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## The Role of Metrical Trees in Rhythmic Adjustment

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## THE ROLE OF METRICAL TREES IN RHYTHMIC ADJUSTMENT\*

BRUCE HAYES

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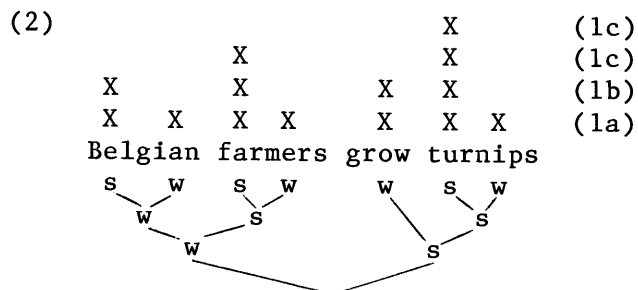
In this paper I will try to bring some evidence to bear on a current controversy within the metrical theory of stress. The first published work on metrical theory, Liberman and Prince (1977), assumed that stress has a dual representation. This involves first a metrical tree, which indicates the relative prominence of syllables and words; plus a metrical grid derived from the tree, which represents prominence as the height of grid columns associated with individual syllables. The role of the grid is to capture native intuitions about syllable prominence, and to determine when phonological rules may adjust the rhythmic structure of the phrase. In later research, this dual representation has been taken to be a redundancy: both Prince (forthcoming) and Selkirk (forthcoming) have suggested that tree structure can be done away with, and that the grids by themselves are an adequate representation for stress. In this paper I will argue that the redundancy is only apparent; and that both grids and trees have distinct roles to play in metrical theory. The first part of the argument will be to present cases that would be impossible to describe under a purely grid-based theory without adding ad hoc conditions to the rules. In the second part, I show that these apparently idiosyncratic facts are actually an automatic consequence of a specific tree-based framework. The theory I will propose makes it possible to collapse together rules that previously had to be stated separately, and to establish a constraint on how rules manipulate tree structure that holds both for metrical phonology and for syntax.

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I will begin by presenting a version of the rules relevant to the argument, taken largely from Liberman and Prince (1977). For the moment we can regard these rules as a convenient means of stating the facts; later on I will argue that they are correct in their outlines. A metrical derivation begins with the creation of trees by the basic rules of English word and phrase stress. Whether we adopt the LP version of these rules or later refinements (cf. Selkirk (1980), Hayes (1982)) will not matter for purposes of our argument. Metrical grids are then constructed from the trees by the rules that I've stated under (1):

- (1) Grid Construction (from Liberman and Prince (1977))
- a. As a place marker, assign every syllable a mark on the lowest level of the grid.
  - b. Assign a mark at level two to the strongest syllable of every phonological word.
  - c. Assign sufficient additional marks so that the strongest syllable of every constituent labeled S has a higher grid column than the strongest syllable of its weak sister.

The rules of (1) are illustrated in (2). Each row of grid marks is annotated with the rule that gave rise to it.



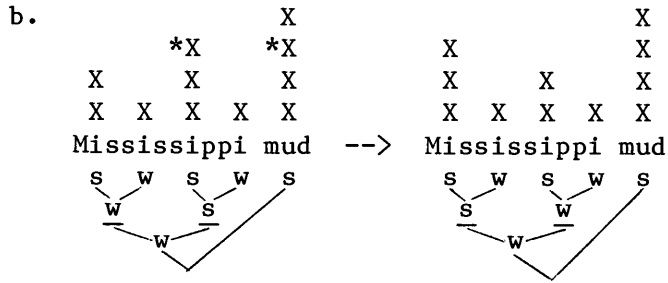
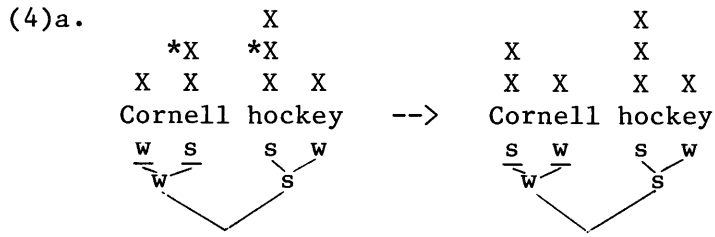
The grids created by (1) determine when the basic stress contour may be adjusted by later rules for rhythmic purposes. The best-known rule of this sort is the Rhythm Rule, formulated by Liberman and Prince as in (3):

- (3) Rhythm Rule
- |   |     |     |     |   |
|---|-----|-----|-----|---|
| w | s   | --> | s   | w |
|   | 1 2 |     | 1 2 |   |

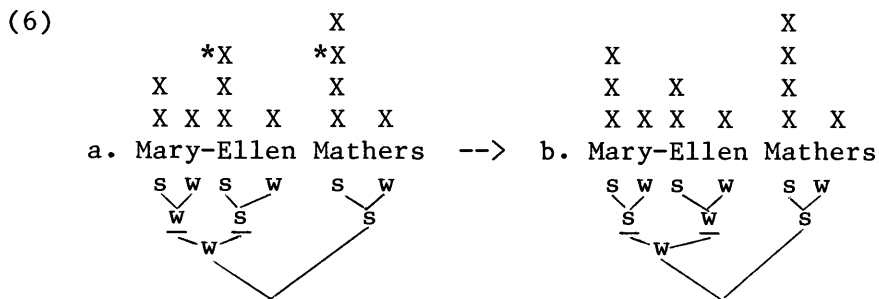
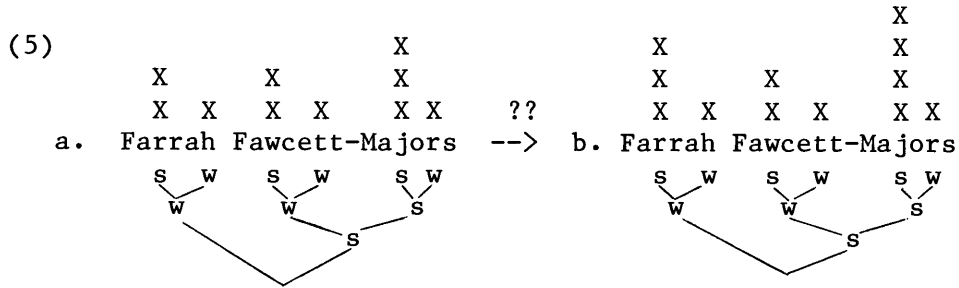
- where (a) 2 is not the strongest element of its phrase.  
 (b) The application of the rule alleviates a stress clash.

(4) illustrates how the Rhythm Rule applies in Cornell hockey and Mississippi mud. Stress clashes in these examples are marked with asterisks, and the nodes that get relabelled are underlined:

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Lieberman and Prince's work actually posits two rules of rhythmic adjustment. The second rule is based on the fact that in right branching structures that are labelled WWS, an alternating prominence pattern usually develops that cannot be derived by relabelling the tree. For example, the stress pattern of Farrah Fawcett-Majors, under (5), displays the same sort of rhythmic alternation found in the left branching form Mary-Ellen Mathers, under (6). But it's only in the left-branching case that alternation can be achieved by the Rhythm Rule. The rules we have stated so far provide no way of getting from the predicted form (5)a to the correct output (5)b.



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In fact, this problem is quite general. As (7) shows, it is easy to construct pairs of examples that differ in their labelling and direction of branching just like (5) and (6), yet are homophonous:<sup>1</sup>

- (7) a.  $\begin{array}{ccc} 2 & 3 & 1 \\ \text{[sea-green]} & \text{soup} & \end{array}$  = see  $\begin{array}{ccc} 2 & 3 & 1 \\ \text{[green]} & \text{soup} & \end{array}$   
        $\begin{array}{ccc} 2 & 3 & 1 \\ \text{[twenty-eight]} & \text{steaks} & \end{array}$  = twenty  $\begin{array}{ccc} 2 & 3 & 1 \\ \text{[ate]} & \text{steaks} & \end{array}$   
        $\begin{array}{ccc} 2 & 3 & 1 \\ \text{[twenty women's]} & \text{jackets} & \end{array}$  = twenty  $\begin{array}{ccc} 2 & 3 & 1 \\ \text{[women's]} & \text{jackets} & \end{array}$

We thus need an additional rule to induce rhythmic alternation in the right branching cases. Liberman and Prince don't formalize this rule, but their article implies something like rule (8), which I will call Beat Addition:

(8) Beat Addition

Freely add additional marks to the grid, provided

- (a) The relative prominence relations specified in the tree are preserved.  
 (b) Alternating rhythm is increased.

Under this proposal, the grid of (5)a can be amplified to produce that of (5)b, since the additional marks that (5)b contains don't violate any of the tree labellings. Beat Addition makes Farrah Fawcett Majors and Mary-Ellen Mathers prosodically homophonous; and the pairs of (7) literally so.

The Rhythm Rule and Beat Addition as I've stated them contain vague clauses requiring that they respectively obviate "stress clashes" and strive for "alternating rhythm." Liberman and Prince try to make these notions precise with a formal definition of stress clash: two grid marks are said to clash if they are adjacent on their level, with no mark intervening on the immediately lower level. But this definition is of no use in predicting Beat Addition, since the input grid in Beat Addition cases doesn't clash. And when one looks at a wider range of data, the definition doesn't work very well for the Rhythm Rule either. In Hayes (forthcoming) I suggest that "stress clashes" play no role in rhythmic phonology, and that the target of the rhythmic adjustment rules is as in (9):

(9) The Principles of Eurhythmy

The Rhythm Rule and Beat Addition apply when as a result the grid more closely meets the following description:

- a. It contains a row whose marks are roughly four syllables apart.

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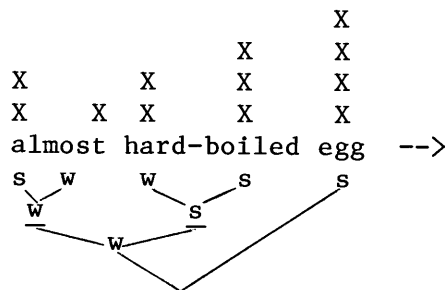
- b. The quadrisyllabic intervals of this row are evenly divided on the next lower level.
- c. The two tallest columns of the grid are spaced as far apart as possible.

For lack of space, I won't be able to motivate these principles thoroughly, although all the examples in this paper conform to them.

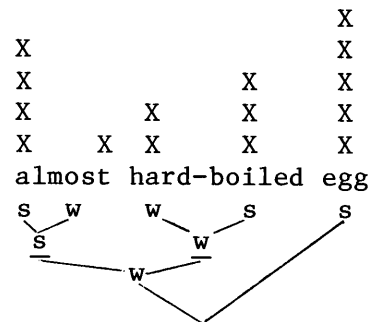
To review the rules presented so far: I have taken over Liberman and Prince's grid construction rules unchanged, as well as their formulation of the Rhythm Rule. I have also adopted an explicit formulation for Beat Addition, which Liberman and Prince suggest but don't formalize. Finally, I have substituted a new statement of the rhythmic targets that the Rhythm Rule and Beat Addition work to achieve.

The argument to be made here is based on an unusual form of stress shift I will call internal rhythm. This is the rhythmic adjustment of a sequence that is subordinated to a stronger stress on its left. Internal rhythm typically arises in derivations where a higher level constituent undergoes relabelling first. For example, (10) undergoes first external rhythm on the constituent almost hard-boiled, then internal rhythm on the constituent hard-boiled:

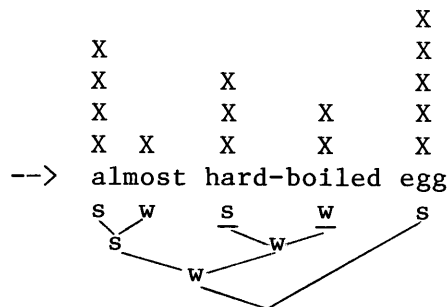
(10)a.



b.



c.



Some further examples of internal rhythm are listed in (11).

(11)a.        2        3        1  
a hundred thirteen men

(cf. a hundred thirteen)

              2        3        1  
b. a pleasantly underripe pear

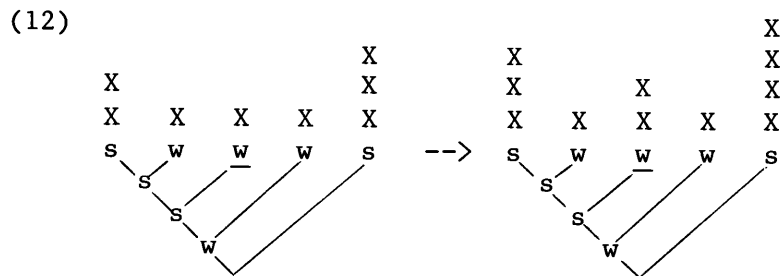
(cf. pleasantly underripe)

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- c. an<sup>2</sup> incredibly<sup>3</sup> debonaire<sup>1</sup> guy (cf. incredibly<sup>2</sup> debonaire<sup>1</sup>)
- d. Soviet<sup>2</sup>-Japanese<sup>3</sup> relations<sup>1</sup> (cf. Soviet<sup>2</sup>-Japanese<sup>1</sup>)
- e. the<sup>2</sup> Michigan<sup>3</sup>-Tennessee<sup>1</sup> football (cf. Michigan<sup>2</sup>-Tennessee<sup>1</sup>)  
game

Prince (forthcoming) denies that internal rhythm exists. But his examples are all of the kind in which the rules of eurhythmy (9) would discourage stress shift in any event. Selkirk (forthcoming) admits internal rhythm, and supports her claim with examples that conform to (9).

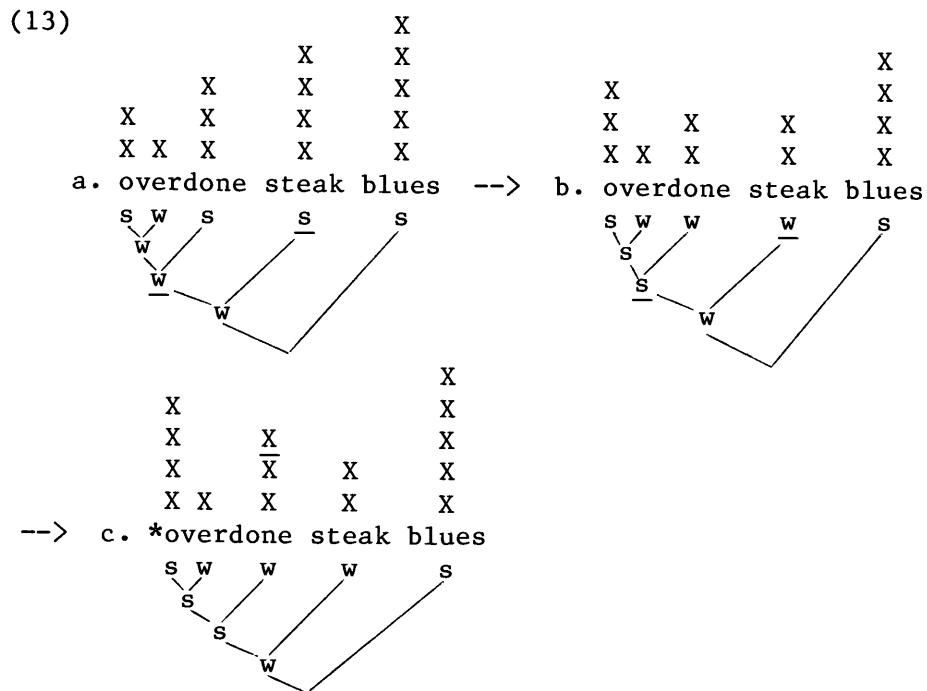
At this point we can return to our original claim: that despite Prince and Selkirk's efforts, trees should not be eliminated from metrical theory. Here is the structure of the argument: if the Rhythm Rule strives for internal rhythm, it's plausible that Beat Addition should do this as well--in general, the two rules share the same rhythmic targets. (12) shows a schematic configuration where Beat Addition could in principle create alternating rhythm--it would add a mark to the underlined constituent, as well as the two terminal S nodes.



But when we look at actual examples of this kind, we find that Beat Addition is unexpectedly blocked--for some reason, this particular tree shape forbids Beat Addition, even when the grid conditions would favor it. This is *prima facie* evidence that the trees are not dispensable.

Having outlined the argument, let's look at some actual data: in (13), the configuration of (12) has been created by applying the Rhythm Rule to the outer constituent overdone steak. We are then in a position to induce internal rhythm by promoting the syllable done, using Beat Addition. As the grid of (13)c shows, the resulting form should be prosodically homophonous with an internal rhythm example like (10)c, álmost hárd-boiled égg.

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But such a rendition (\*óverdóne steak blúes) is impossible. The stress contour of (13)b has to be retained, as óverdóne stéak blúes. The difference between (10) and (13) appears to follow solely from the difference in their tree shapes. The effect is quite reproducible, as (14-15) show:

- (14)a. 2 3 4 1  
[nineteen [twenty-four]] Chevy
- b. \*2 3 4 1 (must be 2-3-3-1)  
[[nineteen twenty] Ford] shop manual
- (15)a. 2 3 4 1  
[lovingly [oven-baked]] bread
- b. \*2 3 4 1 (must be 2-3-3-1)  
[[oratorio singer's] day] festival
- c. \*2 3 4 1 (must be 2-3-3-1)  
\*[[Michigan lover's] ball] finance committee

The relevant distinction between the grammatical and ungrammatical cases can be summed up with the constraint under (16), which I offer purely as a descriptive generalization:

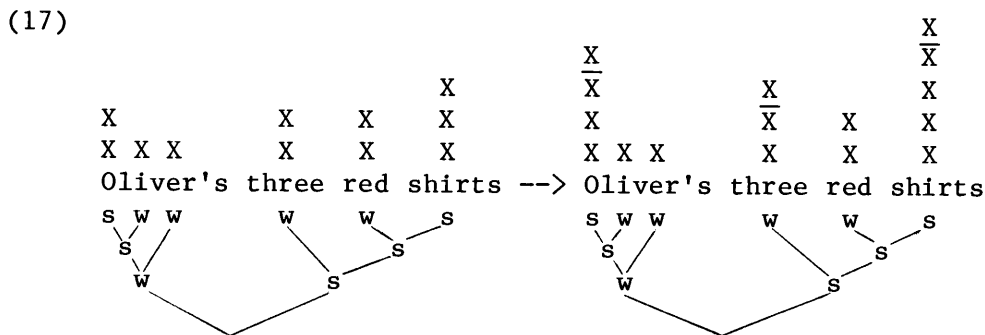
(16) Right Branch Constraint

Beat Addition may not add to a column if the maximal constituent in which it is the highest column forms a right branch.

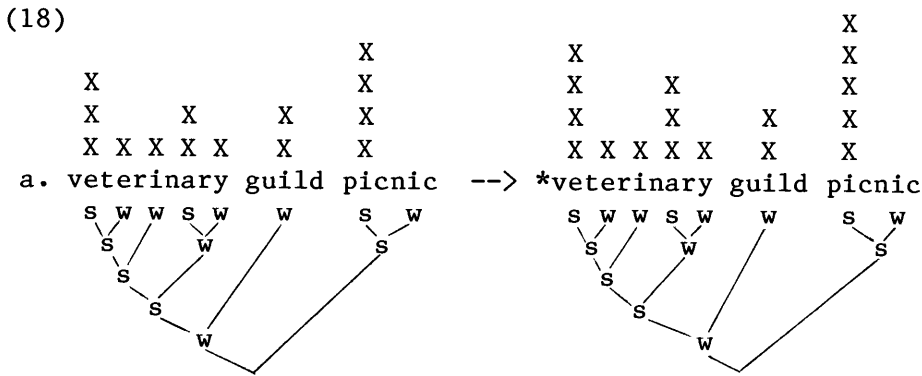


In (13-15), the right branches to which the constraint applies would be done, twenty, singer's, and lover's. The constraint holds up against all the data that I have encountered.

I would not want to argue that the facts of (13-15) would be impossible to account for under a purely grid based theory--only difficult. I will mention two specific problems. First, it will not do to say that Beat Addition never induces internal rhythm, because it does, precisely when the Right Branch Constraint isn't violated:



Second, it wouldn't work to restate the Right Branch Constraint to apply to syntactic right branches only, since the word-internal right branches posited by arborial theory are just as resistant to Beat Addition:



cf. also:

2 3 4 1  
b. \*Kalamazoo Farms Sausage

2 3 4 1  
c. \*preparatory school choices

It should be clear why a syntactic restatement of (16) should work only above the level of the word: it is only at this level that metrical tree structure coincides with syntactic structure.

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Despite these problems, I believe that a grid based theory can be made to handle the facts, provided sufficient ad hoc conditions are added to the rules. But the real challenge for any theory is to explain why the constraint of (16) should hold. It seems unlikely that (16) is learned by induction from the primary data, as the examples that motivate it are of the kind only linguists ever say. But the acceptability judgments are robust: even naive informants who claim they can't hear differences in stress will respond differently to (10) and (13) when asked to tap on a table in time to their speech. (10) comes out as in (19)a; (13) as in (19)b.

- (19) taps: t            t            t            t    t    t    t  
 a. almost hard-boiled egg    b. overdone steak blues

The crucial task for any theory is to show how the contrast falls out from principles which can be independently learned, or (better yet) are universal. In the last part of this paper I will show that the tree theory passes this test.

My proposal is that Beat Addition should not apply to grids, but instead is an arborial rule. The rule will alter the trees only, with the new trees resulting from the rules of (1), which I now take to be well-formedness conditions, reapplying where necessary. The necessary change in the trees can be expressed as a metrical adjunction. Adjunction as a metrical operation is well attested in the literature, cf. the "Stray Syllable Adjunction" proposed by Liberman, Prince and other forms of adjunction developed in Hayes (1981, 1982). An important point about metrical adjunction is that the labelling of the adjoined element is predictable: in all known cases it is weak. This will turn out to be true of our rule as well.

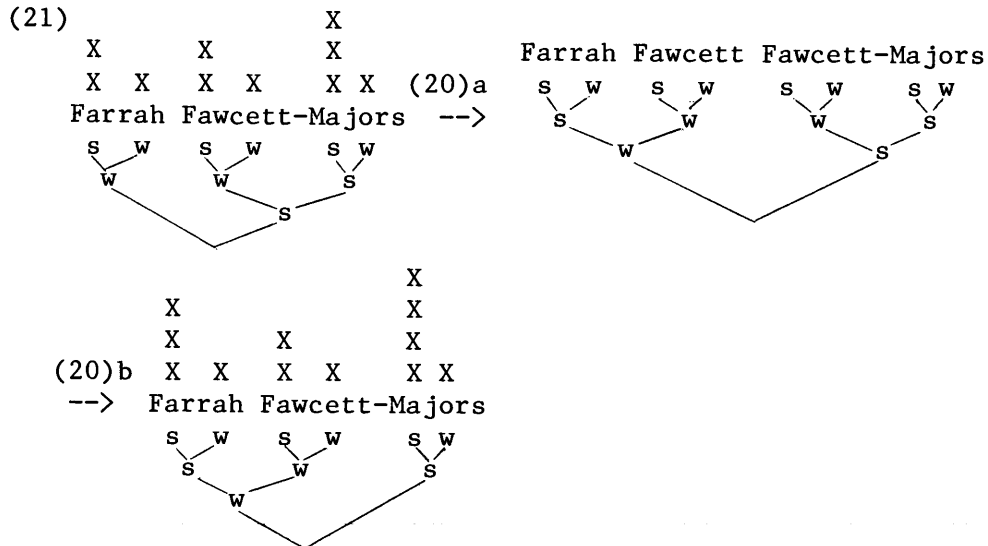
In formulating our rule we will have to be precise about what "adjunction" is intended to mean. The definition under (20), I think, accords fairly well with one's intuitions:

- (20) In the configuration ...X...Y..., where X and Y are metrical nodes, adjoin Y to X means:
- (a) Replace X with a new constituent X' of the form [X Y]. X' retains the old labelling of X, and is internally labelled S W, by convention.
  - (b) Delete the original copy of Y. Prune any nonbranching non-terminal nodes that may result.

The adjunction of X to Y is defined analogously.

Under this definition, the Beat Addition rule can be formulated as a leftward adjunction. For example, the case of Farrah Fawcett-Majors, under (21), involves the adjunction of the node Fawcett to the node Farrah, with concomitant readjustment of the grid. In the first part of the adjunction, a copy of Fawcett is attached as a weak sister to Farrah. In the second part, the old

Fawcett is removed, with pruning of the extra node. The grid construction rules then automatically reapply, giving us the same grid that we had derived earlier.



I conjecture that the arboreal version of Beat Addition should be formulated explicitly as in (22). To keep the new rule distinct from the old, I have renamed it Rhythmic Adjustment. In the rule, X and Y stand for any metrical constituent, while DTE represents the strongest syllable (Designated Terminal Element) of the phrase in which the rule applies.

(22) Rhythmic Adjustment

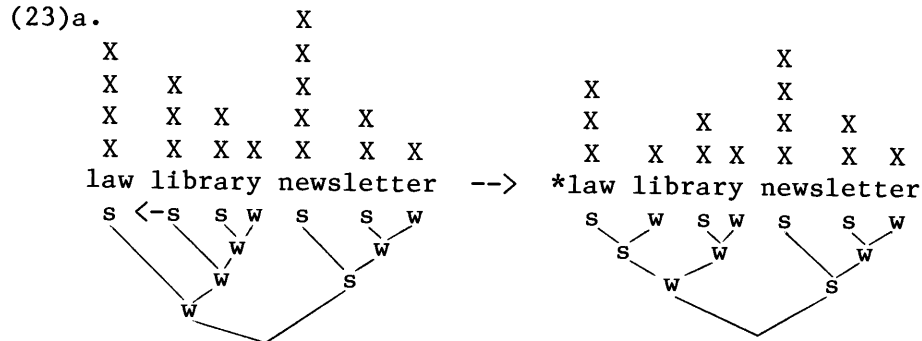
In the configuration ... X Y ... DTE ..., adjoin Y to X.

The way that (22) works in example (21) should be fairly clear: X corresponds to Farrah, Y to Fawcett, and DTE to Maj.

The new rule has two important advantages in a tree-cum-grid framework. Note first that the old rule of Beat Addition essentially recapitulated provision (1)c of the rules of grid construction. In claiming that Beat Addition "preserves the relative prominence relations of the tree," we were directly incorporating provision (1)c into the Beat Addition rule. By reformulating Beat Addition as Rhythmic Adjustment, we derive the extra grid marks from the ordinary rules of grid construction, thus removing the redundancy. Second, the replacement of Beat Addition with Rhythmic Adjustment allows for a more constrained framework. Under the old theory, metrical rules were allowed to apply either to the tree or to the grid representation. The only rule of the latter type was Beat Addition. By reformulating Beat Addition as a tree-based rule, we can maintain a more restrictive theory: the metrical rules may apply only to trees, and the grids become a mere measuring device, limited to providing the trees with a rhythmic interpretation.

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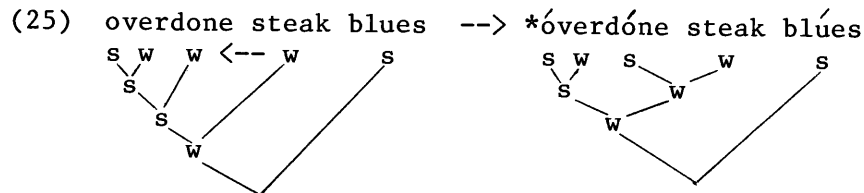
However, as it stands Rhythmic Adjustment overgenerates wildly. For example, in (23) the rule could adjoin the non-maximal constituent lib to law, giving \*law library newsletter.



And with similar derivations, it would also be possible to produce such strange stress contours as those of (25):

- (25)a. <sup>2</sup> \*law <sup>3</sup> newsletter <sup>1</sup> library
- b. <sup>2</sup> \*ten <sup>3</sup> index card <sup>1</sup> dossier
- c. <sup>2</sup> \*two <sup>3</sup> pomegranate juice <sup>1</sup> daiquiris

Another problem with Rhythmic Adjustment is that it allows for violations of the Right Branch Constraint. For example, if in (25) we take X to be done and Y to be steak, we'll get the same bad output as before:



It would be possible to fix these problems by adding more information to the rule--in particular, we could stipulate that X must be a left branch (to fix (25)), and that Y must be labelled weak (to fix (23-24)). But a more general principle can be found that covers both cases, with no change whatever in the rule. My proposal is as follows:

(26) Maximality Principle

Rules that manipulate tree structure must analyze maximal terms.

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"Maximality" is defined as in (27):

(27) Let R be a rule whose SD contains the terms  $t_1, t_2, \dots, t_n$ .

Let T be a tree containing the constituents  $c_1, c_2, \dots, c_m$  ( $m \leq n$ ), matched up to the appropriate terms of R.

$c_i$  of T is maximal iff there is no node  $c_i'$  that

- (a) satisfies R
- (b) dominates  $c_i$
- (c) does not dominate any other member of the sequence  $c_1, c_2, \dots, c_m$ .

The intuitive sense of (26) is that rules will not apply to small constituents if larger ones are available that don't overlap. The maximality constraint rules out all the ill-formed examples we have seen: in (23), Rhythmic Adjustment cannot analyze li as Y, since the constituent library dominates li without dominating X (law) or DTE (news). In (25), Rhythmic Adjustment cannot analyze X as done, since the constituent overdone dominates done without dominating steak or blues. The only possible application of Rhythmic Adjustment to these forms is vacuous, recreating the structure of the input.

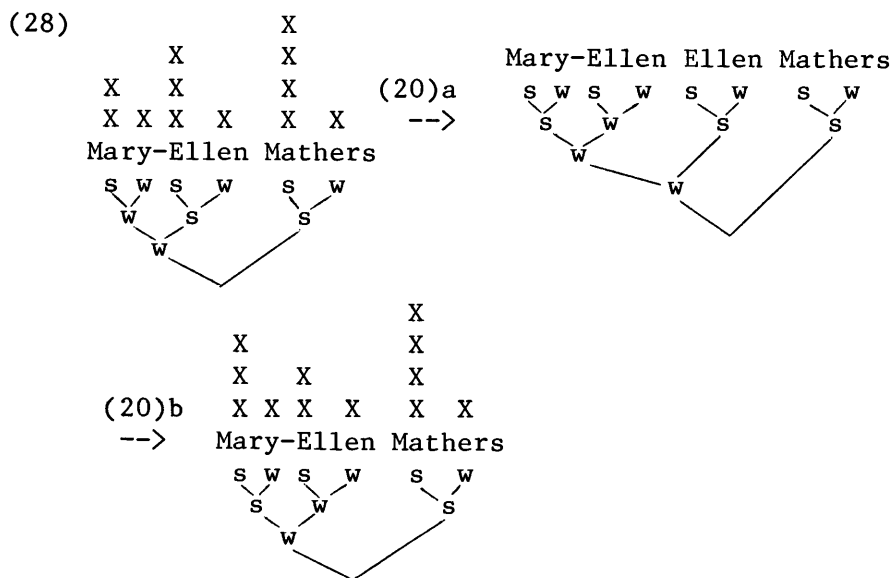
What other evidence is there supporting the maximality condition? One source is Dell's (1981) account of phrasal stress in French. The facts Dell describes motivate a rule in our framework that adjoins weak constituents in either direction. As with English Rhythmic Adjustment, the rule can be greatly simplified if we assume it is subject to maximality.

More important, maximality can be supported by evidence from syntax as well, as it can account for all of the empirical consequences of Bresnan's (1976) Relativized A over A Condition. In fact, maximality improves on Bresnan's formulation, as it doesn't have to refer to the distinction between context and target predicates. My conjecture is that maximality is a constraint that applies across linguistic components, constraining the way in which all rules may analyze constituent structure. The fact that maximality can be generalized across both phonology and syntax might be taken as an indirect argument in favor of metrical trees, since a purely grid-based theory of stress could never capture this parallelism.

One final argument for the approach I've taken involves the relationship of the Rhythm Rule and what we previously were calling Beat Addition. As I said before, there is evidence that the two rules serve essentially the same rhythmic ends. In addition, their outputs are prosodically homophonous, as the examples of (7) show. Finally, I argue in Hayes (forthcoming) that both rules are forbidden from adding to grid columns that are only one mark high. So there's every reason to believe that the Rhythm Rule and Beat Addition are the same rule. My argument for Rhythmic Adjustment is that, unlike Beat Addition, it includes the Rhythm Rule as a special

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case. Under the definition of adjunction (20), which I assume is noncontroversial, the Rhythm Rule is simply Rhythmic Adjustment when X and Y happen to be sisters--the adjunction of a strong node to its weak sister amounts to the relabelling of the constituent that dominates both of them. I've shown this under (28): a copy of Ellen is made a weak sister of Mary, then the original Ellen is deleted from the tree. The result is a relabelled Mary-Ellen.



To summarize, I will return to some questions posed earlier. First, we asked why Beat Addition should be subject to such a quirky constraint as (16). Under the account I've proposed, the constraint needn't be stipulated arbitrarily, but is a direct consequence of the theoretical framework. If grids are unavailable as a domain for phonological rules, then there is no way that Beat Addition could be formulated other than as an adjunction; i.e. as something like Rhythmic Adjustment. As an arboreal rule, Rhythmic Adjustment is necessarily subject to maximality, of which the Right Branch Constraint is a direct consequence. Our confidence in the analysis is increased by two further results: the oddball derivations of (23-24) are ruled out, and the Rhythm Rule and "Beat Addition" can be collapsed together.

The larger issue we addressed was the relative merits of grids-only versus grid-and-tree frameworks for the description of stress. This issue will ultimately be decided only through comparing the explanatory power of the two theories in a large number of cases. In this particular instance, the trees appear to win: as far as I can tell, a grid theory can avoid Right Branch Constraint violations only through brute force, ad hoc modification of the rules. In addition, we have blunted one of the principal arguments for grid theory--that trees are redundant--with the establishment of clear, separate roles for trees and grids. Trees are now the sole domain of phonological rules, while grids assign the tree its rhythmic interpretation.

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FOOTNOTES

\* I would like to thank Alan Prince, Pat Keating, and the members of the UCLA Phonology Seminar for their comments on an earlier version of this paper.

<sup>1</sup> No theoretical status should be attributed to the numbers in the examples; they are only a shorthand notation for prominence rank.

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