

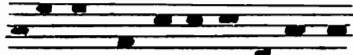
A NEW FORMALIZATION OF DOWNDRIFT¹

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1. Background

1.1. Downdrift. Downdrift is a phenomenon (see for instance Welmers [1959], Winston [1960], Schachter [1961], Arnott [1964]) occurring in many tone languages which have primarily level (as opposed to contour) tones, including some languages with glides which are analyzable as sequences of level tones (Woo [1969], Lanham [1963]). Downdrift is basically a progressive overall lowering of pitch throughout a phrase. Specifically, in a sequence of High tones or Low tones all tones have the same pitch value, while in a sequence High-Low-High (Low-High-Low) the second High (Low) tone is one pitch step lower than the preceding High (Low) tone. It is thus possible for a High tone late in a phrase to have lower absolute pitch than a Low tone early in the same phrase.

These points are illustrated in the following example from Akan, a West African language (Schachter and Fromkin [1968:108]):

	òbékó Kùmásé ándpá yí	
	L H H L H H H L H H	
tonemes:		
surface pitch:	3 1 1 4 2 2 2 5 3 3	'He will go to Kumase this morning'

Numerical values are assigned to each tone level, with the lowest numerical value representing the highest pitch. It is important to note that while the phonetic realization of these tone drifts downward, the relative contrasts between high and low tones are preserved. This downward drift is generated at a relatively late stage in the grammars of these languages, the rule for it occurring after all tonal rules which affect the tonemes of the languages have applied. The downdrift rule is, in fact, a phonetic rule since it converts phonological binary features to phonetic scale features, but it is an early phonetic rule since the pitch numbers assigned represent only relative and not exact pitch intervals.

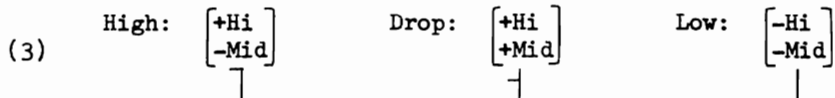
¹I would like to thank my colleagues Bob Hsu, Irwin Howard and Chin-Wu Kim for their helpful suggestions and pertinent comments on earlier drafts of this paper.

For instance, pitch 2 is lower than pitch 1, and 3 is lower than 2, but no claim is made about the relative sizes of the intervals 1-2 and 2-3. (When a better understanding of the phonetic facts is available it may be possible to construct further rules, operating on the output of the downdrift rule, to produce more precisely the surface pitch intervals.)

1.2. Downstep or "Drop" tone. Some languages with downdrift have an additional complication. Besides the normal Low-High and High-Low tonal sequences, there are also sequences of a High tone followed by a Lowered High (or Drop) tone. Here the Drop tone is not at the same level as the preceding High tone (as would be expected if it were a normal High tone), nor is it as low as a low tone would be in the same position. E.g.



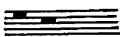
Although a Drop tone is contrastively lower than a preceding High tone and contrastively higher than a following Low tone, it is nearer in pitch to the preceding High than to the following Low, as illustrated in (2), above. Thus High, Low and Drop tones can be described in feature notation as follows (Fromkin [1972:60]; tone letters from Chao):



(The features Hi and Mid are used here for easier reference to Fromkin [1972]. For use in a grammar I would prefer features such as Raised (Maddieson [1971]) and Modify (Woo [1969]) in order to avoid confusion with High and Mid vowels.)

The distribution of Drop tones is restricted--they can occur following High tones or Drop tones, but never following Low tones. They are also never phrase initial. It has been found that in many instances a Drop tone arises from an underlying Low-High tone sequence from which the Low tone has disappeared after downdrift has been applied. E.g.

(Fromkin [1972]):

(4)	/mɛ́ ʒbɔ́/	'my stone'
	H L H	
	1 3 1	underlying pitches
	1 3 2	after downdrift has applied
	1 2	after /ɔ́/ is deleted by Vowel Deletion Rule
	[mɛ́ bɔ́]	final result 
	1 2	

There are two basic consequences of the disappearance of the intervening Low tone: (1) the following High tone (=Drop tone) is one step below the preceding High tone as would be expected from a High-Low-High sequence; (2) the next Low tone in the phrase is one step below its expected value.

It is likely that all Drop tones can be diachronically derived from tonal systems with only two underlying tones: High and Low. Synchronically, such a solution is not always tenable. For instance in Akan, (Fromkin [1972:59]) "there are formatives which now have 'downstep' tones which cannot be derived from high tones after the deletion of low tones without a great deal of ad-hocery". Unless one is willing to set up underlying Low tones which never appear on the surface, i.e. which are "absolutely neutralized" (Kiparsky [1968]), it is necessary to give Drop tone a phonemic status (though still somewhat restricted in its privileges of occurrence.)

2. Fromkin's rules for Downdrift/Drop tone pitch assignment

2.1. In Fromkin's paper "Tone features and tone rules" [1972] she reformalizes the rules for pitch assignment and downdrift in Akan. (For earlier formalizations see Schachter and Fromkin [1968], Schachter [1969].) She assumes that there are three phonemic tones: High, Low, and Drop. They are represented by tonal features as in (3). Her first rule assigns a pitch value of 1 to all High and Drop tones ([+Hi]), and a pitch value of 3 to all Low tones ([-Hi]). Pitch assignment (p. 58):

- (5) a. [+Hi] ---> p 1
 b. [-Hi] ---> p 3

Her Downdrift rule then revises these pitches progressively downward by recomputing the pitch value of a [-Hi] (Low) tone from the value of the preceding [-Hi] tone, and the pitch value of a [+Hi] (High or Drop) tone from the value of the preceding [+Hi] tone. Downdrift (p. 60):

$$(6) \quad [aHi] \rightarrow [aHi \ p \ \langle +1 \rangle_{1,2}] / \left[\begin{array}{c} aHi \ p \\ \langle -Mid \rangle_1 \end{array} \right] \langle [-aHi]_1 \rangle_2 \left[\langle +Mid \rangle_1 \right]$$

which expands to the following set of disjunctive rules by the conventions for indexed angle brackets used in Chomsky and Halle [1968:107]:

$a = +:$

$$(6a) \quad [+Hi] \rightarrow [+Hi \ p+1] / \left[\begin{array}{c} +Hi \ p \\ -Mid \end{array} \right] \left[\begin{array}{c} \text{---} \\ +Mid \end{array} \right] \quad \text{using } \langle \rangle_1$$

$$(6b) \quad [+Hi] \rightarrow [+Hi \ p+1] / [+Hi \ p] [-Hi]_1 \text{ ---} \quad \text{using } \langle \rangle_2$$

$$(6c) \quad [+Hi] \rightarrow [+Hi \ p] / [+Hi \ p] \text{ ---}$$

$a = -:$

$$(6d) \quad [-Hi] \rightarrow [-Hi \ p+1] / \left[\begin{array}{c} -Hi \ p \\ -Mid \end{array} \right] \left[\begin{array}{c} \text{---} \\ +Mid \end{array} \right] \quad \text{using } \langle \rangle_1$$

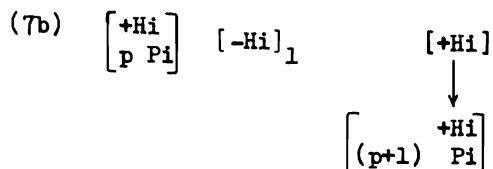
$$(6e) \quad [-Hi] \rightarrow [-Hi \ p+1] / [-Hi \ p] [+Hi]_1 \quad \text{using } \langle \rangle_2$$

$$(6f) \quad [-Hi] \rightarrow [-Hi \ p] / [-Hi \ p] \text{ ---}$$

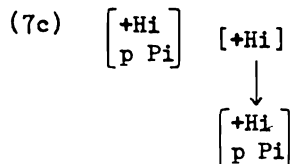
Note that subrule (6d) can never apply since no tones in this language will ever be specified [-Hi, -Mid] and thus the conditions can never be satisfied. In order better to illustrate how these rules are expected to work, they can be schematically restated in (7) below. It should be kept in mind that [+Hi] refers to both High and Drop tones, while [+Mid] refers only to Drop tones. In this restatement a new (phonetic) feature Pitch has been added to the feature matrices.

$$(7a) \quad \left[\begin{array}{c} +Hi \\ -Mid \\ p \ Pi \end{array} \right] \quad \left[\begin{array}{c} +Hi \\ +Mid \end{array} \right] \\ \downarrow \\ \left[\begin{array}{c} +Hi \\ +Mid \\ (p+1) \ Pi \end{array} \right]$$

Drop tone is one step lower than an immediately preceding High tone

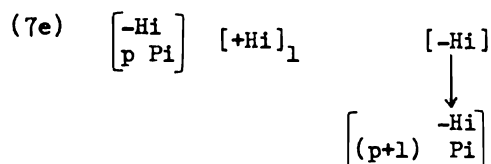


High or Drop tone is one step lower than the nearest preceding High or Drop tone (any number of Low tones may intervene)

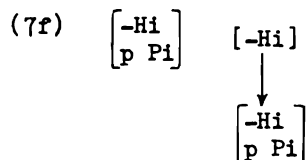


High or Drop tone has the same pitch as an immediately preceding High or Drop tone

(7d) Cannot apply



Low tone is one step lower than the nearest preceding Low tone (any number of High or Drop tones may intervene)



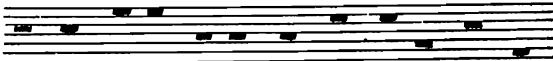
Low tone has the same pitch as an immediately preceding Low tone

The application of the Pitch Assignment rule (5) and the Downdrift rule (6) is exemplified below on a sentence from Akan (Schachter [1961:235]).

/ Mè-dè-mé-ń-nà-m-fò-nó-bá-à-mé-fì /
 L L H H L L L H H L H L

by (5): 3 3 1 1 3 3 3 1 1 3 1 3
 by (6e): 4
 by (6f): 4 4
 by (6b): 2
 by (6c): 2
 by (6e): 5
 by (6b): 3
 by (6e): 6

giving (8): 3 3 1 1 4 4 4 2 2 5 3 6



'I brought my friends to the house.'

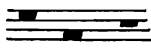
2.2. The single example which Fromkin uses to illustrate her rule includes only a limited subset of those tonal sequences which can occur, judging from the description in Schachter and Fromkin (p. 110). Specifically, tonal sequences such as phrase initial-High-Low-High, or Drop-Drop are not exemplified. If we apply her rules to such sequences, however, we derive surface pitch sequences which contradict the verbal descriptions and other facts about downdrift that appear in Schachter and Fromkin's phonology of Akan.

For instance, if we apply her rules to a sequence # H L H (where # denotes phrase boundary) we get:

/ H L H /

by (5) : 1 3 1
 by (6b): 2

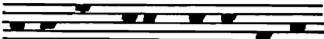
giving (9): 1 3 2



The pitch intervals here are inconsistent with the pitch intervals given in most other examples of downdrift: the step from High to Low is only down 2 (normally it is shown as being down 3) while the step from Low to High is only up 1 (normally it is shown as up 2). Is this a peculiarity

of phrase initial High tones, or is it due to the fact that rule (5) assigns pitch 3 to the Low tone but that this pitch value is never subsequently modified by the Downdrift rule to produce the expected pitch value 4 (and hence the expected intervals)?

Even in Fromkin's own example (p. 61), her rules do not produce the pitch intervals that one might expect from looking at other examples of downdrift.

	/ àbèrántéé békó èhó /	'The young man will go there.
	L L H DH H H L H	
by (5) :	3 3 1 11 1 1 3 1	
(6a) :	2	
(6c) :	2 2 2	
(6e) :	4	
(6b) :	3	
giving (10) :	3 3 1 22 2 2 4 3	
		

Here again the step from High to Low is only down 2 while the step from Low to High is only up 1 at the end of the phrase. In this case these intervals will not matter since a subsequent Vowel Deletion rule will delete the final Low vowel, leaving a surface Drop tone at the end of the phrase.

(10) àbèrántéé békó èhó
3 3 1 22 2 2 4 3

Vowel Deletion gives:

(11) àbèrántéé békó øhó
3 3 1 22 2 2 3

Will a vowel disappear in all cases in which reduced intervals are produced? Or do reduced intervals characteristically follow Drop tones? For it is the presence of the (underlying) Drop tone in the tonal sequence which causes the reduced intervals at the end of the phrase. In fact, if a phrase should have a sequence of High and (underlying) Drop tones, uninterrupted by any Low tones, the more Drop tones in the sequence the more inaccurate the assigned pitch of a following

Low tone will be. Are such sequences prohibited in Akan? They are allowable in Efik, another West African language exhibiting downdrift and Drop tone phenomena for which these Akan rules would seem to be applicable. For the sake of argument and illustration let us look at an extreme example from Efik, in order to further explore the mechanics of Fromkin's rules (Winston [1960:186]):

/ Èkpényòṅ émèn ínùèn ònyòṅ édí úfòk /
 L H D H D H D H D H D H L

by (5) : 3 1 1 1 1 1 1 1 1 1 1 3
 (6a) : 2
 (6c) : 2
 (6a) : 3
 (6c) : 3
 (6a) : 4
 (6c) : 4
 (6a) : 5
 (6c) : 5
 (6a) : 6
 (6c) : 6
 (6e) : 4

giving (12) : 3 1 2 2 3 3 4 4 5 5 6 6 4



'Ekpenyong picked it up and came home'

instead of the expected realization:

(13) : [Èkpényòṅ émèn ínùèn ònyòṅ édí úfòk]
 3 1 2 2 3 3 4 4 5 5 6 6 9

which corresponds to Winston's own diagram (p. 186). The discrepancy arises from the fact that the Downdrift rule (6) assigns pitch to a Low tone immediately following a sequence of [+Hi] tones by referring only to the pitch of the last overt Low tone, without regard to how many covert Low tones (in the form of Drop tones) might be intervening (sub-rule 6e).

2.3. Can these difficulties be resolved while retaining the general framework of Fromkin's rules? In her formulation a Low ([-Hi]) tone gets its pitch by reference to the pitch of a preceding Low ([-Hi]) tone, while a High or Drop tone ([+Hi]) gets its pitch from a preceding [+Hi] tone. The problem arises with the (historical) disappearance of the Low tones that once occurred before the Drop tones. Should these implicit Low tones be reintroduced before each Drop tone? In Schachter and Fromkin's phonology of Akan they already have the necessary mechanisms for handling these ghost Low tones. In a number of places in the phonology (e.g. P16, p. 249, P65, p. 261) there are rules of the general form:

$$\emptyset \rightarrow \left[\begin{array}{l} +\text{Segment} \\ \alpha\text{Tone} \end{array} \right] / (\text{a specified environment})$$

where $\alpha = +$ or $-$, [+Tone] = [+Hi] (High tone), [-Tone] = [-Hi] (Low tone). These matrices have no other features specified, i.e. they are purely tone-bearing segments. Late rules of Tone Incorporation (P85) and Tone Simplification (P87) eliminate these otherwise featureless tones, combining their tones with the tones of neighboring segments. Since the Downdrift rule (P86) precedes the Tone Simplification rule, a ghost Low tone can be represented as [+Segment, -Tone] up through the application of the Downdrift rule and then be eliminated by the Tone Simplification rule. This was in fact Schachter and Fromkin's solution in 1968. With the adoption of this solution and a modification of the initial pitch assignment rule Fromkin's 1972 Downdrift rule will work. But, ironically, in her 1972 paper Fromkin objected to such a solution on the grounds that some Drop tones are not plausibly generated from underlying Low-High sequences from which the Low tone disappears (see above, §1.2). Furthermore, introducing an absolutely neutralized segment such as the ghost Low tone for a very restricted purpose is questionable on theoretical grounds (cf. Kiparsky [1971]).

2.4. There are, however, more serious formal objections to Fromkin's formulation. This rule (6) is notationally extravagant, using some of the most powerful devices of generative phonology, such as the sub-one notation to indicate one or more segments of a specified kind

(e.g. [-Hi]₁), as well as indexed angle brackets which are costly at the least and of questionable validity in general.

Another formal objection has to do with the manner in which Rule (6) must be applied to produce the correct output, namely, each of the six sub-rules must be tried on the first syllable until a sub-rule is found that will apply to the tone of that syllable or until all six sub-rules have been unsuccessfully tried on that syllable. Then, and only then, does the focus of the application move to the second syllable, where again all the sub-rules are tried until one is found that will apply. Any other mode of application will give the wrong results even with the modifications mentioned in 2.3. Thus, in effect, this one "schema" constitutes a cycle of rules that is to be applied syllable by syllable from left to right (cf. examples in 2.1 and 2.2). The little evidence that has been advanced to support such a mode of rule application (Anderson [1968]) has been tellingly argued against by Johnson ([1970:92-118]).

A formulation of the Downdrift rule without angle brackets or assumption of the syllabic cycle would be formally preferable. In order to arrive at such a formulation it is necessary to re-analyze the problem.

3. Re-analysis of the problem

First let us review the facts regarding pitch intervals, as they can be gleaned from the various papers on Akan (Schachter [1961], Schachter and Fromkin [1968], Schachter [1969], Fromkin [1972]). In Schachter and Fromkin, downdrift is described as follows: "...the pitch intervals between a low tone and a following high tone is always less than that between a high tone and a following low tone" (p. 106). Thus the sequence L H L is realized [- ⁻ _], which can be expressed in terms of relative pitches as 3 1 4, with a step up of 2 between Low and High, and a step down of 3 between High and Low (cf. Schachter and Fromkin, p. 107). A Drop tone is one step lower than the preceding High (or Drop) tone (Drop tone cannot occur after Low tone). Thus H D D is realized as [⁻ - _], and expressed numerically as 1 2 3. Two consecutive High (Low) tones will be on the same pitch level, i.e. there is no step up or down between them: H H, [⁻ ⁻], 1 1; L L, [_ _], 4 4. Thus the characteristic tonal relationships of downdrift and Drop tones can be expressed entirely in terms

of steps up or down between consecutive tones without reference to tones earlier in the sequence. Using Fromkin's convention that the highest pitches have the smallest numbers, these relations can be expressed as follows:

Low High	step up 2	pitch increment of -2
{ High } Drop } Low	step down 3	pitch increment of +3
High Drop	step down 1	pitch increment of +1
Drop Drop	step down 1	pitch increment of +1
High High	no step	pitch increment of 0
Low Low	no step	pitch increment of 0
# High	initial pitch assignment of 1	
# Low	initial pitch assignment of 3	

4. Reformulation of the rules for Downdrift

In formulating rules for downdrift according to this analysis, only the first syllable of a phrase is given an initial pitch assignment. Every other syllable is assigned an appropriate pitch increment value which describes the tonal step down (positive value) or up (negative value) from the syllable immediately to the left of the syllable in question. (A zero pitch increment carries the information that a syllable has the same tone as the syllable to its left.) Finally, using the assigned pitch value of the phrase initial syllable as a base, the pitch value of each syllable is computed from left to right across the phrase. This is done by adding (algebraically) the pitch increment of the syllable in question to the pitch value of the previous syllable. (I am indebted to Bob Hsu for this formalization.)

As a first step all syllables are arbitrarily assigned a pitch increment of 0 (zero). This serves also to introduce the Pitch feature to all appropriate vowels.

$$(14) \quad [+Syl] \quad \longrightarrow \quad \begin{bmatrix} +Syl \\ 0 \quad P_1 \end{bmatrix}$$

Then the initial syllable of the phrase is assigned a pitch value:

(15) [+Hi] → [1 Pi] / # ____ initial High has pitch 1

(16) [-Hi] → [3 Pi] / # ____ initial Low has pitch 3

Next the pitch increments are reassigned wherever there is a step up or down (rule order here is arbitrary):

(17) [-Hi] → [+3 Pi] / [+Hi] ____ High-Low steps down 3

(18) [+Hi] → [-2 Pi] / [-Hi] ____ Low-High steps up 2

(19) $\begin{bmatrix} +Hi \\ +Mid \end{bmatrix}$ → [+1 Pi] Drop tone steps down 1

Finally pitch values are computed from left to right across the phrase by adding each pitch increment to the pitch value of the preceding syllable:

(20) [q Pi] → [(p + q) Pi] / [p Pi] ____

This rule must apply from left to right in the phrase, but according to Howard's directional theory of rule application (Howard [1972]) this directionality is a formal consequence of the shape of the rule itself, having the environmental determinants to the left of the focus, and need not be separately specified.

Following are some sample derivations with the new rules:

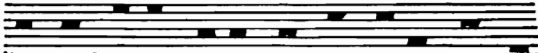
		/òbékó Kùmásé ánòpá yí								
		L H H			L H H H			L H		H
	hi	-	+	+	-	+	+	+	-	+
	mid	-	-	-	-	-	-	-	-	-
by (14):		0	0	0	0	0	0	0	0	0
(16):		3								
(17):					3			3		
(18):		-2			-2			-2		
giving (21):		3-2	0		3-2	0	0	3-2	0	
applied by (20):		3	1	1	4	2	2	5	3	

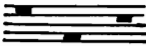
just before rule (20) is giving the same result as (1)

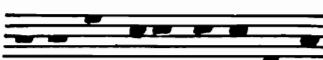


In detail, rule (20) does not apply to the first vowel of (21) since this vowel has no vowel to its left. The second vowel has $P_i = -2$ while the

vowel at its left has $P_i = 3$. Adding these we get $(3-2) = 1$ for the pitch of the second vowel. Moving on, the third vowel has $P_i = 0$ while the second vowel now has $P_i = 1$. Adding these we get $(1+0) = 1$ for the pitch of the third vowel. The fourth vowel has $P_i = 3$ while the third vowel now has $P_i = 1$. Adding we get $(1+3) = 4$ for the pitch of the fourth vowel. And so on.

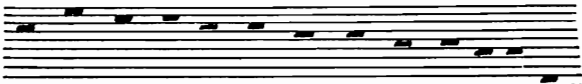
	/ Mè-dè-mé-ń-nà-m-fò-nó-bá-à-mé-fi /	
	L L H H L L L H H L H L	
hi	- - + + - - - + + - + -	
mid	- - - - - - - - - - -	
by (14):	0 0 0 0 0 0 0 0 0 0 0 0	
(16):	3	
(17):	3 3 3	
(18):	-2 -2 -2	
and(20):	3 3 1 1 4 4 4 2 2 5 3 6	giving the same result as (8)
		

	/ H L H /	
hi	+ - +	
mid	- - -	
by (14):	0 0 0	
(15):	1	
(17):	3	
(18):	-2	
and(20):	1 4 2	giving a better result than (9) since it generates the correct step between initial High and following Low.
		

	/ àbèrántéé' békó' èhó' /	
	L L H DH H H L H	
hi	- - + ++ + + - +	
mid	- - - +- - - - -	
by (14):	0 0 0 00 0 0 0 0	
(16):	3	
(17):	3	
(18):	-2 -2	
(19):	1	
and(20):	3 3 1 22 2 2 5 3	giving a better result than (10) since the last Low has pitch 5 rather than 4.
		

		/ Èkpényòṅ émen ínuèṅ ónyòṅ édi úfòk /												
		L	H	D	H	D	H	D	H	D	H	D	H	L
hi		-	+	+	+	+	+	+	+	+	+	+	+	-
mid		-	-	+	-	+	-	+	-	+	-	+	-	-
by(13):		0	0	0	0	0	0	0	0	0	0	0	0	0
(16):		3												
(17):													3	
(18):			-2											
(19):				1		1		1		1		1		
and(20):		3	1	2	2	3	3	4	4	5	5	6	6	9

agreeing with
(13) as desired



Rules (14)-(20), although greater in number than Fromkin's rules, are formally much simpler, and seem to capture better the essence of the pitch relationships between neighboring tones, especially when Drop tones are involved. If, in any particular language, it is desired to consider Drop tones to be phonetic rather than phonemic, by deriving them from Low-High sequences in the underlying representation, these same rules, omitting rule (19) which deals with the Drop tone, would still produce the correct pitch relationships, as long as the rule which deletes the Low tones follows these rules.

5. Summary

In this paper we have examined some proposed rules (Fromkin [1972]) for describing the tonal phenomena of downdrift and Drop tones, and have found them to be inadequate both in descriptive accuracy and in economy of formal apparatus. We have proposed an alternative set of rules which are accurate in so far as we understand the phonetic situation and which are formally much simpler.

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