Access to an intermediate level for tonal constraints: tone in Mituku

John Goldsmith
The University of Chicago

1 Introduction

This paper presents some straight-forward facts from the tonal system of a Bantu language, Mituku, described by Stappers (1973). The interest of the facts lies in the way they help clarify notions about constraints and certain kinds of representation-based generalizations. As we shall see, there is a simple principle at work to which we can appeal in order to explain why in a small number of cases – and only in these cases – a contour tone can appear on a single vowel. The contour-toned vowels in question are among those where the vowel can be shown to be the surface manifestation of two distinct vowels at deeper level (indeed, the two vowels are from distinct morphemes). Mituku, we will say, displays the *no more than one tone per vowel* (*1TperV*) restriction. It is, of course, an utter banality in the world of tonal systems to find a restriction on tone to the effect that no more than one tone may appear per mora (or short vowel), and indeed it is that banality that reassures us that we have the right generalization here. But the *1TperV* generalization does not hold for Mituku on the surface, and there is no plausible way that the restriction can be revised or rewritten so as to make it a surface restriction or constraint – and still do its job correctly in Mituku.

The picture that appears to be appropriate for Mituku is one that explicitly recognizes three levels of phonological representation, minimally: a phonetic representation, an underlying representation, and mediating between these two, a level of representation whose existence is known to us primarily through the constraints that can be expressed there and only – or preferentially -- there. Most theories of phonology of this century have incorporated some version of this picture, which can be restated thusly: the relationship between outer form – phonetics – and the underlying representation of the morpheme is the composition of two components, as in Figure 1, where I have used very neutral terminology to describe both the representations (underlying, intermediate, surface) and the ways in which representations at these levels are related (sectors 1 and 2).

Now, optimality theory (Prince and Smolensky to appear, and elsewhere) has left the door open to more than one interpretation. It can be interpreted as a general computational scheme which can be used to model the input-output relations of components as in (1), and on that view, one could compose any number of sets of such OT devices; on that interpretation, optimality theory makes no claim about its output being in any sense a surface representation as understood by linguists; it could, in the terminology of Figure 1, be an account of how "sectors" work. On other interpretations (more theoretically ambitious interpretations), optimality theory replaces the compositional character of alternative approaches, and the consequences for our understanding of phonology are considerably more wide-reaching. (Consequences of a principle being wide-reaching are not grounds for firmer belief in that principle, needless to say.) The analysis of Figure 1 would be ruled out on that interpretation. The evidence discussed in this paper weighs in

favor of the first, less ambitious intepretation, and against the second, as the reader shall see.

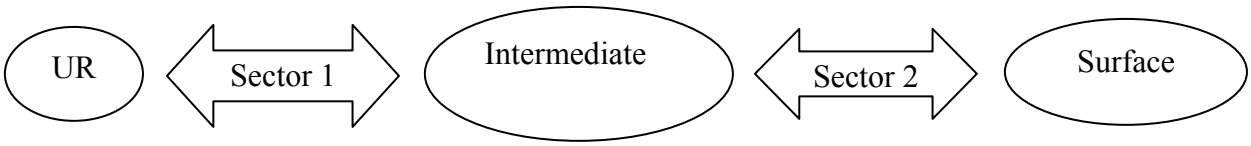


Figure 1

2 Some basic facts about Mituku

The basic facts to bear in mind about Mituku are the following, several of which are already offered by Stappers:

1. On the surface, a syllable will bear one of four identifiable tones: High, Low, Falling, or Rising; in addition, between two Highs (or a High and a Falling tone), downstep (also known as tone slip) can occur. Downstep is well-known to students of tone languages; its phonetic manifestation is a lowering by about a whole step (in the ordinary musical sense of the term) of the pitch of a High tone, and all subsequent High tones in the phrase.[1.] We will see shortly that the downstep is the result of a floating Low tone, a state of affairs frequently found among African languages. It is not hard to show that the Falling tone is the result of the concatenation of a High tone and a Low tone, and that the Rising tone is the result of the concatenation of a Low tone and a High tone.

2. Under some conditions, vowels may appear in hiatus, that is, following one another directly without intervening consonants. In such cases, the vowels appear in separate syllables. Under other conditions (which will be the ones that interest us in this paper), sequences of vowels merge to form a single syllable, including the case where the second vowel is the Tense Marker of the verb.

When a surface syllable is the realization of two separate vowels (which means in Mituku that the vowels are from separate morphemes), the vowel that is realized cannot be phonetically distinguished from a vowel which is the realization of a single underlying vowel -- or to put the matter more simply: there is no surface vowel length contrast (and

there is no underlying vowel length contrast either, a separate matter), regardless of the source and composition of the surface vowel in question. This is the first of the two important facts about Mituku tone to bear in mind.

The second important fact is this: a contour tone (i.e., Rising or Falling tone) may appear on a vowel if and only if that vowel is the realization of two underlying vowels (or vowel positions, to make the same point in slightly different terms). And the floating Low tone which concerns us in this paper obeys this principle absolutely: it will associate with a vowel (or vowel position) if and only if such a vowel position is available and accessible, and will otherwise not be associated to any vowel. But the level at which this behavior can be thus expressed and thus understood is not the surface level: it is an intermediate level of representation which contains information (such as syllable length) which is not represented on the surface.

The Mituku verb has a morphological structure which is similar to that described for many Eastern Bantu languages. Reduced to the simplest elements that concern us (and ignoring certain complexities that are amply described by Stappers , and which do not bear on our interests), we may say that a finite verb begins with a Subject Marker (SM), which is followed by a Tense Marker (TM), an optional Object Marker (OM), the verb radical, an optional sequence of derivational suffixes, and a Final vowel (FV), which marks tense and mood.

The infinitive differs from the finite verb by having neither Subject Marker nor Tense Marker, and in their stead has a nominal prefix (*ku*-).

From a tonal point of view, each of the groups of morphemes just listed other than the derivational suffixes may display behavior that shows that it is underlyingly specified for

tone. That is, some morphemes in each of these groups consistently display the same tone in all environments (High or Low tone), and we would naturally interpret this as the realization of that morpheme's underlying tonal specification. And a High/Low contrast is found within each morphological class, which is to say that our decision to mark the morphemes tonally underlyingly cannot be replaced by a decision to assign tones by rule. Verb radicals (to take the simplest example) divide into two classes, those which are consistently High in all contexts (and thus are High underlyingly), and those which are Low in most or all contexts. Object Markers are likewise divided into two groups, those which are consistently Low in tone, and those which are consistently High.

This brief discussion does leave open the possibility that the High versus Low contrast in Mituku could be viewed as a contrast between vowels linked to a High tone and vowels linked to no tone, a High/0 contrast, as has been argued for in a range of languages.[2.] We will see that in some cases, the evidence in Mituku clearly resolves the ambiguity between these two ways to analyze a surface High/Low contrast, and when the data disambiguates the analysis, it always points in the direction of a High/Low contrast rather than a High/∅ contrast.

3 The issue: the number of levels in phonological theory

The prime interest of the material discussed in this paper derives from the fact that it demands an analysis with three levels of representation, because there is a level of representation distinct from both the underlying and the surface phonological levels at which a simple phonological constraint must be stated. This constraint is a familiar one: a vowel may be associated with at most one tone; or, putting the same matter slightly

differently, a toneless vowel (but only a toneless vowel) will associate with a floating (i.e., a vowelless) tone at this derived phonological level. We will be at pains to make clear that the level at which this generalization must be stated is not the underlying level (for the constraint is operative on a representation which is the *output* of a phonological rule) nor the surface (for on the surface, there is no indication that a vowel is long or bimoraic, though only the vowels which were bimoraic at a deeper level are candidates for associating with two tones on the surface).

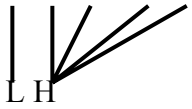
4 The tone of the infinitive

The tone of the infinitive is largely a direct expression of the underlying tonal specifications. The examples in (1)-(2) illustrate that the verb radical bears its own underlying tone, either High or Low, and in the infinitive it is followed by a suffixal High tone which associates with all following extensions.[3.] The raised exclamation point marks tonal downstep, which we return to below.

(1) Infinitive, Low radical

(a) No Object Marker (OM)

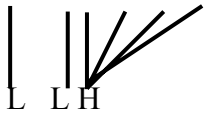
ku pị lị́ngánị́sá



"faire tournoyer..."

(b) Low toned OM

ku mu pị lị́ngánị́sá



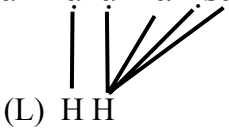
(c) High toned OM

ku bá pị lị́ngánị́sá

(2) Infinitive, High radical

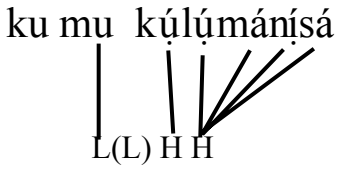
(a) No OM

ku kúlúmánísá

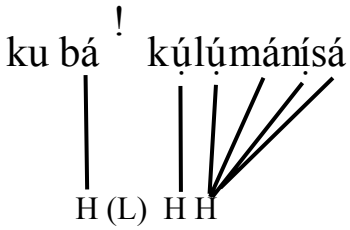


"rassembler (des gens)"

(b) Low toned OM



(c) High toned OM



Object Markers, whose presence or absence is determined by syntactic considerations, are specified underlyingly as either High or Low, and retain that tonal specification in all contexts, as we see illustrated in (b,c) in both (1) and (2).

In the case of the High toned radical (2a,b,c), a floating Low tone is specified as preceding the High-toned radical. This is the Low tone which is the focus of the discussion of this paper, and it appears before all High-toned radicals, though not before Low-toned radicals. In the cases illustrated in (2), there is only one place where the floating Low tone could be phonetically perceptible, and that is in case (2c), where it appears floating between two High tones. In this case, the Low tone creates a downstep -- that is, the pitch of the second High is lowered by about a whole musical step, the same degree of lowering that it would display if a fully realized Low tone had appeared before it. This tonal effect is indicated by a raised exclamation point.

5 The Historical Past

The historical past is marked in Mituku by a Tense Marker of the form -*a*- with no associated tone. In the next section we will compare this Tense Marker to that of the optative, which is similarly composed of a Tense Marker -*a*-, but this time associated with a High tone. (Many of the most volatile and interesting Tense Markers from a tonal point of view have the segmental form -*a*-; see Goldsmith 1984a for a discussion of this.)

The first half of the relevant data is presented in (3), where we see the tonal behavior of Low toned verb radicals, with Low (a,b,c: *tu*-) and High (d,e,f: *ba*-) toned Subject Markers, and each with no Object Markers, with a Low toned Object Marker (here, -*mu*-),

and a High toned Object Marker (*-ba-* and *-tu-). Underlying* forms are given in the first column, with surface forms on the right. In each case the essential difference between the underlying forms and the surface form is that the vowel of the Subject Marker and the vowel of the Tense Marker have merged to form a single syllable. That merged syllable surfaces with a level tone, however, either Low or High, depending on the tone of the Subject Marker. As we shall see below, there are other cases where the merger of the Subject Marker and an *-a-* Tense Marker (from a different tense, however) gives rise to a syllable with a contour tone (High-Low [Falling] or Low-High [Rising]). In light of this behavior which we shall encounter in the next section, we can tentatively (but correctly) draw the conclusion that the Tense Marker of the Historical past is itself toneless underlyingly. Hence it contributes no tone(s) to the syllable formed when it merges with the preceding Subject Marker. Forms with High-toned verbs are given in (4) (All the verbal forms in (3) and (4) are followed by the word *múno* in Stappers (1973).)

(3) Historical past, Low toned verb

	Underlying form	Surface form
a.	tu a piḷiṇganiṣa	t a piḷiṇganiṣa
	L L	L L
b.	tu a mu piḷiṇganiṣa	t a mu piḷiṇganiṣa
	L L L	L L L
c.	tu a ba piḷiṇganiṣa	t a bá piḷiṇganiṣa
	L H L	L H L
d.	ba a piḷiṇganiṣa	b á piḷiṇganiṣa
	H L	**H L**
e.	ba a mu piḷiṇganiṣa	b á mu piḷiṇganiṣa
	H L L	H L L
f.	ba a tu piḷiṇganiṣa	b á tú piḷiṇganiṣa
	H H L	H H L

(4) Historical past, High toned verb

	Underlying form	Surface form
a.	tu a kụlụmaṇisa	t a kúlụmaṇisa
	L (L) H	L (L) H
b.	tu a mu kụlụmaṇisa	t a mu kúlụmaṇisa
	L L (L)H	L L (L) H
c.	tu a ba kụlụmaṇisa	t a bá! kúlụmaṇisa
	L H (L) H	L H (L) H
d.	ba a kụlụmaṇisa	b â kúlụmaṇisa
	H (L)H	H L H
e.	ba a mu kụlụmaṇisa	b á mu kúlụmaṇisa
	H L (L) H	H L (L) H
f.	ba a tu kụlụmaṇisa	b á tú ! kúlụmaṇisa
	H H (L)H	H H (L) H

The forms in (4) show us two critically important aspects of Mituku tone. First, they illustrate in 4c and f the presence of a floating Low tone that is realized as a downstep in front a High toned radical, although that downstep is phonetically perceptible only when a High toned syllable immediately precedes, for in Mituku, as in most languages with downstep, the difference between a High tone and a downstepped High tone is phonetically perceptible only immediately after a High tone. Secondly, and more importantly, we find in the right-hand version of (4d) a Falling tone on the surface syllable *bâ*, the syllable which is the merger of the Subject Marker *bá-* and the Tense Marker *-a-*. This is the first instance that we have seen of a contour tone, and it illustrates the generalization that a contour tone can appear on a syllable in Mituku only if the syllable is derived from a bi-moraic representation at a deeper level (which means, in fact, that the syllable is bimorphemic). And where does the Low tone come from, the second half of the falling tone? It is not particularly difficult to see that this Low tone is the same Low tone that in examples (4c and f) created the downstep; here, however, the Low is phonetically manifested. The Low, that is, is a Low that ultimately comes from the High toned radical (note that there is no parallel Low tone at play in the parallel cases in (3), the cases constructed from a Low toned radical). That floating Low tone associates with the *-a-* of the Tense Marker precisely because the Tense Marker is a toneless vowel.

We thus find an association is created between the (toneless) Tense Marker *-a-* and the (vowelless) L tone. The examples in (4e) and (4f) show that this added association line appears only when its addition would not cross an already present association line.

We may summarize our conclusions so far in this way: At a certain level of representation (and we must dig a bit deeper to be clearer on precisely what that means),

the representations in Mituku appear to undergo a rule that adds an association line between any toneless vowel and any vowelless tone, with the understanding that such a rule cannot create an association line crossing another association line. Put slightly differently, we can say that (at that certain level of representation) there is a strong pressure (due, if you prefer, to a highly ranked constraint) for all vowels to be associated with at least one tone, and for all tones to be associated with at least one vowel; but that pressure (or constraint) is not as highly ranked as the generalization that an association line in underlying representations may not be crossed by another association lines. Rather than get bogged down in a formulation any more precise than this -- committing us to either a rule-based or a constraint-based formalization -- let us merely note that there are quite a few variations on each style of description, and that the situation we are looking at in Mituku is simple, and not difficult to state in the vernacular of several theories.

While we are not yet in a position to settle definitively at what level our generalization is to be stated, we can already note this: the generalization cannot be stated on the surface, since the association site for the floating Low (which is the vowel position, or the mora, of the Tense Marker -*a*-) is not distinct from that of the Subject Marker on the surface. Put another way, there is no representational difference *on the surface* between a short vowel derived from a short vowel, and a short vowel derived from a long vowel. Hence the rule(s) or constraint(s) involved must address a level of representation deeper than the surface. (We will see in our discussion of the optative tense that this level cannot be the underlying level, either, but rather must be a derived level of representation.)

6 The Optative Tense Marker -á-

The optative tense in Mituku is formed, like the Historical Past, from a Tense Marker of the form -*a*-. In the optative, however, the Tense Marker is clearly associated with an underlying High tone. Consider the data in (5) and (6), which we will explore case by case.

In (5a), the Rising tone on the first syllable of the surface form shows us immediately that we are dealing with a Tense Marker with a High tone (it has here combined with a Low toned Subject Marker to create a Rising tone). In this respect the optative Tense Marker is minimally different from the historical past Tense Marker, though as we shall see shortly, there are cases where the optative Tense Marker loses its High tone, and it then behaves just like the historical past's Tense Marker (this happens clearly in cases (5c) and (6a,c); there are other cases where the rules that we will posit delete the Tense Marker's H tone, but where this has no perceptible result, and in those cases I have not indicated the effect of the H-tone deletion.).[4.]

Of the six forms in (5a-f), only (5c) requires the application of any tonal rule to derive the surface form. In (5c), however, we see no trace of the Rising tone on the first syllable that the other parallel cases display. (5c) requires the postulation of a rule of Rising Tone Absorption,[5.] a widespread rule among the Bantu languages. This rule is formalized in (7).

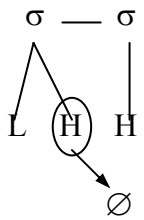
(5) Optative tense, Low toned verb

	Underlying forms	Surface forms
a.	tu a piḷiṇganiṣa	t ă̌ piḷiṇganiṣa
	L H L	L HL
b.	tu a mu piḷiṇganiṣa	t ă̌ mu piḷiṇganiṣa
	L H L L	L H L L
c.	tu a ba piḷiṇganiṣa	t a bá piḷiṇganiṣa
	L H H L	L H L
d.	ba a piḷiṇganiṣa	b á piḷiṇganiṣa
	H H L	HH L
e.	ba a mu piḷiṇganiṣa	b á mu piḷiṇganiṣa
	H H L L	H H L L
f.	ba a tu piḷiṇganiṣa	b á tú piḷiṇganiṣa
	H H H L	H HH L

(6) Optative tense, High toned verbs

	Underlying forms	Surface forms
a.	tu a kụlụmaṇisa	t ă̌ kúlụmaṇisa
	L H (L) H	L H (L) H
b.	tu a mu kụlụmaṇisa	t ă̌ mu kúlụmaṇisa
	L H L (L) H	L H L (L) H
c.	tu a ba kụlụmaṇisa	t a bá! kúlụmaṇisa
	L H H (L) H	L H (L) H
d.	ba a kụlụmaṇisa	b â kúlụmaṇisa
	H H (L) H	H L H
e.	ba a mu kụlụmaṇisa	b á mu kúlụmaṇisa
	H H L (L) H	H H L (L) H
f.	ba a ba kụlụmaṇisa	b á bá ! kúlụmaṇisa
	H H H (L) H	H H H (L) H

(7) Rising Tone Absorption[6]

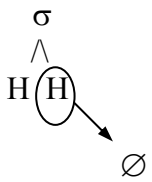


The final cases which interest us are those in (6), formed with a High-toned verb and thus possessed of a floating Low tone on the analysis which we are exploring. In cases (6a) and (6c), the High tone of the Tense Marker is deleted by the rule of Rising Tone Absorption

In (6a), though not in (6c), the Floating L tone can (and thus will) associate with the now-toneless vowel-position of the Tense Marker. Since this is merged with the Low-toned vowel of the Subject Marker, however, the effect of the "docking" of the Low tone is imperceptible. In cases (6b) and (6c), the Floating Low tone cannot associate because it would have to cross the association line of the intervening Object Marker.

We turn now to the last three cases in (6), cases d, e, and f, where a High toned stem is formed with a High toned Subject Marker. In all three cases, we have a High toned Subject Marker merged with a High toned Tense Marker, followed by one of three possibilities: a floating Low (case d); an associated Low (case e); or an associated High (case f). If no rules were to apply, we would expect to find a High on the first syllable in all three cases (formed from joining of the Subject Marker High and the Tense Marker High). However, we find a High tone on this first syllable only in cases e and f; in case d, we find a Falling tone, clearly the result of the docking of the floating Low to the vocalic position of the Tense Marker. If the Tense Marker is free to associate with the floating Low in this context, though, there must be a rule which deletes the Tense Marker's High tone. This, we suggest, is an intrasyllabic version of Meeussen's rule, formalized in (8).

(8) Intrasyllabic Meeussen's Rule



This rule will delete the High tone of the Optative tense in all three cases in (6d, e, f), though its effects will be masked in cases (e,f), for the result remains phonetically unchanged in those two cases. In (6d), however, the effect of Meeussen's Rule is to free the vocalic position of the Tense Marker so that it may now associate with the floating Low tone of the High-toned stem. (Note that this rule will also apply in an imperceptible fashion in (5d,e,f), though I have not marked its effects in the surface forms).

The reader must bear in mind that each of the thirty forms which we have looked at refers not simply to itself, but to each of an indefinite number of forms made up of morphemes with the same underlying tones: each is a point in the tonal paradigm of verbs, and stands for a limitless number of verbs. In that sense, the "single" case in (6a), for example, represents not just one word in the Mituku vocabulary, but an unbounded set of cases, and fully one sixth of all verbs in the Optative tense.

7 When does the floating tone associate?

It is now time to pull together the threads of this analysis. Three facts have emerged:

Point 1. There are no bimoraic representations of vowels on the surface: that is, there are no long vowels (on the surface).

Point 2. The floating Low tone associates with a vowel position if and only if there is a toneless vowel with which it can associate without crossing an association line.

Point 3. The toneless vowel with which the floating tone associates may be either underlyingly toneless (the case of the Tense Marker of the Historic Past) or it may be made toneless by rule (either by Rising Tone Absorption or by Meeussen's Rule).

When does the floating tone association described in point 2 occur, or at what representation? Point 1 establishes that it cannot even be described using a surface representation, and Point 3 establishes that it cannot be described using an underlying representation. The conclusion is inescapable that the generalization stated in Point 2 must "occur" on -- or be stated with respect to -- an intermediate level of representation. Most phonological theories have well-defined levels of this sort, whether it be called the phonemic level, the output of (a stratum of) the lexical phonology, W-level representation, or some other term.

Only theories with no more than one or two levels of phonological representation will founder on such facts, theories such as Koskenniemi's two-level model (embodied, for example, in the PC-Kimmo system) or, more recently, one interpretation of optimality theory, as we noted earlier.

I do not think that the structure of the data offered here are in any way particularly unusual, and it should be borne in mind that the nub of the argument is not that the relationship between the underlying and the surface can be, or should be, decomposed into two or more composed operations, with one feeding the other. The argument is that there is a simple constraint which governs where and when the floating tone will associate, but the level at which this simple constraint ("associate a floating tone to a toneless vowel so long as this involves no crossing of association lines") is an intermediate level of representation, neither the underlying nor the surface representation.

8 A speculative note

I would like to speculate briefly on the likely origin of the *1 tone per vowel* constraint. I believe that the biological substratum that underlies much autosegmental structure, as well as the relations between the rows on a metrical grid, is the phase-locking of biological oscillators, an area that has been the center of considerable attention by scientists interested both in the neuroanatomy and functioning of the central nervous system.[7] It is a banality to observe that rhythm is important in languages; metrical phonology is indeed based on the interacting and intersecting rhythms of syllabicity and stress. But what are the consequences for linguistics of taking this seriously? Rhythmicity, both in neural organization and in overt behavior, is the result of neural oscillators passing regularly through repeated cycles of activation, and the most important (and well-studied) properties of collections of such neural oscillators is their strong attraction to phase-locking (especially at 1:1 ratio, but also at 2:1 and other rational ratios).

In early work on autosegmental phonology, it was often said (correctly, no doubt) that the function of association lines was to indicate the co-registration, in abstract or concrete time, of elements on the autosegmental tiers they linked. We can today, I think, ask for a more concrete explanation of that phonological metaphor. An action which unrolls in time, such as a sequence of segments or moras, requires a timekeeper (often referred to as a *Zeitgeber* in the literature; see the references cited in note 7) which completes one cycle with each unit of the action.

In work that has grown out of the network models developed with Larson,[8] I have been exploring ways of modeling the dynamics of accent systems. Each row of a metrical grid is modeled by an oscillator with a basic (or *natural*) frequency (the frequency at which it

would oscillate if not coupled or driven by external forces), and these oscillators are coupled to one another by links of varying strengths. Under a wide variety of settings, as noted in the neural network literature (see again note 7), attractor states are those where the oscillators are in phase-lock: that is, the the peak of a relatively low-frequency oscillator consistently coincides with the peak of a relatively high-frequency oscillator. While this modeling is most easily interpretable in the case of rhythmic metrical systems, it is tempting to view the timing tier in a phonological model (or simply, in this case, the mora tier) as a relatively high-frequency *Zeitgeber*; the circumstances under which two tones could be associated with one mora would be one in which the oscillator associated with the tonal tier reached a frequency twice that of the mora. But the natural frequency of the tonal tier is normally lower than that of the moraic tier, and a probabilistic argument can be made that a two-to-one alignment of tones to moras would arise only under relatively rare conditions. If this line of attack proves useful and valid, it suggests that both formal and functional explanations may be grounded in dynamical explanations.

References

Archangeli, D. and D. Pulleyblank (1994) . *Grounded Phonology*. Cambridge: MIT Press.

Clements, G. N. (1979). The description of terraced-level tone languages. *Language* 55: 536-558.

Ermentrout, Bard. (1994) An introduction to Neural Oscillators. In F. Ventriglia, ed., *Neural Modeling and Neural Networks*. Pp. 79-110.Oxford: Pergamon Press.

Glass, Leon and Michael C. Mackey (1988). *From Clocks to Chaos*: *The Rhythms of Life.* Princeton: Princeton University Press.

Goldsmith, J. (1984a). Bantu -a-: The Far Past in the Far Past. In *Précis from the 1984 African Linguistics Conference*, ed. R. Schuh. Los Angeles: University of California.

Goldsmith, J. (1984b). Tone and Accent in Tonga. In G. N. Clements and John Goldsmith (eds.) *Autosegmental Studies in Bantu Tone.* Dordrecht: Foris Publications.

Goldsmith, J. (1984c). Meeussen's Rule. In M. Aronoff and R. Oehrle (eds.) *Language Sound Structure*. Cambridge: MIT Press.

Goldsmith, J. (1987). Stem Tone Patterns of the Lacustrine Bantu Languages. In David Odden (ed.), *Current Approaches to African Linguistics (vol. 4)*. Dordrecht: Foris Publications.

Goldsmith, J. (1993). *The Last Phonological Rule: Reflections on Constraints and Derivations*. Chicago: University of Chicago Press.

Goldsmith, J. (1994). A Dynamic Computational Theory of Accent Systems. In Jennifer Cole and Charles Kisseberth, eds., *Perspectives in Phonology*. Stanford: Center for the Study of Language and Information. pp. 1-28.

Haken, Hermann. (1987). *Synergetics: an Introduction*. 3rd edition. Berlin: Springer Verlag.

Hyman, L. M. and R. Schuh. (1974). Universals of Tone Rules: Evidence from West Africa. *Linguistic Inquiry* 5: 81-115.

Kelso, Scott. (1995). *Dynamic Patterns: The Self-Organization of Brain and Behavior*. Cambridge: MIT Press.

Larson, Gary. (1992) *Dynamic Computational Networks and the Representation of Phonological Information.* PhD dissertation, University of Chicago.

McCawley, J. (1970). Some tonal systems that come close to being pitch accent systems but don't quite make it. In *Papers from CLS 6*. Chicago: CLS.

Odden, D. (1994). Adjacency Parameters in Phonology. Language. *Language* 70: 289-330.

Postal, P. (1968). *Aspects of Phonological Theory*. New York: Harper and Row.

Pulleyblank, D. (1986). *Tone in Lexical Phonology*. Dordrecht: D. Reidel.

Prince, A. and P. Smolensky (to appear). *Optimality Theory*. Cambridge: MIT Press.

Stappers, L. (1973). *Esquisse de la langue mituku*. Tervuren: Musée Royal de l'Afrique Centrale.

Stevick, E. (1969). Tone in Bantu. *International Journal of American Linguistics* 35:330-341

[1.] See Clements 1979, for example, for further discussion of downstep.

[2.] See, for example, Stevick 1969, McCawley 1970, Goldsmith 1984b, Pulleyblank 1986, and many other sources too numerous to mention.

[3.] Following standard Bantu notation, a vowel with a dot underneath indicates a vowel higher (or tenser) than their counterparts without the underdot.

[4.] This may create some confusion, in that I give some surface forms in which Meeussen's Rule's effect is not shown: cases where a single syllable bears a sequence of two High tones, as in (5d,e,f), for example. The reader should understand that these double High sequences are (according to our analysis) actually simplified to a single High tone.

[5.] The term *absorption* for this phenomenon is due to Hyman and Schuh 1974.

[6.] There is an important point lurking in the details of the formalization of this rule; the point remains regardless of whether one conceives of the generalization as a rule or as a representational constraint. The point is this: for the rule to come into effect, the *syllable* with the Rising tone and the *syllable* with the High tone must be adjacent. However, paradoxical as it may sound, the *tones* comprising the Rising tone and the High tone need not be adjacent: they may be separated by the floating Low tone. Thus it appears we must specify on which tier adjacency is required, and the requirement is adjacency on the syllable tier.

There has been much discussion in the tonal literature regarding just this question, though posed slightly differently. The effects of what is known as Meeussen's Rule in Bantu tone studies (Goldsmith 1984b,c) operate to lower or delete a High tone following a

High tone, and in most (though not all) languages this restriction is interpreted as requiring that the tones be associated with successive syllables. In at least one case, the two tones need not be associated with successive vowels. In Goldsmith 1987 I suggested that the widespread Eastern Bantu pattern (specific to certain tenses) by which a High tone appears on the second mora of a Low-toned stem, and on the Final vowel of High-toned stems, could best be understood as the effects of Meeussen's rule applying between the stem-tone and the second-mora High tone (no longer distance effect there) and also between the second-mora High tone and the Final Vowel High tone; the latter case would in general be a long-distance Meeussen's Rule effect. If this is correct, then we have further cases where adjacency must be parameterized to select, or not to select, adjacency on one tier or another. There is material enough to fill a book on this subject, and the interested reader may consult Archangeli and Pulleyblank (1994, especially chapter 1), Odden 1994, and many other studies.

[7] Glass and Mackey (1988) is the classic reference, but work in this area has burgeoned over the last ten years with the development of non-linear dynamics. Work of Haken (1987), and following him, Kelso (1995), is particularly relevant. An overview of mathematical modeling in this area is given in Ermentout (1994).

[8] See, for example, Goldsmith (1993, 1994) and Larson (1992).