Formal Properties of Stress Representations*

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1. BACKGROUND

In the 1960's several attempts were made at formalising phonological theory, resulting in systems as diverse as those of Peterson and Harary (1961), Batóg (1967) and Chomsky and Halle (1968). Of these works, the most impressive is the last. SPE, as it is commonly referred to, contains a lengthy discussion of English word stress. Batóg (1967), which is probably the most thorough in its development of the formal foundations, does not include a discussion of suprasegmental or prosodic phenomena, although the phonological theory he sets out to formalise, Harris' (1951) structuralistic account, is by no means silent about such issues. In this respect, there is a marked difference between SPE and Batóg's little book. Batóg himself remarks:

> "There are two things absent from our system: the theory of junctures and the theory of suprasegmental elements of utterance. The reason of our omitting them is that both of them are still immature and they require a more full elaboration by linguists themselves. In their present state they are not fit for logical analysis and formal treatment." (op. cit., 120)

Chomsky and Halle made an attempt in SPE to treat suprasegmental phonology as segmental phonology, that is, they extended the feature framework to treat suprasegmental phenomena like stress, and segmental phenonema in a unified manner. In so-called standard generative phonology, which is the phonological tradition originating in SPE, this has been one of the leading ideas. A rather sharp reaction to this segmental approach in the mid-1970's has given rise to metrical phonology, which employs several types of hierarchical representation to deal with suprasegmental phonology. The metrical theories that now dominate the field seem to agree that the SPE policy of representing stress as segmental

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features is basically incorrect and that an entirely different prosodic theory is needed for the proper treatment of stress and other suprasegmental phenomena, like vowel harmony or tone. In a sense, then, modern metrical theory appears to agree with Batóg's assessment of the state of suprasegmental phonology in the 1960's.

This state of affairs in contemporary phonology raises the question which this paper tries to answer: Just how different are the 'flat' segmental representations of standard generative phonology and the 'hierarchical' ones of metrical theory? My aim is to show that segmental representations using numerical features can be defined that are isomorphic with metrical trees and metrical grids (cf. Liberman and Prince 1977 on these notions). This implies that every rule which can be stated for metrical trees or metrical grids, can be stated for numerical representations in the style of SPE as well.

2. NUMERICAL REPRESENTATIONS AND METRICAL GRIDS

In the notation of SPE, stress patterns are indicated in the phonological representation by assigning natural numbers to the vowels. SPE uses the interpretation convention that when the stress goes up, the numbers go down. So a vowel with the stress feature [1 stress] is more heavily stressed than a vowel with the feature [2 stress]. To make the comparison with metrical grids a little easier, we will adopt the somewhat more natural convention that the numbers go up when the stress goes up in this section. (Of course, this convention does not make any difference for the representations at hand, since we are interested in their form, not in their interpretation.)

Formally, we will define numerical stress representations as strings of ordered pairs. The left hand member of each ordered pair will indicate a syllable, the right hand member will indicate the stress level of that syllable. Here we deviate from SPE, but since we may assume some percolation convention which sends the stress number of a syllable to its vocalic nucleus, this does not really matter. The stress levels are taken from some interval $I = [1,n]$ of N, the set of natural numbers.

> *Definition 1*
> Fix a set S of syllables. Let I be some interval [1,n] of N. Then we define a *numerical stress representation* as a string over S x I.

The notion of a numerical stress representation as defined above is of course a very crude notion. For phonological purposes, many such representations are uninteresting, so further restrictions on the set of possible numerical stress representations are called for. Later on, we will encounter some of these futher restrictions. Before considering these, we will first consider the related notion of a metrical grid. What metrical grids are, is usually made clear by giving examples of diagrams of particular metrical grids. Here is an example from Prince (1983: 21):

(1) *Diagram of a metrical grid*

```
                         x
x                        x
x   x                    x
x   x    x    x     x    x
Jim saw her in the park
```

In such diagrams, the height of the column of marks above each syllable indicates in a pleasant visual way its stress level. It is immediately clear that the nuclear stress of this sentence is on the syllable *park*, and that *Jim* is more heavily stressed than *saw*.

In Liberman (1975: 280) a formal definition of the notion of a metrical grid is given, which is presented below in definition 2 in a somewhat simplified form:

> *Definition 2*
> A *metrical grid* is a structure $(\pounds,F)$, where $\pounds$ is an ordered set of ordered sets $(L_i)_{1 \leqslant i \leqslant n}$ and F is a function mapping each member of L_{m+1} onto some member of L_m in an order preserving way: if ℓ_i and ℓ_j are members of L_{m+1}, then $F(\ell_i)$ is ordered before $F(\ell_j)$ just in case ℓ_i is ordered before ℓ_j.

Actually, Liberman states an additional requirement on well-formed metrical grids, which we will consider shortly.

In Liberman's definition, F provides the columns of the grid: for two elements are in the same column on adjacent levels iff the function F maps one of them onto the other. The ordered sets L_i, on the other hand, provide the horizontal rows.

For the purposes of stress theory, Liberman's definition is too liberal, because it enables one to distinguish between grids that should be equivalent. For example, one could distinguish all of the following four metrical grids:

(2)

```
        x                  y
x       x          y       y
New     York       New     York

        y                  x
x       x          y       y
New     York       New     York
```

Let us therefore adopt a more restrictive definition of metrical grids, which allows them less expressive power.

> *Definition 3*
> A *proper metrical grid* is a structure (X,*), where X $\subseteq$ A x I, I as in def. 1, A a string of syllables, and * the ordering of X derived from the ordering on A in the following way: (a,m)*(b,n) iff a comes before b in the string A. We further require that (a,n) in X if (a,n+1) is, and that for every a in A: (a,1) is in X.

To see the motivation behind this definition, note that a diagram such as (1) above is completely specified by giving (1) the labels of the rows, (2) those of the columns and (3) the horizontal and the vertical specifications of the marks. It is easy to see that A provides the horizontal coordinates of the diagram, I the vertical coordinates (number the rows 1 to n from the bottom to the top) and X those pairs of coordinates on which there is a mark.

By way of example, consider the following proper metrical grid for the expression *New York*: < { (New,1), (York,1) (York,2) } , {(New,1) *(York,1), (New,1)*(York,2) } >. In the form of a diagram, this becomes:

(3) *Diagram of a proper metrical grid*

```
        x      2
x       x      1
New     York
```

It is important to note that the distinctions in (2) above cannot be expressed in the present formalisation, since the marks only indicate whether a particular pair of coordinates is a member of X. Therefore we have only two options available in the diagram for each pair of coordinates: either a mark or a blank.

Proper metrical grids are rather redundant. Therefore we want to consider a less redundant structure.

Definition 4.
A *reduced proper metrical grid* is a substructure R of a proper metrical grid G, such that (x,n) in X_R iff no pair (x,m), where m is less than n, is in X_G, and $*_R$ is the restriction of $*_G$ to X_R.

A reduced proper metrical grid gives only the maximal members of each column in the grid's diagram. Those are the only entries we need to know: all lower entries are in the non-reduced grid as well, and all higher entries are of course not in the non-reduced grid.

Fact 1
On reduced proper metrical grids, the ordering * is linear.

To see this, note that (x,m) and (y,n) are unordered in a metrical grid only if x = y. In reduced metrical grids, no pairs (x,m) and (y,n) exist, such that x = y, and m ≠ n.

Next we will consider the relation between reduced proper metrical grids and numerical stress representations. This relation turns out to be extremely straightforward:

Fact 2
(X,*) is a reduced proper metrical grid if and only if it is a numerical stress representation.

According to this fact, the notions of a reduced proper metrical grid and a numerical stress representation coincide. To see this, just note that any string A can be written as a structure (X,*), where X is the set of A's elements and * is the linear ordering of the string (i.e. *a**b* means that *a* comes before *b* in A).

Since it is clear that we can construct a unique reduced proper metrical grid for every proper metrical grid and reconstruct the proper metrical grid from its reduced counterpart, we can safely state the following result:

Fact 3
The notions of a numerical stress representation, a proper metrical grid and a reduced proper metrical grid are notational variants.

In connection with definition 2, it was mentioned that Liberman's definition of a metrical grid is in fact somewhat more complicated than stated there. Liberman requires that grids like (1) above are ruled out by definition. He states the requirement that if two marks are adjacent on some level, they should be separated by at least one and at most two marks on the next lower level, if such a level exists. In diagram (1), the marks for *Jim* and *saw* are adjacent on the second level, yet the marks for these two syllables are adjacent on the first, the lowest, level as well. Similarly, *saw* and *park* have adjacent marks on level two, but in this case the number of intervening marks on the next lower level is too high: 3.

In the formalism of proper metrical grids, Liberman's requirement can be formulated as follows:

Definition 5.
An *alternating proper metrical grid* is a proper metrical grid G, such that if (x,n+1) and (y,n+1) in X_G and there is no (z,n+1) such that (x,n+1)*(z,n+1) and (z,n+1)*(y,n+1), then we have in X_G at least one and at most two (z,n), such that (x,n)*(z,n)*(y,n).

For numerical stress representations, a similar restriction can be formulated:

Definition 6.
An *alternating numerical stress representation* is a numerical stress representation such that if (x,m) and (y,n) in the string, $1 < m \leqslant n$, and there is no (z,k) between (x,m) and (y,m) such that $k \geqslant m$, then we have at least one and at most two (z,k) such that (z,k) between (x,k) and (y,k) in the string and $k = m - 1$.

By inspection of these definitions, we have:

Fact 4.
(X,*) is a reduced alternating proper metrical grid iff it is an alternating numerical stress representation.

This fact is completely analogous to fact 2. As a corollary, we further have:

Fact 5.
Alternating numerical stress representations, alternating proper metrical grids and reduced alternating proper metrical grids are notational variants.

Just how useful alternating proper metrical grids are as a tool for describing stress patterns, is not clear. We saw that a reasonable grid description like (1) above is outside the scope of alternating grids. In fact, even such pleasant alternating grids as the one in (4) below are ruled out:

```
(4)  x                               x   3
     x       x       x       x       x   2
     x   x   x   x   x   x   x   x   x   1
     a   b   c   d   e   f   g   h   i
```

Grid (4) is ruled out because there are three elements between the marks for *a* and *i* on level 2, although the marks for *a* and *i* are adjacent on level 3.

For the purposes of linguistic theory, it seems better to drop the strong alternation requirement on proper metrical grids (in Prince (1983), the best paper so far on the role of metrical grids in the description of stress phenomena, no such requirement is made). On the other hand, ordinary proper metrical grids allow stress descriptions that never occur in anyone's stress theory. For example, grids like the one in (5) below should be prohibited:

(5) *A stupid grid*

```
x   x   x   3
x   x   x   2
x   x   x   1
a   b   c
```

So it seems reasonable to state at least the following well-formedness condition on metrical grids:

Definition 7.
A *good grid* is a proper metrical grid with the property that $m \neq n$ whenever (a,m) and (b,n) are adjacent and maximal members of X.

Grid (5) is not a good grid, since (a,3) and (b,3) are adjacent and maximal in their column, yet their right hand members are equal. The same is true for (b,3) and (c,3).

The corresponding notion for numerical stress representations is stated in the following definition:

Definition 8.
A *good numerical stress representation* is a string of pairs (x,n), such that for any two adjacent pairs (y,m) and (z,k): $m \neq k$.

It is reasonable to require that every stress representation be good in the sense defined above. It is doubtful whether a stronger condition should be postulated, to wit, that any two syllables should have different stress levels. Call a stress representation *ideal* when it conforms to definitions 7 or 8, but with the adjacency condition dropped. We will see in the section about metrical trees that tree representations are ideal stress representations.

A nice consequence of ideal representations is the following:

> *Fact 6.*
> Ideal stress representations have a unique syllable bearing maximal stress ('designated terminal element').

It seems desirable that every stress description contains a unique designated terminal element bearing the main stress. It is not clear, however, that the formalism of the representation should take care of this. Since we need stress *rules* as well, to specify the position of the main stress in particular languages, we have another mechanism at our disposal. On the other hand, we might state in our general definition of metrical grids that they should contain a unique designated terminal element, without having recourse to ideal metrical grids.

> *Definition 9.*
> A *pointed metrical grid* is a good grid with the property that it contains a pair (x,n) such that for every (y,m): $m < n$. Call this pair its point.

It is obvious that the point of a metrical grid is its designated terminal element.

> *Definition 10.*
> A *pointed numerical stress representation* is a good numerical stress representation such that there is a pair (x,n) in the string such that for every (y,m): $m < n$.

Summary. In this section, we have considered a great many definitions of metrical grids. Of these, good grids and pointed grids appear to be most useful for linguistic purposes. For every type of grid, there is an equivalent numerical stress representation. These numerical stress representations are identical with reduced grids. So we might conclude that numerical stress representations of the types considered above are just less redundant versions of metrical grids. As a corollary we have that every rule statable on metrical grids, is statable on the corresponding numerical stress representations as well.

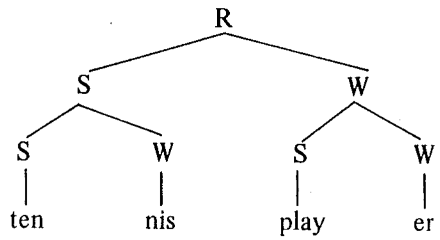
3. METRICAL TREES AND NUMERICAL STRESS REPRESENTATIONS

Today, the most popular way of representing stress is drawing a so-called metrical tree. Now what is a metrical tree?

> *Definition 11.*
> A *metrical tree* is a rooted binary branching tree, whose root is labeled by R, whose other nonterminal nodes are labeled by S or W, and whose terminal nodes are labeled by syllable symbols. Furthermore, if a node is labeled W (S), then its sister is labeled S (W).

Here is an example of a metrical tree:

(6)



In these trees, S means 'Strong' and W means 'Weak'. From (6) we learn that *tennis* has a heavier stress than *player*, since the node dominating the string *tennis* is S, and the node dominating *player* is W. Likewise, in *player*, the first syllable has a heavier stress than the second.

Naturally, the syllable that is dominated by S only is heavier than all other syllables. In (6), this syllable is *ten*. It is an immediate consequence of definition 11 that there is always a unique syllable dominated by S only.

> *Fact 7.*
> The designated terminal element of a metrical tree is the terminal node that is dominated by S and R only.
> *Fact 8.*
> Every metrical tree has a unique designated terminal element.

These two facts turn out to follow directly from a more general proposition about metrical trees:

> *Fact 9.*
> Metrical trees are ideal stress representations.

Ideal stress representations were defined in the previous section as stress representations in which no two syllables have the same stress values. We will say that two syllables in a metrical tree have identical stress values iff their top-to-bottom paths are labeled identically. For example, the top-to-bottom paths in (6) are labeled RSS, RSW, RWS and RWW. So in (6) no two top-to-bottom paths are labeled identically. We will now derive fact 9 by proving the following claim:

> *Fact 10*.
> Let X and Y be two different top-to-bottom paths in a metrical tree T. Then X and Y are labeled differently.

Proof: Let X be $(x_1,..,x_n)$, where $x_1,..,x_n$ are (non-terminal) nodes in T and Y be $(y_1,..,y_m)$. For any node x, let v(x) denote its label. Since T is rooted, $x_1 = y_1$. Let k be the maximal number such that $(x_1,..,x_k) = (y_1,..,y_k)$. Since $x_1 = y_1$, k is at least 1, and since $X \neq Y$, k is less than n. The string $(x_1,..,x_k)$ is the common part of X and Y. Now suppose that X and Y are labeled identically. Then for every i, $v(x_i) = v(y_i)$. Therefore $v(x_{k+1}) = v(y_{k+1})$. We know that x_{k+1} and y_{k+1} are sister nodes, since they have a common immediate dominating node: $x_k = y_k$. But then one of them should be labeled W and the other S, by definition 11. This contradicts our assumption that $v(x_{k+1}) = v(y_{k+1})$. Since the latter assumption follows from our initial assumption that X and Y were labeled identically, this initial assumption must be false. Q.E.D.

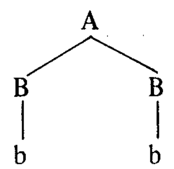
Another elementary property of metrical trees has been stated in an earlier paper of mine (Hoeksema 1982):

> *Fact 11*.
> Any metrical tree T is completely characterised by the left-to-right ordering of its top-to-bottom paths.

For instance, if T is the metrical tree in (6), then the ordered set of its top-to-bottom paths can be written as ((ten, RSS), (nis, RSW), (play, RWS), (er, RWW)).

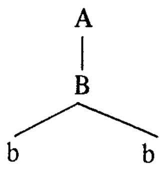
Not every tree is completely characterised by the set of its top-to-bottom paths in the linear order of its terminal elements. Take for example the following tree:

(7)



This tree has the following string of vertical paths: ((b, AB), (b, AB)). This string, however, is not unique for (7), since the tree in (8) below has exactly the same string of vertical paths:

(8)



These examples do not contradict fact 11, however, since both (7) and (8) are ruled out as metrical trees.

Let us now prove fact 11. We will do this by proving a somewhat stronger claim. We say that a phrase structure grammar G has the *Path-Tree Property* iff every one of its derivation trees is uniquely characterised by the linear string of its vertical paths. Here is the claim we will prove:

> *Fact 12.*
> A context-free phrase structure grammar G has the Path-Tree Property if every production rule has the form $A \rightarrow x_1 ... x_n$, where $x_i \neq x_{i+1}$ for every i such that $1 \leqslant i < n$.

Proof: Let T be any tree, then its path-representation p(T) is the string $((a_1, X_1), \dots, (a_n, X_n))$, where $a_1..a_n$ is the terminal string of T and X_i is $(v(x_1),..., v(x_n))$, where $x_1..x_n$ is the string of nodes dominating a_i, such that x_i immediately dominates x_{i+1}. We have to show that the mapping p is one-to-one on the domain of trees generated by a grammar of the form specified in fact 12 above. In other words, if $p(T_1) = p(T_2)$, then $T_1 = T_2$. We will prove this by showing how T can be recovered from p(T) in a unique fashion. First note that for every X_i in p(T), its first element is identical to that of any other X_j, to wit, the root of T. We will write this first element as $f_1(X_i)$. In general, $f_n(X)$ is the n-th element in the string X. So $f_1(X_1) = f_1(X_2) \dots = f_1(X_n)$ = the root of T. Now we try to find the daughters of this root. For every X_i, going from 1 to n, draw a new node labeled by $f_2(X_i)$ iff $f_2(X_i) \neq f_2(X_{i+1})$, to the right of the previously drawn daughters of the root. However, if $f_2(X_i) = f_2(X_{i+1})$, then these symbols must correspond with the same node in T, because two adjacent nodes labeled identically are ruled out by the condition on G in fact 12. For every new node established in this fashion, we can find its daughters etc., until the whole tree T is recovered. Since the instructions to draw new nodes are unambiguous, fact 12 follows. Q.E.D.

In order to show that fact 12 implies fact 11, we have to show that any metrical tree is generated by a context-free grammar of the type specified in fact 12. From the definition of metrical trees, it is immediately clear that any such tree is generated by a context-free grammar employing the following production rules:

(9) *PS-rules for metrical trees*
$X \rightarrow S\ W \mid W\ S$
$X \rightarrow x$
(where X = R,S or W and x is a syllable symbol)

Inspection of these rules suffices to see that they are of the required type.

Let us now turn to the main question of this section: Can metrical trees be written as numerical stress representations? In other words, is it possible to define a class of numerical stress representations that is equivalent to the class of metrical trees?

The answer to this question turns out to be rather simple, once we use the concept of a path-representation. In this respect, a path-representation plays the same role here as reduced grids did in the section about metrical grids.

First I will sketch a rather attractive mapping from metrical trees to numerical stress representations which I have presented in my above mentioned paper, Hoeksema (1982).[1]

Definition 12.
Let f be a mapping from $\{S,W,R\}^*$ into $\{1,0,\ell\}^*$, where ℓ indicates the empty string, such that f(S) = 0, f(W) = 1, and f(R) = ℓ. For strings $(x_1..x_n)$ we define $f(x_1..x_n) = (f(x_1)...f(x_n))$. Let $\overline{X}$, where X is any string $(x_1..x_n)$, indicate its reverse $(x_n..x_1)$. If T is a metrical tree, then its associated numerical stress representation $n(T) = ((a_1, f(\overline{X}_1)),..., (a_n, f(\overline{X}_n))$, where $((a_1, X_1), ..., (a_n, X_n)) = p(T)$.

What we get by this mapping is a stress representation in binary numbers. To get ordinary numerical stress representations, we only have to translate the binary numbers into decimal numbers. By way of example, we will derive the numerical representation of the tree in (6).

First, we form its path-representation: ((ten, RSS), (nis, RSW), (play, RWS), (er, RWW)). Next, we turn the paths around and substitute 1 for W, 0 for S and delete R: ((ten, 00), (nis, 10), (play, 01), (er, 11)). Finally, we translate the binary numbers into the decimal system: ((ten, 0), (nis, 2), (play, 1), (er, 3)). Notice that this numerical representation is different from the ones considered earlier, in that the numbers go down when the stress goes up. If we keep that in mind, we will see that the mapping is quite appropriate, since it correctly assigns the main stress to *ten*, and it assigns heavier stress to *play* than to *nis*.

It is useful to compare the mapping of definition 12 with the algorithm given in Liberman and Prince (1977: 259) for the conversion of trees into number representations. Before doing so, we will first state the following proposition:

> *Fact 13.*
> The mapping from metrical trees into numerical stress representations described in definition 12 is one-to-one.

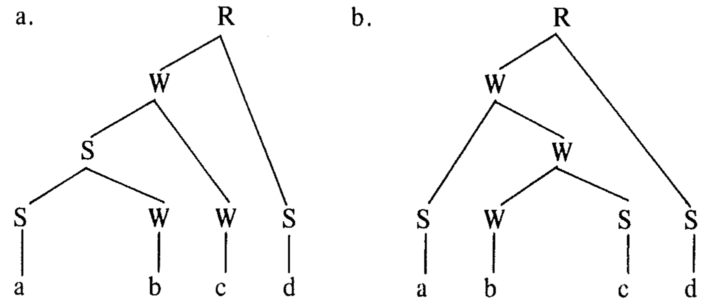
This property is very important, for it guarantees that we always can recover a tree from its numerical representation. If that were not possible, then the two representations would not be equivalent. Since fact 13 immediately follows from definition 12, a proof is not necessary.

Let us now consider the mapping given by Liberman and Prince. Here is the slightly more elegant formulation of this mapping by Prince (1983: 22):

(10) *Stress numbering*
For any terminal node *a*, determine the first W that dominates *a*. Count the number of nodes that dominate this W. Add 1. This is the stress number of *a*.

This mapping is certainly not one-to-one. To see this, consider the following two metrical trees:

(11) a. b.



The stress numbering system of Liberman and Prince treats these trees as equivalent. Each has the following numbering: ((a,2), (b,4), (c,3), (d,1)). In contrast, our numbering system would yield different numerical representations for these trees: the associated numerical stress representation of tree (11a) is ((a, 1), (b, 5), (c, 3), (d, 0)), and that of tree (11b) is: ((a,1), (b,7), (c,3), (d,0)). Notice that our stress representations, though different from those of Liberman and Prince, agree with theirs in the relative values of the stress numbers. More precisely, we claim that:

> *Fact 14.*
> For any two terminal nodes x,y in a metrical tree: if x has a higher stress number than y under the Liberman and Prince mapping, then x has a higher stress number than y under our mapping.

Recall that under the Liberman and Prince mapping x has a higher number than y iff the path from the lowest W dominating x upward to the root is longer than the corresponding path for y. But the length of these paths is equal to the length of the stress numbers in binary in our mapping, as we may skip the 0's coming before the first 1. So if x has a longer binary stress number than y, then evidently x has a higher decimal number than y.

Let us now compare the metrical tree representations with the structures studied earlier, metrical grids and numerical stress representations. From fact 13 we know that we can define a class of numerical stress representations that are equivalent with metrical trees. That does not imply, however, that trees and numerical representations in general are notational variants. One important difference between grids and numerical representations on the one hand and metrical stress representations is that there is only a finite set of metrical trees for some string X, but an infinite number of grids and numerical representations. In fact, the number of metrical trees for a given string X is a function of the length of X.

In order to make a fair comparison we will assume that there is some upper bound to the number of grids or numerical representations that one may associate with a given string. The following requirement seems natural:

> *Definition 14.*
> Call a metrical grid *well-behaved* iff it has at least as many columns as rows.

According to this definition, a metrical grid is well-behaved if the number of stress levels it can distinguish is not higher than the number of syllables in the string. Likewise, a well-behaved numerical stress representation on a string X can be defined as a string over XxN, such that for any (x,n) in the string $n \leq |X|$.

Even if we restrict our attention to well-behaved good grids, there are still many more such grids than metrical trees. For instance, on a string of four elements, there are 40 possible metrical trees, but 108 well-behaved good grids. Only in the case of well-behaved ideal grids, is the number less than the number of trees: 4! = 24. But if we require that each tree has uniform [S W] or [W S] labeling or obeys the condition that a right node is strong iff it branches, or the condition that a left node is strong iff it branches, we are left with only 18 different trees (cf. Halle and Vergnaud 1978 for discussion of these further restrictions on the labeling of metrical trees).

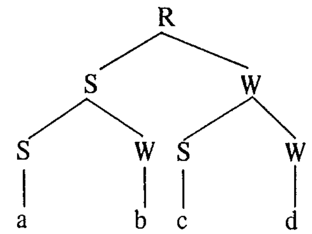
Now we must face something of a dilemma. Should we prefer metrical trees to grids or numerical representations just because there are less of them (if we ignore the 'ideal' representations for the moment)? On the other hand, we might need more distinctions than the tree theory provides us with. For example, if we want to make a distinction between 7 stress patterns and tree theory allows for just 4 patterns, then we have to make arbitrary assignments for at least 3 of the patterns in question. The issue is further complicated by the fact that tree theory may be supplemented by more non-terminal vocabulary (cf. the introduction of feet-symbols in Selkirk 1980).

A drawback of tree theory is that constituency is often rather arbitrary. As this point has been stressed already by several people (e.g. Prince (1983), Van Zonneveld (1982)), I will not dwell on it here. In this respect both numerical representations and metrical grids are superior, because they are not committed to the existence of the constituents in question.

Another point in favor of grids and numerical representations is that they need not be ideal stress representations in our technical sense. For the unprejudiced observer, it appears to be possible that two non-adjacent (or even adjacent) syllables in a string have the same stress level. Trees deny this possibility, as do all other ideal representations. An example that comes to mind is the stress pattern in a Dutch word like *genade* /χəna.də/ 'mercy'. Here the two shwa's appear to be equally weak.

Finally, it should be noted that relative stress is often a very opaque notion in tree theory. For example, it is impossible to tell whether *b* is stronger than *c* in the following tree or vice versa:

(11)



In this tree, it is quite obvious that *a* is stronger than *b*, that *c* is stronger than *d*, that *ab* is stronger than *cd*, for that is what the labeling tells us.

What reason is there to suspect, however, that the weak daughter of a strong node, like *b*, is stronger than the strong daughter of a weak node, like *c*? One has to invoke some numbering convention, such as the one of Liberman and Prince considered above. However, as Prince (1983: 22) puts it, there is nothing inherent in the tree system that would lead to the particular rank ordering of terminals entailed by this numbering convention. So this convention involves an auxiliary hypothesis of considerable complexity and indeed - from the metrical point of view - arbitrariness. To phrase it differently, if trees were really good representations of stress, then we would not need any auxiliary representations such as numerical representations or grids, unless, perhaps, these representations would follow directly from the tree notation.

Taken together, these arguments against the use of metrical trees in the description of stress are quite compelling to my mind. What exactly will turn out to be a good representation of stress, I do not profess to know. Here I agree with Bruce Hayes,[2] who remarked that there are theories of stress employing grids, and ones employing trees, as well as theories employing both, but the correct theory will probably employ neither.

NOTES

1. There is an obvious reformulation of the mapping for those tree theories which allow labels other than R, S and W (cf. Selkirk 1980). If *n* is the number of labels in the theory under consideration, then we will translate the paths into *n*-ary numbers. Again, the mapping is one-to-one.
2. In his talk at the ZWO-Workshop on Nonlinear Phonology, Amsterdam, August 8 1983.

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