Quantitative Consequences of Rhythmic Organization *

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Stress is not one thing but many things. Among the contributing systems, current understanding — flowing from Liberman (1975) — distinguishes grouping; grid prominence; and tonology: each with its own laws. Grouping or rhythmic constituency joins elements into local relations and defines the role 'strong(er,est) element' or 'head' of a prosodic category such as foot (the latter term from Prince 1983:22). The metrical grid gives a hierarchy of prominence rather than constituency. Tonology, which has a full life away from considerations of rhythm and grid prominence, also interacts with them in significant ways. The story of stress will therefore be the story of these systems: their internal properties; their relations; the factual domains each is to be held accountable for. None of these is fixed in advance by logic or by theory-free empirical certainties; hence the diversity and confusions of the live field of inquiry as it is practiced today.

Here we will be concerned with the principles of grouping structure. The goal is to extend Hayes's (1985) findings about rhythmic asymmetry and bring them into the purview of linguistic theory proper, so that consequences may be deduced for phonological and morphological processses that depend on prosodic constituency. The study of stress systems alone does not (we will see) provide sufficient evidence to distinguish among plausible alternative views of foot structure, at least at the level of gross and robust results where argument is most secure. Therefore we turn – and arguably must turn – to other domains richer in the kind of evidence we seek: the phonology of quantitative alternations; and prosodic morphology, in which morphological categories like *stem, affix, base* are delimited in terms of prosodic categories like heavy/light syllable and foot (McCarthy & Prince, refs.).

In order to get this project off the ground, we will commit broadly to two thematic ideas which have been playing an increasingly promising role in phonological thought. First, we will assume that the relative well-formedness or markedness of representations is evaluated by conditions that hold generally over all levels of derivation, with some parametrization possible between languages and lexical strata. The idea here is that the space of phonological representations has a nontrivial universal markedness structure on it, subject to direct theoretical explication. Foundational work which explores this idea in modern prosodic terms would nonexhaustively include Liberman (1975), Liberman & Prince (1975), Goldsmith (1976), Cairns & Feinstein (1982), Prince (1983a), Selkirk (1983), Clements (1988), Kaye & Lowenstamm (1984, 1986), Kaye, Lowenstamm & Vergnaud (1985), McCarthy (1986), Goldsmith (1989).

Second, we assume that there is a substantial class of rules whose mode of operation is to increase the well-formedness of representations, as defined by the kind of conditions just alluded to.

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Given a representational space with a markedness structure on it, the natural way to navigate around this space is to move upward in relative well-formedness. This notion has strong affinities with the Harmony Theory of Smolensky (1986), developed to explicate the dynamics of certain kinds of 'neural' networks; Goldsmith (1989,1990), working explicitly from Smolensky, takes this as a central principle delimiting the course of derivation.[1] Ideas of this character, traceable back at least to Kisseberth (1972), have played an important role in the development of metrical and autosegmental phonology and have been pursued in various forms in the works mentioned above as well as in Myers (1989), Yip (1988), Paradis (1988), Paradis & Prunet (in prep.), Singh (1987), and others. There are a quite a number of ways of implementing the thematic idea; for present purposes, we need only commit ourselves to 'some version' of the theory. More specific commitments may be found in Prince & Smolensky (in prep.). The importance of the general idea for present concerns is that it will allow us to argue back from process to structure.

(1) **Notation and Terminology**

Rhythmic groups will be shown bracketted or separated by periods; heads will sometimes be bolded; curly braces {} will mark syllables that stand outside binary feet.
With apologies to tonology, H = heavy syllable; L = light syllable.
The symbol σ=syllable; μ=mora; C,v refer descriptively to consonants and vowels, not to skeletal positions, whose existence is not assumed.
|X| will indicate the size, in appropriate units, of the constituent X.
⟨x⟩ signifies extrametrical x.
Curly ≻ means 'is better than or preferable to'.
S = strong(er) element, W = weak(er) element of rhythmic unit.
The foot [W S] will be termed *iambic*; the foot [S W] *trochaic*. The terms 'left-headed' and 'right-headed' will be avoided because they imply a symmetry that does not exist.
LR→ betokens iteration in the indicated direction, ←RL iteration in the other.

I. FEET

1. The Role of Weight: The Weight-to-Stress Principle

It is commonly found that heavy syllables attract stress. Within metrical theory, being stressed has a kind of formal ambiguity: it can mean either 'occupying the strong (head) position of a foot' or 'registered as prominent on the grid'. One may ask, then, whether the stress-attraction of heaviness follows from the principles of foot-form or from the principles which determine grid prominence. Foot-theorists have in general gone for foot-theoretic explanations (Prince 1976; Halle & Vergnaud 1978; Hayes 1980/1; Hammond 1986), but there is by now good evidence that the effects of weight cannot be reduced to foot-structure without damaging the *theory* of foot-structure.

One line of evidence comes from the existence of 'unbounded' stress systems: those in which main-stress falls on the nearest heavy syllable to an edge, and in words lacking heavy syllables, on an edgemost (light) syllable. Foot-theoretic accounts of these systems require not only the addition

[1] Goldsmith's work is notable in that, beyond providing for well-formedness-increasing rule-application, it also recognizes rules which are not so motivated, and offers a sharp hypothesis about their position in the grammar.

of an otherwise undetected foot-type, the unbounded, to the primitive repertory, but also a new condition on heaviness (the Obligatory Branching parameter). If the intrinsic affinity of heavy syllables for prominence is recognized, then such systems emerge naturally as the foot-free combination of heavy-syllable prominence with the quite independent ability of phonological rules to refer to the edges of domains (For detailed discussion, see Hayes 1980/1, Prince 1983a:73-79).

A second line of evidence comes from recent work disclosing pure weight-effects in bounded systems. Everett & Everett (1984) and Everett (1988) establish that the Amazonian language Pirahã has the following stress rule:

(2) "Stress the rightmost token of the heaviest syllable type in the last three syllables of the word."
— Everett 1988: 208.

This is entirely parallel, abstracting away from the three-syllable domain, to the unbounded type "stress the rightmost heavy syllable, or lacking heavies, the rightmost syllable," the only difference being that Pirahã uses a multi-degree weight scale rather than the familiar two-degree scale.[2] Therefore, the same weight-into-prominence description should apply. The theory of Prosodic Circumscription (McCarthy & Prince 1990a) provides the means for securing the 3–syllable domain. Prosodic Circumscription allows a phonologically-defined subdomain to be treated as the full domain in which a linguistic process operates. In the case at hand, that domain is a version of the Minimal Word – one bisyllabic foot plus one (extrametrical) syllable.[3] Within that domain, weight is assessed and enhanced, undoubtedly by applying the End Rule to a grid representation of weight, as suggested in Davis (1988).[4]

We therefore conclude that the following principle governs the well-formedness of metrical representations:[5]

(3) Weight-to-Stress Principle. (WSP) If heavy, then stressed.

Here 'stressed' assuredly means 'prominent on the grid'. If the notion 'strong element (head) of a foot' is not always cashed in for grid-prominence, as seems likely, given the wide-spread attestation of multi-foot systems with narrow possibilities for the prominential or accentual realization of foot-heads, then 'stressed' in (3) participates fully in the ambiguity of the term, and refers both to grid-prominence and to foot-position, whichever is at hand. In that case, WSP serves to define a

[2] Under the ordinary binary weight contrast, "rightmost token of the heaviest syllable type" = rightmost heavy syllable if there is one, otherwise final syllable.

[3] The trisyllabic domain, which appears frequently in stress and accent rules, is also found as the target of Cupeño templatic morphology (McCarthy & Prince 1990a: 234).

[4] The idea of securing a bounded domain in which stress is determined dates back, in metrical theory, to van der Hulst (1985) and reappears in McCarthy & Prince (1990a). See van der Hulst (1990) for a thorough exploration of the idea.

[5] McCarthy & Prince (1986: 9) give a gradient version of the same general idea.

correspondence which holds between notions of salience in three domains: syllabic weight (heaviness), foot structure (headship), and grid (prominence).

The WSP (3) has by contraposition a useful equivalent which will figure in the argument:

(4) **WSP** (contraposed). If unstressed, then light.

Kager (1989) proposes (4) as a principle in its own right. Note that (4) is an exact logical equivalent of (3), just a way of rephrasing it; anything true of one must be true of the other.

Since stressed syllables are not infrequently made heavy in the course of phonological derivation, it is commonly assumed that the converse of the WSP – 'if stressed, then heavy' – holds tendentially in the same way that the WSP does. This we specifically deny: the WSP is not a 'tendency', nor is its converse a principle;[6] we will seek elsewhere for the source of quantitative consequences of stress.

2. Grouping

Our concern is with foot structure sensitive to the quantity — moraic composition — of syllables. The WSP is offered here as an absolute condition on such foot types: they must meet its provisions. Little will be said about purely syllabic stress systems.[7]

The WSP, then, limits bisyllabic foot types to the following short list:

(5) **Bisyllabic Foot Types obeying WSP**
a. Iambic. L**H**, L**L**
b. Trochaic. **H**L, **L**L

The putative iambic type [H**L**] violates the WSP: its unstressed syllable is heavy; similarly for the putative trochaic type [**L**H]. A foot type [H H] would force an unstressed heavy syllable under either iambic or trochaic construal. Note that the WSP admits the foot [L L] as either iambic or trochaic.

This repertory is of course exactly the one assumed in the first flowering of metrical theory (*e.g*. Halle & Vergnaud 1978; Hayes 1980/1). And indeed the WSP is just a broader version, not limited to foot-structure, of the basic assumptions that defined that repertory. Thus, if 'W-nodes may not branch', in the sense of Hayes (1980/1), then unstressed syllables must be light; and heavy syllables must be stressed. The WSP yields a pleasing symmetry: trochaic mirrors iambic. However, in one of the most striking and unanticipated empirical findings of recent years, Hayes (1985) demonstrates that there are major asymmetries between iambic and trochaic modes of organization: roughly, iambic systems tend to enhance quantitative contrasts; trochaic systems do not (this latter to be qualified as we proceed).

[6] A more even-tempered position would hold that Stress-to-Weight is a principle, but one with a different position than Weight-to-Stress in the ranking of rhythmic priorities.

[7] If all syllables in the language are monomoraic, then any stress alternation must appear to be syllabic. Whether all quantity insensitive alternations can be reduced to moraic alternation in this way remains to be seen.

Hayes's findings for quantity can perhaps be summarized in two statements, where the notation |X| means 'the size of X':

(6) **Iambic Quantity (IQ)**.
In a rhythmic unit [W S], |S| > |W|, preferably.

(7) **Trochaic Quantity (TQ).**
In a rhythmic unit [S W], |S| = |W|, preferably.

In light of the thematic commitments sketched above, the appropriate response to these observations is to seek principles of linguistic theory from which they follow. These principles can be related to various psychological observations, but such observations do not tell us what we want to know. We want to be able to deduce a typology of feet for stress systems to build with; and we also want to be able to invoke the same formational principles to govern the quantitative augmentations and diminutions that depend on rhythmic organization, as well as the choice of templatic units in prosodic morphology.

Taken as measures of markedness, the generalizations *Iambic Quantity* and *Trochaic Quantity* impose further structure on the repertory of bisyllabic feet. (The sign '≻' means 'is better than'.)

(8) **Bisyllabic Foot Types Evaluated**
a. Iambic. L**H** ≻ L**L**
b. Trochaic. **L**L ≻ **H**L

The remaining feet to be considered are the monosyllables: H and L. Monomoraic (stressed) feet [L] are strongly discriminated against, even banned from many systems, and they do not serve when the category *foot* is called on in prosodic morphology (McCarthy & Prince 1986 1990a).[8] Under the familiar moraic analysis of weight, by which heavy syllables have two moras and light syllables just one, the contrast in relative well-formedness between monosyllabic feet [H] and [L] can be attributed to a demand for binary analysis of the foot.

(9) **Binarity**. Feet should be analyzable as binary.

Of all feet, only [L] fails to meet *Binarity*: the feet HL, LH, LL are binary on syllables, and the foot [H] is binary on moras.

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[8] Some theorists take account of this by banning monomoraic feet altogether (Selkirk; Giegerich; McCarthy & Prince; Kager). Hayes (1986), on the other hand, assigns them special status in one sense – they are claimed to be always headless – but otherwise they are treated on a par with all other legitimate feet. Recall that Hayes's (1986) theory is not a markedness theory, and does not take account of any notions of optimality, although his important descriptive work does, informally.

Hayes (1989) turns away from the headless foot, but we retain it in our discussion, as it is one of the most interesting developments of the Hammond (1984/8)-derived 'bracketted grid' notion, in which head is a category rather than a relation (strongest), as in previous work.

We may now evaluate all feet by how well their quantitative structure meets the structural requirements of Binarity (9) and IQ/TQ (6,7):

(10) **All Feet Evaluated**

Satisfy:	**IQ/TQ, Bin**		**Bin**		**Neither**
a. Iambic	LH	$\succ$	{LL, H}	$\succ$	L
b. Trochaic	{LL, H}	$\succ$	HL	$\succ$	L

On this accounting, [H] is a first-rate trochaic foot because it has two formally equal parts (its moras), but by that very token [H] will rank below [LH] as an iamb.

Scrutiny of Table (10a,b) shows a remarkable fact: despite the iambic-trochaic difference, the two rankings of quantitative patterns are entirely compatible. This allows us to hypothesize that there is a single *grouping generalization* that applies across the iambic/trochaic divide, and perhaps even embraces Binarity. It would order feet as in (11), collapsing the two scales in (10a,b):

(11) **Grouping Generalization**

LH $\succ$ {LL,H} $\succ$ HL $\succ$ L

What we want now is a single principle of grouping from which the ranking (11) follows. Evidently the ideal group is [x y] where $|y| > |x|$. We need to measure divergence from this ideal: $|y| = |x|$ diverges somewhat; $|x| > |y|$, with full quantitative inversion, diverges more; and the unit foot [x] diverges most. (Thus, from the grouping point of view, quantitative iambicity is the paragon.) To formalize the notion of divergence from an ideal, we avail ourselves of the notions of Harmony Theory (Smolensky 1986; Prince & Smolensky, in prep.), which Smolensky has characterized, in the linguistic context, as a form of 'quantitative computations with markedness theory': we give a function which assigns a numerical harmony value to the relevant groupings.

(12) **Grouping Harmony**

Let *G* be a Rhythmic unit, at most binary on syllables or moras.
Let X be the first element of G.
Let Y = G – X.
Let |Z| be the size of Z.

We define the Harmony $\mathcal{H}$ of G as follows:[9]

$$\mathcal{H}(G) = |Y| / |X|$$

The Harmony function $\mathcal{H}$ assigns the following ratings to the syllable-groups, where the prosodic size of syllable is measured in moras.[10]

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[9] This modifies a suggestion from Kevin Hegg, who proposed an additive measure.

[10] If we want to drive [L] off the scale, we could take log $\mathcal{H}$ as the appropriate measure; or, more prosaically, demand positive harmony of all participants.

(13) **Harmony Ratings**

a. LH	=	$[\mu\ \underline{\mu\mu}]$	*Harmony* = **2**
b. LL,H	=	$[\mu\ \ \underline{\mu}\ ]$	*Harmony* = **1**
c. HL	=	$[\mu\mu\ \underline{\mu}]$	*Harmony* = **½**
d. L	=	$[\mu\ \ \_\ ]$	*Harmony* = **0**

The term Y = *G* – X contributing the numerator in underlined.

The generalization *Trochaic Quantity* – that [S W] favors equality of S and W – follows now for feet because [L H] is ruled out as a trochee by the WSP. (Recall that the WSP is an absolute condition on admissibility of feet.) The hierarchy thus truncated includes H, LL, HL, and L, and is ranked by the $\mathcal{H}$ values (13 b,c,d).

A further Hayes (1985)-type observation that ought to follow from the theory is the converse of Trochaic Quantity (7), going from quantity to stress, taken in McCarthy & Prince (1986: 9) to be an independent principle and there dubbed "Trochaic Default":

(14) **Trochaic Stress**

In a rhythmic unit [x x] of equal elements, the preferred pattern is [S W].

For x = σ, this is Hayes's (1985) observation that quantity-insensitive languages are overwhelmingly trochaic. In the present terms, the question is: how can [LL] be preferably trochaic, given only Grouping Harmony and the WSP as guiding principles? Grouping Harmony is independent of prominence, and [L L] meets the WSP as *either* [S W] or [W S].

The key is that rhythmic category (iambic/trochaic) is assigned not foot-by-foot, but uniformly across a class of items (*e.g.* the words) in a language.[11] Because of the uniformity requirement, the iambic vs. trochaic decision has priority over Grouping Harmony, despite local circumstances in which allowing for a mixed prominence pattern might actually give better foot-by-foot (or word-by-word) harmony. Trochaic systems, for example, ban the foot LH, even though it is ideal as a group; iambic systems accept words containing only light syllables (but see footnote 10). Grouping Harmony, therefore, functions to rank alternatives within the two rhythmic categories.

The problem at hand is to make the iambic/trochaic decision, given that the rhythmic units in a system are going to be composed of elements accounted equal. To make this decision, we need to be able to compare harmony not just within rhythmic category but across the iambic/trochaic divide. We have the notion 'harmony of [x y] as a group,' which gives rise to the iambic and trochaic scales (10); we need the further notion of 'harmony of group [x y] *as-an-iamb/trochee*', which attaches an absolute value to ordinal position within the separate iambic/trochaic scales. A straightforward

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[11] Uniformity typically holds across an entire language, defining the stress pattern of words as either iambic or trochaic. In Yidin^y, though, (Dixon 1977; Nash 1979; Hayes 1980/1) the domain of uniformity is the *word:* words containing a long vowel at the end of a foot are iambic, other words are trochaic. Some preliminary discussion of uniformity is found in McCarthy & Prince (1986: 9).

way to do this would be to normalize the values assigned by Grouping Harmony, shown in (13), so that the top of each scale rates a '1'. This can be accomplished, for example, by dividing the Grouping Harmony of a given unit by the maximum Grouping Harmony obtainable within the rhythmic category. Call this measure 'Rhythmic Harmony' ($\mathfrak{R}\mathcal{H}$):

(15) **Rhythmic Harmony** ($\mathfrak{R}\mathcal{H}$)

Let g,f range over groups of units.

Let Rcat $\in$ {iambic, trochaic}.

$$\mathfrak{R}\mathcal{H}(g, \text{Rcat}) = \mathcal{H}(g) \,/\, \max\{\, \mathcal{H}(f), \text{all } f \in \text{Rcat}\}$$

The foot [x x] is the optimal trochee; its $\mathfrak{R}\mathcal{H}$ value is 1. As an iamb, it is second-rate: its $\mathfrak{R}\mathcal{H}$ value is ½. Therefore, if we are given that rhythmic units will be of the form [x x], we can conclude that trochaic assignment will optimize Rhythmic Harmony, and we can therefore deduce that such systems will tend to the trochaic.

3. Stress Patterns

To define a stress pattern requires not only access to a vocabulary of feet, but also a method for deploying them on word-forms. We will assume, as usual, that foot-parsing sweeps directionally across its domain. But we deny the usual claim that the *largest* possible foot is chosen at each step of the parse; rather, we claim that the parsing algorithm, in accord with the harmony structure on the foot-vocabulary, must choose the *best* foot.

(16) **Harmonic Parsing.** In the directional sweep (←RL, LR→) of foot-parsing, build the *best* foot — the one with maximum $\mathfrak{R}\mathcal{H}$ — from the materials available at the moment of parsing.

For iambic systems, Harmonic Parsing is indistinguishable from the standard maximality-based approach. This is because in the iambic scale, reproduced below, rhythmic harmony correlates misleadingly with size:

(17) **Iambic Rhythmic Harmony Scale**

LH $\succ$ {LL,H} $\succ$ L

The trochaic scale has a size-inversion, due to the relatively poor grouping status of HL:

(18) **Trochaic Rhythmic Harmony Scale**

{LL,H} $\succ$ HL $\succ$ L

Consequently, by Harmonic Parsing, the unit HL will be avoided when possible, contrary to the predictions of maximality theory.[12]

Significant effects can be seen when a trochaic pattern is imposed in an initial-to-final (LR→) sweep. By far the clearest and most discussed example is the stress pattern of Cairene Arabic, particularly as extended to (much longer) Classical Arabic words "as pronounced by teachers at Al-Azhar Mosque and University in Cairo and at Dār al-'Ulūm, the teachers' training college of Cairo University" (Mitchell,1975:76). Generative understanding of the pattern is due to Langendoen (1968) and to McCarthy (1979), whose original metrical analysis remains compelling in all fundamentals. The crucial patterns are displayed in (19):

(19) **Cairene pronunciation of Classical Arabic**

a. šájarah	šája. {ra ⟨h⟩}	'tree', clause final.
b. šajarátu	šaja. rátu	'tree', nom. sg.
c. šajarátuhu	šaja. rátu. {hu}	'his tree'
d. šajaratuhúmaa	šaja. ratu. húma ⟨a⟩	'their-two tree'
e. kátaba	káta. {ba}	'he wrote'
f. katabátaa	kata. báta ⟨a⟩	'they-two wrote'
g. kaatába	kaa. tába	'he corresponded' *káata. {ba}
h. qattálat	qat. tála ⟨t⟩	'she massacred' *qátta {la⟨t⟩}
i. ʔadwíyatu	ʔad. wíya. {tu}	'drug', nom.sg. *ʔadwi. yátu
j. ʔadwiyatúhu	ʔad. wiya. túhu	'his drug'
k. ʔadwiyatúhumaa	ʔad. wiya. túhu. {ma ⟨a⟩}	'their-two drug'
l. mustaqbílun	mus. taq. bílu ⟨n⟩	
m. bulahníyatu	{bu} lah. níya. {tu}	
n. darábt	{da} ráb. t	'I/you(sg.) beat'
o. yursiláan	yur.{si} láa.n	

The mainstressed syllable is shown with an accent-mark. Monomoraic syllables outside binary feet are enclosed in braces: they can be regarded as unparsed elements (McCarthy & Prince 1986, 1990a) or headless feet (Hayes 1986); at any rate, monomoraic stressed feet are, on the analysis suggested here, disallowed (see fn. 10). Final syllables must receive special treatment: here final heavy syllables (CVC#, CVV#) are treated as light, by extrametricality of the final mora, indicated by ⟨x⟩. Superheavies (CVCC, CVVC), which appear only at the end of the word, are analyzed as ordinary nonfinal heavy syllables CVV/CVC followed by an additional extrasyllabic C. Other

[12] Note an alternative approach in which LH can be a trochee, and is just rated worse that L; and HL an iamb, again rated worse than L. Harmonic Parsing will eliminate these from visibility, except under odd circumstances (like final syllable extrametricality). This approach would require revising the WSP so that it would contribute finitistically to harmony, a move whose utility will re-emerge in section 6.2.1. Right now, framed as an absolute condition, the WSP can be thought of as assigning a disharmonic penalty of $-\infty$ to any violators.

approaches to final syllable behavior are conceivable, with various consequences for the monomoraic foot issue, but they will not be enumerated here, since they do not alter the main point of the argument.

Trochaic feet are assigned LR→; main stress falls on the last foot-head in the word, perhaps because the *End Rule*(*Final*) applies to a grid-representation in which foot-heads are prominent. The crucial cases for Harmonic Parsing are (19, g-o). The word *ʔadwíyatu*, for example, submits to two possible analyses, given the foot repertory:

(20) a. ʔad. wíya. {tu}
b. * ʔadwi. yátu

Harmonic Parsing forces (20a), because the foot [ʔad] = [µ µ] is superior groupingwise to [ʔadwi] = [µµ µ]. Notice that the parsing decision is made locally: even though the incorrect ʔadwi.yátu (20b) has the not-inconsiderable virtue of avoiding the unparsed sequence (or monomoraic headless foot) *{tu} at the end of the word, there can in fact be no anticipatory admission of the secondbest HL foot.

Trochaic foot-parsing running the other way, ←RL, will produce rather different results. Let us consider Latin (or English), where this pattern occurs with syllable extrametricality.

(21) **Trochaic ←RL**
a. spátu ⟨la ⟩
b. a. róː ⟨ma⟩
c. per. féc ⟨toː ⟩
d. ínte ⟨ger⟩

The key contrast is between forms like quantitatively isomorphic forms like *qattálat* (19h) and *íntegere* (21d). In the first move of the latinate ←RL parse, working the end of the word, the choice is between [té] and [ínte]. Though neither is optimal, HL is preferred to L alone. In Cairene, starting at the beginning of the word, the choice is between [qat] and [qatta]; the better-structured group [qat] is chosen, leaving *talat* for the next foot. Notice that Latin, under the usual assumption of final syllable extrametricality, must admit monomoraic feet: *e.g.* [cá]⟨noː⟩. Consequently, *[in][té]⟨ger⟩ is a real danger.

In sum: The foot theory presented here, based upon the interaction of the Weight-to-Stress Principle and the notion of Grouping Harmony, predicts, under Harmonic Parsing (15), a leftward-rightward structural asymmetry in trochaic systems. Versions of metrical theory such as Hayes (1980/1), which admit the same foot repertory but call upon maximality rather than markedness in parsing, predict symmetry. Although trochaic quantity-dependent systems do not appear to occur in anything like the abundance of iambic systems, the facts currently available suggest that the prediction of asymmetry is borne out.

4. Comparison with Moraic Foot Theory: the Weakness of Stress

Hayes (1985), which draws the original distinction between iambic and trochaic systems, suggests a biconditional relation between quantity-insensitivity and trochaicity. While quantity insensitivity does strongly implicate trochaicity, it is not at all true that trochaicity is restricted to purely syllabic alternating systems — as we have just seen. Responding to this fact, McCarthy & Prince (1986) and Hayes (1986/7) independently notice that the trochaic idea — equality of members — can be realized in a weight-respecting fashion through the offices of the traditional bimoraic foot. These authors, then, place an absolute ban on HL, allowing only LL and H as full realizations of the trochaic foot.[13]

Surprisingly, perhaps, the Moraic Trochee (MT) theory and the current theory are not easily distinguished in terms of evidence from stress patterns. Iterating LR→, they give identical results. Harmonic Parsing entails that [HL] will never be formed left-to-right, its availability masked by the superiority of [H], leaving only [LL] and [H] as accessible binary feet – just those admitted by MT theory.

Working ←RL, the two theories will countenance different representations when faced with need to analyze an unparsed sequence HL. Harmonic Parsing produces [HL] and the MT theory [H]{L}, where {L} notates a headless foot or unfooted syllable. But if monomoraic elements outside binary feet are stressless, the two theories imply identical prominence relations, since [**H**L] is equivalent to [**H**]{L} in prominence distribution. We therefore have the following theorem:

(22) **Theorem.** The Harmonic Parsing Trochee is prominentially equivalent to the Moraic Trochee, when iterated ←RL, if monomoraic feet are stressless or disallowed.

Detailed proof is given in the Appendix. A quick corollary can be obtained for iambic systems, by simply inverting the sense of everything in Theorem (22) – swap trochee for iamb, ←RL for LR→. By mirror image symmetry, the considerations that establish (22) also show that LR→ footing with a Moraic *Iamb* – the foot [μ μ] with iambic heading – is prominentially equivalent to standard iambic footing.

(23) **Corollary.** The standard iamb, built LR→, produces representations prominentially equivalent to those built from the Moraic Iamb, if monomoraic feet are stressless or disallowed.

The Corollary (23) is particular striking, because the great preponderance of iambic systems — and there are many such, particularly in North America — show Left-to-Right construction.[14] Thus, if

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[13] Recall that Hayes (1986/7) admits [L], but regards it as stressless; McCarthy & Prince deny the existence of [L]. Neither theory can stand unmodified in the face of the empirical (like Latin cánoː), and either stressed [L] or stressed (gridwise or word-level) unfooted material must evidently be allowed (Kager 1989), but we will not take up the question here.

[14] Not all, though. Tiberian Hebrew (Prince 1975; McCarthy 1979; Prince 1985) shows a ←RL iamb. As does Tübatulabal (Voegelin 1935), Aklan (Hayes 1980/81), and perhaps Yapese (as described, but not so analyzed, in Hayes 1980/81).

we are content to go with the majority and hope that dissenters can be subdued, we have arrived at a situation where the central bulk of known patterns can be built from a strictly bimoraic foot,[15] trochaic in either direction, iambic LR→.

This reductive tactic stands in direct contradiction to the theory propounded here: and we now turn to two distinct sources of evidence from the larger world of prosodic structure which will establish the soundness of our premises, and allow us to dismiss the generalized bimoraic theory resoundingly and deal a blow or two to the bimoraic-trochee theory as well.

II. Quantitative Consequences

Because the principles proposed here are taken to evaluate all representations and not merely to provide an underlying vocabulary from which deviation is expected, we can draw from them a variety of predictions about the quantitative consequences of imposing iambic or trochaic rhythm.

5. Iambic Quantity

The grouping theory says that [x y] prefers |y| > |x|. For the iamb [WS], this accords perfectly with the WSP (3). On the assumption, noted in the introduction, that a substantial class of rules is devoted to optimizing representational harmony, we expect the following developments:

(24) **Iambic Quantitative Dynamism.** In a rhythmic unit [W S],

a. Lengthening. S should tend to lengthen. (GH)

b. Shortening. W should tend to shorten. (GH, WSP)

The lengthening property follows directly from Grouping Harmony. The shortening property also improves Grouping Harmony; in addition it accords with the WSP, particularly in its contrapositive form, "if unstressed, then light".

These are exactly the properties that Hayes (1985) found characteristic of iambic systems; readers are referred to that paper for citation of a number of examples of lengthening of syllables under iambic stress, reduction of syllables under iambic weakness.

6. Trochaic Quantity

For Hayes (1985), working with the assumption that trochaic systems are simply syllabic and insensitive to quantity, the primary feature of the trochaic is what might be called *stability*: a unit

[15] The generalized all-foot bimoraic theory has been proposed speculatively by Armin Mester (1990). The work of Kager fits in this view, as does that of Giegerich, cited above, and recent work by Mark Hewitt and H. van der Hulst (see bibliography). Indeed, aspects of the theory of Halle & Vergnaud (1987) might well be rationalized in these terms. In their text Halle & Vergnaud adhere, perhaps too closely, to the doctrines of Prince (1983a), assuming a grid-based rule for dealing with heavy syllables.

[x x] should display neither increase nor decrease in its elements. However, extending the trochaic idea to quantitatively-differentiated systems predicts certain dynamisms as well, which involve the shifting of substandard rhythmic units up the scale of well-formedness. The trochaic hierarchy {LL,H} ≻ HL ≻ L yields two kinds of expected shifts:

(a) elimination of the worst foot [L], a process also predicted to be found in iambic systems, which share the harsh evaluation of [L]; and

(b) elimination of [HL], which can have no iambic analog, since the long iambic foot [LH] is, by Grouping Harmony, optimal.

Let us begin with (b), elimination of [HL], the most characteristically trochaic prediction, and then turn to scrutiny of (a), elimination of [L].

6.1 Trochaic Shortening

The way to improve a (trochaic) foot [**H**L] is to shorten the H, yielding a foot [LL]. But this is surely a most surprising development: one by which *stressed* vowels lose weight. This flies in the face of the commonly-held belief that stressed syllables will always seek to enlarge themselves. Nevertheless, Grouping Harmony is clear on the point: [LL] is superior to [HL]. And the predicted phenomenon is observed.

A striking example is provided by the much-discussed rule of *Trisyllabic Shortening* in English (Jespersen (1909, Chomsky & Halle 1968), through which long vowels in stressed antepenultimate syllables come, often, to be short. The rule poses two structural puzzles:

(i) why *ante*penultimate (but not also penultimate)?
(ii) why shortening (and not lengthening)?

The first has been resolved definitively in Myers (1985, 1988). Due to final-syllable extrametricality, a stressed antepenult and and a stressed penult differ crucially in their structural relationship to a following syllable, as shown below:

(25) **Foot structure wrt Penultimate and Antepenultimate stress**

a. Penultimate.	… [**σ**] ⟨σ⟩ #
b. Antepenultimate	… [**σ** σ] ⟨σ⟩ #

Some typical English examples are given in (26):

(26)

a.	óːmen	→	[óː] ⟨men⟩		
b.	óːmin+ous	→	[óːmin] ⟨ous⟩	→	[**ó**min] ous
c.	sáːn+ity	→	[sáːni] ⟨ty⟩	→	[**sá**ni] ty

The stressed penult forms a foot by itself; the stressed antepenult is joined to a following syllable. Consequently, the principles of rhythmic harmony predict that the foot containing the antepenult could profit from a reformation mapping it from [HL] to [LL]. Shortening the main-stressed syllable of the word accomplishes exactly this; but no such maneuver is indicated for words like [óː] men. Rhythmic Harmony thus explains the shortening effect.

Myers makes the clinching observation that when the final syllable is *not* extrametrical and so is paired footwise with the penult, as with the anomalous adjective suffix *-ic*, the penult vowel tends strongly to shorten.

(27) **Nonextrametricality ⇒ Penult Stress, Shortening**

a. métal	me [tállic]
b. c**óː**ne	[c**ó**nic]

Example (27a) shows how the suffix *-ic* induces penult stress, even on short vowels, indicating that it is not extrametrical. Example (27b) shows the characteristic (if not exceptionless) shortening. For the first time, sense has been made of the conjunction of pre-stressing and shortening in such affixes. And this evidence shows that 'Trisyllabic Shortening', being Trochaic Shortening, occurs in bisyllables when conditions are right.[16]

American English also provides another unambiguously bisyllabic version of the phenomenon. The vowels in the Latinate prefixes *re-* and *pre-*, when unstressed and proclitic (*re*deem, *pre*tend) are realized freely as something, or anything, between schwa and short tense [i]. Elsewhere, when stressed, their value is determined by Rhythmic Harmony, as seen in the nouns listed below:

(28) **Trochaicity in Certain Latinate Prefixes**

rébel	récord		résignation	[rɛ−]
réːbàːte	réːflèx		réːlàxation	[ri−]
préface	prélate	prémise	présentation	[prɛ−]
préːfèct	préːlàːte	préːfix	préːsèntation	[pri−]

In every case, when the prefix heads a bisyllabic foot, it shows up with a short vowel; when it is in a monosyllabic foot, the vowel is long. A straightforward way to handle the alternation would be to endow the prefixes with long vowels underlyingly, and shorten them (post extrametricality-loss!) in the trochaic environment; more interesting, but fraught with unsolved technical problems, would be to regard their length as unspecified and filled in with the unmarked, rhythmically expected values. Now, the case here would be more compelling if the example-list in (28) were less than exhaustive. But the evidence nonetheless suggests that the prefixal alternations in general (of which a sample

[16] Myers himself agrees with Stampe (1973/79) and Borowsky (1986) in assuming a rule of syllable-closing backwards resyllabification (mapping e.g. *co*.nic into *con*.ic) which triggers closed-syllable shortening. A possible argument in favor of the present approach is that it avoids the resyllabification rule, for arguments against which see Halle & Steriade (1989). See also note 17 below. More interestingly, closed-syllable shortening itself can be construed as subcase of Trochaic Shortening, *v.* section 7.2 *inf.*, recapturing the Stampe-Myers generalization.

is provided in the rightmost column) are due not to Trisyllabic but to Bisyllabic Shortening.[17] Consequences for the cyclic grammar of English are deep, but cannot be taken up here.

The phenomenon of trochaic shortening clearly militates against mirror-image symmetrical views of foot structure, which see iamb and trochee as twins merely going opposite directions in time. Its import for deciding among theories of trochaicity is less clear. Bimoraic trochee theory will also treat the relevant input structures as special: our [HL] will correspond to [H]{L}, where by {L} is meant either a headless foot or no foot at all. Trochaic Shortening, accompanied by a re-parse would map the sequence [H]{L} to the foot [L L], eliminating {L}. Now, it would certainly be possible to reconfigure Grouping Harmony so as to *exclude* [HL] while recognizing and imposing a low evaluation on {L}, thus encouraging {L}-elimination. The present theory, regardless of alternatives, still has the not inconsiderable virtue that it entails the existence of Trochaic Shortening; and, the issue of foot-shape being strictly an empirical one, in section III below we shall examine direct evidence for the existence of [HL].

6.2 Effects involving Stressed Monomoraic Feet

What to do with [**L**]? Grouping Harmony ranks it at the bottom of the scale, and interpretations of the Grouping Harmony values are available which would ban it entirely (see fn. 10). Within the domain of stress, outright destressing or stress-shift off an offending monomoraic foot is expected. Quantitatively, holding stress constant, two basic possibilities present themselves:

(i) **Incorporation:** [L]X → [L L]
(ii) **Expansion:** [L] → [H]

Let us consider them in turn.

6.2.1 Incorporation: the Shortening of Unstress

The classical example is the rule active at a certain point in Latin, known under the cryptic abbreviation *Brevis Brevians* for its effects on early verse (Plautus, Terence), and called "iambic shortening" in W. S. Allen's invaluable study of Greek and Latin prosody (Allen 1973). *Brevis Brevians* is a rule of post-stress reduction which applies most obviously to shorten final long vowels in disyllables with light initial syllables. Examples include the following (Allen 1973: 179):

(29) a. egoː → ego
b. citoː → cito
c. modoː → modo

[17] In very recent work, appearing even as I write, Hayes (1990) reports and analyzes a perfectly unambiguous and phonologically general case of bisyllabic Trochaic Shortening in Fijian, which has a Latin/English-like stress pattern without extrametricality. Hayes points out that the Stampe-Myers interpretation of 'Trisyllabic' Shortening as a closed-syllable effect is untenable in Fijian, which lacks closed syllables completely; the rhythmic explanation of the type offered here faces no plausible competitor.

d. *bene: → bene
e. *male: → male
f. *duo: → duo

g. ambo: *no change*
h. longe: *no change*

Allen also shows that the process took place under secondary stress, citing forms where the shortened vowel was later lexicalized, like *pàte̲fácio, càle̲fácio*, as well as early historical forms like *àmi̲cítiam, uère̲bá:mini,* where the later language shows restored length, due to the influence of related words like *amí:cus*[18] (Allen 1973: 181).

Brevis Brevians also affects syllables heavy by virtue of consonantal closure. Allen (1973:182-3) cites the following examples from Plautus:

(30) **Plautine scansions**

	Words		Scanned like
a.	adest	≡	a.de. ~
b.	senex	≡	se.ne .~
c.	volupta:tes	≡	vo.lu. ~
d.	juventu:te	≡	ju.ve. ~
e.	guberna:bunt	≡	gu.be.~
f.	uter vostro:rum	≡	u. te . ~
g.	dedit do:no:	≡	de.di. ~

The reduction enforced by Brevis Brevians is thus not merely vowel-shortening. Kager (1989) proposes a syllabic restructuring process 'deweighting' which renders syllable-final consonants nonmoraic and by the same token shortens long vowels. See Kager (1989:139,163-168,291-294) for details; McCarthy (1979) for the basic notion of syllabic isomerism; and Hayes (1989) for further applications.

Brevis Brevians takes an [S W] unit that is quantitatively [**L** H] and maps it into the preferred trochaic foot form [**L** L]. For Allen, this motivates and delimits the process: it functions "to create a normal disyllabic stress matrix," where *stress matrix* is Allen's term for the bimoraic trochee (Allen 1973: 163-70, 179). Crucially, Brevis Brevians does not apply when the stressed syllable is heavy (e.g. á*m*bo:, *lón*go:). In such cases, the stressed syllable is already an optimal bimoraic foot [μμ], and appending a light syllable to it would only damage its rhythmic status, yielding the poor group [μμ μ].

In terms of the present theory (or rather, the family of theories to which it belongs), something like Allen's explanation goes through. The **L**H group is not, and cannot be, a trochaic foot; but is rather parsed as a sequence of a (stressed) monomoraic foot + something else: [**L**]H. The crucial effect of the process is to eliminate the monomoraic foot, by incorporating a reduced version of the

[18] Forms like ami:cus show that rule came into the language after the prehistoric stage when stress (accent?) was strictly initial (Allen 1973:181).

following syllable into it. The way things have been set up here, the string **L**H is not directly evaluated as a unit; rather its sequential structure has consequences for footing that *are* evaluated. Whether or not the extreme desirability of the output [L L] plays an important role is masked by the extreme undesirability of the input [**L**]H.

The sequence **H**H is under no such rhythmic pressure, lacking the monosyllabic foot. Perhaps this suffices to explain its stability under Brevis Brevians. If so, then the status of [HL] is not an issue, and Brevis Brevians provides no information about iambic/trochaic asymmetry, since it turns solely on the low status of [L], the worst foot *tout court*.

If the status of [HL] as an output is to come into the calculation, there must be a source of pressure on the final H that is independent of preceding context. A natural candidate is the WSP: on the assumption that the extrametrical syllables of Latin are truly stressless, heavy finals will violate the WSP. Therefore the H →L reduction is motivated, context freely, to increase satisfaction of the WSP; but it is blocked in HH#, we'd argue, by the bad Rhythmic Harmony status of [HL]. This is an attractive argument, because it provides a principled basis, in the WSP, for the Brevis Brevians mode of resolution of the [L] problem – *reduction* of following H rather than expansion of the [L]. To make the argument go, of course, we'd have to modify the the status of the WSP, revising it from an absolute to a relative constraint.

But a puzzle lurks in the argument, as John McCarthy has observed. Above, we saw that the WSP has primacy over Grouping Harmony in establishing the foot repertory: thus [**L**H], the best group, is nevertheless an impermissible trochee because it violates the WSP. Here, on the other hand, we want to say the opposite – that Grouping Harmony has primacy over the WSP, blocking [HL] from [H]H. Though problematic, the apparent contradiction is not one of logic, because the two contests of WSP *v.* GH are fought on different empirical territory. Trochaic foot theory needs [L][H] ≻ [LH]; Brevis Brevians needs [H]H ≻ [HL]. Reformulation of the WSP is too consequential a matter, however, to be undertaken lightly, and we will leave the matter unresolved here.[19]

A strikingly similar phenomenon is found in English, known in certain circles as *Fidelholtz's Law* (Fidelholtz 1967; Allen 1973). The memorable observation is that the word 'Arab' submits dialectally to only two pronunciations: [éy][rǽb], with two stresses, and [érəb], with one; missing are two-stress [é][rǽb] and one-stress [éyrəb]. What this pattern avoids, as we predict, in addition to the monomoraic stressed foot, is the foot [H L]. If the rule responsible is correctly construed as the reduction of the final closed (heavy) syllable, then it parallels the Brevis Brevians pattern quite closely. For further exemplification and assessment of the rule's role in the vocabulary at large, see Ross (1972: 254-258).

[19] Notice that if the final H's of Latin are indeed stressed, then the WSP as formulated above is entirely satisfied, and therefore irrelevant. Further, if they are stressed, then another form of analysis altogether presents itself: destressing in clash, entailing Kagerian deweighting. As observed in Prince (1983b), where this analysis was proposed, when heavy syllables are given a bipositional representation (Prince 1983a), the sequence L.H = X.Xx with clash, but H.H = Xx.Xx without clash. (Here 'X' spells a 2-level column of grid entries.) Further scrutiny of this nexus of issues is obviously required.

6.2.2 [L] Expands: Lengthening Stressed Syllables in Trochaic Systems

On the face of it, it might appear that stressed syllables ought never to lengthen in trochaic systems. However, there are perfectly clear cases of exactly this. Consider Chamorro, the language of Guam. In her major and influential study of the stress-phonology of the language, Chung (1983) reports that "vowels are lengthened if they bear primary stress and occur in a penultimate open syllable." The process offers a direct challenge to (a) the Hayesian claim that trochaic systems do not enhance quantitative contrast, and (b) our denial of the converse of the WSP — 'if stressed, then heavy'.

Primary stress in Chamorro regularly falls on one of the last three syllables in the word, excluding certain stress-attracting prefixes: it is final in a few Spanish loans (e.g. *kafé*), antepenultimate in a number of words, "virtually all of which have a light penult;" and in the great majority of cases, penultimate. The centrality of penult stress emerges under morphological derivation: *all* suffixes induce it, regardless of the base. The diagnosis, then, is that stress is trochaic, sensitive to quantity, and occasionally subject to extrametricality of final syllables. (Final consonants are assumed to be extrametrical, so that final syllables are always light.) The lengthening process can be seen in the following examples:

(31) **Chamorro Stressed Penult Lengthening**

/nana/	n**áː**na	'mother'
/alitus/	al**íː**tus	'earrings' < Sp. arete
/higadu/	**í**gadu	'liver' < Sp. hígado

It is striking that lengthening does not happen in *all* stressed open syllables, which would suggest a simple stress-to-weight relationship, but is limited to the penult. Chung remarks on the complementarity of penult lengthening with Trisyllabic – antepenult – Shortening, which we are now in a position to understand.

Suppose that the Chamorro process is initiated by detaching the last syllable, when weak, from the foot it belongs to; this may be thought of as a kind of 'feature-changing' application of extrametricality (the same kind of idea is proposed in another context[20] by Wilkinson 1987/8). The effect of this detachment will vary with input: for penult-stressed items, it will render the main-stress foot monomoraic; for *ante*penultimately stressed items, in which the final syllable is already extrametrical and therefore extrapedal, the foot structure will be unaffected. The derived monomoraic foot then expands to canonical size.

(32)	**Input**		**Exm.**		**[μ] ⇒ [μμ]**
a.	[nána]	→	[ná]*na*	→	[n**áː**]na
b.	[íga]du	→	*no effect*		*not applicable*

[20] Due to the intervention of intellectually responsible authorities at some crucial juncture, the idea does not appear in the published version.

Junko Itô points out that this analysis raises the question of why a final-stressed vowel (*kafé*), which necessarily inhabits a monomoraic foot, does not lengthen. This could be due to the exceptional, lexically specified character of final stress (unlikely, since lengthening is a low-level rule); or more plausibly, to an independent limitation on the lengthening of final vowels, of a sort commonly encountered — it is also operative, for example, in Italian (Chierchia 1986; Burzio 1987) and Choctaw (Lombardi & McCarthy 1990a).

A virtually identical process is found in the history of Italian (and in the phonetic lengthening of vowels under stress in the contemporary language). Calabrese (1983/4) writes that "… there is a constraint on lengthening and diphthongization in Italian; no lengthening or diphthongization occurs when the stressed vowel is in the antepenultimate syllable, i.e. in the case of antepenultimate stress." Calabrese cites these examples of the historical diphthongization under stress of lax mid vowels:

(33) **Italian < Latin**

	A.P.	**Penult**	**Glosses**
a.	m**é**dico	p**ié**de < p**é**de(m)	'physician'/ 'foot'
b.	s**é**colo	m**ié**le < m**é**le(m)	'century' / 'honey'
c.	p**ó**polo	**uó**mo < h**ó**mo	'people' / 'man'
d.	st**ó**maco	c**uó**re	'stomach' / 'heart'

Clearly, the same analysis holds here as in Chamorro – expansion under stress of open syllables, but only when they occupy monomoraic feet. Since Latin stress calls on extrametricality generally (as opposed to Chamorro, where it is an occasional lexical option), it may be that no feature-changing rule of extrametricality is involved; fixing the details will require closer consideration of the immediately pre-Italian state of the late Latin language.

Lengthening under stress, then, need not contradict trochaic norms. The real source in the cases examined here is Binarity, the requirement that feet consist of two elements; and Binarity is shared equally with iambic systems. Trochaic structure contributes only inasmuch as it places a weak element at the end of the word, where it is a candidate for re-interpretation as extrametrical. The Chamorro/Italian phenomenon is really a kind of compensatory lengthening in which the loss to be compensated for is not an outright deletion but a *restructuring* that is equivalent in its effects. By the same token, so-called Trisyllabic Shortening is a kind of compensatory shortening, in which loss of a mora from the stressed vowel compensates, as it were, for the appearance of an extra mora in the foot.

Two further expectations should be noted. First, because the structural property that excludes penults from Trisyllabic Shortening is by hypothesis the same as what leads to Penult Lengthening — final syllable extrametricality — , we should expect to find the two processes co-occuring in the same language. For example, in an English-like language one might expect at least a lexical tendency to have bisyllables of the form HL in word classes where extrametricality is general.[21] Second,

[21] The Italian family of languages may well provide the case we are looking for. Hayes (1990) observes that various Italian dialects at various times have shown Trisyllabic Shortening; this in addition to the penult lengthening discussed here.

because the explanation is based on moraic structure rather than vowel length, we expect consequences for the realization of consonants as well: lightening of the first syllable of a foot [HL], perhaps by a syllabic restructuring operation like Kager's 'deweighting', will not only shorten vowels and geminates, but render nonmoraic any syllable-closing consonants. These will contrast with the fully moraic consonant closing a foot [H]. We expect, then, to find notable phonetic differences between syllable final consonants depending on foot-position. These are well-known in spectacular cases like Estonian (see Lehiste 1965; Prince 1980, *etc.*), but further research is needed to clarify the subtleties.

6.3 Lengthening of Trochaic W

Grouping Harmony rewards the lengthening of constituent-final elements. Since, under the present theory, this is restricted only by the WSP, a further prediction is that it should be possible to lengthen a weak element *sub*moraically – that is, so long as the increase does not count as moraic weight and invoke the WSP. This is what we find in Estonian, both as the phonological 'third degree of weight' in syllables, and as the 'half long vowel' and what Lehiste has called 'ambiguous quantity' in consonants (Prince 1980). Similar phonetic phenomena are found in Finnish as well (Lehiste 1965; Dunn 1990).

7. Conundrum & Extensions

7.1 Conundrum

The major conundrum posed by the present theory, as indeed by any attempt to enlarge upon the fundamental insights of Hayes (1985), is not far to seek: if trochaicity inhibits strong-syllable lengthening and weak-syllable reduction, favoring a balanced rhythmic unit [x x], then why in a manifestly trochaic language like English are stressed syllables lengthened and stressless syllables reduced?[22] Such, I fear, is the course of Galilean science, that does not scruple to render the obvious inexplicable. Clearly, we are missing something; but how could we not? Aimed specifically at the role and interplay of weight and rhythmic organization, the present proposals do not address the character of what in traditional terms is referred to as 'dynamic' or 'expiratory' stress. Perhaps when that is brought into serious consideration, the enhancements of prominence characteristic of English-like languages will come to be understood.

[22] Along the same lines, the Nordic law that stressed syllables must heavy provides an obvious apparent challenge to our claim that the converse of the WSP does not have principle status, as Jim Cathey has reminded me. Note, however, that the Nordic phenomenon arose in word forms largely of the shape CVCV, with initial syllable stress, and so could actually be due to the same sort of extrametricality process visible in Italian and Chamorro: thus it is neither necessary nor desirable to take the facts as immediately disconfirmatory. The other major contributor to the Nordic phenomenon was the lengthening of monosyllables CVC to CVːC or CVCː, a minimal word effect (McCarthy & Prince 1986), argued in Riad (1990) to follow from the introduction of final consonant extrametricality in Old Swedish. See Árnason (1980) for much relevant discussion.

7.2 Extensions (micro)

Suppose speculatively that the same principles that determine foot-organization apply at the micro-level of syllabic structure. Some of the basic observations about syllables then follow.

Onset Principle. [CV...] ≻ [V...]. This repeats at the micro- level the grouping generalization: [x y] prefers |y| > |x|. Consonants being phonetically much shorter than vowels, CV is therefore a fine group, V or VC much less so. The onset-rime sequence is a micro-iamb. Thus, a consonant (or consonant-cluster of licit sonority profile) should be grouped with a following rather than a preceding vowel.

Rime Structure. VV ≻ VC. Rime structure is typically fixed as micro-trochaic, with the most prominent element standing initially; Grouping Harmony stills predicts that the final element should be longer rather than shorter, and this is certainly the case. A poor rime indeed is VːC, analogous to the [HL] trochee. Note that there is no constraint analogous to Binarity on Rimes, and the unit Rime is in fact superior.

Closed Syllable Shortening. VːC → VC. This eliminates one of the worst rimes, in a way that mimics Trochaic Shortening (HL → LL). If this parallel holds, then Closed Syllable Shortening and Trochaic Shortening derive from the same principle, recapturing the relationship posited by Stampe and Myers, which they achieve by routing Trochaic Shortening through Closed Syllable Shortening.

7.3 Extensions (macro)

If it is true, as asserted in Hammond (1990), that all *superfeet* – rhythmic groups FF – are SW, then the present theory offers an approach to explanation. Under the assumption that the measure of superfoot elements is just F, rather than σ, then superfeet must always of the form [x x]. The optimal $\mathfrak{R}\mathcal{H}$ value would be obtained by assigning super-trochaic prominence to any such unit.

Some refinement of the present theory, which is built around syllabic-moraic contributions to foot structure, will be required to make this all go through; but the game appears to be worth the candle.

8. Summary of Quantitative Findings: Stroke & Counterstroke

With a harmony structure on representations, such as has been proposed here, and with rules operating to increase harmony, an initial typology of rhythmically-driven quantitative dynamisms emerges. Viewed alone, the iambic type — lengthen S, shorten W — might be taken to reflect nothing more than a simple biconditional weight-to-stress and stress-to-weight relationship: 'heavy iff stressed.' The trochaic type fills in the picture, falsifying the biconditional right-to-left: stress does not imply heaviness. Since [μ μ] ≻ [μμ μ], Trochaic Shortening may affect stressed syllables in bisyllabic feet, as in the rule *Trisyllabic Shortening*.

Lengthening under stress is not banned from trochaic systems, but is severely restricted: it should occur only in monomoraic feet. The shortening type **L**H → **L**L, as in Brevis Brevians, also eliminates a monomoraic foot. The Brevis Brevians *failure* of HH to reduce to HL might also be telling us about HL's relatively poor rhythmic status, and thus providing us with further evidence about trochaicity, but any result along these lines awaits further development of the theory.

Two effects, then, are proper to trochaic systems and absent from iambic systems, refuting time-symmetric foot theories: shortening of stressed syllables; and the limitation of stress-lengthening to monomoraic feet.

Within the trochaic domain, the evidence reviewed here falls short of definitively elevating the present approach over a bimoraicist view which denies the possibility of [HL]. In particular, one could base a rather attractive theory of quantitative effects on the observation that [μ μ] ≻ [μ],{μ}. All of the cases we've discussed would turn on the elimination of [μ] or {μ}, and the concomitant creation of [μ μ] as an output. Both theories agree on the need to eliminate [L]. (Brevis Brevians eliminates [L] by joining it with a following suitably-modified syllable; stress-lengthening of the Chamorro/Italian type eliminates [μ] by inflating it to [μμ].) Bimoraicist theory must recognize and evaluate stressless {L}. Since our [HL] is be the bimoraicist's [H]{L}, Trochaic Shortening functions to eliminate {μ}. The principal difference thus far disclosed lies in the treatment of **H**L, which the present theory theory evaluates directly through the general Grouping Harmony principle. But the two approaches are not strictly equivalent, since (given various complexities) {L} can appear in other places besides directly adjacent to H. Rather than attempt a delicate argument on this point, we turn to an area where this is some hope of having the foot declare itself unmistakably.

III. Prosodic Morphology Effects

9. Introductory

Prosodic morphology is the study of processes of word formation in which morphemes are defined or constrained by their *shape* rather than by their segmental content. Under the Prosodic Morphology Hypothesis of McCarthy & Prince (*e.g.* 1986, 1990a), shape-constraints are always given in terms of prosodic categories: mora, syllable, foot, word. If the Prosodic Morphology Hypothesis is correct, systems of shape-invariant morphology should provide an invaluable source of evidence about the character of prosodic categories. We will review four such systems — two iambic, two trochaic — arguing that they provide crucial supporting evidence for the foot theory advanced here. Except where noted, the material discussed below is drawn from joint work with John McCarthy (see refs.).

10. Iambic Systems

10.1 The Classical Arabic Nominal System

The canonical noun stems of Classical Arabic fall into a small number of shapes.[23] Table (34) presents all of them in the handy C,v summary form:

[23] By 'canonical' is meant, at least, 'capable of forming a broken plural' (McCarthy & Prince 1990a,b). The stem-forms cited exclude inflectional suffixes.

(34) **Noun Stem Canons of Classical Arabic**

Bi-μ	Tri-μ	Tetra-μ	Special
σ,σσ:iamb	σσ: iamb	σσ: iamb+iamb	σσ: anti-iamb!
CvC.C	CvCvv.C	CvCCvv.C	CvvCv.C
CvCv.C		CvvCvv.C	CvCCv.C
(Cvv.C)			

Final stem consonants are extrasyllabic, as shown, and do not contribute to the weight of final syllables.[24] Arabic syllables, then, are of the form Cv(X), for X=C,v, where vv always signifies a long vowel.

It is obvious that canonical noun stems must no longer than biyllabic. In addition, the first three columns fall under a striking prosodic generalization, first adumbrated in the work of Fleisch (1968): they can be parsed into iambic feet. For the two- and four-mora forms, this not distinct from parsability into trochaic feet, since the feet are [μμ]; but iambicity is crucial in distinguishing the canonical trimoraic form CvCvv.C (LH) from the anti-iambic forms CvvCv.C and CvCCv.C (HL).

A sense of the actual distribution of shape-types in the lexicon can be gathered from table (35), modified from McCarthy & Prince (1990b: 24), displaying the results of a survey of all nouns that take broken plurals listed in the first half (up to p. 613 of 1010) of Wehr's *Dictionary of Modern Written Arabic*:[25]

(35) **The Facts**	**2 moras**.............		**3 moras**......................		**4 moras**
			Iambic	**anti-Iambic**	
Biliterals	barr	sabab	jadiid	baarir	jaaruur
% of Nouns	6%	<1%	3%	<1%	<1%
% of Bilits.	~60%		~30%		
Triliterals	baħr	badal	ʕataan	kaatib	jaamuus
% of Nouns	27%	7%	18%	12%	2%
% of Trilits.	41%	11%	27%	18%	3%
Quadriliterals				xanjar	rasmaal
% of Nouns				14%	11%
% of Quadrilits.				54%	46%

Glosses:
Biliterals: pious/ tent-rope,reason/ new/ ?/ drawer (of desk).
Triliterals: sea/ replacement/ female donkey/ writer, scribe/ buffalo.
Quadriliterals: dagger/ capital (*i.e.* $).

[24] Since all noun suffixes begin with vowels, and since nouns are always suffixed (except in pause), stem-final consonants never do belong to the stem-final syllable.

[25] Modern written Arabic is sufficiently close to Classical Arabic to justify the use of the statistics so derived.

On the face of it, table (35) holds out little hope that any foot-level prosodic constraint is at work in the lexicon: all possible bisyllables are attested. Among trimoraic forms, anti-iambs HL are perhaps even significantly more frequent than iambs (26% of trimoraic nouns anti-iambic, vs 21% iambic). However, a closer look shows that anti-iambs fall almost entirely into two narrow classes: quadriliterals like *xanjar*; and triliterals CaaCiC like *kaatib*, which are all lexicalized active participles of Form I verbs (*katab-* = write; *kaatib* = writer, scribe, secretary). The contrast between iambic and anti-iambic triliterals is clear in table (36), reproduced from McCarthy & Prince (1990b:28):

(36) **Iambic vs. Anti-Iambic *Triliteral* Noun Stems**

CvCvv.C			**CvvCv.C**		
CaCiiC	265	57%	CaaCic	263	**97%**
CiCaaC	106	23%			
CaCaaC	37	8%	CaaCaC	7	3%
CaCuuC	29	6%	CaaCuC	1	–
CuCaaC	25	5%			
CiCiiC	1	–			
TOTAL	463			271	

The iambic forms are well-represented in virtually every normal vowel-pattern class, but fully 97% of the anti-iambs have the pattern *a-i*, because they are derived from Form I verbal participles.

Excluding the de-verbals, then, leaves only the quadriliterals CvCCv.C (e.g. *xanjar*). Here the relevant factor is surely the sheer number of consonants in the root. Given the limited syllable-structure options of the language, the frame CvCCv.C is just the minimal syllable sequence that allows all 4 consonants of the quadriliteral root to be expressed. We conclude that *xanjar* and the like actually have *no* prosodic template — form is driven by substance here, subject only to the syllabifiability constraint on noun stems.[26]

The Arabic nominal lexicon is delimited by three sets of conditions: those defining roots; those defining stems (both noun and verb); those defining nouns in particular. Roots meet the following two constraints:

[26] It might be thought that since prosodic morphology is about templates, the existence a no-template category is somehow deconstructive or contrary to the spirit of the enterprise. The opposite is true, as McCarthy & Prince (1986) make clear. The Prosodic Morphology Hypothesis (template = prosodic category) cannot begin to work unless the basic analytic assumption of generative grammar – that observed forms are emergent from the interaction of various modules of constraint – is vigorously adhered to. After all, most reduplicative and templatic forms do not look, on the face of things, just like prosodic categories; if they did, the Prosodic Morphology Hypothesis would be little more than a tired cliché. The prosodic template is one form of constraint, interacting with other (language-specific, language-general) principles of syllabification, association, phonology, and morphology. Whatever aspects of surface prosody are predictable on other grounds cannot therefore be attributed to the template itself; if the prosody is entirely predictable on other grounds, then there is no prosodic template.

(37) **Root Canon**

(a) **Segmentism**. Roots are 2,3,4 consonants long.[27]

(b) **Expression**. All root consonantism must be expressed.

Both noun and verb stems must satisfy the following conditions:

(38) **Stem Canon**

(a) **Stem Closure**. All stems end in C (which is licensed, then, by *stem*, not syllabically.)

(b) **Maximal stem**. $|\text{stem}| \leq \sigma\sigma$

(c) **Minimal stem**. $|\text{stem}| \geq \text{F}$ (*[CvC] = [μ])

For the Minimal Stem condition (c), we assume that monomoraic F is disallowed in the language, or at least never called by prosodic morphology (see fn. 10); the lower bound on stem size then follows from the lower bound on foot size (Prince 1980, McCarthy & Prince 1986). The Stem Closure condition (a) means that final consonants are not taken into account by prosodic conditions, because their licensing is morphological rather than phonological. One final issue of detail deserves note: stem final syllables are open (modulo the final C), except in monosyllables, where they are closed, the form Cvv.C being rare and often derived from CvG.C, for G a glide.

On top of these lexically general constraints, the noun stems require two further category-specific conditions:

(39) **Noun Canon**

(a) **Prosodic Perfection**. Admit an N-stem if it can be exhaustively parsed into iambic feet.

(b) **Segmental Compulsion**. Admit an N-stem if its root segmentism is minimally expressed.

These are admissibility conditions, individually sufficient; neither one is necessary, but together they specify the set of licit lexical forms. *Prosodic Perfection* admits all the forms in the first three columns of table (34), but says nothing about anti-iambic CvCCv.C and CvvCv.C. *Segmental Compulsion* admits CvCCv.C for quadriliteral roots only. The form CvvCv.C, *i.e.* CaaCi.C, is a deverbal product of derivational morphology.

The iambic character of the nominal system is further displayed in the productive category of broken plural formation, which circumscribes the initial two-mora-sized substring of a noun stem and maps it onto an iambic template, descriptively *CvCvv-* (for full analysis, see McCarthy & Prince 1990a). The two mora domain is the minimal (iambic) foot; the output template is the maximal

[27] Counting to 3 and 4 is, of course, anomalous in the context of current theory; and presumably should be eliminated in favor of an interaction with licit prosodic structures.

iambic foot.[28] The productive plural is therefore a kind of augmentative morphology, which goes from minimal to maximal in the iambic rhythmic category.[29]

The nominal morphology of Classical Arabic, both in the static stem canon and in the pluralization process, therefore provides us with direct evidence that the iamb must be defined to include the foot [LH], refuting a strict mora-binarist interpretation of stress data.

10.2 The Yawelmani Verb

Archangeli (to appear) has revealed an astonishingly similar system of templatic morphology in the Yawelmani verb, which was previously thought to be based on a variegated and prosodically incoherent set of C-V sequencing constraints (Archangeli 1983).

In the earlier paper, Archangeli demonstrates that the verbal system is based on a root-and-pattern morphology. Roots contain 2 or 3 consonants and a single vowel, on separate planes. There are three distinct prosodic shapes that roots may assume. Affixes fall into two types: those that select for base-shape, forcing any root they appear with to assume the selected shape; and those that are neutral, allowing the root's lexically specified shape to emerge. The shape canons are given in (40):

(40) **Yawelmani Verb Templates**

Root Size	**(No Template)**	**Heavy Syllable**	**Iamb**
Biliteral	CvC	CvvC	CvCvv
Triliteral	CvCC	CvvCC	CvCvvC

Archangeli (to appear) argues, convincingly, that since the number of consonants in the templates is identical to the number of consonants in the root, the templates should not themselves stipulate slot number and should be given only as prosodic categories: syllable, heavy syllable, iambic foot (see fn. 26). With an eye on the Arabic phenomenon of quadriliteral anti-iambism (CvCCv.C = HL), let us experimentally assume that *Segmental Compulsion* (39b) holds as well in Yawelmani. The 'syllable' class CvC(C) can now be identified as having no template at all — it is just the minimal prosodic expression of the Yawelmani root.[30] This leaves CvvC(C) and CvCvv(C), two iambic feet: one monosyllabic, the other bisyllabic. The Yawelmani mora is vocalic; the feet are therefore [μμ] and [μ μμ], the latter being the best or canonical iamb. The Yawelmani verb is like the Arabic noun, then, in that it admits both monosyllabic and bisyllabic forms; unlike the Arabic noun canon, however, only the best iamb may be used. Here are some examples:

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[28] In McCarthy & Prince (1990a), the input domain is treated as a bimoraic trochee; but there is no evidence for specifically trochaic headedness. To be sure, the domain is bimoraic, but iambic systems admit bimoraic feet as well.

[29] Compare in this regard the y-grade morphology of Choctaw, which Lombardi and McCarthy (1990) show to circumscribe a domain equal to the maximal iambic foot LH, which is then mapped to HH. From the present point of view, we can see the output as a sequence of 2 minimal feet. Choctaw then fits into the mold of prosodically augmentation, starting up where Classical Arabic leaves off: it circumscribes a single maximal iambic foot and maps it two minimal (iambic) feet.

[30] As in Archangeli's analysis, a 3rd consonant is licensed as extrametrical (Itô 1986).

(41) Base+Af	Surface	Gloss	Root	Base
Minimal Expression of Root				
a. caw-hin	[cawhin]	‘shouted’	cw, a	caw
b. hogn-hin	[hoginhin]	‘floated’	hgn, o	hogn
Monosyllabic Foot				
c. c’uum-hin	[c’omhun]	‘destroyed’	c’m, u	[*c’uu*]m
d. cuupn-hin	[coopuhun]	‘consented’	cpn, u	[*cuu*]pn
Bisyllabic Foot				
e. panaa-hin	[panaahin]	‘arrived’	pn, a	[*panaa*]
f. yawaal-hin	[yawalhin]	‘followed’	ywl, a	[*yawaa*]l

The surface forms show the effects of other well-known processes of Yawelmani phonology: epenthesis, closed syllable shortening, and long-vowel lowering. (Note *yawaal*iwsel ‘follow’ and *c’oom’*aahin ‘destroy’, which establish the underlying forms (41c,f).) The prosodic morphology is defined on a representation that shows none of the disruptions introduced by the prosodically-ameliorative processes of the language (see fn. 26).

11. Trochaic Systems

We now complete the argument by examining two trochaic systems.

11.1 Japanese Loanword Abbreviation

Japanese has a productive strategy for shortening loanwords, analyzed in detail in Itô (1990). The crucial contrasts are shown in table (42), assembled from Itô’s work.

(42) Loanword	Abbreviated	Bad
a. **Bimoraic**		
opereeshon	ope	
sabotaaju	sabo	
gurotesuku	guro	
b. **Possible Trimoraic**		
saikederikku	saike	
sandoitchi	sando	
pankuchaa	panku	
c. **Impossible trimoraic**		
demonsutoreeshon	demo	*demon
anaakisuto	ana	*anaa
rokeeshon	roke	*rokee

The examples in (42a) show that an allowed truncation output is the the bimoraic foot, which is well-established in Japanese (Poser 1984, 1990; Tateishi 1989; Itô 1990). The examples in (42b) show that the output needn't be strictly bimoraic; this contrasts with the other foot-based processes in Japanese, in which strict bimoraicity is apparent. Not just any trimoraic sequence is admitted: the *iambic* sequences (42b) are completely disallowed. In our terms, the Japanese system is fully trochaic, allowing all variants of the trochee (HL as well as LL), in the same way that the Arabic noun is fully iambic (allowing LL as well as LH). If this is correct, then Japanese allows us to see the whole trochaic panoply, and provides the longsought unmistakable evidence that HL does indeed belong. Some caution is in order, because Itô (1990) has developed a persuasive analysis that retains strict bimoraicity of the foot, while explaining a broader range of abbreviation phenomena (in particular, the occurrence of *trisyllabic* trimoraic forms): the reader is referred to that work.

11.2 The Classical Arabic Verbal System

The Classical Arabic verb exhibits 15 derivational categories or 'Forms' which are expressed through choice of template and, in some Forms, affixal material as well (McCarthy 1981); in total, 6 different templates are employed in the system. Listed below are the consonant/vowel sequences admitted by the templates:

(43) **Classical Arabic Verbal Canons**

a.	CvCv.C	CvCCv.C	CvvCv.C
b.	CCvCv.C	CCvCCv.C	CCvvCv.C

As with the noun, we posit that the stem-final C is extrasyllabic, licensed by the category *Stem* rather than prosodically (38a).[31] Once this analytical step is taken, it is clear that the c,v-sequences of (43a) are all and only the bisyllabic trochaic feet LL, HL. Those in (43b) are arrived at by preposing a single consonantal element to the trochaic types of (43a); Moore (1990) and McCarthy & Prince (1990b) argue that this element is properly construed as a prefix, with which a general de-transitivizing function can be associated. Moore holds the prefix to be a mora; McCarthy & Prince, a degenerate syllable; for present purposes, its importance is only that it can be properly eliminated from consideration, leaving behind a coherent prosody.

McCarthy & Prince (1990b) pursue a different line of analysis: taking HL to be prosodically nonunitary, they argue that the bisyllabic verbal base should be analyzed into two constituent morphemes: a syllable, light or heavy, that varies with Form, and a suffixal light syllable marking the category *verb*. The template is therefore held to be the composite $\sigma + \sigma_\mu$. If the present approach is correct, there is no need to localize the verbal category marker by morphologically separating off the last syllable (or, looked at another way, the last vowel, which could be directly constrained,

[31] For the verb this is a more daring move than for the noun, where the stem-final C never joins the stem-final syllable. Verbal affixes are both consonant- and vowel-initial, so that the surface quantity of the stem-final syllable varies: ka.**ta**.b+at 'she wrote' *vs*. ka.***tab***.+tu 'I wrote'.

segmentally, to be short). The category verb is marked by the higher-order condition that the base of the verbal template must be a bisyllabic trochee; all variants are admitted; and it follows from foot theory that the last syllable is light.

The Classical Arabic noun and verb are thus rhythmically counterposed, as trochaic against iambic. This is reminiscent of (if rather more dramatic than) the prosodic separation of nouns and verbs in English, where noun stress falls generally farther from word-end than verbal stress, due to the extrametricality of noun-final syllables (Ross 1971; Hayes 1982).

12. Conclusion

In this paper a theory of rhythmic organization has been presented which calls on one parameter — the choice between iambic and trochaic headedness — and two supporting principles. The *Weight-to-Stress Principle* (3) defines a relationship between the *size* of an element and its prominence. *Grouping Harmony* (12) imposes a markedness structure on feet, measuring their deviation from the ideal final-long form. Both of these should undoubtedly be generalized to range over units larger and smaller than those considered here; and the WSP should undoubtedly be relativized so that it can interact more subtly with Grouping Harmony. But even in the preliminary and limited form given them here, the two principles interact to define (a) possible stress patterns, (b) possible rhythmically-driven quantitative dynamisms in both iambic and trochaic systems, and (c) possible target shapes for prosodic morphology. The factual burden of the paper has been to show that the predicted possibilities in each of these domains are observed in the world. If the analyses propounded or sketched here are correct, or even on the right track, then the ambiguities and deficiencies of any one domain are answered in the others, weaving an ineluctable web of confirmation.

APPENDIX. Proof of Theorems.

Definitions.

Quantity Sensitive Trochee (QST): foot [σ (μ)], with foot-initial prominence; maximal unit always chosen in foot parse. (Hayes 1980/1).

Quantity Sensitive Iamb (QSI): foot [(μ) σ], with foot-final prominence; maximal unit always chosen in foot parse. (Hayes 1980/1).

Bimoraic Trochee/Iamb (MT/MI): foot [μ (μ)], with maximal unit chose in foot parse. Here [μ] is headless & stressless, notated {μ}; this notation may also be interpreted to mean that *no foot* is built over a free monomoraic stretch — the prominential consequences are the same (Hayes 1986/7; McCarthy & Prince 1986).

Theorem 1. $(\text{QST} \equiv_p \text{MT})_{rl}$. The Quantity-Sensitive Trochee is prominentially equivalent to the Moraic Trochee when iteration proceeds ←RL, if monomoraic feet are stressless or disallowed.

Pf. Let Σ be any string of syllables. Let Σ_{QST} be the result of ←RL parsing of the string Σ by QS Trochees; let Σ_{MT} be the result of ←RL parsing of Σ by Moraic Trochees. We show that Σ_{QST} and Σ_{MT} have the same prominence pattern, by induction on the length of Σ.

QST-rl and MT-rl clearly agree on monosyllabic Σ. Now consider any Σ of length greater than 1, and suppose QST and MT agree in prominence up to σ_n, where where we count *n* from the end of the word. We show that QST-rl and MT-rl then must agree on σ_{n+1}.

QST-rl and MT-rl agree that all heavy syllables receive stress, so if σ_{n+1} = H it must be stressed under both. We need only consider the cases where σ_{n+1} = L.

Case 1. Suppose σ_n is stressless in both Σ_{QST} and Σ_{MT}. Then σ_n = L. Since we are assuming σ_{n+1} = L, the sequence σ_{n+1} σ_n = L L will be footed together, devolving stress upon σ_{n+1}. So QST and MT agree that σ_{n+1} is stressed.

Case 2. Suppose σ_n is stressed. We show that σ_{n+1} = L is unstressed.
Under either QST and MT, we are looking at ...L [σ_n..., where σ_n begins a foot, and we are trying to determine the fate of L = σ_{n+1}. Clearly, L cannot be stressed here – it can either be {L}, or the weak member of a foot.

To show this, we have three subcases to consider, depending on what precedes σ_{n+1}.

Case 2.1. The preceding environment is null; σ_{n+1} is the first syllable of the word. We are looking at # L [σ_n... and under both QST and MT, we will have σ_{n+1} = L parsed as monomoraic {L}.

Case 2.2. σ_{n+1} is preceded by a light syllable; we are looking at ...L L [σ_n... Here, under QST and MT, σ_{n+1} forms the weak member of the foot [L L].

Case 2.3. σ_{n+1} is preceded by a heavy syllable; we are looking at ...H L [σ_n... . Here, under QST, σ_{n+1} forms the weak member of a foot [H L]. Under MT, σ_{n+1} will form a monomoraic unit, and the sequence will be footed ...[H] {L} [σ_n... . In either case, σ_{n+1} is stressless. This actually the only case where QST and MT differ at all; and they differ structurally, not prominentially. □

Corollary. $(\text{QSI} \equiv_p \text{MI})_{lr}$. The Quantity Sensitive *Iamb* is prominentially equivalent to the *Moraic* Iamb when iterated LR→, if monomoraic feet are stressless or disallowed.

Pf. The argument is the same as for the theorem, except that we count n from the beginning of the word; all diagrams will appear in mirror image form. □

Theorem 2. $(\text{QST} \not\equiv_p \text{MT})_{lr}$. QST and MT are *not* equivalent when iterated LR→.

Pf. Consider the sequence ...H L_1 L_2... . QST-lr will parse it as follows: ...[H L_1] [L_2..., rendering L_1 stressless. But MT will parse it ...[H] [L_1 L_2]..., stressing L_1. □

Corollary. $(\text{QSI} \not\equiv_p \text{MI})_{rl}$. The Quantity Sensitive Iamb and the Moraic Iamb are *not* equivalent when iterated ←RL.

Pf. Apply the argument of the theorem in mirror-image form to the string ...L L H . □

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