A Unified Account of Positional Asymmetries in Metrical Domains*

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ABSTRACT

The paper addresses a number of well-known asymmetric positional restrictions in metrical domains, including weight-by-position, diphthongal moraicity, the Iambic / Trochaic Law, and related quantitative processes. The proposed analysis exploits rhythmic constraints in Optimality Theory (Prince & Smolensky 1993; Van de Vijver 1998) to develop a unified account for these phenomena, showing that a range of facts can be accounted for in terms of rhythmic well-formedness without appeal to ad hoc explanations.

1. INTRODUCTION

Metrical groupings, like other phonological constituents, are normally subject to a requirement of headedness, assigned with reference to the left or right domain-edge. Headedness alone, however, is insufficient to capture a range of cross-linguistic asymmetries which obtain in various types of metrical groupings, and prosodic theory has innovated a number of devices in order to account for them, e.g. weight-by-position, positional restrictions on diphthongal moraicity, the Iambic / Trochaic Law, and certain quantitative processes in iambic systems. The present analysis proposes to do away with these in favour of a single mechanism involving the interaction of rhythmic constraints in Optimality Theory (Prince & Smolensky 1993; Van de Vijver 1998; Kager 1999), which are formally independent of headedness.

We begin by reviewing a number of rhythmic asymmetries in syllable-internal as well as foot-internal prominence relations, and in section 2 we present an Optimality Theoretic analysis to account for them. Section 3 addresses the interaction of rhythmic constraints with those enforcing headedness, exploring the typological predictions made by the proposed model. A summary and concluding remarks are offered in section 4.

1.1 HEAVY SYLLABLES: WEIGHT-BY-POSITION AND DIPHTHONGAL MORAICITY

The notion of *weight-by-position* (e.g. Hayes 1989; cf. Kager 1999:147), whereby consonants in certain languages receive a mora by virtue of being in the syllable coda, is well-established in metrical phonology, and is crucial to explaining the stress systems of numerous languages. Weight-by-position imposes no moraicity requirement on syllable onsets, however, accounting for the cross-linguistic observation that while coda consonants often contribute to

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syllable weight, syllable onsets (almost) never do. An important implication of this is that at the level of metrical structure, the two moras of a heavy CVC syllable are systematically organised into a trochaic metrical constituent, as shown in (1b) below.[1]

(1)	a.	b.	c.	(2)	a.	b.
	*[. *]	[* .]	*[. *]		[* .]	*[. *]
	μ μ	μ μ	μ μ		μ μ	μ μ
	C V C	C V C	C V C		C V G	C G V

The iambic structure in (1a) is illicit because the moraic consonant is the syllable onset rather than the syllable coda, while that in (1c) is ruled out by *Sonority Sequencing* (e.g. Clements 1990) since the syllable peak (indicated by '*') is not the most sonorous melody in the syllable.[2]

Similar facts obtain in heavy syllables containing diphthongs. Rosenthall (1994) and Casali (1998) exploit the constraint SONFALL — requiring falling sonority across the two moras of a heavy diphthong — to rule out heavy CGV configurations such as (2b), ensuring that bimoraic diphthongs form trochaic metrical constituents like that in (2a). This accounts for the cross-linguistic observation that diphthongs with a rising sonority contour behave as phonologically light, while falling diphthongs behave as phonologically heavy, as illustrated by the Spanish data in (3) below. (Data from Rosenthall 1994:135-9.)

(3) Closed syllables in Spanish

a. $[C_0GVC]_\sigma$	mwer.te	'death'
	sjes.ta	'siesta'
	pwer.ta	'door'
b. $[C_0VGC]_\sigma$	*mewr.te	
	*sejs.ta	
	*pewr.ta	

Although Spanish allows both rising and falling diphthongal sequences, only rising diphthongs can occur in closed syllables.[3] The absence of falling diphthongs in closed syllables can be explained by a two-mora limit if the (bimoraic) representation for falling diphthongs in (2a) is assumed in conjunction with moraic coda consonants.

The observations in (1) and (2) can be accounted for in a unified manner by assuming that within a heavy syllable it is the first mora which bears stress and manifests prominence on the metrical grid (Prince 1983; Kager 1993; Mellander 2001; cf. Kenstowicz & Rubach 1987). This move assigns a trochaic prominence profile to heavy monophthongs as well, creating a uniform metrical representation for heavy syllables — a desirable effect given that bimoraic syllables of CVC, CVG, and CVV shapes generally behave symmetrically within a given language. This stipulation, however, while descriptively adequate, misses the generalisation that a strong preference for trochaic rhythm is observable in other metrical domains as well.

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[1] In structural representations I indicate syllable boundaries with square brackets and foot boundaries with parentheses. I use 'C', 'V', and 'G' to refer to consonants vpwels, and glides, respectively.

[2] Alternately, this restriction can be accounted for in terms of HEAD-PROMINENCE (Piggott 1998; Mellander 2001, 2002), a constraint which demands that constituent-heads have greater intrinsic prominence than dependents. See Mellander (2002) for a formal analysis along these lines.

[3] There are a number of exceptions to this generalisation. Citing Harris (1983), Rosenthall (1994:139) lists *vein.te*, *trein.ta* and *aun.que*. José Alvarez (p.c.) notes two additional exceptions: *seis.cien.tos* and *pleis.to.ce.no.*

1.2 QUANTITY-INSENSITIVE FEET

Many languages provide clear evidence for the metrical organisation of syllables into binary feet. In systems where foot parsing is insensitive to syllable quantity, syllables are consistently grouped into left-headed *syllabic trochees* (Hayes 1995). The absence of corresponding *syllabic iamb* systems cross-linguistically is captured formally by eliminating the quantity-insensitive iamb from the inventory of possible foot types (given in (4) below, cf. Kager 1993). In other words, the asymmetry is encoded directly into the foot inventory as a primitive.

(4) The Universal Foot Inventory (Hayes 1995)

Syllabic Trochee (σ̲ σ)
Quantity-insensitive

Moraic Trochee (σ̲ σ) [μ μ] or (σ̲) [μ μ]
Quantity-sensitive

Iamb (σ σ̲) [μ μ μ] or (σ σ̲) [μ μ] or (σ̲) [μ μ]
Quantity-sensitive

The inventory in (4) also reveals asymmetries in quantity-sensitive systems. These will be taken up in the following section.

1.3 QUANTITY-SENSITIVE FEET

The asymmetric realisations of quantity-sensitive feet (shown in (4) above) are standardly understood to follow from the Iambic / Trochaic Law (ITL: e.g. Hayes 1995; cf. McCarthy & Prince 1986; Prince 1992; Kager 1993, 1999; Revithiadou & Van de Vijver 1997; Mellander 2001, 2002), which expresses a preference for durational evenness in trochaic groupings and durational unevenness in iambic groupings. This asymmetry is manifested directly in the foot inventory; notice in (4) that while the canonical moraic trochee contains two moras, the canonical iamb contains three.

The ITL's effects are also visible in quantitative processes which enforce canonical foot shape. One such process is *iambic lengthening*, whereby open syllables in the head of an iambic foot are augmented in order to produce canonical uneven iambs (Hayes 1985, 1995). The most common form of augmentation is vowel lengthening, although consonant gemination and glottal insertion occur as well. All three types of iambic lengthening occur in Kari'ña, a Cariban language spoken in Eastern Venezuela (Alvarez 2000, to appear; examples are given in (5) below).

(5) Iambic Lengthening in Kari'ña (Alvarez to appear)[4]

a.	/s-epema-po-ða/	(se.pèe)(ma.póo)ða	'I sell it'
	/etapurunnaka-rɨ/	(e.tàa)(pu.rùn)(na.káa)rɨ	'to open'
	/s-akononto-ða/	(sa.kòo)(nón)(to.ða)	'I accompany him'
b.	/adu-ko/	(a.dúk)ko	'fry it'
	/s-upi-ða/	(su.pîj)ja	'I look for it'
	/aðu-to-ko/	(a.ðút)(to.ko)	'fry them'

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[4] Capital /V/ represents a vowel which harmonizes with the (first) vowel in the root. I follow Van de Vijver (1998) in positing feet at the right word-edge.

c. /s-eta-sen/ (se.táh)seŋ 'I hear them'
/k-upi-ko/ (ku.píh)ʃo 'look for me'
/kVs-kupi-i/ (ki.ʃih)(ʃu.pi) 'don't wash him'

In Kari'ña, iambic feet iterate from left to right with augmentation in all non-final open syllables in the head position of a foot. Vowel lengthening is shown in (5a); consonant gemination ((5b)) occurs after high vowels, and insertion of the glottal fricative [h] ((5c)) occurs before [s] (or [ʃ] resulting from palatalization).

The three manifestations of iambic lengthening can be analysed in a unified manner if the process is understood as one of mora insertion in the (non-word-final) head syllables of iambic feet. This rule is given in (6) below.

(6) Iambic Lengthening (Hayes 1995:242; cf. UNEVEN-IAMB: Kager 1999:151)

$$\emptyset \rightarrow \mu \;/\; \begin{matrix} (. & *) \\ \sigma & \underline{\sigma} \\ | & | \\ \mu & \mu \end{matrix}\_\_ \qquad \text{except in word-final position}$$

Iambic lengthening is extremely common; Hayes (1995:83) lists 19 languages which undergo iambic vowel lengthening, consonant lengthening or both, compared to only 5 trochaic languages which adjust syllable shape to produce canonical even trochees (p148) — this despite the fact that trochaic systems are far better-attested across the world's languages than iambic ones. Moreover, while ITL-driven quantitative adjustment is restricted to the main stress foot in trochaic systems, iambic languages manifest lengthening in every (non-final) foot in the word. The pervasiveness of iambic lengthening is no accident; in the following section it will be argued that iambic lengthening arises as an imperative of rhythmic well-formedness under constraint interaction.

2. RHYTHMIC CONSTRAINTS IN METRICAL DOMAINS

2.1 THE RHYTHMIC BASIS OF IAMBIC LENGTHENING

In an extensive investigation of iambic stress systems, Van de Vijver (1998) derives a number of interesting effects through the interaction of rhythmic constraints in Optimality Theory. A central aspect of Van de Vijver's analysis is the idea that iambic systems are characterized by the avoidance of metrical prominence at the edges of prosodic words. This effect is formalized by means of *EDGEMOST, which is assumed to be highly ranked in iambic languages. Given in (7) below, *EDGEMOST militates against prominence at the left and right edges of the prosodic word.

(7) *EDGEMOST (Van de Vijver 1998)[5]
Edge-adjacent elements may not be prominent.

*EDGEMOST forces a left-aligned foot to have an iambic prominence profile, and accounts for the absence of final stress[6] in iambic systems — even when final syllables are footed, as illustrated in (8) below.

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[5] The avoidance of domain-peripheral prominence is a common property of languages. Examples include peninitial and penultimate stress (cf. NONFINALITY: Prince & Smolensky 1993), as well as V2 effects in syntax which have been argued to be phonological in nature (Rice & Svenonius 1998; Bošković 2001). Thanks to Loren Allen Billings for pointing this out to me.

[6] This also accounts for the absence of *right-to-left* iambic systems, which would have final stress.

(8) Stressless feet at the right edge (Van de Vijver 1998:45)

Input: σσσσ	*EDGEMOST	PARSE-HEAD
a. ☞ $\vert$(. *)(. .)$\vert_{PWd}$ σ σ σ σ		*
b. $\vert$(. *)(. *)$\vert_{PWd}$ σ σ σ σ	*!	

Candidate (8b) fatally violates *EDGEMOST due to prominence in the rightmost syllable of the prosodic word, leaving candidate (8a) as optimal, despite a violation of low-ranking PARSE-HEAD, the constraint demanding overt realisation of foot-heads.

Although Van de Vijver appeals to a different mechanism to account for iambic lengthening,[7] the process can be explained straightforwardly through *EDGEMOST if the latter is enforced at the moraic level with respect to the edges metrical feet. In an iambic foot, augmentation of the accented syllable through mora-insertion creates a buffer separating the prominent mora from the right foot-edge, thereby forestalling a violation of *EDGEMOST. This solution is particularly attractive since the high ranking of *EDGEMOST in iambic systems is independently motivated by the distribution of stressed syllables.

Iambic lengthening through satisfaction of *EDGEMOST is illustrated in (9) below. Candidate (9a) fatally violates *EDGEMOST due to prominence on an edge-adjacent mora. This violation is avoided through mora insertion in (9b), the optimal candidate, at the expense of a violation of low-ranking DEP-μ.

(9) Iambic Lengthening

Input: $σ_μσ_μ$	*EDGEMOST	DEP-μ
a. (. *) μ μ σ σ	*!	
b. ☞ (. * .) μ μ μ σ σ		*

Finally, the absence of lengthening in word-final feet in iambic systems is understood as a consequence of the fact that these feet lack stress (see tableau (8)).[8] The lack of prominence in these feet means that *EDGEMOST is satisfied without lengthening, as illustrated below.

(10) No Iambic Lengthening in final position

Input: $σ_μσ_μ\vert_{PWd}$	*EDGEMOST	DEP-μ
a. ☞ (. .)$\vert_{PWd}$ μ μ σ σ		
b. (. . .)$\vert_{PWd}$ μ μ μ σ σ		*!

[7] According to Revithiadou & Van de Vijver (1997), iambic lengthening arises through the convergence of two processes: lengthening of stressed elements and lengthening of domain-final elements.

[8] Van de Vijver (1998) takes the same position, although for different reasons; since lengthening is interpreted as a phonetic manifestation of stress, the absence of stress entails the absence of lengthening.

Candidate (10b) is ruled out by a fatal violation of DEP-μ, leaving (10a) as the optimal output. Since more insertion would yield no gain in rhythmic well-formedness, such a move constitutes a gratuitous violation of faithfulness. On this view, iambic systems are those which avoid peripheral prominence in two distinct metrical domains: prosodic words and feet.

2.2 TROCHAIC RHYTHM AND BINARY DOMAINS

In many systems, the requirements of *EDGEMOST are outweighed by those of PEAK-FIRST, a competing rhythmic constraint (given in (11) below) which demands that prominence occur initially in metrical groupings. Satisfaction of *both* PEAK-FIRST and *EDGEMOST is thus impossible within a single stress domain, and their opposing requirements are mediated through constraint interaction.

(11) PEAK-FIRST (Mellander 2002; cf. TROCHEE: Van de Vijver 1998)[9]
Prominence is manifested on initial elements.

A special case of constraint interaction is that of binary domains, where PEAK-FIRST and *EDGEMOST invariably generate a trochaic rhythmic profile regardless of their relative ranking. This fact is exploited by Van de Vijver to explain the tendency for iambic systems to display initial stress in disyllabic words (e.g. Kari'ña, Carib[10]), and can be generalized straightforwardly to other binary domains. In (12) and (13) below, the two possible rhythmic profiles for a quantity-insensitive foot are evaluated against the two possible constraint rankings. The tableaux illustrate how both rankings select the same output candidate — the trochee (cf. Trochaic Default: McCarthy & Prince 1986).

(12) PEAK-FIRST >> *EDGEMOST: Trochaic Rhythm

Input: σσ	PEAK-FIRST	*EDGEMOST
a. ☞ (* .)		*
b. (. *)	*!	*

(13) *EDGEMOST >> PEAK-FIRST: Trochaic Rhythm

Input: σσ	*EDGEMOST	PEAK-FIRST
a. ☞ (* .)	*	
b. (. *)	*	*!

Candidate (12b) fatally violates PEAK-FIRST due to non-initial prominence and is thus ruled out in favour of candidate (12a). In (13), both candidates violate *EDGEMOST, since both contain a stressed syllable adjacent to a foot-edge. Candidate (13b) is eliminated by PEAK-FIRST, however, due to non-initial prominence leaving candidate (13a) as optimal. The absence of quantity-insensitive iambic systems thus emerges as a case of invariant trochaic

[9] Extension of this model to moraic domains requires minor modification of Van de Vijver's TROCHEE constraint. The latter requires that a strong beat be followed by a weak beat within a foot, and is thus violated by a unary domain (*) while PEAK-FIRST is not (see section 3.1). Conversely, PEAK-FIRST is violated by a ternary domain with medial prominence (. * .) while TROCHEE is not.
[10] The initial syllable of disyllabic words in these and certain other Cariban languages is lengthened. This lengthening may be predicted if a structure such as that in (24b) below is assumed (cf. Central Slovak in section 3.2), if PWd-level rhythmic constraints outrank foot-level rhythmic constraints in these systems.

prominence in binary domains. Since both trochaic and iambic parses will manifest edge-adjacent prominence, the two candidates will incur offsetting violations of *EDGEMOST, leaving PEAK-FIRST as the decisive constraint, regardless of its relative ranking.

Exactly the same mechanism accounts for invariant trochaic mora-rhythm in heavy syllables (see (1) and (2) above), eliminating the need for asymmetric constraints on positional moraicity such as Weight-by-Position and SONFALL. This will be taken up in the following sections.

2.2.1 WEIGHT-BY-POSITION

Since n most languages syllables are limited to a maximum of two moras, we expect the internal rhythmic organisation of heavy syllables to mirror the rhythmic structure of other binary domains, i.e. to display an invariant trochaic pattern. Weight-by-Position, which assigns moras exclusively to *postvocalic* consonants within a syllable, can be understood as a monifestation of rhythmic well-formedness at the subsyllabic level (cf. Prince 1983). Since the *positional* aspect of Weight-by-Position can be accounted for in terms of independently-motivated rhythmic constraints, it is unnecessary to repeat this information in a constraint specific to this phenomenon. Instead, we appeal to the following general constraint, requiring consonants to be associated with a mora. (For alternative views see Broselow, Chen & Huffman 1997; Rosenthall & Van der Hulst 1999.)

(14) MORAIC-C (cf. WEIGHT-BY-POSITION)
Consonants are moraic.

MORAIC-C expresses a preference for all consonants to project prominence onto the metrical grid, i.e. moraic (cf. Sherer 1994). This constraint differs from WEIGHT-BY-POSITION solely in that it does not stipulate a specific configurational relationship (coda position) with respect to the syllable. As we will see below, configurational restrictions on moraic consonants follow from rhythmic well-formedness.

In languages with moraic consonants MORAIC-C outranks DEP-μ, as illustrated in (15) below, which evaluates moraic representations of a VC syllable.

(15) Moraic consonants

Input: VC	MORAIC-C	DEP-μ
a. ☞ [* .] μ μ V C		*
b. [*] μ V C	*!	

Candidate (15b) fatally violates MORAIC-C due to a nonmoraic consonant, leaving candidate (15a) as optimal despite a violation of low-ranked DEP-μ for mora insertion. The opposite ranking is given in (16) below.

(16) No moraic consonants

Input: VC	DEP-μ	MORAIC-C
a. [* .] μ μ V C	*!	
b. ☞ [*] μ V C		*

Candidate (16a) fatally violates DEP-μ due to mora insertion leaving candidate (16b) as optimal despite a violation of low-ranked MORAIC-C. The potential for moraic consonants thus arises when MORAIC-C is ranked above DEP-μ.

Even in languages which allow for moraic consonants, however, those in onset position are normally nonmoraic.[11] This effect follows from the interaction of *EDGEMOST and PEAK-FIRST, as shown in (17) below. (Recall from section 1.1 that candidates with rhythmic prominence associated to C positions are ruled out by other constraints.)

(17) No moraic onsets[12]

Input: CV	*EDGE	PK-FIRST	MORAIC-C	DEP-μ
a. [. *] μ μ C V	*	*!		*
b. ☞ [*] μ C V	*		*	

While both candidates incur offsetting violations of *EDGEMOST, candidate (17a) fatally violates PEAK-FIRST due to non-initial prominence, leaving candidate (17b) as optimal. Thus, in systems where rhythmic constraints are highly ranked onset consonants surface as nonmoraic.

This is also the case in CVC syllables, as shown in (18) below.

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[11] See Davis (1988) for discussion of exceptions to this generalisation.

[12] Here and in the following tableaux we abstract away from the relative ranking of *EDGEMOST and PEAK-FIRST, since both possibilities yield the same output in binary (and unary) domains (see section 2.2). Furthermore, we assume a high ranking constraint militating against trimoraic syllables (cf. *3μ: Kager 1999:268).

(18) Heavy CVC

Input: CVC	*EDGE	PK-FIRST	MORAIC-C	DEP-µ
a. [· *] µ µ C V C	*	*!		*
b. [*] µ C V C	*		**!	
c. ☞ [* ·] µ µ C V C	*		*	*

Candidate (18a) is ruled out by PEAK-FIRST due to prominence on a non-initial mora. Both remaining candidates violate MORAIC-C because of a nonmoraic (onset) consonant, but candidate (18b) incurs a second and fatal violation of this constraint for a second nonmoraic consonant (in coda position). This leaves candidate (18c) as optimal despite a violation of lower-ranked DEP-µ.

When the relative ranking of MORAIC-C and DEP-µ is reversed, however, neither onsets nor codas surface as moraic. This is illustrated in (19) below.

(19) Light CVC

Input: CVC	*EDGE	PK-FIRST	DEP-µ	MORAIC-C
a. [· *] µ µ C V C	*	*!	*	
b. ☞ [*] µ C V C	*			**
c. [* ·] µ µ C V C	*		*!	*

Candidates (19a) and (19c) incur fatal violations of PEAK-FIRST and DEP-µ, respectively, leaving candidate (19b) as optimal despite two violations of low-ranked MORAIC-C. Tableaux (18) and (19) demonstrate how onset consonants remain nonmoraic regardless of the status coda consonants within a given grammar. The effects of Weight-by-Position thus follow straightforwardly from the satisfaction of rhythmic well-formedness constraints. Onset consonants are (generally) weightless because a moraic onset necessarily produces a rhythmically ill-formed structure.

2.2.2 MORA-LOSS IN RISING DIPHTHONGS

The interaction of rhythmic constraints also provides an explanation for the absence of heavy rising (CGV) diphthongs in the vast majority of the world's languages (cf. SONFALL: Rosenthall 1994; Casali 1998).

Following Rosenthall & Van der Hulst (1999), I assume vowels to be underlyingly moraic. Consequently, when an underlying sequence of two vowels surfaces as a light diphthong, MAX-µ is violated. To avoid this, a CVG sequence is parsed as bimoraic, as illustrated in (20) below.

(20) Heavy CVG

Input: CVG	*EDGEMOST	PEAK-FIRST	MAX-μ
a. ☞ [* .] μ μ C V G	*		
b. [*] μ C V G	*		*!

Candidate (20b) fatally violates MAX-μ due to mora loss, leaving candidate (20a) as optimal. This is not the case in CGV sequences, however, as illustrated in (21) below.

(21) Light CGV

Input: CGV	*EDGEMOST	PEAK-FIRST	MAX-μ
a. [* .] μ μ C G V	*	*!	
b. ☞ [*] μ C G V	*		*

While candidate (21a) satisfies MAX-μ because both vocalic moras are present in the output, it is dispreferred on rhythmic grounds to the monomoraic output in (21b). Specifically, candidate (21a) incurs a fatal violation of PEAK-FIRST, leaving candidate (21b) as optimal.

If rhythmic constraints are highly ranked, the satisfaction of MAX-μ through full realisation of underlying moraic content is subordinated to the demands of rhythmic well-formedness. CVG sequences and CGV sequences yield different quantitative outputs because satisfaction of rhythmic constraints in a bimoraic parse is possible *only* with the trochaic rhythmic profile of a (C)VG sequence, and crucially not with the iambic rhythmic profile of a (C)GV sequence. In a CVG sequence ((20)), rhythmic constraints do not express a preference between monomoraic and bimoraic parses, allowing full satisfaction of faithfulness constraints through a bimoraic parse. In a CGV sequence ((21)), however, rhythmic constraints prefer a monomoraic parse over a bimoraic one at the expense of faithfulness. Mora-loss in rising diphthongs thus follows straightforwardly from the enforcement of rhythmic constraints which are generalizable to other phenomena, eliminating the need for an *ad-hoc* solution like SONFALL.

2.3 RHYTHMIC VARIABILITY IN QUANTITY-SENSITIVE FEET

While quantity-insensitive feet and heavy syllables are restricted to maximal binarity at the level of metrical representation, this is not the case for quantity-sensitive feet.[13] As a consequence, the rhythmic well-formedness of various configurations in such systems depends crucially on the relative ranking of constraints. In grammars where PEAK-FIRST outranks *EDGEMOST, the even trochee ((22a)) and single heavy syllable ((22c)) emerge as rhythmically optimal feet. This is illustrated below. Such grammars correspond to moraic trochee systems in the Hayesian framework (e.g. Fijian, Latin).

[13] See Mellander (2001, 2002) for discussion on the maximal expansion of quantity-sensitive feet.

(22) PEAK-FIRST >> *EDGEMOST: moraic trochees

		PEAK-FIRST	*EDGEMOST
a. ☞	(* .) μ μ σ σ		*
b.	(. *) μ μ σ σ	*!	*
c. ☞	(* .) μ μ σ		*
d.	(. * .) μ μ μ σ σ	*!	

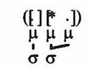
(23) *EDGEMOST >> PEAK-FIRST: canonical iambs

		*EDGEMOST	PEAK-FIRST
a.	(* .) μ μ σ σ	*!	
b.	(. *) μ μ σ σ	*!	*
c.	(* .) μ μ σ	*!	
d. ☞	(. * .) μ μ μ σ σ		*

The opposite ranking corresponds to iambic systems like Kari'ña, and is illustrated in (23). In such a grammar, the canonical iamb emerges as the optimal output since only a trimoraic structure with medial prominence (a moraic amphibrach; Kager 1993) satisfies *EDGEMOST by avoiding prominence on both foot-initial and foot-final moras.

The canonical iamb is not the only candidate which would satisfy *EDGEMOST, however. Notice that both configurations in (24) below contain three moras and have medial prominence. What then determines the relative well-formedness of these two structures?

(24) Trimoraic feet with medial prominence

a.  iamb

b.  trochee

The answer is PEAK-FIRST. While both configurations fare equally well on the two constraints with respect to foot boundaries, the iambic profile of the heavy syllable in (24b) triggers an additional violation of PEAK-FIRST with respect to syllable boundaries, as shown in (25) below.

(25) Rhythmic well-formedness within the foot *and* syllable

		*EDGEMOST	PEAK-FIRST
a. ☞	([.][* .]) μ μ μ σ σ	*	*
b.	([. *][.]) μ μ μ σ σ	*	**!

Both candidates incur offsetting violations of *EDGEMOST for edge-adjacent prominence within the syllable. While both candidates incur one violation of PEAK-FIRST for lack of initial-prominence on the foot-initial mora, (25b) incurs a second and fatal violation of PEAK-FIRST for non-initial prominence within the syllable.

Durational asymmetries attributed to the ITL can thus be understood as the syllable-level manifestations of mora-level rhythmic organisation under constraint interaction. Quantitative evenness co-occurs with trochaicity because PEAK-FIRST can be satisfied within a binary metrical domain. By contrast, satisfaction of *EDGEMOST requires a *ternary* metrical domain, implying quantitative unevenness (since three moras cannot be divided evenly across two syllables). This unevenness is realised as iambicity — that is, (μ.μ́μ) and not *(μμ́.μ) — because the iambic realisation of the trimoraic foot is rhythmically superior to its trochaic (μμ́.μ) counterpart with respect to PEAK-FIRST. These results are summarized in (26) below.

(26) The Iambic Trochaic Law as a derived rhythmic effect

a. *Even Quantity:*	(μμ)	(* .)	([*][.])
b. *Uneven Quantity:*	(μμμ)	(. * .)	([.][* .])

Summing up the results so far, the interaction of rhythmic constraints accounts for a range of asymmetries in the rhythmic organisation of metrical groupings at various structural levels. We have presented evidence for the *EDGEMOST at both the PWd-level and foot-level, and for PEAK-FIRST at both the foot-level and syllable-level. In the following section we will briefly examine systems in which the demands of rhythmic constraints are overridden by those enforcing a conflicting constituent headedness.

3. THE INTERACTION OF RHYTHM AND HEADEDNESS

As in other phonological domains, headedness in metrical feet can be formalized through alignment constraints, as illustrated in (27) below.

(27) ALIGN-L/R(FOOT, HEAD) (cf. McCarthy & Prince 1993)
The head syllable of a foot is left- / right- aligned within the foot.

The interaction between headedness and rhythmic constraints in metrical feet makes certain typological predictions. In grammars where rhythmic constraints outrank headedness constraints, the resulting foot structures will reflect the ITL, i.e. uneven iambs and even trochees, as shown in (28a), below. This is also the case in grammars where headedness constraints outrank rhythmic constraints, but where the demands of each constraint type do not conflict, as shown in (28b). Thus, six out of eight logically-possible rankings yield even trochees and uneven iambs.

(28) Typology of quantity-sensitive feet

a.	*EDGE	>>	PK-F	>>	AL-L	>>	AL-R		*uneven iambs*
	*EDGE	>>	PK-F	>>	AL-R	>>	AL-L		*uneven iambs*
	PK-F	>>	*EDGE	>>	AL-L	>>	AL-R		*even trochees*
	PK-F	>>	*EDGE	>>	AL-R	>>	AL-L		*even trochees*
b.	AL-R	>>	AL-L	>>	*EDGE	>>	PK-F		*uneven iambs*
	AL-L	>>	AL-R	>>	PK-F	>>	*EDGE		*even trochees*
c.	AL-R	>>	AL-L	>>	PK-F	>>	*EDGE		*even iambs*
d.	AL-L	>>	AL-R	>>	*EDGE	>>	PK-F		*uneven trochees*

The rankings in (28c) and (28d) generate stress systems which do not respect the ITL. Both rankings correspond to attested systems, however, and will be discussed in the following sections.

3.1 VOWEL REDUCTION AS MORA-LOSS

Quantitatively even iambs occur in systems where ALIGN-R(FT, HD) is highly ranked, forcing iambic footing in spite of the ranking PEAK-FIRST >> *EDGEMOST. Yet even in these systems, rhythmic well-formedness is often optimized through mora-loss in metrically weak positions. On the surface, this is manifested as extreme vowel reduction or deletion in many iambic systems.[14] By way of example, consider the Eastern Ojibwa data in (29) below.

(29) Eastern Ojibwa (Piggott 1980, Halle & Vergnaud 1987, Hayes 1995)[15]

a.	/ninamadabimi/	(nnà)(mdá)(bmì)	'we(excl.) sit'
b.	/adaaweewigamigw/	(dàa)(wée)(gà)(mìk)	'a store'

The forms in (29) correspond to the metrical structures in (30) below.

(30) Eastern Ojibwa stress

```
a. (    *)  (    *)  (    *)
        μ        μ        μ
   nØ  ná   mØ  dà   bØ  mì

b. (  * .)  (* .)  (   *)  (*)
      μμ     μμ        μ    μ
   Ø  dàa    wée   Ø   gà  mìk
```

Since PEAK-FIRST outranks *EDGEMOST in Eastern Ojibwa, the desire for initial prominence is second only to the requirement that the head syllable be right-aligned within the foot. Both demands are satisfied through deletion of the weak foot-initial mora, as illustrated in (31) and (32) below. Notice that this process is parallel to mora-loss in rising diphthongs (see section 2.2.2).

[14] For discussion on the analysis of vowel reduction as mora loss see Crosswhite (1999) and references cited therein.

[15] Piggott (1980) notes that not all vowels are deleted entirely.

(31) Mora-loss in an even iamb

Input: $\sigma_\mu\sigma_\mu$	ALIGN-R	PK-FIRST	*EDGE	MAX-μ
a. (* .) μ μ σ σ	*!		*	
b. (. *) μ μ σ σ		*!	*	
c. ☞ (*) μ σ σ			*	*

(32) Mora-loss in an uneven iamb

Input: $\sigma_\mu\sigma_{\mu\mu}$	ALIGN-R	PK-FIRST	*EDGE	MAX-μ
a. (. * .) μ μ μ σ σ		*!		
b. ☞ (* .) μ μ σ σ			*	*

Candidate (31a) fatally violates ALIGN-R due to nonalignment of the foot-head with the right edge. Candidates (31b) and (32a) fatally violate PEAK-FIRST for lack of initial prominence, leaving candidates (31c) and (32b) as the respective optimal outputs, despite violations of low-ranked MAX-μ.

While mora-loss in metrically weak syllables is consistent with the spirit of the ITL in that it increases the durational contrast between syllables in iambic feet, it is problematic for the Hayesian framework in that it destroys the canonical uneven iambic foot (see example (4)). When analysed in terms of rhythmic well-formedness, however, the process finds a structural analogue in the loss of initial moraicity in rising (iambic) diphthongal sequences, and the resulting iambic foot is still uneven, containing a weightless dependent syllable (see Piggott 1998 for discussion of weightless syllables in trochaic systems). Finally, the fact that feet containing a single mora are well-formed means that the footing of final syllables such as that in (29b) / (30b) to account for stress in unproblematic for the theory (cf. Hayes 1995).

3.2 IAMBICITY AT THE SUBSYLLABIC LEVEL

A final prediction of the typology in (28) above is the existence of systems where a highly-ranked ALIGN-L constraint imposes trochaic footing in spite of the ranking *EDGEMOST >> PEAK-FIRST. In such a system we would expect to find uneven trochaic feet of the type in (24b) above, where the internal prominence contour of the heavy syllable is exceptionally iambic. This appears to be thae case in certain dialects of Central Slovak, a trochaic language which enforces a three-mora limit on foot shape through vowel shortening in the dependent position of feet (Bethin 1998; Mellander 2002; cf. Kenstowicz & Rubach 1987; Rubach 1993).[16] As shown below, this process is triggered by long monophthongs ((33a)) as well as rising (iambic) diphthongs ((33b)).

[16] Such an analysis is not tenable in dialects with heavy falling diphthongs, such as Ipel': *powne* 'full' (Krajčovič 1988:267). Note that coda consonants do not contribute to syllable weight.

(33) Rhythmic shortening in Slovak (Kenstowicz & Rubach 1987)

a.	/dlaat-aax/	(dlaá.tax)	'chisel' locative pl.
	/muudr-ii/	(muú.dri)	'wise'
b.	/mliek-aax/	(mlié.kax)	'milk' locative pl.
	/biel-ii/	(bié.li)	'white'

The fact that rising diphthongs trigger rhythmic shortening implies that they are quantitatively equivalent to heavy syllables, i.e. that they are bimoraic. A rising sonority profile, however, demands an iambic rhythmic organisation at the subsyllabic level. Clearly, the forms in (33b) have the metrical structure in (24b), and it is conceivable that the long monophthongs in (33a) exhibit iambicity at the subsyllabic level as well (Kenstowicz & Rubach 1987).

Such a configuration allows for satisfaction of both ALIGN-L and *EDGEMOST at the expense of PEAK-FIRST, as illustrated in (34) below.

(34) Rhythmic well-formedness under ALIGN-L (cf. (25))

		ALIGN-L	*EDGEMOST	PEAK-FIRST
a.	([·] [* ·]) μ μ μ σ σ	*!		*
b. ☞	([· *] [·]) μ μ μ σ σ			**
c.	([*] [·]) μ μ σ σ		*!	

Candidate (34a) fatally violates ALIGN-L due to nonalignment of the head syllable with the left foot-edge, while candidate (34c) fatally violates *EDGEMOST for prominence on an edge-adjacent mora. This leaves candidate (34b) as optimal despite two violations of PEAK-FIRST: one for non-initial prominence within the foot and one for non-initial prominence within the syllable. Both the trochaic shape of the trimoraic foot as well as the occurrence of an iambic mora-prominence profile within a heavy syllable follow straightforwardly from the simultaneous satisfaction of ALIGN-L and *EDGEMOST.

We can thus conceive of Central Slovak as a trochaic system which exploits a foot-internal organisation characteristic of iambic systems.[17] This result follows straightforwardly under constraint interaction when trochaic headedness is imposed upon a rhythmically iambic system.

4. SUMMARY

This paper has presented an alternative to current theoretical explanations for asymmetric rhythmic patterning in metrical groupings. In binary domains, including the syllable-internal mora prominence of heavy syllables, the invariability of initial prominence eliminates the need for positional restrictions on moraicity such as weight-by-position and SONFALL. In quantity-sensitive feet, the effects of the ITL are explained in terms of rhythmic

[17] Thanks to Moira Yip for pointing out to me that quantity relations in Central Slovak resemble those found in iambic systems.

well-formedness with respect to foot-internal as well as syllable-internal mora-prominence. Finally, by formally de-linking headedness from the underlying rhythmic organisation of prosodic constituents, the analysis accounts for mora-loss in iambic systems as well as the unusual structure of feet and syllables in certain Central Slovak dialects.

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RÉSUMÉ

Le texte adresse un nombre de restrictions positionnelles dans les domaines métriques bien connues, y compris poids-par-position, moracité diphtonguée, la loi iambique/trochaique, et les processus quantitatifs apparentés. L'analyse proposée exploite les contraintes rythmiques en théorie optimaliste (Prince & Smolensky 1993; Van de Vijver 1998) afin de développer une explication intégrée de ces phénomènes, montrant qu'une gamme de faits peuvent être expliqués en termes de bonne conformation rythmique sans faire appel à des explications ad hoc.