Ternary rhythm in alignment theory

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1 Introduction

Ternary rhythmic systems differ from binary systems in stressing every third syllable in a word, rather than every second. Rhythmic ternarity has been established for only a small group of languages: Cayuvava (Bolivia), Alutiiq (Alaska) and Estonian. Yet the stress patterns of these languages are sufficiently complex and diverse to warrant an on-going debate among phonologists about the implications for metrical theory. Ternary systems have been studied from a series of theoretical perspectives in recent years (see Prince 1980; Halle & Vergnaud 1987; Levin 1988; Hammond 1990; Dresher & Lahiri 1991; Rice 1992; Hewitt 1992; Kager 1993; Hayes 1995). The reason for a fresh look at ternarity is the rise of Optimality Theory (Prince & Smolensky 1993, McCarthy & Prince 1993a), a theory which abandons most devices on which rule-based treatments of ternarity were based. It abandons all serial derivations, and together with it directional foot assignment, as well as any restructuring rules (de-stressing, re-bracketing) on the output of foot assignment. Perhaps most importantly, OT gives up all assumptions on the foot inventory, since it defines foot well-formedness by constraints alone. The goal of this paper is to demonstrate that OT radically restricts the generative power of metrical theory, if only the proper set of constraints are assumed, and if some minimal assumptions are made about phonological representations. Not surprisingly, all gains in restrictiveness result from a radical simplification of constraints, making highly general requirements of metrical structure.

Three major questions will be addressed here. First, what has OT to say about the representational issues in metrical theory, more specifically about the issue of 'flat' feet versus 'internally layered' feet? Second, what extensions of the metrical constraint set are required to analyse rhythmic ternarity in a typologically sound way, that is, without causing massive overgeneration? Third, and most importantly, what are the empirical or theoretical advantages (if any) which OT offers over rule-based theory in the analysis of ternary rhythm? These three questions will be answered as follows.

Under OT, the issue of what types of feet rhythmic ternarity involves is put in a new perspective. In parametric metrical theory a debate has been going on about whether the universal foot inventory should include ternary feet, in addition to binary feet. It has been argued by some that binary feet suffice for both binary and ternary rhythm (Hayes 1995, Hammond 1990, Kager 1993), while others have argued that ternary feet are primitives (Halle & Vergnaud 1987, Dresher & Lahiri 1991, Rice 1992, Hewitt 1991). According to OT, metrical well-formedness is defined by constraint interaction alone.

There is no reason any longer to a priori exclude ternary feet (or any kind of feet) from consideration. The focus of attention thus shifts from the universal foot inventory to the universal constraint inventory. How to define an inventory of metrical constraints that is capable of producing the rhythmic patterns of individual languages, and whose factorial typology maximally matches cross-linguistic variation? To address the latter issue I will compare models on the basis of the factorial typologies of different sets of constraints, arising by permutation of rankings.

Constraints in one set refer to the foot as an internally layered (IL) constituent, with its head as a sub-constituent (Dresher & Lahiri 1991, Rice 1992). Ternarity is due to a constraint requiring that the head be non-final in its foot (Hammond 1990, Prince & Smolensky 1993). This 'IL' model will be shown to be empirically superior to a 'flat' model which omits reference to foot-internal heads. This uses a constraint requiring that feet must not be adjacent, nor final in PrWd (Kager 1994, Kenstowicz 1995). The flat model is fully capable of generating attested ternary stress patterns. However, general considerations of restrictiveness strongly favour the IL model, which produces a much more restrictive factorial typology.

Compared to rule-based theory, the main advantage of OT is that it naturally avoids restructuring rules, which are inherent to rule-based analyses that use IL feet. However, restructuring adds greatly to the generative power of the theory, resulting in substantial overgeneration of patterns.

The organisation of this paper is as follows. Remaining subsections of §1 sketch the OT analysis of binary rhythm, which is based on an interaction of constraints on size of feet, parsing of syllables into feet, and relative position of feet with respect to word edges. §2 introduces the two major hypotheses which will be compared in this paper: internal layering vs. no layering, on the basis of the ternary pattern of Cayuvava pattern. I will show advantages of OT analyses over their counterparts in rule-based theory. §3 accomplishes the same for the ternary pattern of Alutiiq. §4 contains a factorial typology, the heart of the paper. An argument is made in favor of the internal layering hypothesis (rejecting the 'flat foot' hypothesis) on the basis of typological restrictiveness. I will show that the strictly binary model produces non-directional patterns that are not attested in any stress language. Finally §5 contains conclusions.

1.1 Binary rhythm in rule-based theory

Many stress languages display a perfect rhythmic alternation of stressed and unstressed syllables. This rhythmic alternation is always 'directional', that is, oriented with respect to the word end, or its beginning. Pintupi (1a), for example, has binary rhythm oriented with respect to the left edge: the initial syllable and following alternate syllables are stressed (Hansen & Hansen 1969). A right-edge oriented pattern occurs in Warao (1b), where stress is on the penult and alternating preceding syllables (Osborn 1966).

(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’

Rule-based theory (e.g. Hayes 1980, 1995) models binary rhythm by three parametric choices. First, a selection of *binary feet* from the universal foot inventory. For example, both Pintupi and Warao select strong-weak (trochaic) feet. Second, setting a parameter that governs the (non-)iterativity of foot construction. Pintupi and Warao select *iterative* construction, producing an exhaustive parsing of syllables by feet. Due to strict binarity of the parsing units, exhaustivity cannot be achieved in words with an odd number of syllables, where one syllable remains unparsed. The edge at which this occurs (the right edge in Pintupi, and the left edge in Warao) follows from a third parameter setting. This parameter governs the *direction* in which feet are constructed. Here Pintupi differs from Warao: footing starts at the *left* edge in Pintupi, and at the *right* edge in Warao. In sum, binary rhythm involves three factors: foot binarity, exhaustivity, and directionality.

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, hierarchically ranked constraints select the optimal candidate. This is found by a recursive evaluation procedure, which starts with the highest-ranking constraint, and if necessary goes all the way down the hierarchy, until it stops when only one candidate remains.

In the domain of rhythmic stress patterns, OT faces the challenge of defining some non-derivational counterpart of the derivational notion of *directionality*. McCarthy & Prince (1993b) show that this is possible, elaborating on an idea which they attribute to Robert Kirchner. It is based on three constraint types, making requirements of foot size (FT-BIN), exhaustive parsing of syllables by feet (PARSE-SYLL), and relative position of feet with respect to a specific edge of the Prosodic Word (ALL-FT-X). Recall that foot parsing of Pintupi tilts towards the *left* edge of the PrWd. In the examples below this is apparent from forms that have an odd number of syllables (2a, c, e):

(2) a. [$_{\text{Wd}}$ (ŋu.nʲi).tʲu] ‘mother’
b. [$_{\text{Wd}}$ (má.la).(wà.na)] ‘through (from) behind’
c. [$_{\text{Wd}}$ (pú.liŋ).(kà.la).tʲu] ‘we (sat) on the hill’
d. [$_{\text{Wd}}$ (tʲá.mu).(lìm.pa).(tʲùŋ.ku)] ‘our relation’
e. [$_{\text{Wd}}$ (tʲí.ɭi).(rì.ŋu).(làm.pa).tʲu] ‘the fire for our benefit flared up’
f. [$_{\text{Wd}}$ (yú.ma).(ɻìŋ.ka).(mà.ra).(tʲà.ɻa).ka] ‘because of mother-in-law’

Deriving the distribution of feet in (2) involves two notions typical of OT: *constraint interaction* and *minimal violation*. The relevant constraints (Prince & Smolensky 1993; McCarthy & Prince 1993b) are in (3):

(3) a. **FT-BIN**
Feet must be binary under syllabic or moraic analysis.

b. **PARSE-SYLL**
All syllables must be parsed by feet.

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

These constraints are potentially in conflict, as we will find out soon. First, the maximal parsing by binary feet is achieved by ranking FT-BIN » PARSE-SYLL. When binarity is a top requirement, a word of an odd number of syllables cannot be parsed exhaustively, as that would logically imply some deviation from foot binarity. However, violation of PARSE-SYLL must be minimal, so that all parsings are rejected that contain more than a single unparsed syllable (cf. 2a,c,e). In sum, the ranking FT-BIN » PARSE-SYLL enforces a maximal parse of PrWd in binary feet - roughly an alternating pattern, but not yet a pattern that is oriented towards a word edge.

The orientation towards the lefthand PrWd edge is implemented by ALL-FT-L (3c), a constraint stating the (surprisingly strong) requirement that every foot stands in initial position of the PrWd[1]. If ALL-FT-L were undominated by other constraints (that is, if it were surface-true), no candidates with multiple feet would ever be selected. That is, for every candidate with multiple feet, a better one is always available that has only a single initial foot. However, ALL-FT-L cannot have this high-ranked position in Pintupi for the reason that the language has rhythmic alternation, hence multiple feet per word. But ALL-FT-L exerts its influence in a more subtle way, by interaction with PARSE-SYLL[2]. When dominated by PARSE-SYLL, the rôle of ALL-FT-L becomes restricted to selecting the candidate that minimally violates it. This is the output in which all feet are *as close as possible* to the designated PrWd edge, measured by numbers of syllables. We now have all evidence that is necessary for a complete ranking of all three constraints:

(4) FT-BIN » PARSE-SYLL » ALL-FT-L

The *tableau* (5) displays this interaction. Violations of constraints are indicated by asterisks, with fatal violations being indicated with '!'. In the column below ALL-FT-L, each star denotes a distance of one syllable between some foot and the left PrWd edge (while commas separate the violations of individual feet).

(5) Input: /puliŋkalatʲu/	FT-BIN	PARSE-SYLL	ALL-FT-L
a. ☞ [(pú.liŋ).(kà.la).tʲu]		*	**
b. [(pú.liŋ).ka.(là.tʲu)]		*	***!
c. [pu.(líŋ.ka).(là.tʲu)]		*	*, **!*
d. [(pú.liŋ).ka.la.tʲu]		**!*	
e. [(pú.liŋ.ka.la.tʲu)]	* !		
f. [(pú.liŋ).(kà.la).(tʲù)]	* !		**, ****

The ranking FT-BIN » PARSE-SYLL is justified by the rejection of candidates (5e-f), both of which are exhaustively parsed (fully satisfying PARSE-SYLL). However, they pay for this by fatally violating FT-BIN, because they contain feet that either exceed (5e) or fall below (5f) binarity. Next, the ranking PARSE-SYLL » ALL-FT-L is apparent from the rejection of candidate (5d), which has only one foot, at the left edge. It thus satisfies ALL-FT-L, which requires every foot to stand at the left edge of PrWd. However, it also fatally violates PARSE-SYLL. It contains three unparsed syllables, while other candidates are still available (5a-c) which have fewer unparsed syllables. This demonstrates that, as we observed earlier, PARSE-SYLL evaluates candidates on the basis of *gradual* violation (Prince & Smolensky 1993). That is, the degree of violation is what counts, rather than (all-or-none) absence of violation. At this point any remaining candidates (5a,b,c) have two binary feet, differing only in their relative positions. ALL-FT-L, the next constraint down the hierarchy, finally selects (5a) as the optimal candidate, as it has the smallest total number of violations. While (5a) incurs two violations, the other candidates (5b-c) have three and four, respectively.

In sum, languages with strictly binary rhythm all share the constraint ranking of (6):

(6) FT-BIN » PARSE-SYLL » ALL-FT-X

Let us now consider ternary rhythm and the extensions of the ranking (6) which this type of rhythm involves.

2 Cayuvava

2.1 Flat binary feet

Among the ternary stress languages, Cayuvava takes a special position in the sense that its ternarity is almost pure. Its remarkable stress pattern has been documented by Key (1961), and it was analysed in a rule-based framework by Halle & Vergnaud (1987), Levin (1988), Dresher & Lahiri (1991), Hayes (1995), and others. It can be summarised as follows. Disyllabic words are stressed on the penult. In longer words stress falls on the antepenult and on every third syllable preceding it. Each stress is reported to be equally strong. Below I have indicated the binary foot parsing that is predicted by the analysis of Hayes (1995)[3]:

(7) 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)’

Key (1961) provides no examples of monosyllabic content words. I tentatively interpret this as evidence for a disyllabic word minimum. The analysis of Hayes (1995) is in (8):

(8) a. Final syllables are extrametrical (except in disyllabic words).
b. Assign trochees from right to left, under Weak Local Parsing.

Weak local parsing (WLP) is a foot assignment mode in which feet are not constructed back-to-back (as in binary rhythm), but are separated by one unparsed syllable. More precisely, a syllable is skipped each time when a foot has been assigned. In combination with foot binarity, WLP produces interstress intervals of three syllables. Moreover, this correctly predicts that in words of 5 or 8 (or 3*n*+2) syllables, the initial syllable remains unfooted, even though there is sufficient space for a binary foot. No binary foot can be constructed over the first two syllables since WLP must be observed (see 9b). Nor can a degenerate foot be assigned to the initial syllable, since that would violate the ban on degenerate feet (see 9c). In (9) syllables skipped by WLP have been underscored:

(9) a. i.<u>ki</u>.(tá.pa).<u>re</u>.(ré.pe).ha
b. *not*: (í.ki).(tá.pa).<u>re</u>.(ré.pe).ha because of WLP.
c. *not*: (í).<u>ki</u>.(tá.pa).<u>re</u>.(ré.pe).ha because of ban on degenerate feet.

An improvement over this analysis is due to Hammond (1991), who argued that weak local parsing and extrametricality are functionally related: both produce metrifications in which binary feet are followed by a single unparsed syllable, either at the right edge of a word, or at the right edge of a foot. Hammond formalises this into the concept of ‘relativised extrametricality’, that is, relativised to a domain (foot or PrWd).

Next consider an OT analysis of Cayuvava that combines Hayes’s idea of WLP and Hammond’s idea of relativised extrametricality. This is based on the constraint (10):

(10) **Fт+σ**
Every foot must be followed by an unparsed syllable.

On a first superficial inspection, FT+σ has the format of a constraint aligning adjacent prosodic categories, e.g. Align (Ft, Right, σ, Left). However, reference to the *unparsed* status of the syllable makes this questionable. The predicate 'unparsed' actually defines a *negative context*. An accurate description of the 'semantics' of FT+σ, so that it refers to positively defined prosodic entities, reveals that it is actually a *disjunction*, excluding two contexts. One context coincides with that of NONFINALITY (Prince & Smolensky 1993), the second with that of *FTFT (Kager 1994). Accordingly, we must rewrite FT+σ as a disjunction of two constraints[4]:

(11) **FT+σ**

a. NONFINALITY
No foot is final in PrWd.

b. *FTFT
Feet must not be adjacent.

In sum, a flat binary foot model cannot formally unify 'extrametricality' and 'ternarity' in the sense of Hammond (1991). (As I will show later, the disjunction disappears in the internal-layering model, where the equivalent of FT+σ is a simple constraint.)

Observe that there is no need to stipulate that *maximally* one unparsed syllable may follow a foot. This follows naturally from the minimal violation of other constraints, in particular PARSE-SYLL and ALL-FT-X, as I will see below. The full ranking is in (12):

(12) FT-BIN » LXWD=PRWD » FT+σ » PARSE-SYLL » ALL-FT-R

In this hierarchy, GRAMWD=PRWD (Prince & Smolensky 1993) is the OT equivalent of 'culminativity'. (Since every grammatical word must equal a PrWd, it must also have minimally one foot.)

(13) **LXWD=PRWD**
Every grammatical word is a PrWd.

The ranking FTBIN » GRAMWD=PRWD produces the disyllabic word minimum. That is, 'a null-parsing' (Prince & Smolensky 1993; a parsing which has no prosodic structure, hence is equivalent to no output at all) is even preferred over an output that violates FT-BIN. Notice that disyllabic words (7a) violate FT+σ (the rule-based analysis encodes this by exempting disyllabic forms from extrametricality). This property simply follows LXWD=PRWD » FT+σ:

(14) /dapa/	FT-BIN	LXWD=PRWD	FT+σ	PARSE-SYLL	ALL-FT-R
a. ☞ (dá.pa)			*		
b. dapa		*!		**	
c. (dá).pa	*!			*	*

The tableau of a four-syllable word (15) shows that FT+σ dominates PARSE-SYLL. (If the ranking were reverse, candidate 15c would have been selected, satisfying PARSE-SYLL at the expense of FT+σ.) Tableau (15) also shows that of both candidates (15a-b) that satisfy FT+σ, the one is selected that minimally violates ALL-FT-R (15a):

(15) /ariporo/	FT-BIN	LXWD=PRWD	FT+σ	PARSE-SYLL	ALL-FT-R
a. ☞ a.(rí.po).ro				**	*
b. (á.ri).po.ro				**	**!
c. a.ri.(pó.ro)			*!	**	
d. (á.ri).(pó.ro)			*!*		**

The ‘double upbeat’ pattern in (7d, g) shows that FT+σ must dominate PARSE-SYLL. There is room for an additional foot over the first two syllables, as in (16d), yet this is ruled out by FT+σ.

(16) /aripirito/	FT-BIN	LXWD=PRWD	FT+σ	PARSE-SYLL	ALL-FT-R
a. ☞ a.ri.(pí.ri).to				***	*
b. a.(rí.pi).ri.to				***	**!
c. (á.ri).pi.(rí.to)			*!	*	***
d. (á.ri).(pí.ri).to			*!	*	*, ***
e. a.(rí.pi).(rí.to)			*!*	*	**
f. (á).ri.(pí.ri).to	*!			**	*, ****

Finally, the familiar sub-ranking PARSE-SYLL » ALL-FT-R (from §1) produces multiple feet oriented towards the righthand PrWd edge:

(17) /marahahaeiki/	FT-BIN	LXWD=PRWD	FT+σ	PARSE-SYLL	ALL-FT-R
a. ☞ ma.(rá.ha).ha.(é.i).ki				***	*,****
b. (má.ra).ha.ha.(é.i).ki				***	*,*****!
c. (má.ra).ha.(há.e).i.ki				***	**,****!*
d. ma.ra.ha.ha.(é.i).ki				****!*	*
e. ma.(rá.ha).(há.e).(í.ki)			*!**	*	**,****

We can make a first balance of rule-ordering theory and OT. There are two distinct advantages of OT. First, the exemption of disyllabic forms from ‘extrametricality’ falls out naturally from constraint interaction. Disyllabic forms are forced to violate FT+σ because otherwise they would fall short of top-ranking requirements of culminativity (LXWD=PRWD) and binarity (FT-BIN). In rule-based theory this relationship cannot be expressed in the formalism itself, while OT easily captures it. Second, OT explains why the minimal prosodic distance is indeed ‘minimal’. The distance between the rightmost foot and the right word edge, as well as that between two feet, is always precisely one syllable. This is precisely enough to satisfy FT+σ, minimally violating PARSE-SYLL and ALL-FT-R. The notion of ‘minimal violation’ comes for free in OT, whereas it requires stipulation in rule-based theory. On the negative side, it is impossible to formally unify ‘nonfinality’ and ‘ternarity’ into a single constraint.

2.2 Internally layered feet

2.2.1 Rule-based theory

The idea of internally layered feet originates with Prince (1980) and Selkirk (1980), and it has been recently revived in the form of the *resolved foot* of Dresher & Lahiri (1991) and Rice (1992), and in related proposals by Hewitt (1992) and Burzio (1994)[5]. Dresher & Lahiri assume that resolved feet have a *binary head* and an optional *non-head*. For example, consider the resolved moraic trochee in (18).

(18)	a.	*	b.	*
		(* *)		(* *)
		$[\sigma_\mu\ \sigma_\mu]_{Hd}\ \ \sigma_\mu$		$[\sigma_{\mu\mu}]_{Hd}\ \ \sigma_\mu$

Dresher & Lahiri present strong evidence for this foot in Germanic, which is based on verse and foot-based processes[6]. It is called *resolved* because it captures the equivalence of a heavy syllable and two light syllables in head position, which is motivated by the quantitative verse patterns of various languages[7]. Equivalence is expressed rhythmically by the assumption that the head occupies a single position on the grid.

Next consider Dresher & Lahiri’s analysis of Cayuvava. Since this language lacks heavy syllables, all its feet have disyllabic heads (cf. 18a). The analysis is given in (19), its output in (20). I have used square brackets for foot heads, and parentheses for feet.

(19) a. Assign resolved trochees from right to left.
b. Delete binary feet under clash.

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

Both antepenultimate stress and ternary interstress intervals are captured by the ternary foot and the (standard) assumption that where possible, the largest possible foot must be constructed. (Only when no maximal feet can be constructed, a smaller one is built by default. This is supported in Cayuvava, where disyllabic words have non-maximal feet.) The assumption of ternary feet plus foot maximisation produces a formal unification of devices needed for antepenultimate stress and ternary rhythm, which were still separate in the binary foot analysis.

On the negative side, the ternary foot analysis is hampered by a problem related to the pattern of words of *3n+2* syllables (19d, g). After assignment of resolved trochees from right to left, these contain a nonmaximal (binary) foot at their lefthand word edge. (This foot is the inevitable by-product of the very assumption that paved the way to the unification that was mentioned above: where no maximal feet can be built, a smaller one is automatically built by default.) However, binary feet at the left edge of words of *3n+2* syllables do not correspond to phonetic stresses. Dresher & Lahiri attribute the surface absence of initial stress to a foot deletion rule. Recall that the head of a resolved trochee counts as a single strong metrical position. Adjacency of foot heads therefore produces a *clash*. This clash is resolved by deleting the lefthand of two adjacent heads:

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(21)     *-------*         *                            *       *
         *       *   *     *    *         (19b)     * *   *    *    *    *
       ([í.ki]).([tá.pa].re).([ré.pe].ha)    →      i.ki.([tá.pa].re).([ré.pe].ha)
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However, two problems arise for this analysis. First, the assumption that the head of the resolved foot occupies a single position on the grid is not independently motivated for Cayuvava. Its only motivation is to provide a natural status to destressing rule (20b), bringing it in line with Hammond’s (1984) *Clash Resolution Hypothesis*, according to which destressing rules must apply under clash. If each syllable were to occupy a single position on the grid, clash would no longer be present, and foot deletion would violate the Clash Resolution Hypothesis.

Another problem with foot deletion is that it predicts the existence of languages that resolve clash reversely, at the expense of the second foot (cf. ‘post-stress destressing’ in Hayes 1980). This would produce a pattern that is identical to Cayuvava, with the single difference that words of 3*n*+2 syllables are now stressed initially:

(22)
a. a.([rí.po].ro)
b. ([á.ri]).**pi.ri.to**
c. ([á.ri].hi).([hí.be].e)
d. ma.([rá.ha].ha).([é.i].ki)
e. ([í.ki]).**ta.pa.re**.([ré.pe].ha)
f. ([tʃá.a].di).([ró.bo].ßu).([rú.ru].ce)

This pattern, however, is unattested, and strikingly unnatural. As I will now show, both problems are avoided in an OT analysis that uses internally layered (henceforth *IL*) feet.

2.2.1 Internal layering theory

The following set of constraints are required to capture the stress pattern of Cayuvava in an OT analysis based on IL feet. First of all, FT-BIN must be replaced by a constraint requiring that heads be binary (Prince 1980, Dresher & Lahiri 1991):

(23) **HD-BIN**
Heads are binary under syllabic or moraic analysis.

Next, the IL counterpart of FT+σ is the 'nonfinality' constraint in (24):

(24) **MAX-FT**
No head of a foot must be final in the foot.

Using IL feet, the disjunction of contexts observed above with respect to the 'flat foot' constraint FT+σ disappears, in the spirit of Hammond's 'relativised extrametricality'. Unification of 'ternarity' and 'nonfinality' depends on reference to a unique *constituent*, the IL foot. (I will address the balance of functions between MAX-FT and NONFINALITY in section §2.3.)

Constraints are needed that prevent IL feet from growing too large. This is essential: once 'binarity' becomes a requirement of heads (rather than of feet), the maximal size of the foot must be controlled by different means. Different constraints come into play in restricting the distance of the head to both foot edges, left and right. Distance to the right edge is restricted by BOUND (cf. Prince 1980; Kager 1993):

(25) **BOUND**
No foot must end in a sequence of syllables outside the head.

This is essentially an anti-lapse constraint focussing on the right margin of the foot. The asymmetric nature of the constraint is crucial, and it will be motivated in §4.

To control the distance between the head and the left edge of the foot, I propose the following alignment constraint:

(26) **LEFT**
Align (Ft, L, Hd, L)
"Every foot must be head-initial."

Reproducing the metrification in (20) is possible, and it would require undominated MAXFT, LEFT and BOUND.[8] However, for general reasons that will become clear later, I will explore an alternative method of generating the Cayuvava pattern, which maintains PARSE-SYLL, rather than LEFT, as undominated. This ranking is given in (28):

(27) HD-BIN, PARSE-SYLL, BOUND » MAX-FT » LEFT » ALL-FT-R

Tableaux will illustrate this analyis, and motivate the rankings of individual constraints.

Let us start with words of 3*n* (3, 6, 9, etc.) syllables long. The crucial candidates of a six-syllable form are in tableau (28). Undominated PARSE-SYLL and BOUND eliminate the non-iterative candidates (28d) and (28e), respectively. The fully binary parse (28c) is rejected by MAX-FT, after which only two candidates remain. The single-footed (28b) falls victim to LEFT, so that double-footed (28a) is the optimal output, although it one that violates ALL-FT-R.

(28) /arihihibee/	HD-BIN	PARSE-SYLL	BOUND	MAX-FT	LEFT	ALL-FT-R
a. ☞ ([á.ri].hi).([hí.be].e)						***
b. (a.ri.hi.[hí.be].e)					*!**	
c. ([á.ri]).([hí.hi]).([bé.e])				*!**		**, ****
d. ([á.ri].hi.hi.be.e)			*!			
e. a.ri.hi.([hí.be].e)		*!**				

We now have evidence for LEFT » ALL-FT-R (28a versus 28b), as well as for BOUND » ALL-FT-R (28a versus 28d), and PARSE-SYLL » ALL-FT-R (28a versus 28e).

Turning now to 3*n*+1 syllable forms, we find additional evidence for LEFT » ALL-FT-R from the superiority of (29a) over (29c). Observe that this evidence is based on the *gradual* violation of LEFT, rather than on absolute violation, as in the previous tableau. In this tableau we also find evidence for 'directionality': candidates (29a, b) are evaluated as equal by PARSE-SYLL and by all four foot shape constraints (HD-BIN, BOUND, MAX-FT, LEFT). They only differ in the relative position of feet, and here (29a) is minimally better than (29b) in having one fewer violation mark of ALL-FT-R.

(29) /marahahaeiki/	HD-BIN	PARSE-SYLL	BOUND	MAX-FT	LEFT	ALL-FT-R
a. ☞ (ma.[rá.ha].ha).([é.i].ki)					*	***
b. ([má.ra].ha).(ha.[é.i].ki)					*	****!
c. (ma.ra.ha.ha.[é.i].ki)					**!**	
d. ([má.ra].ha).([há.e]).([í.ki])				*!*		**, ****
e. ([má.ra].ha.ha.e.i.ki)			*!|			
f. ma.ra.ha.ha.([é.i].ki)		*!***				

Finally, forms of 3*n*+2 syllables produce evidence for MAX-FT » LEFT. Tableau (30) shows candidates of a five-syllable form. The crucial pair of candidates are (30a) and (30b). The former satisfies LEFT while violating MAX-FT. The latter has the reverse pattern of violations.

(30) /aripirito/	HD-BIN	PARSE-SYLL	BOUND	MAX-FT	LEFT	ALL-FT-R
a. ☞ (a.ri.[pí.ri].to)					**	
b. ([á.ri].pi).([rí.to])				*!		**
c. ([á.ri].pi.ri.to)			*!			
d. a.ri.([pí.ri].to)		*!*				
e. ([á.ri].pi).([rí].to)	*!					**

Comparing the rule-based and OT versions of the (IL foot) analysis of Cayuvava, we find that the main advantage of OT resides in the analysis of words of 3*n*+2 syllables. We have seen earlier that such words are problematic in the rule-based analysis, where they necessitated a binary foot deletion rule (of questionable status).

'Foot maximality' actually becomes a violable constraint MAX-FT, which is ranked below PARSE-SYLL. This ranking correctly predicts that non-maximal feet occur under duress in disyllabic words, see (31):

(31) /dapa/	HD-BIN	PARSE-SYLL	BOUND	MAX-FT	LEFT	ALL-FT-R
a. ☞ ([dá.pa])				*		
b. da.pa		*				
c. ([dá].pa)	*!					

In sum, both the 'flat binary' and 'IL' OT analyses compare favorably to their rule-based counterparts. On comparing both OT models, it perhaps seems that, conceptually at least, the IL model is less adequate than its 'flat' counterpart. Not only does it require an additional level of prosodic structure in the foot, it also requires additional foot form constraints (as compared to the flat analysis) to limit maximal foot size (BOUND, LEFT). I have tabulated these functions, and corresponding constraints, in both models:

(32)		*Binarity*	*Ternarity*	*Maximality*	*Exhaustivity*
a.	Flat foot model:	FT-BIN	FT+σ	(*none*?)	PARSE-SYLL
b.	IL foot model:	HD-BIN	MAX-FT	BOUND, LEFT	PARSE-SYLL

However, when I will discuss the ternary stress pattern of Alutiiq in the next section, I will show that this advantage of the flat model is apparent only, since a constraint that regulates interstress distance is required in this model as well. The typological merits of both models will be compared in §4, using factorial typologies, as a result of which we will derive decisive evidence in favor of the IL model over the flat model.

2.3 MAX-FT and NONFINALITY

An important issue must be addressed before we continue. There is a familiar argument for adopting either 'ternary feet' or 'syllable extrametricality', but not both, in metrical theory. This is the observation that these devices never combine in any language. (If they were combinable, this would wrongly predict languages with pre-antepenultimate stress.) Transposing this argument to OT, are we forced to give up NONFINALITY upon assuming MAX-FT? This seems problematic because NONFINALITY combines multiple functions, all of which must be secured. Compare Prince & Smolensky's (1993:52) formulation:

(33) **NONFINALITY**
No head of PrWd is final in PrWd.

This is, in fact, a complex constraint, which collapses constraints (33a-b), each of which is motivated independently by Prince & Smolensky (1993:40, 43):

(34) a. The prosodic head of the PrWd does not fall on the word-final syllable.
b. The head foot of the PrWd must not be final.

Complexity of NONFINALITY is evident from Prince & Smolensky's assumption that each violation of (34a, b) counts *separately*. And in fact there is good evidence that part (34b) of NONFINALITY is still needed as a separate constraint: many languages avoid stress on a final syllable (Hayes 1995). I therefore assume a stripped version of NONFINALITY (34b).

3 Alutiiq

3.1 Flat binary feet

The ternary rhythmic pattern of Alutiiq (Leer 1985) was analysed in rule-based metrical theory by Halle (1990), Rice (1992), Kager (1993) and Hayes (1995). As other Yupik dialects, Alutiiq has iambic rhythm, and a syllable weight distinction (with long vowels and diphthongs counting as heavy). I will concentrate on words that consist entirely of light syllables. Here stress falls on the second and fifth syllables (generally, on syllables in position 3*n*-1 in the word), as well as on the final syllables of words of four or seven syllables long (generally, words with length 3*n*+1 syllables). The mixed binary-ternary stress pattern of Alutiiq was analysed using binary feet and weak local parsing by Hayes (1995)[9] and Kager (1993)[10]. The pattern which this produces is exemplified below:

(35)	a.	(**p**a.lá).yaq	'rectangular skiff'
	b.	(a.kú).(**t**a.mék)	*akutaq* (a food), abl.sg.
	c.	(**t**a.qá).ma.(**l**u.ní)	'apparently getting done'

d. (a.kú).tar.(**t**u.nír).tuq ‘he stopped eating *akutaq*’

e. (**m**a.ŋár).su.(**q**u.tá).(**q**u.ní) ‘if he (refl.) is going to hunt porpoise’

Lefthand foot edges are detectable in Alutiiq by their initial consonant, which is *fortis*, as has been indicated by boldface. This provides additional evidence for feet, apart from evidence from stress distribution. The rule set predicting pattern (35) is given in (36):

(36) a. Assign iambs from left to right, under weak local parsing.
b. Footing is persistent.

By *persistent footing* (36b), any pairs of syllables that are still unparsed after directional foot assignment must be footed:

(37) (ma.ŋár).<u>su</u>.(qu.tá).<u>qu</u>.ni → (ma.ŋár).su.(qu.tá).(**qu.ní**)

Persistent footing is a parametric option (specified on a language-specific basis). While Alutiiq selects it, Cayuvava clearly does not (as we infer from words of 3*n*+2 syllables, see previous section). The question then naturally arises whether the set of 'flat foot' constraints {FT-BIN, FT+σ, PARSE-SYLL, ALL-FT-X} suffice to capture all differences in metrification between Cayuvava and Alutiiq that Hayes (1995) attributes to persistent footing. Surprisingly, the answer to this question is negative. And once we have added a fifth constraint to the set, it will transpire that we no longer crucuially require FT+σ for ternary rhythm in Alutiiq.

We first establish that no interaction of constraints in the current set accounts for the pattern. First we run into a ranking paradox. On the one hand, FT+σ dominates PARSE-SYLL if we consider words of 3*n* syllables, since syllables remain unparsed in order to satisfy ternarity (cf. 38a). On the other hand, words of 3*n*+1 syllables require a reverse ranking PARSE-SYLL » FT+σ, since here violation of PARSE-SYLL is kept at a minimum, at the cost of violations of FT+σ (cf. 38b):

(38) a. 3*n* FT+σ » PARSE-SYLL
(a.kú).**tar**.(tu.nír).**tuq** > (a.kú).(tar.tú).(nir.túq)
b. 3*n*+1 PARSE-SYLL » FT+σ
(ma.ŋár).su.(qu.tá).(qu.ní) > (ma.ŋár).su.(qu.tá).**qu.ni**

The crucial difference between both cases (38a-b) is that in the latter case, the rejected candidate has a pair of adjacent unparsed syllables, while in the former case, unparsed syllables are separated by feet. Translation of 'persistent footing' into constraint format is now fairly straightforward:

(39) **PARSE-2**
One of two adjacent syllables must be parsed by a foot.

This is essentially a rhythmic constraint which penalises *lapses*[11]. A conceptual flaw is that PARSE-2 stipulates what reasonably ought to follow from the interaction of PARSE-SYLL and FT-BIN[12]. ('Whatever can be a foot, must be a foot'). Yet there is no adequate way to derive the effects of PARSE-2 from such interaction, for the following reason. Violation of PARSE-SYLL is directly proportional to the number of unparsed syllables in a candidate, regardless of their positions relative to one another. In contrast, PARSE-2 is sensitive to the positions of unparsed syllables. A candidate may easily satisfy PARSE-2 if it has multiple unparsed syllables, if only these are non-adjacent. See for example the lefthand structure in (38a).

There is a precedent in the OT literature for constraints that are sensitive to multiple violations on adjacent elements in a representation. Smolensky (1995) has argued for a so-called 'local' conjunction of two constraints into a new complex constraint. If this is feasible, PARSE-2 is simply a 'locally self-conjoined' version of PARSE-SYLL[13].

Let us now consider the ranking that is required for the stress pattern of Alutiiq. The undominated status of FT-BIN and PARSE-2 should be evident from the pattern (35). But in fact we need a third undominated constraint:

(40) **ALIGN-L**
Align (PrWd, L, Ft, L)

Without high-ranking ALIGN-L we would make incorrect predictions about the patterns of words of length 3*n*+1. Both of the candidates (41) satisfy PARSE-2. However, (41b) is superior to (41a), the desired candidate, with respect to FT+σ, as well as to both foot alignment constraints ALL-FT-L and ALL-FT-R:

(41) a. (ma.ŋár).su.(qu.tá).(qu.ní)
b. ma.(ŋar.sú).qu.(ta.qú).ni

It appears that, once we have PARSE-2 and ALIGN-L, crucial evidence for the ranking of FT+σ with respect to PARSE-SYLL vanishes. *All* ternarity effects can now be attributed to ALL-FT-R. See the ranking in (42):

(42) FT-BIN, ALIGN-L, PARSE-2 »ALL-FT-R » PARSE-SYLL, FT+σ

Paradoxically the 'left-to-right' ternary pattern is due to a foot alignment constraint that refers to the *right* edge, rather than the left edge.

This is illustrated in tableaux (43-44). Tableau (43) evaluates metrifications of a seven-syllable form. In general, forms of 3*n*+1 syllables must have minimally *n*+1 feet, if they are not to violate FT-BIN, ALIGN-L or PARSE-2. (With seven syllables, three feet are required.) The interesting two-foot candidate is (43f), which satisfies PARSE-2 while fatally violating ALIGN-L. All of the remaining triplet (43a-c) have three feet, with the leftmost foot initial. These are evaluated by ALL-FT-R, in favour of (43a):

(43) /maŋarsuqutaquni/	FT-BIN	ALIGN-L	PARSE-2	ALL-FT-R	FT+σ	PARSE-SYLL
a. ☞ (ma.ŋár).su.(qu.tá).(qu.ní)				**, *****	**	*
b. (ma.ŋár).(su.qú).ta.(qu.ní)				***, *****!	**	*
c. (ma.ŋár).(su.qú).(ta.qú).ni				*, ***, ***!**	**	*
d. (ma.ŋár).su.(qu.tá).qu.ni			*!	**, *****		***
e. ma.ŋar.su.qu.ta.(qu.ní)		*!	****			*****
f. ma.(ŋar.sú).qu.(ta.qú).ni		*!		*, ****		***
g. (ma.ŋar.su.qu.ta.qú).ni	*!			*		*

Observe that in making a choice among (43a-c), FT+σ is of no help at all, since all three candidates violate this constraint equally (all have two feet that are not followed by an unparsed syllable).

Tableau (43) produced no evidence for the ranking ALL-FT-R » PARSE-SYLL. This evidence is derived from tableau (44). the six-syllable form (44) is bound to a minimum of two feet, if it is not to violate any undominated constraint. (More generally, forms of 3*n* syllables need minimally *n* feet). Two candidates survive undominated constraints: a two-foot form (44a) and an exhaustively parsed three-foot form (44b). Here ALL-FT-R selects (44a) as optimal, since it has one fewer violation mark than its competitor (44b):

(44) /akutartunirtuq/	FT-BIN	ALIGN-L	PARSE-2	ALL-FT-R	FT+σ	PARSE-SYLL
a. ☞ (a.kú).tar.(tu.nír).tuq				*, ****		**
b. (a.kú).(tar.tú).(nir.túq)				**, ****!	***	
c. (a.kú).tar.tu.(nír.tuq)			*!	****	*	**
d. a.(ku.tár).tu.(nír.tuq)		*!		***	*	**

This produces the required argument for the ranking ALL-FT-R » PARSE-SYLL.

Observe the interesting behaviour of ALL-FT-R in (44): since its degree of violation is directly proportional to the sum of violations for individual feet, this constraint exerts pressure to minimise the number of feet (Kager 1994, Kenstowicz 1995). Foot number cannot drop below the minimum guaranteed by PARSE-2, however. Hence the net result of the ranking PARSE-2 » ALL-FT-X is a compromise: a *mixed ternary-binary* pattern.

3.2 Internally layered feet

Again, we compare the flat foot analysis with one in an IL model. A rule-based analysis of Alutiiq using internally layered feet was presented by Rice (1992). Metrifications as predicted by this analysis are exemplified in (45).

(45)	a.	([**p**a.lá].yaq)	'rectangular skiff'
	b.	([a.kú]).([**t**a.mék])	*akutaq* (a food), abl.sg.
	c.	([**t**a.qá].ma).([**l**u.ní])	'apparently getting done'
	d.	([a.kú].tar).([**t**u.nír].tuq)	'he stopped eating *akutaq*'
	e.	([**m**a.ŋár].su).([**q**u.tá]).([**q**u.ní])	'if he (refl.) is going to hunt porpoise'

Observe that the foot heads [...] correspond exactly with binary feet (...) of the analysis discussed in §3.1. The parsing of (45) was predicted by Rice (1992) by the rule set (46):

(46) a. Assign resolved iambs ([σσ]σ) or ([σσ]) from left to right.
b. Restructuring: ([σσ]σ) σ → ([σσ]) ([σσ])

Restructuring is the ternary-foot analogue of 'persistent footing': it is required in words of length 3*n*+1, which would otherwise be metrified with a final unparsed syllable. (The exhaustive parses are independently motivated by foot-initial fortition.)

(47) a. ([a.kú].ta).mek → ([a.kú]).([**t**a.mék])
b. ([ma.ŋár].su).([qu.tá].qu).ni → ([**m**a.ŋár].su).([**q**u.tá]).([**q**u.ní])

Rice argues that restructuring applies under pressure to achieve an exhaustive parsing, while avoiding a degenerate foot, a metrical ideal. This is a highly relevant observation, but I observe that rule-based theory requires a stipulation to this effect. Its equivalent of 'exhaustivity' is embodied by the principle of iterative footing. Undoing the outcome of iterative footing, in order to achieve even 'fuller' exhaustivity, misses a generalisation.

In OT, there is no such loss of generalisation. OT evaluates the 'input' and 'output' metrifications of 'restructuring' as candidates among many others. Exhaustively parsed (48b) is optimal due to the ranking PARSE-SYLL » MAX-FT:

(48) a. ([ma.ŋár].su).([qu.tá]).([qu.ní]) violates MAX-FT
b. ([ma.ŋár].su).([qu.tá].qu).ni violates PARSE-SYLL

The actual distribution of binary and ternary feet that we find in (48a) is regulated by a familiar constraint, ALL-FT-R, which attracts the smallest sized feet to the right edge of the word, since this produces the minimal total violation:

(49)

			Ft_1	Ft_2	Ft_3	*Total*
	a.	([ma.ŋár].su).([qu.tá]).([qu.ní])	-	**	****	******
	b.	([ma.ŋár]).([su.qú].σ).([qu.ní])	-	**	*****	*******!
	c.	([ma.ŋár]).([su.qú]).([ta.qú].ni)	-	***	*****	*******!*

That is, binary feet are stacked up at the right edge of the word. But once we have All-Ft-R, it turns out that the ranking of Max-Ft with respect to All-Ft-R can no longer be determined. All-Ft-R, all by itself, becomes the actual trigger of the ternary effect:

(50)		*Ft*$_1$	*Ft*$_2$	*Ft*$_3$	*Total*
a.	([a.kú].tar).([tu.nír].tuq)	-	***	-	***
b.	([a.kú]).([tar.tú]).([nir.túq])	-	**	****	****!**

All-Ft-R has the effect of minimising the number of feet, within the margins set by constraints that restrict foot size to either of the forms binary ([*Hd*]) or ternary ([*Hd*] σ). As we learned in §2.2, this restriction is due to combined effects of undominated Hd-Bin, Left and Bound. The total ranking is stated in (51a). Observe its close kinship to the ranking of Cayuvava, which I have repeated in (51b) from (28):

(51) a. Hd-Bin, Parse-Syll, Bound, **Left** » All-Ft-R, **Max-Ft** (Alutiiq)
b. Hd-Bin, Parse-Syll, Bound » **Max-Ft** » **Left** » All-Ft-R (Cayuvava)

The crucial difference between (51a-b) resides is the relative ranking of the foot shape constraints Left and Max-Ft. Since Left becomes undominated in Alutiiq, pre-head syllables are now completely ruled out (unlike Cayuvava). But since (as in Cayuvava) undominated Bound still limits post-head syllables to one, an extremely limited array of feet remains in Alutiiq: ternary ([Hd]σ) and binary ([Hd]). Under exhaustive parsing, these foot size restrictions necessarily go at the expense of Max-Ft.

Forms of 3*n*+1 syllables highlight the difference with Cayuvava, stemming from the promotion of Left over Max-Ft. The ternary-rhythmic candidate (52d), corresponding to the optimal metrification in Cayuvava, is now rejected by undominated Left. Under exhaustive parsing, and sharp restrictions on foot shape imposed by Left and Bound, violations of Max-Ft can no longer be avoided. The triplet (52a-b-c), all of which contain a combination of a ternary foot and two binary feet, are evaluated by All-Ft-R, which decides in favour of (52a).

(52) /maŋarsuqutaquni/	Hd-Bin	Parse-Syll	Bound	Left	All-Ft-R	Max-Ft
a. ☞ ([ma.ŋár].su).([qu.tá]).([qu.ní])					**, ****	**
b. ([ma.ŋár]).([su.qú].ta).([qu.ní])					**, *****!	**
c. ([ma.ŋár]).([su.qú]).([ta.qú].ni)					***, ***!**	**
d. (ma.[ŋar.sú].qu).([ta.qú].ni)				*!	***	
e. ([ma.ŋár].su.qu.ta.qu.ni)			*!			
f. ma.ŋar.su.qu.([ta.qú].ni)		*!***				

Tableau (53) of a 3*n*-syllable form shows how MAX-FT redundantly rejects a wholly binary parse (53b) in favour of a ternary parse (53a). Redundantly, that is, because ALL-FT-R already selects the same candidate - simply minimising the number of feet reduces the summed distances of all feet from the right word edge:

(53) /akutartunirtuq/	HD-BIN	PARSE-SYLL	BOUND	LEFT	ALL-FT-R	MAX-FT
a. ☞ ([a.kú].tar).([tu.nír].tuq)					***	
b. ([a.kú]).([tar.tú]).([nir.túq])					**, **!**	***
c. (a.[ku.tár]).(tu.[nir.túq])				*!*	***	
d. ([a.kú].tar.tu).([nir.túq])			*!		**	
e. a.ku.tar.([tu.nír].tuq)		*!				

That is, while MAX-FT might actually dominate ALL-FT-R, there is no crucial evidence for it - any effects of MAX-FT are equally well contributed to ALL-FT-R. (But only the latter constraint, not the former, explains the distribution of feet in 3*n*+1 forms, see 52).

Even though the OT analysis and rule-based analysis (with internally layered feet) are empirically equivalent, the OT analysis is conceptually superior. It directly captures the ‘pressure towards exhaustivity’ into an undominated constraint, while the rule-based analysis requires a stipulation to that effect, as well as restructuring.

To conclude this section, let us briefly look into cases that involve heavy syllables. A small representative set of examples is given in (54), metrified by IL feet[14]:

(54)	a.	([**t**aá]).([**t**a.qá)	‘my father’
	b.	([**n**aá].ma).([**c**i.qúq])	‘it will suffice’
	c.	([**n**aá].qu).([**m**a.lú].ku)	‘apparently reading it’
	d.	([**n**aá]).([**m**a.cí]).([**q**uá])	‘I will suffice’

To accomodate quantity-sensitivity into the analysis, the following two constraints are required, both undominated:

(55) a. **HD-BIN-μ** (Kager 1993)
Heads-of-feet are binary under moraic analysis.

b. **WSP** (Prince & Smolensky 1993)
Heavy syllables must be prominent.

Tableau (56) shows how a sequence of two light syllables lying between two heavy syllables is forced into a binary foot. Ternary candidates are effectively rejected by the battery of undominated constraints.

(56) /naamaciqua/	HD-BIN-µ	WSP	PARSE-SYLL	BOUND/LEFT	ALL-FT-R	MAX-FT
a. ☞ ([naá]).([ma.cí]).([quá])					*, ***	
b. ([naá].ma).(ci.[quá])				*!	**	*
c. ([naá].ma).ci.([quá])			*!		**	*
d. ([naá]).([ma.cí].qua)		*!			***	*
e. ([naá].ma).([ci.quá])	*!				**	*

The input of tableau (57) has the same number of moras as that in (56), but the last two form two light syllables, rather than a single heavy syllable. A ternary foot is prompty selected here:

(57) /naaqumaluku/	HD-BIN-µ	WSP	PARSE-SYLL	BOUND/LEFT	ALL-FT-R	MAX-FT
a. ☞ ([naá].qu).([ma.lú].ku)					***	
b. ([naá]).([qu.má]).([lu.kú])					**, **!**	
c. ([naá.qu].ma).([lu.kú])	*!				**	

4. Internally layered versus flat feet: The factorial typologies

So far in this paper we have seen how internally layered feet and flat feet are employed to analyse the ternary stress patterns of two languages, Cayuavava and Alutiiq. We saw that in rule-based theory, 'flat feet' (Hayes 1995) have two major advantages over IL feet (Dresher & Lahiri 1991). First, flat feet allow a more restricted foot inventory, as no special ternary feet are required. Secondly, flat feet require no restructuring rules on the output of foot assignment (only 'structure-preserving' persistent footing), in contrast to IL feet, which require restructuring (both foot deletion and foot re-bracketing).

We also saw that OT versions of these analyses have some distinct advantages over the corresponding rule-based analyses. Moreover, OT makes both of the advantages that the 'flat' model had over the 'IL' model evaporate. Firstly, size of the foot inventory is not an issue in OT, because constraints alone determine metrical well-formedness. The foot inventory rather becomes an epiphenomenon of constraint interactions. Secondly, the IL-specific problem of restructuring is resolved naturally, since OT defines metrical well-formedness on outputs only, hence requires no restructuring in principle. Should we then conclude that the representation of ternarity ('flat feet' versus internally layered feet) is in fact a *non-issue*? More generally, does OT lead to the inevitable conclusion that representations are of far less importance than we assigned to them until recently? The rest of this paper is devoted precisely to this issue - I will show that phonological representation still matters, in the sense that it empirically affects the choice of proper constraints. Specifically, constraint sets which omit reference to internally layered feet produce flawed factorial typologies.

One particularly useful way of addressing the issue of 'flat' vs. 'internally layered' feet is constructing factorial typologies that result from a total permutation of metrical constraints that refer to either foot type. If we compare these factorial typologies on the criterion of how closely they match actually attested stress systems, we may find reasons to prefer one set of constraints over the other. Any adequate typology should contain all attested core metrical systems (typologies based on a principle-and-parameter approach are presented in Hayes 1980, 1995), while ideally it should not contain more than these. A priori we should not expect a hundred percent match between predicted and attested systems. Hence my evaluation will not involve the simple counting of individual patterns, but rather recurrent classes of patterns which are produced by factorial typologies. I will be particularly sensitive to classes of patterns that are not empirically attested.

Below I will present the factorial typologies that arise from a permutation of a set of metrical constraints. This is a task of considerable analytic complexity, given the number of possible constraint rankings. With seven constraints, the number of rankings is 7! or 5040, with eight contraints 8! or 40320, etc. The actual number of generated patterns is far smaller than this, due to the fact that formally distinct rankings very often produce identical patterns. With the constraints that I have used, this effect by itself produces a reduction by at least 99%. Nevertheless, to decrease the complexity of the comparison, I have chosen to consider only constraints which have crucial relevance to ternarity, that is: constraints which determine the relative position of feet with respect to one another, and with respect to domain edges. Among these are two types of alignment constraint, ALIGN-X and ALL-FT-X, where 'X' is an edge, either left or right. Next I have included constraints that determine the density of foot parsing, that is PARSE-SYLL, and in the case of binary feet, PARSE-2. Distance between stresses, and distance from the right edge, are regulated by MAX-FT in IL theory, and by FT+σ in 'flat foot' theory. I did not include in the factorial typology any constraints governing quantity-sensitivity, foot headedness, or the distinction of main stress versus secondary stress. So in fact what I will develop are the factorial typologies of quantity-insensitive styles of alternation.

Crucially I assume that 'flat' and 'internally layered' OT models are distinguished by their constraint inventories only. This implies that both models evaluate identical sets of candidate outputs, as provided by the *Generator* component. The presence of internal layering is not determined by *Gen*: in fact we may assume that *Gen* supplies any kind of feet, both flat and internally layered, or actually of any kind imaginable. Representational distinctions are detectable only due to constraints that refer to them: distinctions that are never referred enjoy the freedom of being vacuously generated. Nevertheless, to keep the analytic task within reasonable limits, I have chosen to neglect candidate metrifications that contain 'degenerate' (or monomoraic) feet (flat theory) or heads (IL theory). This is not a method of promoting strict binarity into the realms of the universally undominated (although this claim has often been made in the literature). I took this decision on purely methodological grounds: all ternary systems which are known from the literature enforce binarity. Here the main goal of the factorial typologies is to evaluate achievements of two constraint sets with respect to ternary rhythm against *attested* systems. For that reason 'degenerate' feet are not primarily at issue here. (See Green 1994 for discussion.)

As to the results, I will show that both models adequately cover the range of attested stress systems. However, flat foot theory is hampered by serious empirical defects, since it overgenerates to a much larger extent. In particular, some patterns that flat foot theory predicts are of a *non-directional* nature, which is not attested in any language (known from the literature). This overgeneration stems mostly from the interaction of constraints that do not refer to any metrical domain: FT+σ and PARSE-2. In contrast, IL theory does not produce any patterns of this kind, since the analogous constraints of IL theory, MAX-FT and BOUND, refer to a natural metrical domain: the IL foot.

4.1 A factorial typology of internal layering theory

Let us first consider the factorial typology of internal layering theory. Constraints in this theory refer to subconstituents of the foot: the *head* and the *non-head*[15]. Unless specified otherwise, the notion 'head' (of a foot) is taken as exclusively referring to the obligatory foot-internal constituent, not to its strongest syllable. I will consistently assume the head to be binary, not for principled reasons, but for practical ones explained above. Therefore no permutations based on HD-BIN will be considered. A second factor that I will not vary in factorial typology is head-internal prominence, that is, the distinction between trochees and iambs. This decision is based on the finding that style of rhythmic alternation (binary, ternary, or mixed), as resulting from the IL constraint set that I assume, is independent of head-internal prominence. Head-internal prominence is determined by the constraints in (58); heads will be trochaic (as in Cayuvava) when (58a) dominates (58b), and they will be iambic (as in Alutiiq) under the reverse ranking[16]:

(58) a. **TROCHAIC-HD**
Heads are labeled SW.

b. **IAMBIC-HD**
Heads are labeled WS.

A factorial typology of IL theory involves a reranking of four foot shape constraints:

(58)	a.	**BIN**	Align (Foot, Right, Head, Right)
	b.	**LEFT**	Align (Head, Left, Foot, Left)
	c.	**MAX-FT**	The head is non-final in the foot.
	d.	**BOUND**	No sequence of non-head syllables at the end of the foot.

Of these four, the latter three have been introduced earlier in this paper. The fourth, BIN, will be required in the analysis of totally binary stress systems. I assume PARSE-SYLL, governing exhaustivity of metrification, and two kinds of alignment constraints governing relative position of feet with respect to PrWd edges (‘X’ is an edge, either right or left):

(59) a. **PARSE-SYLL** Syllables must be parsed into feet.
b. **ALIGN-X** Align (PrWd, X, Ft, X)
c. **ALL-FT-X** Align (Ft, X, PrWd, X)

Surprisingly, an complete array of core metrical systems arises within a single main branch of the factorial typology. This is the one in which PARSE-SYLL is undominated, by the re-ranking of foot shape constraints and ALL-FT-X. With undominated PARSE-SYLL, the PrWd-alignment constraints ALIGN-L and ALIGN-R no longer function in evaluation, as both are automatically satisfied. Functions attributed to these constraints by McCarthy & Prince (1993b), crucial in bidirectional stress systems, are shifted to other constraints, in particular the foot shape constraints LEFT and BIN, and ALL-FT-X. To emphasise this major property of IL theory (that exhaustive parsing yields the full typology of attested core systems), I will first develop the sub-typology that keeps PARSE-SYLL undominated, before developing remaining sub-typlogies. Rankings that have independent significance (outside undominated PARSE-SYLL) all involve undominated ALIGN-X. However, it will turn out that hardly any of these predicted systems are empirically attested. I will argue that IL theory may safely eliminate ALIGN-X, since this constraint type is not crucial in generating any attested systems; on the contrary, it only adds non-attested systems to the factorial typology.

A broad typology is laid out below. The major three types of systems are (57a-c):

(60) I. PARSE-SYLL undominated:

a. PARSE-SYLL, ALL-FT-X » foot shape constraints (§4.1.1)
NON-iterative systems.

b. PARSE-SYLL, LEFT ~ BIN » ALL-FT-X » MAX-FT (§4.1.2)
BINary systems:

b.i PARSE-SYLL, LEFT » BIN » ALL-FT-X » MAX-FT
BINary systems, left-edge aligned.

b.ii PARSE-SYLL, BIN » LEFT » ALL-FT-X » MAX-FT
BINary systems, right-edge aligned.

c. PARSE-SYLL, LEFT, BOUND » ALL-FT-X » BIN (§4.1.3)
MIxed binary-ternary systems.

d. PARSE-SYLL, MAX-FT, BOUND » ALL-FT-X » BIN (§4.1.4)
TErnary systems.

II. Residual systems: ALIGN-X » ALL-FT-X » PARSE-SYLL (§4.1.5)
DOuble-edge iterative and non-iterative systems (none attested).

4.1.1 PARSE-SYLL and ALL-FT-X undominated: Non-iterative systems

I start my expose by examining the consequences of undominated PARSE-SYLL and ALL-FT-X, which produces non-iterative systems. These have a single stress near the (left or right) edge of PrWd, with apparently no rhythmic stresses. The key insight is that with undominated ALL-FT-X, there can be only one foot, situated at edge 'X'. (For 'X', either left or right will do.) When this foot spans the entire domain, as will be the case under undominated PARSE-SYLL, the location of the single stress coincides with the foot head. Its position follows from the interaction of foot shape constraints that are independently motivated in 'iterative' stress systems. The typology branches out into three systems:

(62)	a.	([σ σ] σ)	PARSE-SYLL, ALL-FT-X, LEFT » BIN	
		([σ σ] σ σ σ σ σ)	Left-edge stress.	(First or second syllable)
	b.	(σ [σ σ])	PARSE-SYLL, ALL-FT-X, BIN » LEFT	
		(σ σ σ σ σ [σ σ])	Right-edge stress.	(Penult or final syllable)
	c.	([σ σ] σ)	PARSE-SYLL, ALL-FT-X, MAX-FT » BIN » LEFT	
		(σ σ σ σ [σ σ] σ)	Near-right-edge stress.	(Antepenult or penult)

All of these patterns are instantiated. Well-known examples are Czech (initial stress) for (62a), French (final stress) for (62b), and Macedonian (antepenultimate stress) for (62c).

In sum, we find that long words can be analysed as single-foot PrWds, in which the head stands near an edge, determined by the interaction of three independently required foot shape constraints: LEFT, BIN, and MAX-FT.

4.1.2 PARSE-SYLL, plus LEFT or BIN undominated: Binary systems

We now enter the sub-typology of iterative binary systems, which are characterised by sequences of stresses at binary intervals that span the entire PrWd domain. The typology is developed by a re-ranking of LEFT, BIN, and ALL-FT-X, while keeping other foot form constraints dominated. As I will show, both 'uni-directional' and 'bi-directional' systems may emerge without assistance of the PrWd-alignment constraints ALIGN-L and ALIGN-R. This approach crucially differs from the standard alignment analysis of bidirectionality (McCarthy & Prince 1993b), which depends on PrWd-alignment.

The key insight is that under exhaustivity, 'iterativity' is enforced by restricting the distance between a foot head and both edges of the foot. Since every foot is 'bound' at both edges, while exhaustivity is still imperative, a metrification into multiple feet results. For binary rhythm, this idea involves a reranking of two foot shape constraints: LEFT and BIN. Both must crucially dominate ALL-FT-X, since otherwise we would, again, generate non-iterative systems (which were discussed already in the previous section).

This subtypology branches out into two directions, depending on the relative ranking of LEFT and BIN.

(63) a. PARSE-SYLL, LEFT » BIN » ALL-FT-X » MAX-FT
Binary systems, left-edge aligned.
b. PARSE-SYLL, BIN » LEFT » ALL-FT-X » MAX-FT
Binary systems, right-edge aligned.

Systems of the type (63a) are characterised by left-aligned feet ([Hd]σ) and ([Hd]), while systems of the type (63b) have right-aligned feet (σ[Hd]) and ([Hd]). This choice can be made on the basis of three-syllable words, while longer odd-numbered words determine the choice of edge toward which the rhythm is oriented. Minimal violation of foot shape constraints predicts that maximally one non-binary foot may occur per PrWd. (Multiple non-binary feet per PrWd add - unnecessary - extra violations of either LEFT or BIN.)

The rhythmic type of (63a) is exemplified by Pintupi (Hansen & Hansen 1969, Hayes 1995), which has stress on the initial syllable and on following alternating syllables. Feet are oriented toward the left edge by ALL-FT-L. The corresponding bidirectional system is exemplified by Garawa (Furby 1974, Hayes 1980), which has stress on the initial syllable, and on alternating syllables preceding the penult. Here feet are oriented toward the right edge, due to ALL-FT-R:

(64) a. Pintupi: PARSE-SYLL, LEFT » BIN » ALL-FT-L

([ŋú.nʲi].tʲu)	‘mother’
([pú.liŋ]).([kà.la].tʲu)	‘we (sat) on the hill’
([tʲá.mu]).([lìm.pa]).([tʲùŋ.ku])	‘our relation’
([tʲí.ɭi]).([rì.ŋu]).([làm.pa].tʲu)	‘the fire for our benefit flared up’

b. Garawa: PARSE-SYLL, LEFT » BIN » ALL-FT-R

([pún.ja].ɭa)	‘white’
([ká.ma].ɭa).([ɽì.ɲi])	‘wrist’
([yá.ka]).([là.ka]).([là.mpa])	‘loose’
([ŋán.ki].ɽi).([kì.rim]).([pà.yi])	‘fought with boomerangs’

A mini-tableau of a five-syllable form of Pintupi is presented in (65):

(65)	Input: /puliŋkalatʲu/	LEFT	BIN	ALL-FT-L
a.	☞ ([pú.liŋ]).([kà.la].tʲu)		*	**
b.	([pú.liŋ].ka).([là.tʲu])		*	***!
c.	([pú.liŋ].ka.la.tʲu)		**!*	
d.	(pu.[líŋ.ka]).([là.tʲu])	*!		***
e.	([pú.liŋ]).(ka.[là.tʲu])	*!		**

Let us now discuss systems that have the reverse ranking BIN » LEFT. A well-known uni-directional example is Warao (Osborn 1966, Hayes 1980), which stresses the penult and preceding alternating syllables. The corresponding bidirectional system is exemplified by Piro (Matteson 1965), which stresses the penult and alternate syllables following the initial syllable[17]:

(66) a. Piro: PARSE-SYLL, BIN » LEFT » ALL-FT-L

(ru.[t͡xí.t͡xa])	'he observes taboo'
([sà.lwa]).(ye.[hká.kna])	'they visit each other'
([pè.tʃi]).([tʃhì.ma]).([tló.na])	'they say they stalk it'
([rù.slu]).([nò.ti]).(ni.[tká.na])	'their voices already changed'

b. Warao: PARSE-SYLL, BIN » LEFT » ALL-FT-R

(ko.[rá.nu])	'drink it!'
(yi.[wà.ra]).([ná.e])	'he finished it'
([yà.pu]).([rù.ki]).([tà.ne]).([há.se])	'verily to climb'
(e.[nà.ho]).([rò.a]).([hà.ku]).([tá.i])	'the one who causes him to eat'

A tableau of a five-syllable word of Warao is given in (67):

(67)	Input: /yiwaranae/	BIN	LEFT	ALL-FT-R
a.	☞ (yi.[wà.ra]).([ná.e])		*	**
b.	([yì.wa]).(ra.[ná.e])		*	***!
c.	(yi.wa.ra.[ná.e])		**!*	
d.	([yì.wa].ra).([ná.e])	*!		**
e.	([yì.wa]).([rá.na].e)	*!		***

This typology of binary rhythm based on undominated PARSE-SYLL comes extremely close to exhausting the range of empirically attested quantity-insensitive patterns.[18] This analysis characterises binary systems as systems that maximise binary feet, and only allow ternary feet under duress (HDBIN, PARSE-SYLL), always at the edge of the domain. This seems to predict that languages should occur that follow the opposite trend: maximising ternarity, and allowing for binarity under duress. We will see this prediction come true in §4.1.3: these are 'mixed' binary-ternary systems, of which we already encountered a real example: Alutiiq.

4.1.3 PARSE-SYLL, LEFT, BOUND undominated: Mixed binary-ternary systems

Genealogically speaking, the closest relatives of the all-binary systems of §4.1.2 are those that minimally differ in the pair of foot shape constraints dominating ALL-FT-X. Suppose that instead of LEFT and BIN, we would select LEFT and BOUND as a pair, again a pair of constraints that restrict the distance between the head and both foot edges.

Promptly we are presented with mixed binarity-ternarity, as seen earlier in Alutiiq in §3.1.

The undominated ranking of PARSE-SYLL, LEFT and BOUND produces a metrification into mixed binary-ternary feet, but only if an important condition is met. That is, ALL-FT-X dominates BIN, in order to give ALL-FT-X its 'foot-expanding' function (as in 68). The reverse ranking only produces an alternative source of the Pintupi pattern. See (68b):

(68)	a.	PARSE-SYLL, LEFT, BOUND » ALL-FT-X » BIN	(binary-ternary: Alutiiq)
	b.	PARSE-SYLL, LEFT, BOUND » BIN » ALL-FT-X	(binary: Pintupi)

(Relative ranking of LEFT, BOUND is immaterial, since these constraints do not conflict.)

A crucial consequence of the demotion of BIN below ALL-FT-X is that feet come to enjoy the additional freedom to expand beyond the (binary) maximum which BIN allows. However, feet must still not grow larger than the maximum size imposed by BOUND: this is maximally one syllable following the head. The question then is: what constraint causes that feet actually take this freedom, and readily expand into ternarity? The answer was already given in the analysis of Alutiiq (and it was suggested even earlier by Kager 1994 and Kenstowicz 1995): given some constraint limiting interstress distance, ALL-FT-X will have the effect of minimising the number of feet, hence maximise their size.

We start to explore the effects of ranking (68a) by examining possible metrifications that are allowed by the undominated constraints PARSE-SYLL, LEFT and BOUND. In fact, the metrifications of words of two, three, or four syllables long are uniquely determined by these undominated constraints:

(69) a. ([σ σ]) b. ([σ σ] σ) b. ([σ σ]) ([σ σ])

In words of five or seven syllables it becomes impossible to achieve exhaustivity without using *both kinds of feet* within the same word (for five syllables, one of each kind; for seven syllables, one ternary foot and two binary feet). The choice between metrifications at the top and bottom is due to different relative rankings of ALL-FT-L and ALL-FT-R:

(70)	a.i	([σσ]) ([σσ]σ)	b.i	([σσ]) ([σσ]) ([σσ]σ)	ALL-FT-L
	a.ii	([σσ]σ) ([σσ])	b.ii	([σσ]σ) ([σσ]) ([σσ])	ALL-FT-R

Observe that ALL-FT-X automatically places binary feet at the 'X' edge of the word.

So far there is still not a single difference with the metrifications of binary systems of §4.1.2. However, in words of six and eight syllables (and longer words) there is finally a choice between metrifications into feet of different sizes:

(71)	a.i	([σσ]) ([σσ]) ([σσ])	b.i	([σσ]) ([σσ]) ([σσ]) ([σσ])	BIN
	a.ii	([σσ]σ) ([σσ]σ)	b.ii	([σσ]) ([σσ]σ) ([σσ]σ)	ALL-FT-L
				([σσ]σ) ([σσ]σ) ([σσ])	ALL-FT-R

Among the possibilities depicted in (71), ALL-FT-X selects metrifications with a minimal number of feet, as these violate ALL-FT-X minimally (recall that each foot which is not at edge X contributes a violation). Under exhaustive parsing, *minimising* the number of feet automatically *maximises* their size, so that ternarity prevails. Moreover, binary feet (if any) cluster at the edge specified in ALL-FT-X, again keeping violation of this constraint to a minimum. These effects (foot size maximisation, and clustering of binary feet at edge 'X') together produce a mixed binary-ternary rhythm. To see how this works in an actual example, reconsult tableau (52-53) of §3.2.

When all the above outputs for different word lengths are combined for PARSE-SYLL » ALL-FT-R, we arrive at the pattern of Alutiiq (iambic heads), and of one of the possible patterns of Estonian (trochaic heads; Hint 1973, Prince 1980, Hayes 1995, Kager 1994):

(66) a. Alutiiq: PARSE-SYLL, LEFT, BOUND » ALL-FT-R » BIN

([**p**a.lá].yaq)	'rectangular skiff'
([**t**a.qá].ma).([**l**u.ní])	'apparently getting done'
([a.kú].tar).([**t**u.nír].tuq)	'he stopped eating *akutaq*'
([**m**a.ŋár].su).([**q**u.tá]).([**q**u.ní])	'if he (refl.) is going to hunt porpoise'

b. Estonian-1: PARSE-SYLL, LEFT, BOUND » ALL-FT-R » BIN

([pí.mes].tav)	'blinding'
([pí.mes].ta).([và.le])	'blinding' (ill.sg.)
([ó.sa].va).([mà.le].ki)	'also more skillful' (abl.sg.)

The interest of Estonian resides in the fact that it has multiple rhythmic patterns, in a free distribution, which are overlapping. For example, next to 'Estonian-1' there is an option of stressing the penult in five-syllable words ('Estonian-2'), which arises by a selection of ALL-FT-**L**. For six-syllable words, a binary pattern is equally possible as well, as seen in 'Estonian-3/4', which are identical to the patterns of Pintupi and Garawa, respectively.

(67) a. Estonian-2: PARSE-SYLL, LEFT, BOUND » ALL-FT-**L** » BIN

([pí.mes].tav)	'blinding'
([pí.mes]).([tà.va].le)	'blinding' (ill.sg.)
([ó.sa].va).([mà.le].ki)	'also more skillful' (abl.sg.)

b. Estonian-3: PARSE-SYLL, LEFT, BOUND » **BIN** » ALL-FT-**L** (=Pintupi)

([pí.mes].tav)	'blinding'
([pí.mes]).([tà.va].le)	'blinding' (ill.sg.)
([ó.sa]).([và.ma]).([lè.ki])	'also more skillful' (abl.sg.)

c. Estonian-4: PARSE-SYLL, LEFT, BOUND » **BIN** » ALL-FT-**R** (=Garawa)

([pí.mes].tav)	'blinding'

([pí.mes].ta).([và.le])	‘blinding’ (ill.sg.)
([ó.sa]).([và.ma]).([lè.ki])	‘also more skillful’ (abl.sg.)

The genealogical proximity of 'binary' Pintupi-like systems and 'mixed ternary-binary' Alutiiq-like systems is demonstrated by their combined appearance in a single language. (The additional interest of Estonian resides in its quantity-sensitive restrictions on stress variability, which is based on a three-way length contrast of syllable weight. Prince 1980, Hayes 1995, and Kager 1994 offer discussion from various perspectives.)

Finally, let us consider other minimal variations on the theme of the general ranking that produces iterative rhythm:

(69) PARSE-SYLL, {*Foot-shape*-1} » ALL-FT-X » {*Foot-shape*-2}

If we wish to avoid any duplications of non-directional patterns, the part {*Foot-shape*-1} must contain minimally two constraints restricting the distance of the head to both edges of the foot. For the left edge, this can only be LEFT. For the right edge, a choice occurs between BIN and BOUND that I have already fully explored in the previous two sections. What remains to be developed are subrankings of (69) that involve a promotion of MAX-FT over ALL-FT-X. These are the topic of the next section.

4.1.4 PARSE-SYLL, MAX-FT undominated: Ternary systems

Moving still farther away from the binary systems of §4.1.2, and the mixed binary-ternary systems of §4.1.3, we now arrive at full ternarity. Fully ternary systems are characterised by undominated PARSE-SYLL and MAX-FT.[19] Again we find relevant a pre-condition for 'iterativity': the domination of ALL-FT-X by the 'left-edge delimiter' LEFT, as well as one of the two 'right-edge delimiters' BIN or BOUND.

The typology of 'absolute' ternarity can be developed by substituting MAX-FT in the skeletal ranking in (69), and permuting other foot shape constraints. Then two rankings arise that have independent significance:

(70) a. PARSE-SYLL, MAX-FT, BOUND » LEFT » ALL-FT-X
Ternary, fixed stress near right edge.

b. PARSE-SYLL, MAX-FT, LEFT » BOUND » ALL-FT-X
Ternary, fixed stress near left edge.

I will now discuss these patterns in this order.

The pattern (70a) is attested in Cayuvava, as we have already seen illustrated in §3.2. It has an (unattested) counterpart that is based on the reverse ranking of foot alignment constraints (with ALL-FT-L taking precedence). Note, however, that the subtle difference between these patterns is revealed only in words of minimally seven syllables long:

(71)

	a. Cayuvava (ALL-FT-R)	b. Unattested (ALL-FT-L)
3	([tó.mo].ho)	([σσ]σ)
4	(a.[rí.po].ro)	(σ[σσ]σ)
5	(a.ri.[pí.ri].to)	(σσ[σσ]σ)
3*n*	([á.ri].hi).([hí.be].e)	([σσ]σ) ([σσ]σ)
3*n*+1:	(ma.[rá.ha].ha).([é.i].ki)	([σσ]σ) (σ[σσ]σ)
3*n*+2:	(i.ki.[tá.pa].re).([ré.pe].ha)	([σσ]σ) (σσ[σσ]σ)

The fact that words of such (excessive) length are necessary to reveal the distinction is a possible explanation for the lack of cross-linguistic contrast.

Pattern (70b) is completely unattested; hypothetical metrifications are given below:

(72)

	a. Unattested (ALL-FT-R)	b. Unattested (ALL-FT-L)
3	([σσ]σ)	([σσ]σ)
4	([σσ]σσ)	([σσ]σσ)
5	([σσ]σσσ)	([σσ]σσσ)
3*n*	([σσ]σ) ([σσ]σ)	([σσ]σ) ([σσ]σ)
3*n*+1:	([σσ]σσ) ([σσ]σ)	([σσ]σ) ([σσ]σσ)
3*n*+2:	([σσ]σσσ) ([σσ]σ)	([σσ]σ) ([σσ]σσσ)

Again, we find that long words (of minimally seven syllables) are required to distinguish both patterns. The fact that neither has been attested may have to do with the fact that a minimal word length of six syllables is required to for multiply stressed-patterns to arise. Note also that such systems are incorrectly predicted by any theory, that is binary or IL, and rule-based or OT. (Rule-based IL theory achieves this by a rule deleting a binary foot in clash, as in Cayuvava, cf. Dresher & Lahiri 1991.) Perhaps a more general explanation for the rareness of fully ternary patterns (only a single language, Cayuvava, is attested) is that these are (too) easily confused with non-iterative patterns.

This completes the subtypology of undominated PARSE-SYLL. In sum, we have found that all predicted patterns are instantiated (with varying degrees of frequence), with the single exception of a handful of fully ternary patterns. When we apply the ‘all-and-only’ criterion of factorial typology, we have now fulfilled the ‘only’ part. Moreover, since as we will see in the next section, the number of empirically attested ‘core’ metrical systems that falls outside this typology is extremely small, the second (‘all’) criterion is also close to being fulfilled. We might be tempted to ‘hard-wire’ exhaustivity into *Gen*, by making PARSE-SYLL universally undominated. However, such a move is completely unnecessary. As long as re-rankings of the constraints in the current set produce no additional patterns that are empirically unattested, we may still consider PARSE-SYLL to be equally violable as any other constraint in the set. However, the results booked so far may cast doubts on the necessity of ALIGN-X, since it was totally irrelevant to these results. In fact, we will see in the next sub-section that empirical arguments for ALIGN-X are fairly weak.

4.1.5 Residual rankings based on undominated ALIGN-X

A number of rankings with independent significance remain to be discussed, all of which are based on undominated ALIGN-X. By 'independent significance' I mean the following. Many rankings in which PARSE-SYLL is crucially dominated, duplicate patterns that were discussed earlier. More precisely, rhythmic patterns are identical, but metrifications may be different. These differences never reside in positions of heads, but always in outer foot bracketing.

For example, any ranking that has ALL-FT-L, LEFT, and BIN undominated, necessarily result in a single strictly binary foot at the left word edge. This stress pattern (first or second syllable stress, dependent on trochaic or iambic prominence) is identical to what results from undominated ALL-FT-L, LEFT, and PARSE-SYLL. Below is an overview of rankings that reproduce familiar patterns:

(73)	a.i	BIN, LEFT, ALL-FT-L » PARSE-SYLL » MAX-FT	(Initial/second)
	a.ii	BIN, LEFT, ALL-FT-R » PARSE-SYLL » MAX-FT	(Penult/final)
	a.ii	MAX-FT, LEFT, BOUND, ALL-FT-R » PARSE-SYLL	(Antepenult/penult)
	b.i	BIN, LEFT » PARSE-SYLL » ALL-FT-X	(Pintupi/Warao)
	b.ii	BIN, LEFT, ALIGN-X » PARSE-SYLL » ALL-FT-Y	(Piro/Garawa)
	c.i	MAX-FT, LEFT, BOUND » PARSE-SYLL » ALL-FT-X	(Cayuvava 71a/72b)
	c.ii	MAX-FT, LEFT, BOUND, ALIGN-**X** » PARSE-SYLL » ALL-FT-**Y**	(71b/72a)

There are potential empirical consequences of differences in foot bracketing, but it has proved difficult to metrical phonologists to find much evidence of this type. Hence I will leave this issue open, and concentrate on patterns that are distinct by the position of the head (from the ones we have already seen).

The empirical contribution of ALIGN-X to the factorial typology resides entirely in the generation of what I will refer to as 'double-edge' patterns. These are patterns in which stress is fixed at both edges of the word, independently of factors that determine rhythm in between. Two sorts of 'double-edge' patterns are predicted: non-iterative 'hammock' patterns, in which both edges are marked by stresses, but medial stresses are absent; and their iterative counterparts, which I will refer to as 'complex bi-directional'.

Some rankings which produce 'hammock' systems (with a single foot at one edge of the domain, and another at the opposite edge) have the following form:

(74) ALIGN-X » ALIGN-Y » ALL-FT-X » PARSE-SYLL

By inserting foot shape constraints into this frame, modulations arise that determine the feet at both edges of the word. When both feet must be binary, the patterns in (75) arise:

(75) Bin, Left, Align-X » Align-Y » All-Ft-X » Parse-Syll

a. ([σσ])σ
([σσ])([σσ])
([σσ])σσσσσσ([σσ])

b. σ([σσ])
([σσ])([σσ])
([σσ])σσσσσσ([σσ])

The ‘initial plus penult’ pattern is attested in Gugu-Yalanji (Oates & Oates 1964), and its mirror image ‘penult plus initial’ pattern in Sibutu Sama (Allison 1979). Corresponding ternary patterns (e.g. ‘antepenult plus initial in words of *minimally six* syllables’) are unattested. Observe that no ranking (of constraints in the current set) that is based on undominated Parse-Syll can generate ‘hammock’ patterns. Exhaustive parsing already implies that both word edges coincide with foot edges. Therefore any relaxation of foot shape constraints that is necessary to expand one of both feet, will be extended to select a single foot spanning the entire word, since this involves no violation of All-Ft-X. But in fact, other (independently required) constraints my be active here, such as Edgemost (Prince & Smolensky 1993), requiring that the prominence peak must fall near an edge.

More extraordinary hammock patterns arise from Align-X » All-Ft-Y, exemplified by (76a-b), with ‘X’ is ‘Left’:

(76) a. Left, Bound, Align-L » All-Ft-R » Parse-Syll
b. Left, Bound, Align-L » All-Ft-R » Bin » Parse-Syll

a. ([σσ]σ)σ
([σσ]σ)([σσ])
([σσ]σ)σσσ([**σσ**]σ)

b. ([σσ]σ)σ
([σσ]σ)([σσ])
([σσ]σ)σσσσ([**σσ**])

Both unattested patterns have a single left-edge stress in four-syllable words, and double edge stress in longer words. The ‘hammock’ foot is either ternary (76a) or binary (76b). Under rule-based theory, only pattern (76a) can be generated. (This takes assignment of a single ternary foot at the left edge, followed by the assignment of a ternary foot, with a binary default, at the other edge.)

Iterative counterparts of ‘hammock’ systems arise as a result of Parse-Syll » All-Ft-R. Only one example of such ‘complex bidirectional’ patterns is attested: Indonesian (Cohn 1989). The penult is stressed, plus the initial syllable in words of minimally four syllables long, plus alternating syllables *preceding* the penult:

(77) Indonesian: Bin, Left, Align-R » Align-L » Parse-Syll » All-Ft-R

a.	bi.([cá.ra])	‘speak’
b.	([kòn.ti]).nu.([á.si])	‘continuation’
c.	([è.ro]).([dì.na]).([mí.ka])	‘aerodynamics’
d.	([à.me]).ri.([kà.ni]).([sá.si])	‘Americanisation’

No ranking based on undominated PARSE-SYLL can generate this pattern, since feet must be (σ [Hd]), so that the seven-syllable word would have it medially, which is impossible under either directionality. However, differences between the patterns of Indonesian and Piro ('simple' bidirectionality) can only be inferred from words that are minimally seven syllables long, which makes the contrast rather subtle, at least.[20] (A ternary analogue of the Indonesian pattern arises by substituting BIN in 77 by MAX-FT and LEFT. The pattern that results is identical to 71b, but deviates in words of 10 or more syllables.)

Only two more rankings with undominated ALIGN-L enjoy independent significance. A kind of mixed binary-ternary hammock pattern arises from the rankings in (78):

(78) a. ALIGN-L, ALIGN-R » ALL-FT-R » PARSE-SYLL
Initial and antepenult, but penult in words of 4 and 5 syllables.

b. ALIGN-L, ALIGN-R » MAX-FT » PARSE-SYLL » ALL-FT-R
Identical, plus ternary alternates preceding the antepenult.

a.	b.
([σσ])([σσ])	([σσ])([σσ])
([σσ]σ)([σσ])	([σσ]σ)([σσ])
([σσ]σ)([σσ]σ)	([σσ]σ)([σσ]σ)
([σσ]σ)σ([σσ]σ)	([σσ]σ)σ([σσ]σ)
([σσ]σ)σσ([σσ]σ)	([σσ]σ)σσ([σσ]σ)
([σσ]σ)σσσ([σσ]σ)	([σσ]σ)([**σσ**]σ)([σσ]σ)
([σσ]σ)σσσσ([σσ]σ)	([σσ]σ)σ([**σσ**]σ)([σσ]σ)

Up to and including words of six syllables, these patterns are identical to familiar attested 'mixed binary-ternary' patterns (e.g. Alutiiq, Estonian). This makes that learning patterns of this kind would require access to words of minimally seven syllables. Perhaps

The contribution of ALIGN-X to the factorial typology of the IL model was evaluated in two ways. First, does it help to generate any attested patterns that cannot be generated otherwise? This question may be answered positively on the basis of 'hammock' patterns (viz. Gugu-Yalanji, Subutu Sama) and 'complex bidirectional' patterns (viz. Indonesian). However, independently required constraints (EDGEMOST) may be involved in hammock patterns, while 'complex bidirectionality' requires empirical strengthening. The second question which we may ask is whether any permutations of ALIGN-X incorrectly predict unattested patterns. I have shown several of such patterns, but for all (except pattern 76) the crucial empirical evidence would consist of very long words. Therefore a functional explanation may be given for the lack of attestation of these complex patterns. In sum, ALIGN-X does not make a substantial positive contribution to the factorial typology, but on the other hand its negative contribution may be neglectable.

4.1.6 Patterns derived by ternary stress rules, but not by constraints

Surprisingly, some of the patterns that rule-based theory can easily derive with ternary feet cannot be derived by constraints. For example, ternary patterns that are generated by ‘assign ternary feet from left to right’ (79a), and its mirror-image pattern in (79b), turn out not be to generable under a constraint-based approach.

(79)	a.	([σσ]**σ)σ**	b.	σ([σσ]σ)
		([σσ]σ)([σσ])		**([σσ])**([σσ]σ)
		([σσ]σ)([σσ]σ)		([σσ]σ)([σσ]σ)
		([σσ]σ)([σσ]**σ)σ**		σ([σσ]σ)([σσ]σ)
		([σσ]σ)([σσ]σ)([σσ])		**([σσ])**([σσ]σ)([σσ]σ)
		([σσ]σ)([σσ]σ)([σσ]σ)		([σσ]σ)([σσ]σ)([σσ]σ)

Note that pattern (79a) minimally differs from Alutiiq in lacking the restructuring rule of Rice (1992) (which would apply to bold-face syllables). Pattern (79b) minimally differs from Cayuvava in lacking Dresher & Lahiri’s rule deleting binary feet (affecting the bold-face feet). By considerations of complexity of derivation, one would therefore expect the patterns of (79a-b), which lack the additional restructuring and foot deletion rules, to be empirically attested, rather than the patterns of Alutiiq and Cayuvava. It is certainly to the credit of OT that it is unable to derive these unattested patterns, while it is perfectly able to derive the attested patterns.

4.1.7 Conclusions

The factorial typology of IL theory includes all attested core metrical patterns. Although it overgenerates to some extent, very few unattested patterns that are predicted by OT are beyond the generative capacities of rule-based theory. Conversely, some patterns that involve maximally simple derivations in rule-based theory, cannot be generated by OT; as I have shown, correctly so, since these patterns are unattested.

4.2 A factorial typology of binary feet

I will now discuss the factorial typology of the ‘flat’ model, to compare it to that of the ‘IL’ model. To facilitate comparison, I will develop patterns maximally along the lines of the IL typology in §4.1. As we will see, the factorial typology of the flat model initially follows that of the IL model with respect to exclusively binary and ternary patterns, but then diverges sharply in the generation of mixed binary/ternary patterns. Specific atypical rhythms arise that are beyond the generative capacity of the IL model (in OT and in rule-based versions). Such ‘strange’ rhythms, unattested in natural languages, all have a single source: the interactions of PARSE-2 and FT+σ. In §4.2.6 an attempt will be made to state alternatives for PARSE-2 that lack these problems, but this will fail. The conclusion will then be that IL theory is more adequate than binary foot theory, since it provides a much more restrictive and more empirically accurate factorial typology.

Analogously to the factorial typology of IL theory, I will not consider any rankings in which FT-BIN (Prince1980, Prince & Smolensky 1993) is dominated.

(80) **FT-BIN**
Feet are binary under moraic or syllabic analysis.

The set of constraints that I will rerank are in (81):

(81)
a. **PARSE-SYLL** Syllables must be parsed into feet.
b. **PARSE-2** One of two adjacent syllables must be parsed into a foot.
c. **FT+σ** Every foot must be followed by an unparsed syllable.
d. **ALL-FT-X** Align (Ft, X, PrWd, X)
e. **ALIGN-X** Align (PrWd, X, Ft, X)

A broad factorial typology is laid out below:

(82)
a. ALL-FT-X » PARSE-SYLL: non-iterative binarity (§4.2.1)
b. PARSE-SYLL » ALL-FT-X: iterative binarity (§4.2.1)
c. FT+σ » PARSE-SYLL » ALL-FT-X: total ternarity (§4.2.2)
d. PARSE-2 » ALL-FT-X: mixed binarity/ternarity (§4.2.3)
e. ALIGN-X: (if independently significant: §4.2.4)

Below I will show that these constraints produce a factorial typology of binary feet that is much less constrained than that of IL theory. The source of the defects are interactions of FT+σ and PARSE-2 that lead to universally unattested ‘non-directional’ patterns.

4.2.1 ALL-FT-X or PARSE-SYLL undominated: Total binarity

All subrankings to be discussed in this section have exact counterparts in IL theory (see §4.1.1). For ease of comparison, I will indicate the corresponding patterns in IL theory in each sub-typology (marked by ‘T’, and the example number). First, when ALL-FT-X is undominated, non-iterative systems arise (because only one foot can stand at the absolute edge of the word). This single-sided non-iterative pattern can be modified into a double-sided pattern by ranking ALIGN-**Y** above ALL-FT-X:

(83) *Non-iterative binary systems*
a. ALL-FT-X » PARSE-SYLL (one edge; T:62a/b)
b. ALIGN-**Y** » ALL-FT-X » PARSE-SYLL (both edges; T:75)

A factorial typology of iterative systems with strictly binary rhythm arises when we keep PARSE-SYLL undominated, and vary the rankings of ALL-FT-X with respect to PrWd-alignment constraints. The overview below refers to corresponding patterns in the IL typology; for that reason I will not exemplify it by patterns:

(84) *Iterative binary systems*

a. PARSE-SYLL » ALL-FT-X
unidirectional (Pintupi/Warao; T:64a, T:66b)

b. PARSE-SYLL, ALIGN-**Y** » ALL-FT-X
bidirectional (simple) (Piro/Garawa; T:66a, T:64b)

c. PARSE-SYLL, ALIGN-**X** » ALIGN-**Y** » ALL-FT-X
bidirectional (complex) (Indonesian; T:77)

4.2.2 FT+σ undominated: Total ternarity

FT+σ is the 'flat-theoretic' counterpart of MAX-FT. When undominated, it forces ternary metrifications in which every foot is followed by an unparsed syllable. That is, no foot is allowed to stand at the right word edge, and no foot may be adjacent to another foot.

First, non-iterative ternarity arises by ALL-FT-R » PARSE-SYLL, as for example in the pattern of (85a). Intraposition of ALIGN-X produces double-sided non-iterativity, as for example in the (non-attested) pattern in (85b):

(85) *Non-iterative ternary systems*

a. FT+σ » ALL-FT-R » PARSE-SYLL (one edge; T:62c)

b. FT+σ » ALIGN-R » ALL-FT-L » PARSE-SYLL (2 edges; T:75 ternary form)

When we reverse the ranking of PARSE-SYLL and ALL-FT-X, we find total ternarity in an iterative version.:

(86) *Iterative ternary systems*

a. FT+σ » PARSE-SYLL » ALL-FT-X
unidirectional (Cayuvava; T:71a)

b. FT+σ » ALIGN-**Y** » PARSE-SYLL » ALL-FT-X
bidirectional (simple) (unattested; T:71b)

c. FT+σ » ALIGN-**X** » ALIGN-**Y** » PARSE-SYLL » ALL-FT-X
bidirectional (complex) (unattested; 'complex' T:71b)

Up to this point, the factorial typology of flat foot theory closely resembles that of IL theory. Now we arrive at the first substantial difference. When we replace PARSE-SYLL in ranking (86a) with PARSE-2, a strange, *non-directional* pattern results:

(87) (σσ)σ FT+σ » PARSE-2 » ALL-FT-L
σ(σσ)σ
σ(σσ)σσ
(σσ)σ(σσ)σ
σ(σσ)σ(σσ)σ
σ(σσ)σ(σσ)σσ
(σσ)σ(σσ)σ(σσ)σ

This pattern is totally unattested among the languages of the world. Its most remarkable aspect is its *lack of consistent directionality*: there is no unique edge (for words of all syllable lengths) with respect to which stress is ‘repetitive’. But upon closer inspection, it appears that the pattern is actually composed of three sub-patterns, one for each of three types of syllable length.

In words of 3*n* syllables, FT+σ » PARSE-2 suffices to uniquely determine both number of feet and their position (as in Cayuvava). ALL-FT-L gets no chance of being involved in selecting the number of feet and their distribution. Observe that any ‘re-shuffling’ of feet (while keeping their number constant) would run into additional violations of FT+σ:

(88) 6 σ (σσ)σ(σσ)σ > $\sigma(\sigma\sigma)\sigma(\underline{\sigma\sigma})$

In words of 3*n*+1 syllables, the pair FT+σ » PARSE-2 again uniquely determines parsing, while ALL-FT-L is still not involved. PARSE-2 selects the most ‘even-spaced’ parse:

(89) 7 σ σ(σσ)σ(σσ)σ > $(\sigma\sigma)\sigma(\sigma\sigma)\underline{\sigma\sigma}$, $(\sigma\sigma)\underline{\sigma\sigma}(\sigma\sigma)\sigma$

Finally, in words of 3*n*+2 syllables, FT+σ » PARSE-2 is still restricting foot distribution, but no lnger uniquely determine it. Violations of PARSE-2 can no longer be avoided since FT+σ reigns supreme. But violation of PARSE-2 is *minimal*, so that unparsed syllables are broken up into shorter chunks. Indeterminacies under FT+σ » PARSE-2 are resolved by ALL-FT-L, which orients feet towards the *left edge*.

(90) 8-*syllable input*	FT+σ	PARSE-2	ALL-FT-L
a. ☞ $\sigma(\sigma\sigma)\sigma(\sigma\sigma)\underline{\sigma\sigma}$		*	*, ****
b. $\sigma(\sigma\sigma)\underline{\sigma\sigma}(\sigma\sigma)\sigma$		*	*, *****!
c. $\underline{\sigma\sigma}(\sigma\sigma)\sigma(\sigma\sigma)\sigma$		*	**, ****!*
d. $(\sigma\sigma)\sigma(\sigma\sigma)\underline{\sigma\sigma\sigma}$		**!	***
e. $(\sigma\sigma)\underline{\sigma\sigma}(\sigma\sigma)\underline{\sigma\sigma}$		**!	****
f. (σσ)σ(σσ)σ(σσ)	*!		***, ******

(If instead ALL-FT-R had been selected, the directional pattern of Cayuvava would arise.)

A minor variation on pattern (87) arises when ALIGN-R is interposed between FT+σ and PARSE-2:

(91) σ(σσ)σ(σσ)σ FT+σ » ALIGN-R » PARSE-2 » ALL-FT-L
σ(σσ)σσ(σσ)σ
(σσ)σ(σσ)σ(σσ)σ

In contrast to the previous pattern this has one 'anchored' (antepenultimate) stress, but it still lacks consistent directionality of remaining stresses.

4.2.3 PARSE-2 undominated: Mixed binarity-ternarity

Recall that in IL theory, mixed binary-ternary rhythm is due to undominated PARSE-SYLL in combination with undominated LEFT and BOUND. (§4.1.3). But in flat foot theory (as seen in §4.2.1), this function is due to undominated PARSE-2, which triggers multiple feet per word (iterativity), without completely fixing their precise distribution. The factorial (sub-)typology of undominated PARSE-2 is developed on the skeletal ranking in (94).

(92) PARSE-2 » ALL-FT-X

Into this ranking, ALIGN-X can be inserted in varying positions.

First, when ALIGN-X is dominated by ALL-FT-X, we find unidirectional ternarity with partial binarity in words of length 3*n*+2 syllables.

(93) a. PARSE-2 » ALL-FT-L
Antepenult plus preceding ternary alternates, plus initial in 3*n*+2.
b. PARSE-2 » ALL-FT-R
Second plus following ternary alternates, plus penult in 3*n*+2.

a.	**(σσ)**(σσ)σ(σσ)σ	b.	σ(σσ)σ(σσ)**(σσ)**
	(σσ)σ(σσ)σ(σσ)σ		σ(σσ)σ(σσ)σ(σσ)
	σ(σσ)σ(σσ)σ(σσ)σ		σ(σσ)σ(σσ)σ(σσ)σ

Pattern (93a) was discussed earlier as (80b), a pattern derivable by ternary rule-based theory ('Cayuvava minus foot deletion'), but correctly excluded by 'OT-cum-IL' theory. Its mirror-image pattern (93b) displays a - universally unattested - 'non-initiality' effect.

Continuing our discussion of the ternary typology, we now arrive at (94), where one ALIGN-X constraint dominates ALL-FT-X. The unidirectional pattern (94a) is attested in

Alutiiq. Its bidirectional counterpart (94b) is unattested. It displays a kind of noninitiality reminiscent of (93b).

(94) a. PARSE-2, ALIGN-**L** » ALL-FT-**R**
Initial plus following ternary alternates, plus penult in $3n$+1 (Alutiiq)

b. PARSE-2, ALIGN-**R** » ALL-FT-**R**
Penult and second plus following ternary alternates, plus $\sigma_{3n\text{-}3}$ in $3n$+1

a. (σσ)σ(σσ)σ(σσ)
(σσ)σ(σσ)σ(σσ)σ
(σσ)σ(σσ)σ(σσ)(**σσ**)

b. σ(σσ)σ(σσ)(σσ)
σ(σσ)σ(σσ)σ(σσ)
σ(σσ)σ(σσ)(**σσ**)(σσ)

Finally, when both ALIGN-X constraints come to dominate ALL-FT-X, we find even more complex patterns. Both patterns of (95) are bidirectional, with either simple (95a) or complex (94b) bidirectionality. (Both patterns are derivable by rule, using bidirectional foot assignment under weak local parsing, plus persistent footing.)

(95) a. PARSE-2, ALIGN-**R** » ALIGN-**L** » ALL-FT-**R**
Penult and initial plus following ternary alternates, plus $\sigma_{3n\text{-}3}$ in $3n$

b. PARSE-2, ALIGN-**R** » ALIGN-**L** » ALL-FT-**L**
Penult, initial, plus ternary alternates preceding penult, plus σ_3 in $3n$

a. (σσ)σ(σσ)σ(σσ)
(σσ)σ(σσ)(**σσ**)(σσ)
(σσ)σ(σσ)σ(σσ)(σσ)

b. (σσ)σ(σσ)σ(σσ)
(σσ)(**σσ**)(σσ)σ(σσ)
(σσ)(σσ)σ(σσ)σ(σσ)

In §4.2.2 we saw non-directionality arising from FT+σ dominating PARSE-2. This may also occur under the reverse ranking of these constraints. Rankings based on PARSE-2 » FT+σ » ALL-FT-X which have independent significance are in (96). Both contain *right* for the edge 'X' in ALIGN-X, ALL-FT-X, and both produce 'non-directional' ternarity:

(96) a. PARSE-2 » FT+σ » ALL-FT-**R** nondirectional, no edge fixed

b. PARSE-2, ALIGN-**R** » FT+σ » ALL-FT-**R** nondirectional, right edge fixed

a. (σσ)σ(σσ)σ(σσ)
(σσ)σ(σσ)σ(σσ)σ
σ(σσ)σ(σσ)σ(σσ)σ

b. (σσ)σ(σσ)σ(σσ)
σ(σσ)σ(σσ)σ(σσ)
(σσ)σ(σσ)σ(**σσ**)(σσ)

Again, we find that interaction of FT+σ and PARSE-2 leads to non-directional rhythms, as in §4.2.2 (undominated PARSE-2).

4.2.4 Residual rankings: ALIGN-X » ALIGN-X » FT+σ

All remaining independently significant rankings are minor variants on rankings discussed in §4.2.2 (undominated FT+σ), which result from a promotion of ALIGN-R.

The first pattern is non-iterative (both edges), and a variant on ranking (85a):

(97) **σσ**(σσ) ALIGN-R » FT+σ » ALL-FT-L » PARSE-SYLL
(σσ)σσσ(σσ) Penult and initial, except in 4σ words.

Next consider both right-aligned variants of the iterative ternary rankings (86):

(98) a. ALIGN-R » FT+σ » PARSE-SYLL » ALL-FT-R
Penult and preceding ternary alternates.

b. ALIGN-R » FT+σ » ALIGN-L » PARSE-SYLL » ALL-FT-R
Penult and initial (except 4σ), plus ternary alternates preceding penult (except σ_3 in 3*n*+1).

a.	b.
σσ(σσ)	**σσ**(σσ)
(σσ)σ(σσ)σ(σσ)	(σσ)σ(σσ)σ(σσ)
σ(σσ)σ(σσ)σ(σσ)	(σσ)σσ(σσ)σ(σσ)
σσ(σσ)σ(σσ)σ(σσ)	(σσ)**σσ**σ(σσ)σ(σσ)

Pattern (98a) is a minimal variant of the Cayuvava pattern (88), with penultimate stress.

A variation on non-directional (97) arises by promoting ALIGN-R over FT+σ:

(99) (σσ)σ(σσ)σ(σσ) ALIGN-R » FT+σ » PARSE-2 » ALL-FT-L
σ(σσ)σ(σσ)σ(σσ)
σ(σσ)σ(σσ)**σσ**(σσ)

Finally, when both ALIGN-X constraints dominate FT+σ, a directional pattern is produced that has fixed stresses at both edges and rhythmic ‘gaps’ in words of 3*n*+1 syllables. As examples, consider both patterns with undominated ALIGN-L:

(100) a. ALIGN-L » ALIGN-R » FT+σ » PARSE-SYLL » ALL-FT-**L**
Initial, penult, plus ternary alternates following initial except 3*n*+1

b. ALIGN-L » ALIGN-R » FT+σ » PARSE-SYLL » ALL-FT-**R**
Initial, penult, plus ternary alternates preceding penult except 3*n*+1

a.	b.
(σσ)(σσ)	(σσ)(σσ)
(σσ)σ(σσ)σ(σσ)	(σσ)σ(σσ)σ(σσ)
(σσ)σ(σσ)σσ(σσ)	(σσ)σσ(σσ)σ(σσ)
(σσ)σ(σσ)σ**σσ**(σσ)	(σσ)**σσ**σ(σσ)σ(σσ)

4.2.5 Flat foot theory: Conclusions and comparison with IL theory

The factorial typology of flat foot theory includes all attested core metrical patterns, in which respect it is equivalent to IL theory. However, flat foot theory overgenerates to a far greater extent than IL theory, in two respects. First, it overgenerates more severely in raw number of patterns that are simply not attested in natural languages. Only compare, for example, the sub-typologies of mixed binary-ternary rhythm of both theories, (68a) verus (93-95). But a second kind of overgeneration by flat theory is even more serious. This is the generation of 'nondirectional' patterns, of which we have seen five examples in this section. Observe that all contain FT+σ and PARSE-2 dominating ALL-FT-X:

(101)	a.i	FT+σ » PARSE-2 » ALL-FT-L	(=97)	No edge, no final feet
	a.ii	PARSE-2 » FT+σ » ALL-FT-R	(=95a)	No edge, final feet occur
	b.i	FT+σ » ALIGN-R » PARSE-2 » ALL-FT-L	(=92)	Antepenult, fixed
	b.ii	ALIGN-R » FT+σ » PARSE-2 » ALL-FT-L	(=98)	Penult, adjacent feet
	b.iii	PARSE-2, ALIGN-R » FT+σ » ALL-FT-R	(=95b)	Penult, no adjacent feet

This kind of rhythmic pattern is categorically absent in languages that are known in the metrical literature. Since all nondirectional patterns are based on the interaction of two constraints, FT+σ and PARSE-2, it remains to be seen whether viable alternatives can be offered for these constraints that do not produce non-directional rhythm. As I will argue such alternatives are highly unlikely, given basic assumptions of the 'flat' model.

First, recall that FT+σ is crucially required in generating the Cayuvava pattern, where it functions to rule out both adjacent feet and final feet. In fact, matters are still worse than this, since I have arged in §2.1 that FT+σ should actually be considered a complex constraint composed of NONFINALITY and *FTFT. When each constraint can be reranked individually, this would make the factorial typology even expand beyond its current size.

Second, PARSE-2 is crucial in the generation of the patterns of Estonian and Alutiiq. It limits inter-foot distance (as well as distance between a foot and the word edge) to one syllable. An inspection of the non-directional patterns in (89) may give the impression that the most problematic aspect of PARSE-2 is that it forces metrifications of the kind $[_{\text{PrWd}}$ σ (σσ) ... at the left edge of a domain. To repair this, one might conceive of some symmetric version of the inherently a-symmetric PARSE-2, such as (102):

(102) **FT←σ**
An unparsed syllable must be preceded by a foot.

Although substitution of PARSE-2 by this constraint eliminates all of the non-directional patterns from the inventory in (101), it also introduces new ones, e.g. (103):

(103)	(σσ)σ	FT←σ » FT+σ » ALIGN-R » ALL-FT-L
	(σσ)(σσ)	
	(σσ)σ(σσ)	
	(σσ)σ(σσ)σ	
	(σσ)(σσ)σ(σσ)	

(σσ)σ(σσ)σ(σσ)
(σσ)σ(σσ)σ(σσ)σ

I conclude that the constraint Ft←σ offers no viable alternative to Parse-2, since it fails to categorically exclude the generation of non-directional patterns. But there is an even more principled reason for which Ft←σ cannot stand the quality test. This reason is that it is really a disguised conjunction of two more basic constraints, Parse-2 and Align-L. If each of the components of complex constraints must also be individually rankable, then the problem with Parse-2 cannot be solved at all.

Nor does a purely rhythmic constraint ruling out rhythmic ‘lapses’ (rather than pairs of unparsed syllables) improve matters. Consider an a-symmetric version of the anti-lapse constraint in (104):

(104) **Lapse**
Every weak element is preceded by a strong element.

This constraint interacts heavily with constraints on foot form (determining trochaic or iambic prominence), which itself opens up a whole new series of patterns. Moreover, it fails to achieve what it should: allowing mixed binary-ternary rhythm when undominated (cf. Parse-2). In six-syllable words, for example, it already forces binary rhythm (105a):

```
(105)  a.   *    *    *                  *          *
            *  *  *  *  *  *        b.   *  *   *   *  *  *
           (σ σ)(σ σ)(σ σ)              (σ σ) σ (σ σ) σ
```

In sum, no adequate alternatives for Parse-2 seem to be available that lack its main disadvantage: generating nondirectionality.

5 Conclusions

Comparing rule-based and OT versions of IL models, OT offers clear advantages over rule-based theory. Rule-based theory requires a class of re-structuring rules in order to trim back any incorrect results of iterative foot construction. Essentially, restructuring is a by-product of the lack of look-ahead capacity of iterative foot construction rules. Restructuring includes foot deletion and foot reparsing. The major conceptual problem is that restructuring is not organically connected with the well-formedness conditions that govern the basic parsing procedure. The result is a clear loss of generalisation. The empirical problem is that restructuring drastically expands both the number and types of patterns that can be generated. OT improves over rule-ordering theory in both aspects, not only by resolving the fragmentation of generalisations (‘parsing’ versus ‘repair’), but also by a highly restricted factorial typology.

Comparing OT versions of IL theory and ‘flat’ foot theory, we find that IL theory is empirically superior, because of its more restrictive factorial typology. At the heart of the overgeneration problem of flat foot theory are non-directional patterns. These stem from the fact that constraints cannot refer to a prosodic domain that is larger than a foot, but smaller than the PrWd. In IL theory, the position of heads is restricted by foot shape constraints that limit the distance between a head and the edge of the word. In contrast, 'flat' foot theoretic constraints can only limit the distance from one foot to another, or from a foot to the word edge.

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NOTES

[1] For other alignment approaches using slightly different assumptions, see Idsardi (1992), Halle & Idsardi (1995), Coleman (1991).

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

[3] Cayuvava lacks a distinction of syllable weight. Adjacent vowels are syllabified as two syllables, rather than as a single diphthongal syllable.

[4] This disjunction is entirely parallel to that in the constraint RHYTHM (Hung 1994) 'A stressed element must be followed by an unstressed element', which combines a second function of NONFINALITY 'No stressed element is final in PrWd' and CLASH 'Stressed elements must not be adjacent'. It has been argued by Elenbaas (1995), however, that both constraints must be independently rankable in Sentani and Southern Paiute. The evidence is based on forms with the rhythmic structure (WS)(SW), which show that NONFINALITY » FTFORM=IAMB » CLASH.

[5] Models that use 'flat' ternary feet (e.g. Halle & Vergnaud 1987, Levin 1988) and their OT counterparts (Kenstowicz 1995) will be briefly addressed in §4.

[6] Specifically, High Vowel Deletion in Old English and Sievers' Law in Gothic.

[7] Evidence for this 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).

[8] The ranking that would accomplish this is:
HD-BIN, LEFT, BOUND » LXWD=PRWD » MAX-FT » PARSE-SYLL » ALL-FT-R.

[9] Manuscript versions of Hayes' book were circulating from 1991 on.

[10] Differences exist between Hayes' and Kager's analyses with respect to definition of the iambic foot. These do not affect the metrification of words with only light syllables, however.

[11] See Green (1994) and Kenstowicz (1995) for an elaboration of this idea.

[12] As was pointed out to me by Jan Don and by an anonymous reviewer.

[13] Locally conjoined constraints, according to Smolenky, are universally ranked above the constraints of which they are composed. Hence we predict: PARSE-2 » PARSE-SYLL.

[14] For reasons of space limitations I refrain from discussing the 'flat' foot analysis of words that contain heavy syllables. For further discussion of issues of quantity-sensitivity in Alutiiq I refer to Rice (1992), Kager (1993), and Hayes (1995).

[15] The status of head-final ternary feet is highly unclear. Rice (1992) argues for head-final feet with trochaic heads in Sentani (a language of New-Guinea, which is reported by Cowan 1965). However, recent fieldwork and an analysis by Elenbaas (1996) suggest basic binarity. Winnebago no longer exemplifies head-final feet with iambic heads, at least if Hayes (1995) is correct in his tone shift analysis.

[16] Headedness constraints are not free of interaction, of course. See discussions in Prince & Smolensky (1993), Hung (1993) and McCarthy & Prince (1993) for the array of interactions of headedness with NONFINALITY, CLASH, etc.

[17] Under exhaustive parsing, a rare kind of bidirectional system, which I will refer to as 'complex bidirectional', cannot be generated. These systems have fixed stress at both edges of PrWd, and alternating binary stresses that start at the edge that is 'dominant' in a trisyllabic word. For example, Indonesian (Cohn 1989) has fixed penultimate main stress, a secondary stress on the initial syllable, and secondary stresses on alternating syllables preceding the penult. (Rather than following the initial syllable, as in Piro. This difference manifests itself in words of minimally seven syllables.) Such systems will be discussed in §4.1.5.

[18] A proposal for patterns with degenerate feet was made by Green & Kenstowicz (1995). See also Kiparsky (1991), Hayes (1995), and Kager (1995).

[19] In strictly ternary systems (of which only one iterative example, Cayuvava, is known) ternarity can be relaxed under duress in the case of sub-minimal words (words which have fewer than three syllables). 'Culminativity' overrides ternarity. In technical terms, this means that LXWD=PRWD may be reranked with respect to HD-BIN and MAX-FT. However, space limitations forbid a full exploration of the factorial typology of these constraints.

[20] In fact, all crucial evidence for this pattern from seven syllable words consists of a handful of loan words from Dutch (*kolonialisasi* 'colonialisation', etc.), which happen to have the same secondary stress pattern in the source language, where it seems to be determined by morphological factors (much as in English).