Tonemic Structure

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"Any extension of segmental phonology to accomodate putative segmental characteristics of tone will raise the question of whether clear cases of segmental features behave similarly, and if not, why not." (Leben 1973, 34)

Introduction: Wherein All is Revealed

The main part of this paper is not so much an analysis of linguistic data as an analysis of a linguistic analysis -- Leben's 1973 study of suprasegmental tone systems. First I'll reconstruct what I take to be the important arguments for suprasegmental tone, and then spell out Leben's formal mechanism (first proposed by Williams, apparently) designed to handle the facts. This will immediately bring us to the strictly formal problems involved; I'll then suggest a whole-heartedly suprasegmental approach -- a "two-tiered" system -- which avoids the difficulties. A natural interpretation of this suggestion makes some claims about possible tone languages, which I'll then have to look into.

But first I must explain some fundamentals of tone systems. In the West African languages I've been looking at, there are only two (or three) underlying tones. Apparently, the underlying tone system in other tone languages -- for example, in eastern Asia -- can be far more complex. It would be entirely foolhardy for me to take the suggestions made here as universal claims. Rather, I am talking about the analysis of a particular kind of tone language: the sort which Williams' and Leben's suprasegmental tone analysis can handle.

Now in these tone languages, apparently all syllabic segments can be said to have a tone, and it can be either a level or a contour tone. The phonological derivation modifies underlying tones in three ways: 1. Reshaping;2. Assignment; and

3. Reassignment. That is: (1) The rules take a two (or three) way underlying distinction among tones and yield virtually a continuum of possible tone levels. (2) The phonological derivation will assign tones to syllabic segments which are underlying unmarked for tone underlyingly. (3) The rules can reassign tone in basically three ways: (a) a "floating tone" must get attached to some syllable under some circumstances; (b) processes like compounding reassign tone systematically; and (c) when a syllabic segment becomes non-syllabic, either through deletion or becoming a glide, its prior tone is shifted to a more suitable substrate.

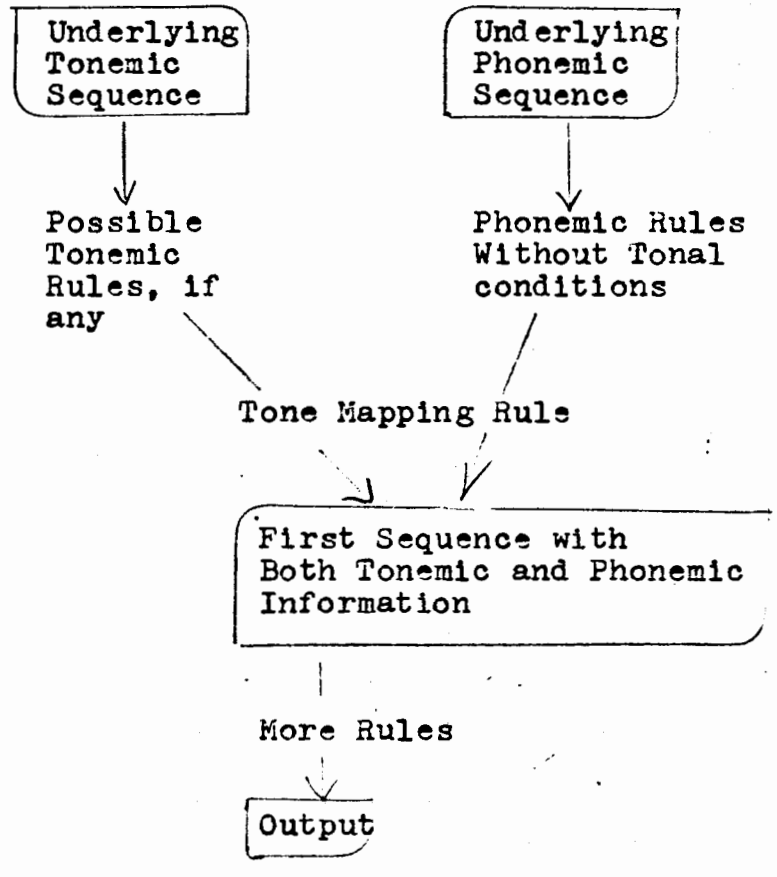
Williams' and Leben's idea was this: underlyingly, morphemes' tones weren't assigned as features of particular segments or syllables, but rather, the tones constituted a sequence of toneme segments in their own right. So, for example, a CVCVCV word with three high-tone vowels would, all other things being equal, have no tones marked on its segments underlyingly, but rather would have a second rank of tonemic information, which would in this case merely be H=High. Now here's what is crucial, and central to Williams' approach (accepted unchanged by Leben): at some point in the derivation, the tonemic sequence is merged with the phonemic by a "Tone Mapping Rule."

What we would have, then, is two parallel derivations, a tonemic and a phonemic, each operating independently of the other -- which means that neither can use information to be found in the other domain to condition its rules. Tonemic

rules cannot have phonological features in their statement, and so on. At the end of the Tonemic derivation, the Tone Mapping Rule maps the tonemic sequence onto particular segments of the phonemic sequence. The tonemic sequence thereafter no longer exists except insofar as it is embedded in the master phonemic sequence. Now the phonemic derivation continues, and subsequent rules can address both tonal and phonemic features in just the way ordinary phonological rules can address different features. Tonemic features have become simply phonemic features, at every point in the derivation past Tone Mapping.

Williams,

Leben



The principle behind the Tone Mapping rule is basically simple: going from left to right on both the tonemic and the phonemic sequence, assign one toneme per syllabic segment. If you run out of tones before syllabic segments, perseverate: assign the final toneme to the rest of the syllabic segments. If you run out of syllabic segments before tonemes, pile up the tonemes on the last syllabic segment. This jam-up, then, is the primary source of contour tones, which are always due to the assignment of different level tones to one syllabic segment. It is an interesting consequence -- one which we'll have to investigate in detail later -- that underlying contour tones could only exist on final syllables, if the tone mapping rule is to work as I have described it.

One last thing before going on to the main part of this paper: I would like to foreshadow the denouement. Leben's claim about the nature of the merger of the tonemic and phonemic sequences is much too strong, I think, even for the types of phenomena he examines. Instead, I will suggest that the two tiers -- the phonemic and the tonemic -- remain separate throughout the segmental derivation.[4] In place of a tone-mapping rule which merges the two tiers into one, I suggest a correspondence rule. In its effect, intuitively speaking, the correspondence rule and the mapping rule are the same: obviously, they must be, if they are to explain the same data. In fact, Leben comes very close to using this system in dealing with floating tones. In any event, I hope to show the following: first, the mapping rule scheme creates situations

where phonological rules must play tricks they really can't, and which they aren't forced to do under the correspondence (two-tiered) scheme; second, whereas Leben's formalism was suggestive of a phonological theory in which segments themselves were broken down into "subsegments", ordered chronologically, the two-tiered system does not condone such divergences from previous descriptions of segmental phonology. Third, the two-tiered approach suggests that rules that must be ordered after "tone mapping" or the correspondence rule may still retain their suprasegmental character. Fourth (really a special case of three), the two-tiered approach suggests that deletion of syllabic segments will not delete tone, even if ordered after a rule that uses information from both the tonemic and phonemic areas. The tone will float to another segment. On Leben's account, the tone would be deleted. Fifth, and most vaguely, the two-tiered approach suggests one part of the characterization of a natural tonemic rule: a natural tonemic rule would be one which reassigns tone contours (according to certain guidelines) but does not change the contour itself. I do not mean, however, that there are no rules that change the contour; however, some tonal rules are far more widespread than others, and we would like to characterize why that might be. Sixth, the two-tiered approach explains how the tonal structure of items deleted through syntactic processes can still participate in tonological rules such as downstep ordered or large-phrase cycles.

I should like to begin, as Leben does, with a discussion of the formal possibilities upon to us in describing tone phenomena: in particular, the problems of floating tones and of contour tones. This will bring us into Leben's formal suggestion for the Tone Mapping rule. Criticisms that I make then should be held in abeyance in the reader's mind until we come to my proposed alternative later in the paper.

Floating tones are tones that are posited to explain tonal variations even though the floating tones have no syllabic or consonantal substrate of their own to hang onto. These floating tones regularly trigger tonemic rules, and are eventually either assimilated or cause a level tone to become a contour tone.

Leben criticizes previous formal representations of floating tones.

> Schachter and Fromkin (1968) permit phonological derivatives to give rise to a tone feature represented on an entity which has no segmental features other than [+seg]. This proposal is reformulated in Fromkin (1972), where these segmentally unspecified entities are characterized as [-seg]. A somewhat similar proposal is made for Nigerian and other languages in Maddieson (1971), but with [-syllabic] substituted for [-seg]. [pp 24-5]

> In the works cited [Bird (1968, 1966, Hyman 1972a,b)] the existence of floating tones hardly constituted a serious problem; this is due largely to the fact that the authors did not concern themselves sufficiently with formalizing their result. However, in works like Schachter and Fromkin (1968), Fromkin (1972) and Maddieson (1971), where formalism was a concern, the problem immediately surfaces..../Schachter and Fromkin (1968) represent floating L in Akan with the matrix [+segment, +L] with no other segmental specifications. This proposal is clearly ad hoc, since no other segmental feature has ever been shown to be capable of this sort of representation. (30-31).

A bit later, Leben says, "Other proposals which have attempted to escape the suprasegmental nature of floating tones are subject

to the same criticisms as the unspecified-[+seg] proposal." (p.32). What are these "criticisms"? Just this: there is no other segmental feature that can stand alone on a segment with no other articulatory features specified (e.g., *$\begin{bmatrix}+\text{seg} \\ +\text{strident}\end{bmatrix}$). In other words, why do tones float, but not stridency? This is the only argument given (this sort of argument of Leben's should be kept distinct from his empirical arguments that tonemic rules do not rely upon segmental information).

Contour tones wreak havoc, too, regarding the segment's simple nature.[1] On p. 36, Leben considers three possibilities for representing contour tones on short vowels: (1) with features like "Rising", "Falling"; (2) with dummy segments like [-seg, +H]; and (3) with his proposal, which we will get to. What is interesting to note at this point is that his argument against (2) is the one mentioned above: he considers the general argument concerning the incoherence of [-seg, +H] to be an argument against employing segments like this either at the underlying level or in a derived structure. This distinction becomes important to Leben (for some reason), as we shall see later (p. below).

This brings us directly to Leben's Tone Mapping proposal.

Leben argues that the segmental information about a morpheme is <u>basically</u> (in some sense) unordered; the formal characterization of a word beginning CV... would include "consonant-initial" (C(1)) and "vowel-second" (V(2)). This can be heuristically represented as "CV...". This, I think, is a mistaken view, perhaps derived from the feeling that marking

an item with a number is a way of indicating its position in a sequence which is formally superior to simply writing out the sequence. Such a "feeling" has, clearly, no basis. Yet using numbers to separate out the feature characterizations to their appropriate segements (as Leben says: i.e., C(2) means the second segment is consonantal) suggests that the natural numbers could enter into the definition of natural classes of features; for example, all features whose subscript was of the form 2n. Or 3n + 1. The point, of course, is that only the relations of identity and non-identity of indices (just as with referential indices in syntax), and the relations of "precedes" and "follows", are allowed -- that is, we are allowed to use just those characteristics of the indices that follow from being linearly ordered, as a sequence is. The assumption that the appropriate formalism for segmental information is as a string predicts this; Leben's stronger alternative does not.

And yet Leben's rule of Tone Mapping makes crucial use of the assumption that all information regarding every segment in a word is available at every other segment in the word. I quote Leben at length:

> To express notions like "first tone on the first vowel" [the first step of the tone mapping assignment], it will be necessary to attach subscripts to the vowels in a string of segments and to the tones in a string of suprasegmentals. Thus, let us assume that the succcessive vowels in a string are marked $V_1, V_2, \ldots, V_m$, and that the successive tones are designated $T_1, T_2, \ldots, T_n$.
>
> To express the environment for the mapping, it is necessary to take note of the following convention, propsed in SPE: "Every segment of a lexical matrix α is marked [α K] for each category [α K] to which α belongs." ... This permits us to express the first part of the mapping rule as follows:

(25) $V_i \rightarrow [\alpha H] / \left[[+j^{th}, \alpha H] \right]$

Condition $i=j$ OR if $j=m$, $i \geq j$

(Clearly Leben intends "n" rather than "m" in the condition).

This rule says that a vowel whose subscript agrees with the number designating the position of the supra-segmental tone acquires that tone as a segmental feature, and that a vowel whose subscript is greater than that of the last tone, the ~~the~~ vowel acquires the last tone as a segmental feature [sic]..../What remains to be expressed is that if some tones are left over, they must be grouped in sequence on the last vowel. This occurrence of a linear sequence of features on a segment is discussed a bit further in the next chapter. To formulate the rule, another convention must be introduced:

(26) A rule mapping a suprasegmental tone onto a segment already specified for a tonal feature does not replace this feature but instead adds another tone feature in sequence.

This convention is also needed for many cases in which a floating tone is added to a segment without replacing the tone already possessed by the segment. [Leben uses this convention elsewhere (p.56) with tones that are at this point in the derivation not suprasegmental - JG]

The remaining part of the mapping rule may now be formulated as:

(27) $V_m \rightarrow [\alpha H] / \left[+j^{th}, [\alpha H] \right]$ Condition: $m<j$

V_m here denotes the last vowel in the string. The arrangement of the tones in their proper sequence must be assured; this is possible in principle, since the proper order of the suprasegmental features is given by the relative values of their subscripts. The formulation of this requirement is not attempted here, but presumably the output of (27) on the last segment of nyàhâ, for example, would resemble the following, where the numerals 1 and 2 give the order of these features on the segment.

$$\underline{a}$$
$$[1, [+H]]$$
$$[2, [-H]]$$

The point of this present paper is that if Leben had indeed attempted to formulate the rule and use it, he would have found it quite unsatisfactory. What he says is fine in principle until one tries to make it quite explicit. Leben's own words come back: "The authors did not concern themselves sufficiently with formalizing their result." Leben continues:

> Obviously, rules (25) and (27) can be collapsed into (29):
>
> (29) $V_i \rightarrow [\alpha H] \;/\; \left[{}_j\overline{H},\ [\alpha H] \right]$ Condition: $i=j$ (a) OR if $j=n$, $i \geq j$ (b) OR if $i=m$, $i \leq j$ (c)

While it is is indeed clear that (25) and (27) should collapse, (29) is not the correct result. Note that as (29) stands, a LHL contour will map onto a CVCV word to form CVCV!

m=2; n=3

i	j	Is (a), (b) or (c) met?
1	1	Yes : (a) $i=j$ ω T
1	2	Yes : (b) $j \neq n$: (F→F) ω T
1	3	Yes : (c) $i \neq m$: (F→F) ω T
2	1	Yes : (b) $j \neq n$
2	2	Yes : (a) $i=j$
2	3	Yes (c) $i=m$, $i<j$

So all tones get mapped to each vowel. What Leben wants, rather, as his condition is: $\left[(i>j) \supset j=n\right]$ AND $\left[(i<j) \supset i=m.\right]$

Recall that Leben says the suprasegmental approach is successful in dealing with two problems in ways superior to the non-suprasegmental: contour tones, whose analysis we have just gone through, and floating tones. Little is said explicitly about them; we shall return later to serious problems for the tone-mapping theory of suprasegmental tone writh regard to floating tones.

Mende

Leben's discussion of phonological processes in Mende contains details of several interesting forms, but, understandably, the report is quite enmeshed with his analysis. Therefore I'd like to lay out the facts first, and see what conclusions they lead to.

(A) Effect of tone-bearing suffixes on stems. Stems that are monosyllabic with a contour tone can become level. This occurs if the stem is falling toned and followed by a low tone suffix, or conversely, if a rising tone stem is followed by a high suffix. The contour tone simplifies to its first element.

HL mbu + L ngaa → mbú ngàa 'owls'
'owl' indef pl.

LH mba + H i → mbà í 'the rice'
'rice' def.

On the other hand, a CVCV + ngàa does this:
'house' H pɛlɛ + L ngaa → pɛ́lɛ́ + ngàa , not *pélè ngàa,
as one might guess if he thought that suprasegmental tones were merged before mapping.

(B) Effect of toneless affixes on stem. The facts here are much like in (A). A toneless affix has no inherent tone; it apparently gets its tone from the syllable before.

ma 'on' hu 'in'

HL mbu ma → mbú mà
LH mba hu → mbà hú

This could be viewed in at least two ways: (1) copy the last toneme from the previous morpheme onto the toneless suffix, and then find yourself back in the situation in (A) above, with toned suffixes. (2) Pretend the boundary between the root and the suffix isn't there when you do the tone mapping rule.

(C) Compounds: For two-word compounds, the only sort discussed, the facts seem to be thus: the first word retains underlyingly its isolation tone contour. The second word starts with the final tone of the first word, and all tones thereafter are low-toned. In particular, if the second word is mono-syllabic and the final tone of the first word (which gets copied) is High, then the second word has a Falling (HL) contour. Furthermore, contour tones in the first word get "simplified" as in parts (A) and (B) above. So:

kɔ́+hani	→ kɔ́ hánì	'weapon, war thing'
kpà+hani	→ kpà hànì	'debt thing'
mbû+hani	→ mbú hànì	'owl thing'
mbǎ+hani	→ mbà hánì	'rice thing'
kɔ́+mɔ	→ kɔ́ mɔ̂	'war person'
kpà+mɔ	→ kpà mɔ̀	'debt person'
mbû+mɔ	→ mbú mɔ̀	'owl person'
mbǎ+mɔ	→ mbà mɔ̂	'rice person'

(D) There is another kind of tone contour adjustment, but this time not for contour tones. There is a large class of words with a LH contour in isolation which simplify to LL under several conditions. This class consists of most, but not all, bisyllabic words with a LH isolation contour. The environments underwhich the tone simplifies are: (a) before $/\overset{i}{\underset{H}{}}/$ (b) as the first word in a compound (e.g., nìkà-hánì); (c) before toneless suffixes (e.g., nìkà má) -- in other words, in the three areas of (A), (B), (C) above.

To explain these four phenomena, Leben proposes the following rules:

(1) Tone Deletion, which I will refer to mnemonically as Contour Flop $\widehat{HL}\ L \rightarrow HL$, $\widehat{LH}\ H \rightarrow LH$

where the tie indicates a contour tone.

(2) Tone Copying, which explains how the second word of compounds gets a copy of the last tone of the first word. This he does not formalize; it is eventually (pp.76-77) shown that Tone Copying occurs before Tone Mapping. I would express it formally $\#\#Q^{\alpha}\#\#\ R\ \#\# \rightarrow \#\#\ Q^{\alpha}\ \#\#\ \alpha\ \underset{R}{L}\ \#\#$

(3) Tone-Spreading: $H \rightarrow L\ /\ L\ \_\_\ H$. This is essentially a rightward shift in contour, as is Contour Flop. Contour Flop is obviously segmental, since it is conditioned by tones being assigned to the same segment; Tone-spreading, however, is held to be tonemic, which is to say, pre-Tone Mapping. The evidence is very slim in Mende, though stronger in the related languages of Bambara and Maninka, dealt with in Leben's chapter four.

Tone Copying is crucial only for Compound Formation. Examples like ^{H}pɛlɛ-hani → pɛ́lɛ́-hánì and ^{LH}nika-hani → nìká-hánì → nìkà-hánì show that nothing as simple as Tone Mapping onto the whole compound at once is going on.

^{LH}mba $^{??}$hani	Underlying
^{LH}mba ^{HL}hani	Compound Rule
mbǎ hánì	Tone Mapping
mbà hánì	Contour Flop

With these rules, which explain why the LH words act as they do described in (D), Leben is able to make an extremely interesting generalization about possible contours of Mende, one expressible only in a suprasegmental framework. All words have as their underlying tonemic representation either L,H,LH,HL, or LHL, which are then mapped onto the word with the Tone Mapping rule. What this does, we might say, is permit Leben to divide by 43 the number of statements necessary to characterize possible contours. Since mbâ shows that three level tones can occur on a vowel, a tri-syllabic word could have 216 possible contours a priori. Other statements might then be needed to state the possible contours for mono- and bi-syllabic words. In any event, Leben's generalization collapses the possible contours into five simple forms, united with a Tone Mapping rule that we know simplifies the Compound Rule's statement independently. This then is a very interesting result of the suprasegmental approach to tone. The non-existence of the HLH contour underlyingly automatically accounts for the non-existence of *mǎ, *lópǒ, *lôpó, *míbàbá, and so on.

Leben points out that his general solution has several counterexamples of a similar nature: bisyllabic words with a LHL contour with a rising first tone and a low second. There is also one anomalous LH bisyllabic word with a rising first tone. Quite correctly, Leben suggests that one solution would be to posit an underlying geminate vowel. He adds that this would still not suffice, for even if tǒlò 'kola nut' were underlyingly /LHL: toolo/, becoming /tòólò/, a syncope rule would be necessary on his scheme to explain why the deletion of

the second vowel did not also delete the tone residing on it. It will be seen that the revision of Leben's formalism that I will suggest would predict that the tone would shift correctly were the underlying vowel deleted.

We have to look at Leben's formalism in detail. The Tone Mapping rule assigns accordion-like a potentially indefinite number of tone features to a segment. Granted, in the most complicated natural case Leben studied, no more than three tones were assigned to a segment, but there is no reason to artificially limit the number of tones that can be assigned to a segment; to do so would merely complicate the formal mechanism.

Now a segment is an ordered sequence of features. The interpretation of each feature in the sequence is a direct consequence of a universal phonological convention of a theory. So, for example, in a simple theory with three underlying features, the description of a segment would be /++-/. The interpretation of each feature is dependent upon a convention within the theory that the feature "high", for example, is given the first place, so this segment represents a "+high" segment.

In the formal theory, then, of segmental phonology, the feature of each row of the segment relates to a different aspect of the sound being represented. There are, furthermore, a specific number of features assigned to each segment; that number is decided by the universal theory in which we are working. Again, another property of the features of a segment is that a permutation of features inside the theory would make no difference to the theory; that is, there is no real difference between two theories which differ only by the order in which they represent the features in a segment. For example, if theory A says the first feature is <u>high</u>, and the second <u>back</u>,

a segment X might be represented /+-.../; theory B says that the first feature is back, and the second is high, and so represents the same segment X by /-+.../. There should be no way to distinguish empirically between these theories, I believe; I will call this the principle of invariance under permutation of features.

This property of feature assignment conventions is abandoned with the tone mapping rule. Three fundamental properties of segmental representation have been discarded so far: the number of features for a fully specified segment is no longer constant; there can be more than one feature specifying the same element of the articulation (in particular, the tone at which the segment is to be produced); and most interestingly, the property of invariance under permutation is lost.

First I will show why this is the case, and then I will say why the property of invariance is valuable and should not lightly be jettisoned, for it represents a solid and valuable constraint on what we use features in segments to mean.

The crucial case where Leben's tone mapping rule acts suspiciously is when two or three tones are being assigned to a segment, producing in effect a contour tone. Let us suppose for sake of argument that the tone features are numerically not the last ones in the feature column. Since we can't know in advance how many tones are assigned to a segment, there can be no universal convention interpreting the features that constitute a segment unless the interpreting device can count both from the bottom and the top. That is, if the tone features were to begin on feature number twelve, then

the first eleven plus and minuses of the segment's specification would be easily interpreted as corresponding one-to-one with the first eleven features. The twelfth feature would be a tone feature; the thirteenth would either be the next tone feature, if the segment had a contour tone assigned to it, or it would be the feature specification for the next phonetic feature in the list of features specified by the theory's convention -- i.e., labial, if the features were listed like this:

1. Height
2. Back
.
.
.
12. Tone
13. Labial
14. .
.
.
Last N. Nasal

There would be a way out of this, surely, if we permitted the formal device to interpret from the bottom up. Then if there were N feature specifications, the last N-12 would be for the features Labial through the last feature, Nasal. They could be associated by pairing up from the bottom of each list, the segment's features and the convention's list of features.

Though there is no problem directly if the tone features are put at the end of the list, the prediction is made that only one kind of feature is possible in a language which can have an indefinite number of features on a segment specified for it.

It does, however, violate what I called invariance under permutation. This is a property of the system that interprets segmental features. It asserts that two particular theories which differ in the way in which the features are listed cannot

differ in the kinds of statements that can be made in the grammars. The principle is an attempt to make sure that segments don't become used as suprasegmental warehouses.

Here is how a possible segmental theory is blocked by the principle. Consider a theory which attempts to treat the voicing of consonants, and even indefinitely long consonant clusters, as a property of the immediately preceding vowel. [isk] would differ from [isg] and [izk], etc., by the features on the vowel /i/. Now if the features assigned to the voicing of /i/, /s/, and /k/ were totally unrelated within the theory, then the theory could be presumably ruled out on both universal and language-particular grounds as having missed something. However, what would prevent someone from saying that vowels can carry a chain of indefinite length with voicing specifications, which later get copied onto consonant sequences? This is the sort of conceivable possibility the principle is designed to rule out. It restricts the possible strategies a grammarian has in explaining languages. If nothing were to eliminate the mentioned theory, the device used could be pushed further and further, with almost all the features winding up on the vowel.

But this "theory" is eliminated on the grounds that once the sequence of voicing features is indexed, the theory is longer invariant under a permutation of these index numbers. The original theory says "Voicing(1) is assigned to a segment 1 away

Voicing(2) " " " " " 2 "

Voicing(3) " " " " " 3 " "

and so forth. The generalization is clear: Voicing(i) is assigned to the i^{th} segment away.

If we permute the index numbers, however, in general

no simple principle can be found, so that no generalization is possible. Thus one theory -- the original -- can state generalizations that the others cannot. And therefore we rule out the original as a possibility.[1]

One might well question why I have assumed that segments' feature specifications form a sequence -- i.e., are matched up one-to-one with the natural numbers. Instead, it might be suggested, the requirement that all features at all times have a specification should be dropped; instead, a segment is an unordered set containing ordered pairs, the first of whose elements is + or -, the second of which is the name of a feature: an arbitrary symbol, in other words. The requirement that all segments have the same number of feature specifications is no longer necessary, and as for the principle of "invariance under permutation" -- well, it hardly makes sense to talk of "permutation" of an unordered set.

This alternative is perfectly reasonable. I only began with an approach wherein features are number in order to be most sympathetic to the system Leben seems to be suggesting. However, in the alternative system just proposed, the principle of invariance under permutation still has significance -- as one would expect, essentially the same significance. It would be reinterpreted to say that the arbitrary symbol used to name the feature (i.e., the second element) <u>is</u> entirely arbitrary, and any other theory which differed only by using a different symbol would not differ in the statements that theory could make. Again, this is a way of saying that feature names do not naturally collapse.

The principle as I have described it is not a logical truth, but it does, I believe, bring to the fore an assumption about what segments are for in the theory. To the extent that it is accepted as a constraint on what sort of power we will impute to the theory, to that extent we cannot accept Leben's solution, for his use of sub-numbered tone features clearly violates the principle.

One's reaction to the criticisms I am making might well be that I am not being fair to Leben's notation, which does, after all, attempt to reflect the natural connection between the tone features on a segment. I can only reply that I am trying to show that making the supra-segmental tone sequences segmental just won't work. I recognize, of course, the intuitive appeal of Leben's rule; I question, however, the formal approach which he takes.

Consider another convention Leben must impose on these segments, one which further casts doubt on the possibility of segmentalizing contours on phonemic segments. When a floating tone on the left is placed on a segment that contains a tone (i.e., $\begin{bmatrix} \varnothing \\ 1.L \end{bmatrix} \begin{bmatrix} V \\ 1.H \end{bmatrix}$), we get: $\begin{bmatrix} V \\ 1.L \\ 2.H \end{bmatrix}$. So we see the feature names are crucial. We must set up a convention that before any rule that threatens to write over the feature specification of feature T1, we must copy it onto feature T2. (Presumably another parallel convention holds with respect to feature T2 and T3, ...) This is a perfectly natural -- indeed, unavoidable -- result, were the tones still constituting an independent sequence; however, Leben's claim is that the tone specifications are segmental after Tone Mapping.

Segmental Sequence Features

After describing these facts about Mende which support a suprasegmental approach to tones (possible morpheme contours, derivation of kinetic -- i.e., non-level -- tones from the amalgamation of level tones) , Leben turns to how he will treat the output of the Tone Mapping rule formally. He posits (p.68) a possible syllabic segment $\left[\overset{a}{[+H][-H]} \right]$ and says, "At first glance, this may appear to contradict the position in chapter 1 rejecting sequence features such as [[+H][-H]] when posited on phonological segments. However, this is not so. We have direct phonetic evidence for the existence of transitions such as HL on words like mbu, and these transitions can be shown to occur phonetically on the short vowels of these words....Thus, no theory can get by without recognizing transitions on single segments....What was declared ad hoc in chapter 1 was the use of such transition features in underlying representations. That is, while we have undeniable evidence for the presence of transition features in surface phonetic representation, we have no evidence for the presence of such features in underlying phonological form." (P.69)

This appears to me extremely limp -- for several reasons. First, no evidence ever automatically contains its own interpretation. If we find /a/ being actually pronounced with a rising tone, this could be interpreted in the phonological theory as a fact about the phonetic features in the output form. -- Or it need not, as in the interpretation I am suggesting. (2) Similarly, we certainly don't have direct evidence that "HL"

is represented on single segments: at best, we could say a set of 1(1 or more) features interpretable as falling is there. (3) To the extent that Leben did argue against sequences like [[+H][-H]]-- and I think he could have argued a good deal more strongly -- then these arguments still hold against them now. None of his arguments were dependent upon the fact that the prohibition was aimed at the underlying representation rather than a segmental representation in general. (4) So once Leben has accepted a phonetic description including this new wild card [[+H][-H]], then it is incumbent upon him to show why this should not be a phonemic possibility, rather than (as he suggests) it being presupposed that such a sequence could not be phonemic. This is obvious: every rule of a grammar is costly, so to speak, and the divergence between surface and underlying form must always be justified. If we grant Leben his surface forms, then admittedly he has motivated the Tone Mapping rule, but not because of a priori arguments, but rather on empirical grounds.

Leben's Discussion of "Downdrift".

It is in this section (224) that Leben considers downstep (or "downdrift", as he calls it; I shall reserve the term "downdrift" for the phonologically unconditioned lowering of tones in a tone or breath phrase, and use the term "downstep" for the phonologically conditioned phonetic lowering in tone of high tones when separated by low tonemes).

As Leben points out in his first chapter, downdrift treats contour tones as sequence of level tones. That is,

a falling tone will have its initial tone lowered before a High+Low sequence just like a High tone would; a rising tone will have its final tone lowered with repect to a preceding high tone, and so forth. Here, as elsewhere, facts that indicate that rising and falling tones are acting as sequence of level tones extend to the obvious parallel facts for Rising-Falling LHL tones (or so Leben indicates).

Now Leben continues, the conclusion that downstep transitions are expressed as sequences of level tones "assumes that downdrift applies at some point after Tone Mapping, and this assumption appears to be true." (He then suggests an argument that the downstep rule is ordered after Tone Mapping in Hausa) But that downstep treats contour tones as sequences of level tones does not suggest or presuppose that downstep follows Tone Mapping; if anything, it suggests that Downstep precedes Tone Mapping.

Why should this be? The basic idea of downstep is very simple. A High tone is phonetically lower than every preceding High tone in the phrase which is separated from it by a Low tone. Once the transition is made from High tone to Low tone, so to speak, the return to High tone can never be fully accomplished until a new phrase is started.

Now, if the tonemes are still suprasegmental at the time of Downstep -- that is, if Downstep precedes Tone Mapping -- then the simple and clear principle of Downstep can be formalized (we shall attempt this below). If, however, Downstep must operate on the output of the Tone Mapping Rule, it will have to handle the following cases. Consider the chart below, where

all the possible combinations that might lead to downstep are laid out. "$H_1 = H_2$" means that H_2 is not downstepped from the preceding High tone; "$H_1 D H_2$" means a downstep transition occurs with the pair. Beneath the chart are four rules that in their own peculiar way summarize the eleven cases of downstep.

Left \ Right	L	H_2	LH_2	H_2L	LH_2L
$H_1 C_0 L_1^{\wedge}$	X	$H_1 D H_2$	$H_1 D H_2$	$H_1 D H_2$	$H_1 D H_2$
H_1	X	$H_1 = H_2$	$H_1 D H_2$	$H_1 = H_2$	$H_1 D H_2$
LH_1	X	$H_1 = H_2$	$H_1 D H_2$	$H_1 \neq H_2$	$H_1 D H_2$
H_1L	X	$H_1 D H_2$	$H_1 D H_2$	$H_1 D H_2$	$H_1 D H_2$
LH_1L	X	$H_1 D H_2$	$H_1 D H_2$	$H_1 D H_2$	$H_1 D H_2$
$\#L_1^{\wedge}$	X	$H_2 = H_1$	$H_2 = H_1$	$H_1 = H_2$	$H_1 = H_2$

What is labeled "Left" (decending rows) is, loosely speaking, the conditioning environment for Downstep. It isn't exactly, for in the third and fifth column, part of the conditioning of H_2's downstep is right there on its own segment.

(A) $H \rightarrow$ 'T-1' / $\left[\begin{Bmatrix}1\\2\end{Bmatrix} H \text{ 'T'}\right] \times [1.\,L]Y —$

(B) $\left[\begin{Bmatrix}1\\2\\3\end{Bmatrix} H \text{ 'T'}\right] \times \begin{bmatrix}1.\,L\\2.\,—\end{bmatrix}$

(C) $\begin{bmatrix}\{1,2\}\ H \text{ 'T'}\\3.\,L\end{bmatrix} \times [\{1,2\} —]$

(D) $\begin{bmatrix}1.\ H \text{ 'T'}\\2.\ L\end{bmatrix} \times [\{1,2\} —]$

} Condition $X, Y \neq$ H tone

I have here adopted a convention that numbers placed within single quote marks represent heights of tones, with the larger numbers representing higher tones.

Granted, the four rules (A) - (D) are very peculiar. The collapsing of feature names is entirely unheard of: it is just another way of expressing a particular boolean condition. That is, $\begin{Bmatrix}1\\2\end{Bmatrix}_H$ is just another way of putting the condition $\boxed{\alpha \vee \beta}$ on the segment $\begin{bmatrix}\alpha\,\text{Feature}_1\\ \beta\,\text{Feature}_2\end{bmatrix}$. I don't want to belabor this point forever, but it must become clear that the formulation of downstep is simply untenable as it is found in this notational system.

Note also that so far we have made no use whatsoever of the ordered-ness of the tone features as they are put onto the segment by the Tone Mapping rule. That is, so far the features on the segment do get interpreted subject to the principle of invariance under permutation. Fine as that is in principle, it shows that so far we have not made use of the device which Leben thought would make his system allow downstep to be expressible even if it were ordered after Tone Mapping. Therefore we must see how we can collapse these four rules -- which are, incidently, intrinsically disjunctive: no two could apply to the same pair of High tones.

To do this, we must say in the formulation of the rule that one feature name can be naturally ordered before another (i.e., explicitly violate invariance under permutation). Rules C and D naturally collapse in this way:

(C,D) $H \rightarrow \text{'T-}i\text{'} \;/\; \begin{bmatrix}i\,H\,\text{'T'}\\ j\,L\end{bmatrix} X \begin{bmatrix}\{1\\2\}-\end{bmatrix}$

Condition: $i<j$

Once we see how this game is played, it's no trouble to collapse rules (A) and (B) also; we end up with the natural rule:

(A,B,C,D) $H \rightarrow$ 'T-i' / $\begin{bmatrix} iH \\ \langle j\ L\rangle_a \end{bmatrix} X \langle [l\ L] \rangle_b Y \begin{bmatrix} \langle k\ L\rangle_c \\ l\ - \end{bmatrix}$

Conditions: $a \vee b \vee c$; $i<j$; $k<l$

Negative Condition: $\langle\ \rangle_b$ contains no H

$X, Y \neq H$

How would this rule have been written if the tones retained their suprasegmental property? As in (E):

(E) $H \rightarrow$ 'T-1'/ $\begin{bmatrix} H \\ \text{'T'} \end{bmatrix} C_0\ L_1^n\ C_0\ -$

The choice as to which to pick is not very difficult.

But note also that there exist rules on the word-cycle which require Tone Mapping or its equivalent to precede them. Downstep occurs on a later, larger cycle, so the mere placement of Downstep earlier in the ordered phonological rules is not sufficient to correct the problem, nor is placement of Tone Mapping after tone phrase rules.

Floating Tones?

There is another egregiously debilitating aspect of Leben's suprasegmental system -- one we promised to return to earlier. Leben drew a bead on other tonologists because of the peculiarity of their treatment of floating tones. Leben claimed that the suprasegmental system virtually predicts the existence of tones without phonemic identity, just as there are toneless morphemes. He declined to mention, however, that inasmuch as he wants downstep to occur after Tone Mapping, and he wants (as he must) floating tones to participate in downstep, we must do something with the floating tones after Tone Mapping. This is really an embarrassment. In the only spot in his thesis where he comes down to the nitty-gritty of the matter, Leben adopts what is essentially my suggestion: keep the tonemic level after "tone mapping". Thus he has as a sample derivation on p. 102:

$$\begin{array}{ll} L_{\emptyset} + {}^{HL}va & \\ L_{v\acute{a}} & \\ v\hat{a} & \text{Tone Mapping} \\ v\acute{a} & \text{Simplification} \\ \hline L_{\emptyset} + v\acute{a} & \text{Input to Downstep} \end{array}$$

There is nothing that can be said here, except perhaps that Leben has permitted himself to pass into the company of these who propose segments consisting of $\left[\begin{smallmatrix}\emptyset\\ L\end{smallmatrix}\right]$!

An Alternative to Tone Mapping

What I would like to suggest to replace a rule of Tone Mapping is a two-tiered appraoch which retains the two sequences of segments, tonemic and phonemic. This suggestion was motivated simply out of an attempt to handle the facts Leben deals with, but it will be seen to have made independently some interesting predictions for simplifying the grammar of Enya, a Bantu tonal language.

First I should say that I consider the arguments for suprasegmental tone to be not only interesting but persuasive. The arguments that tones become segmental are, however, very poor. Rather than to say that the toneme becomes mapped into a tone feature on the phonemic segment, I suggest that a correspondence be formally set up between successive tonemes in the tonemic sequence and successive syllabic segments in the phonemic. The simplest hypothesis is that this correspondence is set up from the very beginning of the derivation. Operations that make the current correspondence untenable -- for example, deletion or desyllabification of a tone-bearing vowel -- will result in a reassignment of the tone. Tones can be exceptionally marked so that they do not ever correspond to particular vowels. This exceptional status with respect to the correspondence rule does not,however, disqualify the toneme from participating in the late rule of downstep, as it would on the "tone mapping" theory.

There are two alternative and equivalent representations for this system. The first is a graphic one showing the

system as literally two-tiered, representing the correspondences with lines. Thus CV̀CV̂ would be represented: CVCV .
LHL

The second is to write out the ordered pairs which form the lines in the first representation. In this second form, we must index the tonemes and phonemes; however, the indices need only be increasing -- they need not form a one-to-one correspondence between natural numbers to N and N syllabic segments. We thus make use only of linearity properties, the equivalent of the notions "left" and "right". Leben used the stronger property of "successor" in order to ensure that all tonemes and phonemss were covered by his mapping rule.

$CV_i\ CV_K$ ... would be represented $(V_i, T_1), (V_K, T_2), (V_K, T_3)$.
$T_1\ T_2\ T_3$

Then there is a well-formedness condition to guarantee in effect that if the correspondence were drawn as in style 1, there would be no crossed lines: $j < \ell$ implies $i \leq k$ for all pairs $(V_j, T_i), (V_\ell, T_k)$.

The Tone Association rule is then formally

$$\begin{matrix}(\text{Phonemic})\ S_i \\ (\text{Tonemic})\ T_j\end{matrix} \longrightarrow \left(\left[\begin{matrix}S_i \\ +\text{assoc}\end{matrix}\right], \left[\begin{matrix}T_j \\ +\text{assoc}\end{matrix}\right]\right) \Big/ \begin{matrix}\#\, C_0\, (Q\,[+\text{assoc}]) \_\_ \\ \#\, (R\,[+\text{assoc}]) \_\_\end{matrix}$$

$$Q, R \neq [+\text{assoc}]$$

The feature "assoc" is an ad hoc bookkeeping device to let the rule iterate in the appropriate way, from left to right. It is interesting to note that while this is the form that it is most obvious to write the rule in in order to make the

formalism pair up vowels and tonemes one-to-one, it is also, delightfully, quite capable of automatically handling correctly the cases where there are too many or two few vowels, since the normal convention is to expand the Q and R variables as far as possible without eating up the focus.

Enya

I had the opportunity to look at a rather detailed grammar of a Bantu tone language, Enya, after completing the paper up to this point.[3] Since the author, Spa, attempted to cover the entire phonology of the language, rather than just a few portions as Leben did with Mende, Bambara, and Maninka, chances were good that evidence would come up which would help decide between the interpretations of suprasegmental tones discussed in this paper, Leben's and mine.

My theory would diverge from Leben's in at least four ways. First, the toneme-to-phoneme correspondence is a matter of correspondence "lines" that can be broken and redrawn at every stage of the derivation, much like the "immediately dominates" lines of a syntactic tree. These connections are ruled by well-formedness conditions: in fact, the tonemic component consists of a correspondence rule, well-formedness conditions ensuring rules operating on either the tonemic or phonemic did not create impossible tonal correspondences, and tonemic rules such as Contour Flop. . . . (Note that there is a natural distinction to be made between rules like Contour Flop - Leben's Tone Deletion - and Tone Spreading, rules which shift contours rightward, and other conceivable but far less frequent rules that actually readjust tonemic contour.)

Given such a system, we would predict that a superficial look at tones should reveal what seems to be a derivational constraint regarding the deletion or desyllabification of tone-bearing vowels linking these changes to toneme-shifting rules. That is, when a rule deleted a vowel,it should appear that some other process could look back in the derivation, find out what

tone was deleted, and resuscitate it by placing it on the neighboring vowel. Such a constraint would, if it showed up, constitute a serious problem for phonology as we conceive of it -- unless we adopt the two-tier system, which predicts it and handles it naturally. In reality, such a "derivational constraint" would be no derivational constraint at all, but a natural consequence of the required connections between the tonemic and the phonemic levels.

Second, I would hope that rules that were written as separate rules in the previous approach would naturally collapse into one another, much as Leben's conditions on the tone mapping rule disappeared in the reformulation.

Third, I would predict that there would exist tone rules with two characteristics: first, they are ordered after some rule that utilizes both segmental and tonological information; and second, the rules treat tones in a way that is formally suggestive of a suprasegmental notation rather than a segmental one (we have already seen one example of this, downstep).

Fourth, I would predict that assimilation rules, even late ones, would not affect tone; thus copying the vocalic features of one segment onto another won't affect the tonal properties of the one copied onto, because its tonal information, so to speak, lives somewhere else and is protected. Leben's theory, holding tone information to be segmental at the late stages of the derivation, predicts the opposite.

I would like to present some evidence that these four predictions which the two-tiered system makes in disagreement with the tone mapping system are all born out in Enyá.

First, there are two derivational constraints imposed by

Spa: Rule I and XX. These cannot be particularly ordered with respect to the other rules, which are mutually ordered, and so Spa calls them "contraintes derivationnelles", which apply "chaque fois qu'une regle quelconque a fourni les données necessaires à son action." (146)

Rule I (I revise the notation slightly)

S_1* [ ] ⊃ [Vowel, +H]

S_2* [ ] ⊃ [Glide, +H, +syllabic]

S_3* [+syll] ⊃ [Glide, +H, -syllabic]

S_4* [+syll, +H] ⊃ [G, +H]

Derivational constraint:
$(S_1 \rightarrow S_2 \rightarrow S_3) \supset S_4$
"Quand un segment portant un ton haut est supprimé ou devient incapable de vehiculer un ton, le ton haut est transfere sur le segment syllabique le plus proche."(139)

The asterisk indicates that the rule is supposed to be a mirror image rule, a further characteristic of rules of Enya that could be eliminated with the dissolution of rules I and XX.

Rule XX

S_1 * [V, αH] [V, {αH, -αH}]

S_2 * [V, αH] [Glide, {αH, -αH}]

S_3 * [V, {αH, -αH, 1 long}] [G]

Lorsque deux voyelles sont contigues et que l'une d'elles est transformée en semi-voyelle, ...la voyelle qui demeure ne subit aucune modification si les deux tons sont identiques. S'ils sont differents, elle s'allonge quelque peut...et prend, outre son propre ton, celui de la voyelle transformée.(144)

alors: $(S_1 \rightarrow S_2) \supset S_3$

Second, these two "derivational constraints" are reflections of the same phenomenon at work, rather than separate rules of the grammar. We also can delete rules like VIII, which "delete" the floating segmental tones after they have imposed their tones on a neighboring syllabic segment. On the two-tiered system, they have in effect moved; in Spa's account, the "floating segment", being a segment, must be deleted. We ccan also do away with rule XIII, which turns a floating tone into a real vowel with all the articulatory features of the vowel it is next to; this output is merely temporary. When we get to rule XXI, a syncope process merges the two vowels into one with a contour tone. These two rules together go by the board.

VIII $G \rightarrow \emptyset \; / \; \_\_ +$

XIII $\left[\#\emptyset\right] \rightarrow \left[\begin{matrix}+V \\ \alpha F_n\end{matrix}\right] / \left[\begin{matrix}V \\ +H \\ \alpha F_n\end{matrix}\right] \_\_ \left(\left[+H\right] X\right) \#\#$

Third, Spa remarks, "les regles tonales ne constitutent pas un systeme a part vis-a-vis des autres regles phonologiques: la regles III par exemple doit s'appliquer avant (10) pour que les verbes au relatif aient une premiere syllabe à ton bas." Rule 10 uses both tonological and phonological information. There is at least one phonological rule acting after rule (10) that acts "as if" tones had not been mapped (a reflection of the derivational constraint): Rule 28 (p.57) deletes a vowel under identity with the following vowel: identity up to, but not necessarily including tone! On the other hand, the supra-segmental tone rule XIX is ordered after this.

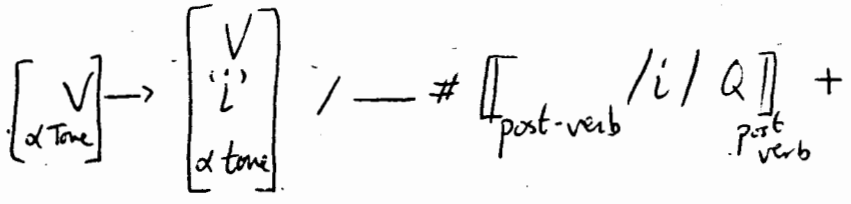
XIX: L→H / H __ L

(Note that this is a "natural" rightward contour shift, precisely

the converse of the "tone spreading" rule of Hyman and Schuh reported by Leben and discussed earlier.)

Fourth, a late ("tardive") rule assimilates all features of one vowel to another -- except for tone.

(44) p.111



natí ᵐbó lakɛ́ ì wɛ́ ⇒
natí ᵐbó lakí ì wɛ́

Conclusion

I have discussed only a part of Leben's arguments for a suprasegmental approach to tones, but I accept his important conclusion, that tones are underlyingly associated with morphemes rather than segments. However, the theoretical arguments he uses against other linguists' descriptions of floating tones redound against his own system as well, and so does his critique of contour tones, though not as directly. In addition, his formal solution to the contour tone problem is inadequate. A simple solution is proposed, one which is theoretically neither weaker nor stronger than Leben's. The alternative is found to have interesting ramifications for the detailed description of Enya.

Footnotes

(1) Contour tones are written /\ = /+\ = Falling

\/ = \+/ = Rising

/ = H, \ = L. In general I shall use accents for post-tone mapping forms, and forms like ^{HL}CV for pre tone Mapping forms.

(2) The method of thinking and even the terminology I've used is pretty obviously borrowed, both from quantum mechanics, which tries to derive itslaws from invariances, and from relativity, which consists largely of basic invariance conditions for theories generated by different observers. Admittedly it is a mode of argumentation not generally used in linguistics, which on the other hand is poorer for the lack. The underlying idea is to translate conservation statements into invariance statements. What kind of phenomena obey the same kind of laws when described from all legitimate points of view? Just precisely those that you will find in the world.

(3) For which opportunity I thank Paul Kiparsky

(4) I say "segmental derivation" by which I mean to suggest that the two tiers really stay separate in all the levels our phonological theory now countenances. Someday, perhaps, a more complete formal theory will arise to describe the articulatory commands involved in the pronunciation of a sentence, organized in just the way the nervous system organizes the instructions to the various parts of the articulatory system: the glottis, the velum, the tongue, the lips, and so on. Likewise, a theory

will arise to explain the way in which a speech signal is decoded and segmentalized. These two presently non-existent theories will obviously have formal levels at which tone information is mushed up with other sorts of information. But equally obviously, the problems and claims of these presently non-existent theories are not my concern here. My claims should be taken, naturally enough, as relevant only to the formal levels of phonology as she stands today.

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