CLASH-SYLL	*HDHD	ALL-FT-L
a. ☞ ([hái:]).([kùs.tes<t>])				hai:
b. ([hái:].kus).([tès<t>])				hai:kus

(93) /truu:tuseleki/	3μ-FT	*CLASH-SYLL	*HDHD	ALL-FT-L
a.☞([trúu:]).([tù.se]).([lè.ki])		*	**	truu:, truu:tu.se
b. ([trúu:].tu).([sè.le].ki)	* !			truu:tu
c. ([trúu:tu].se).([lè.ki])	* !			truu:tu.se
d. ([trúu:tu]).([sè.le].ki)	* !		*	truu:tu

The pattern of the words in the righthand column of (73k-p) is obtained by the ranking (90c-d) *CLASH-SYLL » *HDHD/ALL-FT-L » 3μ-FT:

(94) /káu:kele/	*CLASH-SYLL	*HDHD	ALL-FT-L	3μ-FT
a. ☞ ([káu:ke].le)				*
b. ([káu:]).([kè.le])	* !	*	kau:	

(95) /hai:kustest/	*CLASH-SYLL	*HDHD	ALL-FT-L	3μ-FT
a. ☞ ([hái:].kus).([tès<t>])			hai:kus	*
b. ([hái:]).([kùs.tes<t>])	* !	*	hai:	

(96) /truu:tuseleki/	*CLASH-SYLL	*HDHD	ALL-FT-L	3μ-FT
a. ☞ ([trúu:].tu).([sè.le].ki)			truu:tu	*
b. ([trúu:tu].se).([lè.ki])			truu:tu.se !	*
c. ([trúu:tu]).([sè.le].ki)		* !	truu:tu	*
d. ([trúu:]).([tù.se]).([lè.ki])	* !		truu:, truu:tu.se	

Note that the ternary parsing (96b) is rejected because a more optimal binary parsing (96a) is possible, one which has fewer violations of ALL-FT-L. However, in (94) the ternary parsing is selected since it is the only one which avoids clash. This solves the problem, signalled above in the analysis of Prince (1980), with respect to the distribution of trisyllabic feet in words with overlong syllables. Since the analysis crucially uses a *directionality* constraint, ALL-FT-L, we may conclude from this that the failure of Prince's analysis is due to its complete elimination of directionality.

Finally, let us return to Prince's foot well-formedness rule (75c), which allows the parsing of a heavy adjunct in the first foot if it has an overlong syllable. In my analysis the heavy syllable is actually parsed by the head (cf. 95). The condition that another foot must follow for such feet to be well-formed, which was based on the ungrammaticality of the parsing *([*vánk:rit*<*t*>]), must be attributed to WORD-BINARITY, as in the binary foot analysis (cf. 65).

6.3 A comparison of binary and ternary foot theory

The ternary foot analysis of Estonian has a number of virtues. First, it maintains a maximally restrictive view of syllable parsing, since PARSE-SYLL is undominated. Second, two anti-clash constraints (*CLASH-SYLL and *HDHD) do all the work whereas in the binary foot analysis three were needed (*CLASH-SYLL, *CLASH and *HDHD). On the negative side, a ternary foot analysis expands the inventory of feet as compared to the binary foot analysis. The costs are four undominated foot form constraints (HD-BIN, TROCH-FT, TROCH-HD, L-ADJ), as well as a dominated foot form constraint 3μ-FT, which states that trimoraic syllables must form feet on their own. Overlong *islandhood* was obtained in the binary foot analysis from GR-BIN, which is motivated as a general property of the main stress foot by the Estonian word minimum.

Binary theory has a small number of foot form constraints (FT-BIN, GR-BIN, TROCH-FT) which are all undominated. However, complications with respect to foot parsing arise which require a new constraint PARSE-2, which may be dominated by anti-clash constraints (*CLASH-SYLL). As I have argued, PARSE-2 is simply the mirror-image of FT-BIN, to which it is related in a pair much as PARSE is to FILL. Moreover, PARSE-2 becomes even more attractive if it can be shown that it replaces PARSE-SYLL in all functions, thus eliminating PARSE-SYLL as a universal constraint. However this crucially involves an interpretation of ALL-FT as a constraint which evaluates distance from the word edge on a foot-by-foot basis.

7 Cayuvava

To demonstrate the generalisability of the analyses of ternary rhythm of Estonian, I will briefly discuss the ternary stress pattern of Cayuvava. The pattern has been analysed in a rule-based theory by Halle & Vergnaud (1987), Levin (1988), Dresher & Lahiri (1991), and Hayes (forthcoming).

Cayuvava (Key 1961) has no contrast of syllable weight. Stress falls on the antepenultimate syllable and on every third syllable preceding it. However, disyllabic words are stressed on the penult. Each stress is reported to be equally strong. The source contains no monosyllabic content words, which I take as evidence for a disyllabic word minimum.

7.1 A binary foot analysis

The rule-based binary foot analysis of Hayes (forthcoming) is given in (97), while its output pattern is given in (98):

(97) a. Final syllables are extrametrical, except in disyllabic words.
b. Assign trochees from right to left, under weak local parsing.
c. No persistent footing.

(98)	a.	(dá.pa)	'canoe'
	b.	(tó.mo).ho	'small water container'
	c.	a.(rí.po).ro	'he already turned around'
	d.	a.ri.(pí.ri).to	'already planted'
	e.	(á.ri).hi.(hí.be).e	'I have already put the top on'
	f.	ma.(rá.ha).ha.(é.i).ki	'their blankets'
	g.	i.ki.(tá.pa).re.(ré.pe).ha	'the water is clean'
	h.	(tʃá.a).di.(ró.bo).ßu.(rú.ru).ce	'ninety-nine (first digit)'

This pattern is oriented towards the *righthand* PrWd edge (compare 98b). Accordingly, we require PARSE-2 » ALL-FT-R. The 'double upbeat′ pattern in (98d, g) shows that *FTFT dominates PARSE-2. Although there is room for an additional foot over the first two syllables, this is ruled out by *FTFT. Dominated by *FTFT is the familiar sequence of PARSE-2 and ALL-FT-R, whose ranking produces multiple feet oriented towards the righthand PrWd edge. In sum, the core of the pattern is the constraint interaction of (99):

(99) *FTFT » PARSE-2 » ALL-FT-R

This ranking instantiates the third type of system predicted in § 3.

Let us now look at the remaining constraint interactions which underlie the Cayuvava pattern. First, the final unparsed syllable in (98b-h) requires *Non-Finality* (Prince & Smolensky 1993, Hung 1994):

(100) NONFIN: No foot is final in PrWd.

It corresponds to extrametricality in a rule-based analysis. We need not stipulate that the distance between the rightmost foot and the PrWd edge is limited to one syllable. This follows from minimal violation of ALL-FT-R.

The fact that disyllabic words have a binary foot in violation of NONFIN follows from undominated GRAMWD=PRWD (Prince & Smolensky 1993):

(101) GRAMWD=PRWD: Every grammatical word is a PrWd.

Ranking FTBIN » GRAMWD=PRWD produces the disyllabic word minimum.

Finally the single foot in (98d) shows that NONFIN dominates PARSE-2. If the order were reverse, this would produce two binary feet separated by an unparsed syllable, satisfying *FTFT while improving syllable parsing, at the expense of NONFIN. These constraints form the mini-grammar in (102):

(102) Undominated: FT-BIN, GRAMWD=PRWD, *FTFT
Dominated: NON-FIN » PARSE-2 » ALL-FT-R

Two example *tableaux* are in (103) and (104). I do no consider any output candidates which violate undominated constraints.

(103) /aripirito/	*FTFT	NONFIN	PARSE-2	ALL-FT$_1$-R	ALL-FT$_2$-R
a. ☞ a.ri.(pí.ri).to			*	to	
b. a.(rí.pi).ri.to			*	ri.to !	
c. (á.ri).pi.(rí.to)		* !			pi.ri.to
d. (á.ri).(pí.ri).to	* !			to	pi.ri.to
e. a.(rí.pi).(rí.to)	* !	*			ri.to

(104) /arihihibee/	*FTFT	NONFIN	PARSE-2	ALL-FT$_1$-R	ALL-FT$_2$-R
a. ☞ (á.ri).hi.(hí.be).e				e	hi.hi.be.e
b. a.ri.hi.(hí.be).e			* !	e	
c. a.(rí.hi).hi.(bé.e)		* !			hi.be.e
d. a.(rí.hi).(hí.be).e	* !			e	hi.be.e
e. (á.ri).(hí.hi).(bé.e)	* ! *	*			be.e

7.2 A ternary foot analysis

A rule-based ternary foot analysis was given by Dresher & Lahiri (1991)[16], who analyse the pattern of Cayuvava by the resolved trochee (72a). Since there is no weight contrast, all feet have disyllabic heads, with an optional righthand adjunct. The analysis is given in (105), its output in (106).

(105) a. Assign resolved trochees ([σ_s σ_w] σ_w), ([σ_s σ_w]) from right to left.
b. Delete binary feet under clash.

(106)
a. ([dá.pa])
b. ([tó.mo].ho)
c. a.([rí.po].ro)
d. a.ri.([pí.ri].to)
e. ([á.ri].hi).([hí.be].e)
f. ma.([rá.ha].ha).([é.i].ki)
g. i.ki.([tá.pa].re).([ré.pe].ha)
h. ([tʃá.a].di).([ró.bo].ßu).([rú.ru].ce)

Observe that antepenultimate stress is now captured by foot maximality rather than by extrametricality, as in the binary analysis discussed in § 2.1.

Clash deletion (105b) is motivated by words of *3n+2* syllables (cf. 106d, g). After assignment of ternary feet from right to left these contain a binary foot at the lefthand word edge. Since (by resolution) the head of a resolved foot counts as a single strong metrical position, adjacency of heads produces a clash, which is resolved by deleting the lefthand of two adjacent heads:

```
(107)   *---------*     .           .  .    *      .
       ([á.ri]).([pí.ri].to)  =>    a.ri.([pí.ri].to)
```

In a constraint-based ternary foot analysis in the spirit of Dresher & Lahiri's clash-avoidance, *HDHD dominates PARSE-SYLL. The rôle of PARSE-SYLL in Cayuvava becomes restricted to selecting the candidate with the minimal number of unparsed syllables. In particular PARSE-SYLL must still dominate ALL-FT-R in order to derive *rhythm*. I conclude that even ternary foot theory cannot maintain undominated PARSE-SYLL for all rhythmic stress systems.

In Dresher & Lahiri's analysis, ternarity of the final foot follows from construction of maximal feet, which starts at the righthand edge. In a constraint-based analysis, a special constraint is required for final ternarity because *HDHD does not affect the distance from the word edge. I restate NONFIN on the head of the foot, subsuming syllable extrametricality:

(108) NONFIN: No head of a foot is final in PrWd.

NONFIN of course dominates ALL-FT-R and also PARSE-SYLL, as (110) will show. It is dominated by GRAMWD=PRWD, as it is violated only in disyllabic words. Pulling all this together, we arrive at the full analysis:

(109) U: HD-BIN, GRAMWD=PRWD, TROCH-HEAD, TROCH-FT, *HDHD
D: NONFIN » PARSE-SYLL » ALL-FT-R

Consider the *tableaux* (110-111), which only contain candidates which satisfy undominated HEAD-BINARITY and both constraints on foot form.

(110) /aripirito/	*HDHD	NONFIN	PARSE-SYLL	ALL-FT_1-R	ALL-FT_2-R
a. ☞ a.ri.([pí.ri].to)			**		
b. a.([rí.pi].ri).to			**	to !	
c. ([á.ri].pi).([rí.to])		* !			ri.to
d. ([á.ri]).([pí.ri].to)	* !				pi.ri.to
e. a.([rí.pi]).([rí.to])	* !	*	*		ri.to

(111) /arihihibee/	*HDHD	NONFIN	PARSE-SYLL	ALL-FT_1-R	ALL-FT_2-R
a. ☞([á.ri].hi).([hí.be].e)					hi.be.e
b. a.ri.hi.([hí.be].e)			* ! **		
c. a.ri.([hí.hi].be).e			* ! * *	e	
d. a.([rí.hi].hi).([bé.e])		* !	*		be.e
e. ([á.ri])([hí.hi])([bé.e])	* ! *	*			be.e

This concludes the ternary foot analysis of Cayuvava[17].

8 Conclusions

I will now summarise the conclusions of the paper. In strictly binary rhythmic languages edge-oriented foot distributions are the result of an interaction between two constraints: PARSE-SYLL (or PARSE-2!) requires syllables to be parsed by feet, while ALL-FT pulls feet toward word edges. Since all feet are binary, the notion of *variable interstress interval* is irrelevant. The motivation for testing constraint-based theory with respect to ternary stress languages such as Estonian is the variability of the interstress interval, and its consequences for both PARSE-SYLL and ALL-FT.

First, the advantages of constraint-based theory over rule-based theory in the analysis of ternary rhythm can be summarised as follows. Rule-based theory requires a class of refooting rules in order to trim back any incorrect results of iterative foot construction. These include persistent footing, foot deletion, foot reparsing, etc. The major problem with refooting rules is that these are not formally connected with the well-formedness conditions which govern primary foot parsing. The outcome is a clear loss of generalisation. Constraint-based theory improves over rule-based theory not only by fully eliminating refooting but most importantly by presenting a unified account of foot well-formedness.

Second, the merits of the binary foot representation of ternary rhythm as compared to ternary foot representation. In binary foot theory, ternary rhythmic intervals imply a constraint *FTFT, and a resulting sharp increase in the number of syllables which are left unparsed by feet. This complicates the interaction between syllable parsing and alignment, with a new constraint PARSE-2 as its result. This is counter-balanced by the restrictive set of feet. On the alternative theory with ternary feet, foot size itself becomes a variable factor. This theory offers a restrictive view of syllable parsing, although it is not possible to universally define a rhythmic stress system as one with undominated PARSE-SYLL, as Cayuvava shows.

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NOTES

[1] For other alignment approaches using slightly different assumptions, see Idsardi (1992), Halle & Idsardi (forthcoming), Coleman (1991).

[2] Foot Binarity was first formulated by Prince (1980: 535).

[3] For treatment of consonant extrametricality in Optimality Theory, see Prince & Smolensky (1993).

[4] According to Hayes (forthcoming), this defines the syllabic trochee in languages lacking syllable weight contrasts. Accordingly a degenerate foot is universally defined as ‘monomoraic’ rather than 'monosyllabic’.

[5] This was argued earlier by Kager (1993b).

[6] Quantity-sensitivity and the rôle of the WEIGHT-TO-STRESS PRINCIPLE will be addressed in § 4.

[7] Alternatively unparsed syllables may be derived by generalising the notion of extrametricality so as to include foot-peripheral syllables (*Relativised Extrametricality*, Hammond 1990).

[8] Kager (1993a, b) argues for a similar paralellism in clash avoidance, formulated either on strong moras or syllables.

[9] As a part of the foot-by-foot interpretation, it must be assumed that the order in which feet are evaluated (from 'left to right') always matches the word edge specified by ALL-FT, i.e. *left* in Estonian. This redundancy may constitute a drawback of foot-by-foot interpretation.

[10] Hayes (forthcoming) proposes that overlong syllables are trimoraic, and are optionally treated as either monosyllabic or disyllabic.

[11] I have not included PARSE-SYLL since its effects are subsumed under other constraints, as shown before.

[12] Trisyllabic words do not, compare possible (*jál*:)(*kè.tes*<*t*>) in (86a).

[13] We seem to witness a convergence of *CLASH-SYLL and light-heavy avoidance - when both are violated, the output is rejected, irrespective of the ranking of each of the two individual constraints. This cannot be treated under standard assumptions on ranking of OT, however.

[14] An initial light-heavy sequence is treated as a single head in Germanic.

[15] A similar proposal was made by Selkirk (1980) for English stress.

[16] See also Halle & Vergnaud (1987) and Levin (1988).

[17] A possible objection against ternary foot theory is that it predicts unattested rhythmic patterns in which each *fourth* syllable is strong. Such would indeed arise if *HDHD were combined with high-ranked *FTFT (which rules out adjacent feet). However ternary foot theory has no reason to assume a constraint *FTFT, since *HDHD suffices. A second potential objection is that combining dactyls and NONFIN at the right edge predicts unattested *preantepenultimate* stress. However this objection does not hold if NONFIN refers to the head of the foot, rather than to the foot itself.