

# The Unnatural Tonology of Zina Kotoko<sup>1</sup>

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## 1. Introduction

A fundamental question which has arisen many times in the course of phonological research is whether phonology is “natural”. Early work in the theory of Natural Phonology (Donegan 1978, Donegan & Stampe 1979, Dressler 1984, Stampe 1973 inter alii) and the phonetic basis of phonological processes (Ohala 1981 inter alii) emphasised the importance of phonetic factors in understanding phonological processes, so Donegan 1978:3 states “Natural processes, then, are the natural and automatic responses of speakers to the articulatory and perceptual difficulties which speech sounds or sound sequences present to their users”, Donegan & Stampe 1979:128 hold that the subject matter of linguistics is anything that can be connected to some other domain, so “In the case of natural phonology this means everything that language owes to the fact that it is *spoken*”, and Ohala 1990 claims that “For true explanations for speech sound behavior, phonetics now outstrips autonomous phonology”. Similar lines of investigation suggesting a major role for phonetic principles in phonetically-driven phonological theories are pursued in Archangeli & Pulleyblank 1994, Boersma 1998, Flemming 2002, Hayes 1999, Hume 1997, Kirchner 1998, Kochetov 2002, Pierrehumbert 2000, and Steriade 1999, 2001 inter alii, leading to a shift of attention in the direction of how “actual substance”, i.e. the articulatory and acoustic properties of sounds, controls phonology, and whether the continuous mathematics of phonetics is actually part of a grammar.

As a counterpoint to such phonetically-driven research, it is also argued in works such as Anderson 1981, Blevins 2004, Hale & Reiss 2000 a,b, Hyman 2001 and Kaye 1989 inter alii, that, to paraphrase Hyman, phonetic determinism is not a principle of grammar, that phonetic factors are outside of the domain of grammar, and that phonetic influences on phonology are best understood as being mediated through separate theories of language learning and historical change. The goal of phonological theory, thus, is to “define the set of *computationally possible* human grammars” (Hale & Reiss 2000b: 162).

This paper presents data from the tonology of the Chadic language Kotoko, which are relevant to the question of how close phonetics and phonology need to be. I show that phonological grammars can contain rules (or analogous principles) which are phonetically “unnatural”, that is, which fly in the face of phonetically-driven reasoning. The significance of the following analysis of Kotoko tone is that it supports the existence of a phonological grammar whose purpose is the computation of surface variant forms of morphemes, a phonological grammar which is subject to the kinds of conditions that we expect in a discrete, symbolic-computational phonological account, rather than reflecting the physically-based restrictions which we would expect in a strictly phonetic view of phonological processes. While phonetics may have an indirect influence on phonology by shaping the data that are the basis of grammar-construction, such influences are relatively weak and do not trump the existing contrasts and alternations that the child needs to learn in the ambient language. Since the data are primary in grammar-construction and can be historically influenced by many different factors, phonological grammars can end up being phonetically unnatural. As we shall see, the kind of phonetic unnaturalness found in Zina Kotoko is of the type predicted to be possible from formal principles of phonology. Thus Kotoko has a perfectly natural phonological grammar, since the nature of phonology is not the same as the nature of phonetics.

## 2. The Natural Phonology of Consonant-Tone Interaction

There is a substantial literature addressing the crosslinguistically recurrent way in which consonants affect tone. Beach 1924:80 observes that Xhosa tones have lower variants after voiced consonants, and Haudricourt 1954 explains the historical development of tones in Vietnamese by reference to the voicing of the initial obstruent. Bradshaw 1999 studies these phonetic trends both from a phonetic and phonological perspective, documenting such effects in a number of languages. A robust empirical generalization which emerges from this study is that so-called “depressor” consonants have a “lowering” effect on a following tone. Exactly what constitutes a “depressor” consonant varies somewhat from language to language — indeed the variable definition of “depressor” even within a language is the crux of this paper — but as a first approximation, depressor consonants are the voiced obstruents. A typical example, from Siswati, is seen in (1). In this language, H tone shifts rightward to the antepenultimate syllable, yielding the alternations between the two columns. If that syllable has a “depressor” onset, the H tone surfaces as a rising tone.

(1)	kú-ɬal-a	“to sit”	ku-ɬál-el-a	“to sit for”
	kú-fik-a	“to arrive”	ku-fík-el-a	“to arrive for”
	kú-gez-a	“to bathe”	ku-gěz-el-a	“to bathe for”

Such a lowering effect has been experimentally documented as an imperceptible phonetic effect in many languages including English, French, Yoruba and Thai. In many such cases, it is clear that the effect is not the result of a discrete phonological operation, and requires the continuous mathematics of phonetic implementation for an adequate description. It is also found as a very noticeable but non-contrastive surface effect in some languages (Shona, Mayogo). In Siswati, there is a marginal phonemic contrast between level H and rising tone after sonorants, so that rising tones have become phonologized in that language, thus the effect is definitively within the scope of phonology for this language.

Another effect which depressor consonants are known to have is blocking of tone spreading. An example is the blockage of leftward H spread in Suma (Bradshaw 1999). Suma verb roots are lexically toneless, and receive their surface tones by spreading from a tonally specified tense-aspect suffix. The imperfective suffix *-í* spreads its H tone to the left up to and including the root initial syllable, as long as the preceding consonant is not a voiced obstruent. Compare the imperfectives and perfectives of the roots in (2) — underlining indicates nasalization.

(2)	<i>Imperfective</i>	<i>Perfective</i>	
a.	n̄íkír-í	n̄íkír-ā	“exaggerate”
	kír-í	kír-ā	“look for”
	dáf-í	dáf-ā	“make”
b.	đíkíl-í	đíkíl-ā	“tickle”
	bùs-í	būs-ā	“be bland”
c.	bé	bē-ē	“refuse”

These data show a number of things about consonant-tone interaction in Suma. First, leftward spreading of M is not affected by the nature of the initial consonant (see (2b)). Second, tone-consonant dependency specifically affects leftward spreading, and is not a surface condition on possible consonant-tone sequences as shown by the fact that monomoraic [bé] has a level H after a voiced obstruent. Other data in the language point clearly to the phonological nature of this relationship — it cannot be reduced to a surface phonetic prohibition against depressors followed by MH sequences (cf. *zānó* “peanut”), and cannot be reduced to the phonetic implementation of H in dimoraic or longer stems, cf. *dúù* “bridge”.

Phonetically speaking, there are two effects on  $F_0$  attributed to consonant type. The first and most robust effect is that  $F_0$  rises, i.e. is initially lowered, after voiced obstruents, and falls (is initially raised) after voiceless obstruents. The phonetic literature on the role of sonorants is not quite so clear: some studies attribute a pitch-lowering effect on (voiced) sonorants (Maddison 1984), but the observed effects of sonorants have primarily been investigated in the context of the transition from low  $F_0$  to high  $F_0$ , e.g. [...àná...], and has not been convincingly demonstrated in the phonetic context [High  $F_0$ ...Sonorant... High  $F_0$ ], e.g. [...áná...]. A second, less well-studied effect is the influence of a following consonant on  $F_0$ .  $F_0$  rises (is finally raised) before coda glottal stop, and falls (is finally lowered) before coda *h*. Jones & Knudsen 1977 observe that the three tones of Guelavia Zapotec have higher allophonees before glottal stop; Hombert, Ohala & Ewen 1979 study this influence of following laryngeal glides in Arabic and Ohala 1979 provides experimental verification of this generalization from Hindi. Lehiste & Peterson 1961 conclude that in English, consonants have no effect on preceding  $F_0$ .

A number of phonetic causes have been proposed to explain these effects. For example,  $F_0$  is directly correlated with transglottal airflow, and there are higher airflow rates at the release of voiceless consonants but lower airflow rates at the release of voiced obstruents.  $F_0$  is also directly correlated with larynx height, and voiceless obstruents have higher larynx position than voiced ones do. Finally increased cricothyroid activity correlates with higher pitch and voicelessness.

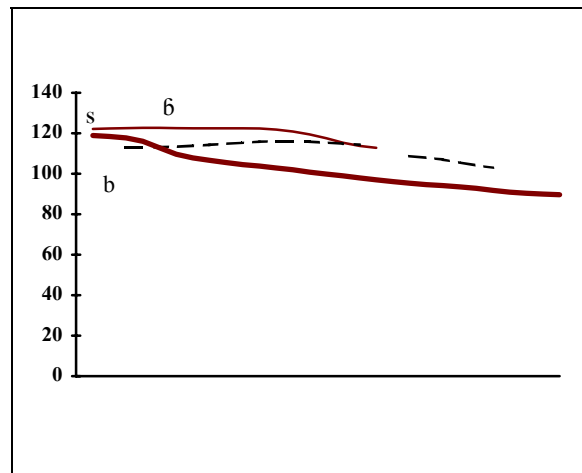
In framing the question about consonant-tone interaction, I have referred to the class of “depressor” consonants, and an important question then must be answered as to what consonants those are. The most basic and wide-spread class of depressor consonants are the voiced obstruents: if a language has any “depressors”, this class of consonant partially defines the depressors. In some languages, voiced sonorant consonants also act as depressors, thus in Nupe, Ngizim, Ewe and Kanazawa Japanese, some rules group voiced obstruents and sonorants together. This grouping together of obstruents and sonorants is grammaticalized, to the point that in Ngizim and Ewe, sonorants are depressors for one rule but not for another consonantally-conditioned rule (see Bradshaw 1999 for discussion).

One observation which has emerged from the crosslinguistic study of depressor effects is that implosives are *not* known to be depressors, and are actually associated with higher phonetic pitch. The non-depressor nature of implosives is seen in numerous languages, including Suma, various Southern Bantu languages, Sayanci, Ngizim, Mulwi, Miya, Podoko, Dagare, Ebrie and Yaka. From the perspective of phonetically-driven accounts of phonology, it is important to know what we should expect, theoretically speaking. The literature on this topic is not very extensive, but the consensus seems to be that implosives do not have a phonetic pitch lowering ef-

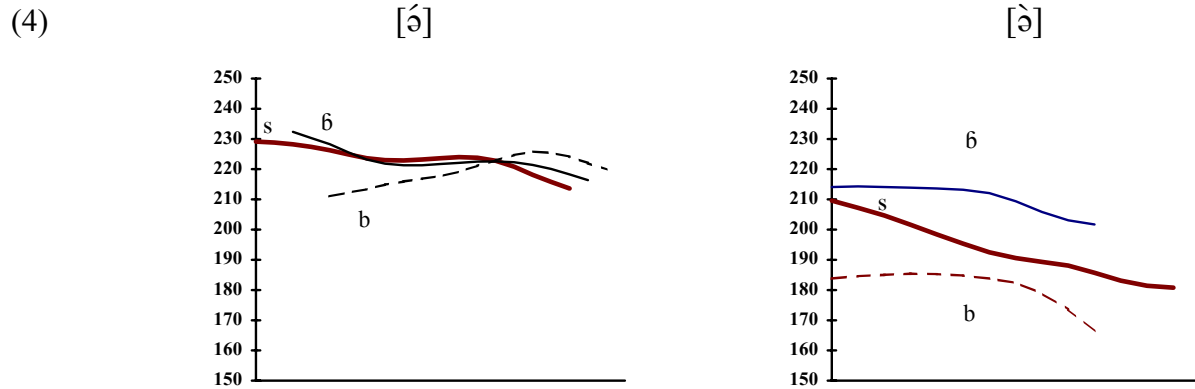
fect, and may even have a raising effect. Ohala 1973:3 states “...implosives seem to raise tone on the following vowel” and (p. 9) that “Implosives must cause elevated pitch by the high rate of air flow through the glottis generated by the rapidly descending larynx (Ladefoged, personal communication).” Hombert 1978:91 confirms this view. Instrumental data from languages having implosives is not easy to find, but Demolin 1995 states that in Lendu,  $F_0$  can be very high during the prevoicing of the voiceless implosives and this carries over into the following vowel.  $F_0$  is slightly higher after voiceless implosives than after voiced implosives. Kutsch Lojenga 1994 shows similar results for related Ngiti, and Wright & Shryock 1993 demonstrate that implosive [ɓ] in SiSwati does not have a lowering effect, and does have a pitch-raising effect an intermediate between [p<sup>h</sup>] and [m]. Finally, Clements & Osu 2002 study a series of consonants in Ikwere, which contrasts [b], voiced “pressureless” [b̥], and voiceless ingressive [ʔ] which is described as being similar to an implosive. They note that at the release of the consonant, the highest pitch is found after [ʔ], then [b̥], and the lowest pitch is found after [b].

The pitch tracings in (3) from Kihehe support this correlation between higher pitch and implosives, which behave unlike plain voiced consonants. It can be seen that the dashed line representing pitch after a voiced obstruent is initially lower, compared to pitch after the voiced obstruent [s] (thick solid line) and the implosive [ɓ] (thin solid line).

(3)



A similar graph of the effect of consonant type on the pitch of following H and L toned vowels from Kotoko is seen in (4).



Thus it would be phonetically uncontroversial to find that implosives do not function as depressors.

### 3. The Phonological Account of Consonantly-Induced Tone Lowering

The phonological literature generally has made little comment on the status of implosives in understanding the basis of consonantal effects on tone. The phonetic tone raising hierarchy of Hyman & Schuh 1974 places implosives at the maximum raising end of a scale of the propensity to raise or lower  $F_0$  / tone.



In addressing the question what causes tone lowering — specifically answering the question whether voicing causes tone lowering, Hyman 1973:164 denies such a causal relation, saying “That this is not the is first seen from the fact that implosives (which are *voiced*) have the same effect on tone as *voiceless* obstruents”. Similarly, Demolin 1999:319 notes that “This pitch raising after implosives is rather puzzling given that voiced obstruents tend to be tone depressors”. These observations may argue that phonetic  $F_0$  perturbation effects are not caused by voicing, but this still leaves open the question of whether phonological voicing is the cause of grammaticalized tone lowering effects.

To address this phonological question, we must first consider the feature specification of implosives. The standard account of implosive consonants is that on the surface, they are [+voice, +constricted glottis]. However, phonological rules do not always operate on surface specifications (in rule-based grammar, they never do), and the underlying or derived representations of implosives may be rather different across languages. One possibility is that these consonants are simply [+c.g.], where voicing is redundant and predictable from the underlying [+c.g.] nature of the consonants. Is voicing contrastive in [+c.g.] consonants? Examples are quite uncommon. One clear clear case is presented by Ngiti and Lendu, which actually contrast voiced and voiceless implosives. However, these languages present no phonological consonant / tone interaction at all, so they do not clarify the treatment of implosives for tonal phonology.

An unclear case is presented by many Southern Bantu languages which have both implosive [ɓ] and ejective [pʰ]. The ejective quality of [pʰ] et al. is very weak, and [pʰ] does not contrast with plain [p] — surface [pʰ], or something like it, may simply be considered to be the pronunciation of unaspirated /p/ in these languages. In a number of languages, implosives are the surface pronunciation of [+voice] stops. This is especially true in a band of Eastern Bantu languages ranging from Kipare to Kimatuumbi, also is also found in a number of Nilotic languages. In other words, in addressing the root causes of any phonological effects of implosives on tone, it is necessary to pay heed to the phonological contrastiveness of voicing in implosives.

A language which contrasts voiced and voiceless obstruents, but has only one kind of glottalized consonant — voiced implosives — thus allows two feature specifications for implosives. They may be [+voice, +c.g.], or they may be simply [+c.g.], depending on whether you are considering a representation with predictable values specified (in which case implosives are [+voice]) or one with only contrastive values (in which case implosives do not share anything with [+voice] consonants).

In testing the phonological effects of consonants on tone, especially in testing for a divergence between patterns of phonetic implementation versus symbolic phonological grammar, it is also essential to draw evidence from uncontroversial phonological processes. In raising questions about the difference between phonetics and phonology, I understand “the theory of phonology” to refer to the formal theory of phonological grammars; if phonology is taken to refer to something broader, such as “human ability to produce and process speech sounds”, we will necessarily find a very different answer to the question “what is possible?”. The phonological grammar is thus not held responsible for the small and noncontrastive F<sub>0</sub> manipulations found in connection with consonant voicing in English, Yoruba, or Kikerewe. An adequate description of such effect requires a vastly richer descriptive apparatus to cover such range of phonetic F<sub>0</sub> contours than can be justified in phonology. Therefore subphonemic F<sub>0</sub> effects as found in languages like Shona are not necessarily within the scope of phonological theory, so they cannot be used to justify strong conclusions about what is possible in phonological theory.

It is equally important that potentially controversial consonant / tone effects be documented with synchronically viable processes, not historical residue, since as noted in the introduction, the theory of grammar is not the same as the theory of language change and acquisition. An example of a “historical residue” variety of consonant / tone effect is found in Gbe languages such as Ewe (or Gen, in the case of the following data). A generalization has been observed that root-initial H in nouns becomes a rising tone after voiced obstruents so that è-*vé* → è-*vě* “monitor lizard”, cf. [àtá] “thigh”. The synchronic motivation for such a tone lowering rule is rather weak. There are no alternations which justify this rule, so one can equally well say that these words have underlying rising tones. In addition, rising tones are also found after initial non-depressors (è-*tǎ* “head”), and there exist surface H tones after L plus depressor (àkòdú “banana”, bàbá “mud”). This particular Ewe example is “theoretically harmless”, in that no major theoretical conclusions hinge on the question of there being such a process in a grammar. Controversial conclusions must be justified on the basis of non-controversial evidence: in the following section, I demonstrate that implosive consonants in Kotoko behave as depressor consonants with respect to M tone, contrary to crosslinguistically well-attested phonetic and phonological trends, and that this pattern is uncontroversially a part of the phonological grammar because it underlies morphophonemic tone alternations in the system of verb inflection.

#### 4. Consonant-Tone Effects in Zina Kotoko

Kotoko is a member of the “B” group of Central Chadic, also known as Biu-Mandara. Other “dialects” are spoken in Nigeria and Chad, and include Afade, Lagwan, Mser, Mpade, Maslam, Malgbe and Mazera. There is a high degree of variation between these dialects, judging from existing publications on Kotoko and the statements of those familiar with the languages. The following orthographic conventions will be observed in this paper: <c> represents [č / tʃ], <gh> = [ɣ], <'> = [ʔ], <'b> = [β], and <'d> = [ɗ]. The language has three distinctive tones: L marked with a grave accent, H marked with acute accent, and M which is unmarked. Lexical tone is contrastive in nouns but not in verbs, which receive surface tones in a predictable manner based on an interaction between suffixal tones or floating tones indicating tense-aspect, and phonological rules which include consonantly-conditioned tone lowerings. There are a number of distinct tone lowering rules in the grammar which refer to different classes of consonants. The consonants of the language can be descriptively arranged into the hierarchy (6) where voiced obstruents at the left end of the hierarchy exhibit the greatest participation in these tone lowering rules, and voiceless obstruents and [h] never trigger tone lowering.

$$(6) \quad \text{voiced obstruents} > \text{sonorants} > \text{ʔ} > \text{implosives} > \left\{ \begin{array}{c} \text{voiceless obstruents} \\ \text{h} \end{array} \right\}$$

I discuss three of these consonantly-triggered tone rules here. The first such rule lowers H tones to M after voiced obstruents and sonorants, but not after implosives — this rule is relatively uncontroversial in terms of the phonetic naturalness of these consonantal effects. The second rule lowers M tone to L after voiced consonants and implosives, and is one of the novel contributions of this language to tone typology, in showing that implosives can be depressor consonants. The third rule lowers M tone to L before a voiced obstruent: this rule demonstrates that phonological conditioning by a following consonant is also a possibility, despite the contrary indications from phonetics. I begin the exposition of Kotoko tone by considering the infinitive, which shows no consonantal effects.

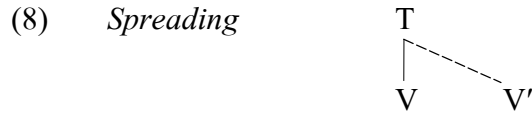
##### 4.1. The Infinitive

The infinitive is formed by affixing -à after the verb stem. All vowels in the infinitive are L-toned, regardless of the consonants in the stem.

(7)	bəl-à	“flow”	bghwàr-à	“jump. pl.”
	dəmàkwy-à	“throw pl.”	zy-à	“beat”
	ʔək-à	“snatch”	ʔdèh-à	“write”
	hàr-à	“find”	kwìc-à	“cut”
	sàb-à	“grow”	tàm-à	“touch”
	cèngh-à	“be sated”	kà'd-à	“cross”

The consonantly-triggered tones rules lower H and M tones after depressor consonants; there is no raising effect of consonants on L tones, so underlying L tones are invariant with respect to the

preceding consonant. There are numerous ways of deriving the all-L outputs above, but for the sake of concreteness, I assume that there is a L tone inserted into the representation in the infinitive which links to the first stem vowel, and then spreads to the right by the following rule.



The specific mechanism for deriving this pattern is unimportant for the remainder of the analysis. The operation of Spreading (8) will be relevant at later points in the analysis.

#### 4.2. Future

The future tense is morphologically similar to the infinitive, selecting the suffix *-à*, but also taking a prefix *n-*. The first syllable of the stem has an underlying H tone and subsequent vowels have L tone. The surface tone on that first syllable depends on the nature of the previous consonant. If that consonant is *h*, a voiceless obstruent, or an implosives — the usual non-depressor consonants — the first tone is H.

<i>H after h,</i>				
(9) a.	n-hár-à	“find”	n-híyàr-à	“bite pl.”
	n-hórc-à	“slice”	n-hós-à	“throw”
b.	n-sáp-à	“chase”	n-sáb-à	“grow”
	m-páy-à	“bury”	n-ká’d-à	“cross”
	n-cónh-à	“be sated”	n-sók-à	“send”
c.	n-’dóv-à	“put”	n-’dáh-à	“write”
	n-’dóh-à	“write”	m-’bál-à	“dance”

However, if the first consonant is a voiced obstruent, a sonorant, or a glottal stop, the tone of the first vowel is M.

(10) a.	n-jagh-à	“dig”	n-ghag-à	“close”
	n-zəgl-à	“carry”	n-gə’b-à	“answer”
	m-ban-à	“bathe”	n-dunkw-à	“throw”
	m-vənh-à	“vomit”	n-gulàn-à	“laugh”
b.	n-yey-à	“call”	n-wurgy-à	“buy”
	n-wac-à	“leave”	n-wuràgyà	“buy pl.”
	n-law-à	“fight”	n-ləhày-à	“fear”
	n-ra’d-à	“pull”	m-mar-à	“die”
c.	n-’əkf-à	“approach”	n-’ək-à	“snatch”

The fact that glottal stop causes tone lowering is of some significance since glottal stops are not empirically known as depressor consonants: this issue will be set aside for the moment,

and the rule will simply be stated as in (11), pending a formal account of these changes in the final section.

- (11) *H-Lowering*  
 $H \rightarrow M / D \text{ \_\_\_}$  (D = voiced consonants and glottal stop)

The analysis of the tone of the future tense thus posits an initial H followed by a L, where the L spreads from the second stem syllable to the end of the word. That initial H is then subject to the H-lowering rule (11).

#### 4.3. Recent Past

In the recent past tense, a different tone is associated to the stem; in addition, the clitic *-ém* follows the verb, subject to morphosyntactic conditions (see Schmidt 2002). The tone of the first syllable is M after [h] and voiceless obstruents, as seen in (12).

- |         |         |            |         |                  |
|---------|---------|------------|---------|------------------|
| (12) a. | her-ém  | “bite”     | hərc-ém | “slice”          |
|         | hwat-ém | “inflate”  | həl-ém  | “steal”          |
| b.      | skal-ém | “pay back” | sap-ém  | “chase”          |
|         | pay-ém  | “bury”     | kah-ém  | “take a handful” |
|         | ka’d-ém | “cross”    | sək-ém  | “send”           |
|         | tam-ém  | “touch”    | cənh-ém | “be sated”       |

Underlying L tones are invariant across consonantal contexts, and we have seen in the previous section that underlying H tones surface as H after voiceless consonants, by process of elimination we can conclude that the tone of the recent past tense is underlyingly M tone, which then surfaces directly when preceded by a voiceless consonant.

After the remaining consonants, underlying M appears as L. The consonants which cause lowering of M include voiced obstruents, sonorants, glottal stop and, most significantly, implosives.

- |         |         |               |           |             |
|---------|---------|---------------|-----------|-------------|
| (13) a. | ghàg-ém | “close”       | gàh-ém    | “pour”      |
|         | zəgl-ém | “carry”       | bghwàr-ém | “jump pl.”  |
|         | gə’b-ém | “answer”      | gə’d-ém   | “open”      |
|         | gùlm-ém | “twist”       | vàlf-ém   | “give back” |
|         | dùnk-úm | “throw”       | zàk-ém    | “beat”      |
|         | vìt-ém  | “blow a fire” | jìk-úm    | “begin”     |
| b.      | yèy-ém  | “call”        | wèh-ém    | “be tired”  |
|         | làb-ém  | “tell”        | rà’d-ém   | “pull”      |
|         | màr-ém  | “die”         | làkf-ém   | “bring”     |
| c.      | ’əkf-ém | “approach”    | ’ək-ém    | “snatch”    |
| d.      | ’dèv-ém | “put”         | ’dèh-ém   | “write”     |
|         | ’bàl-ém | “dance”       | ’dàm-ém   | “eat”       |

This pattern can be explained by positing a floating M tone affix for the recent past, which links to the first stem syllable and is then subject to the following consonantly-triggered tone lowering rule.

- (14) *M-Lowering*  
 $M \rightarrow L / D' \text{ \_\_\_}$  (D' = voiced consonants, glottal stop and implosives)

Note that this rule is triggered by a different class of consonants, D', which adds implosives to the set D.

Polysyllabic verbs have essentially the same tone pattern, with the tone of the first syllable being determined by the initial consonant. Subsequent syllables also bear that tone, regardless of the consonant which immediately precedes.

- |      |           |            |            |                |
|------|-----------|------------|------------|----------------|
| (15) | wùràgì-ém | “buy pl.”  | lǎhàɣ-ém   | “fear”         |
|      | bùghùr-ém | “jump”     | vènàh-ém   | “vomit”        |
|      | gùlàn-ém  | “laugh”    | bàtàkwì-ém | “puncture pl.” |
|      | hǎnani-ém | “burn pl.” |            |                |

This is explained structurally by the hypothesis that there is a single tone linked initially to the first syllable and spread to following syllables. Since the initial consonant is a depressor in (16a), the medial non-depressors *t*, *kw* have no influence on that tone and similarly because the initial consonant is a non-depressor in (16b), the medial depressors *n* cause no lowering of that tone.

- |      |    |                   |    |             |
|------|----|-------------------|----|-------------|
| (16) | a. | $M \rightarrow L$ | b. | $M$         |
|      |    |                   |    |             |
|      |    | batakwi # ém      |    | hǎnani # ém |

One further tone rule is motivated by the data of the recent past tense. While initial voiceless consonants are generally followed by M tone rather than L tone in this tense, just in case the stem medial consonant is a voiced obstruent, the initial tone surfaces as L.

- (17) sàb-ém “grow”                      sxàjì-ém “be able”

Contrast these examples with *tam-ém* “touch”, which exhibits a M tone (not L) before a voiced sonorant. The crucial factors determining the application of this rule is that the triggering consonant must be specifically an obstruent, and it also must follow the M toned vowel. Finally, considering the H toned future tense form *nsábà* where there is no lowering, this rule is specifically limited to affecting M tone.

- (18) *Pre-depressor lowering*  
 $M \rightarrow L / \text{ \_\_\_ } \begin{bmatrix} +\text{voice} \\ -\text{sonor} \end{bmatrix}$

## 4.4. Habitual

The habitual provides a context for confirming the three tone rules which were motivated above, since this tense has a ditonal melody MH. The surface realization of that melody depends on the number of underlying syllable in the stem, so monosyllabic stems have an underlying H tone (which is subject to H-lowering), and polysyllabic stems have underlying H on the last stem syllable and M on the preceding syllables. Though we will present these two cases separately to make clear how consonants affect tones in both contexts, there is a single underlying tone for all habituals verbs, MH. The second tone on that sequence maps to the final vowel of the stem, and if there are any remaining vowels in the stem — as will be the case with polysyllables — the M tone links to the stem initial vowel.

With monosyllabic roots, the underlying H is retained as such after non-depressor consonants.

(19)	sí	“drink”	tór	“sharpen”
	skwál	“want”	páy	“bury”
	hí	“like”	hér	“bite”
	’dí	“be wet”	’bál	“dance”
	’dám	“eat”	’dán	“tie”

If the initial consonant is a depressor — a voiced obstruent or sonorant in (20) — the tone lowers to M. The case of glottal stop will be considered later.

(20)	gwi	“sprout”	ru	“go”
	gaw	“beg”	jam	“ask”
	ban	“bathe”	val	“give”
	gul	“scratch”	yey	“call”
	mar	“die”	lum	“shave”
	nghay	“play”	law	“fight”

There is a surface complication in this tense, which selects no segmental inflectional marker, that schwa appears at the end of verb stems which underlyingly end in a consonant cluster or an obstruent. No words in the language end in consonant clusters or obstruents, and the following rules of epenthesis explain the presence of final schwa.

(21)	$\emptyset \rightarrow \text{ə} / [-\text{sonorant}] \_ \#$	$\emptyset \rightarrow \text{ə} / \text{CC} \_ \#$
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Given such rules of schwa-epenthesis, the following examples also illustrate the monosyllabic pattern, a H on the initial syllable, since the stems in (22) are underlyingly monosyllabic.

(22)	kwá'dó	“finish”	kwásó	“break”
	káhó	“take a handful”	ká'dó	“cross”
	cónhó	“be sated”	sápó	“chase”
	sáká	“send”	sábó	“grow”
	hwátó	“inflate”	hórcó	“slice”
	'dáhó	“inject”	'dóhó	“write”

Given an underlying H which marks the tense, these forms are predicted by the rules posited above. Implosives and voiceless consonants do not affect H tone, and the H then spreads to the epenthetic vowel via Spreading (8). Also, comparing *sábó* “grow (habitual)” and *sàb-ám* “grew (recent past)”, we predict that Pre-Depressor Lowerer does not affect this root since only M is lowered before a voiced obstruent.

When the initial consonant is a depressor — voiced obstruent, sonorant, or glottal stop, the tone is lowered by H-Lowering (11). This tone then spreads to the final syllable by (8), and again the properties of the medial consonant are not relevant for determining the surface tone of the epenthetic vowel.

(23)	a.	ghagə	“close”	jaghə	“dig”
		zəghə	“distribute”	gəgə	“do”
		labə	“tell”	jagə	“cook”
		gulmə	“twist”	'əkə	“snatch”
	b.	ghacə	“run”	zakə	“beat”
		vitə	“blow a fire”	vyatə	“blow fires”
		mikə	“forget”	gahə	“pour”
		ra'də	“pull”	gə'bə	“answer”

A superficially different pattern is found with polysyllabic verb stems, namely MH. Since this pattern has two tones, we can independently test the effect of the various depressor-induced tone lowering rules. The underlying MH melody surfaces unchanged if the first and last stem consonants are non-depressors.

(24)	sakí	“send pl.”	kwasí	“break pl.”
	kwakwí	“insult pl.”	kahí	“take handfuls”

If the first consonant is non-depressor and the last is a depressor, all vowels have M tone.

(25)	səmi	“hear”	hənani	“burn pl.”
	tami	“touch pl.”	cuwi	“cry”

Underlyingly, [səmi] is /sə mí/. H-lowering applies to the final H in these examples, giving M, because of H-Lowering. Since the final tone is H and is subject to (11), it is predicted — correctly — that implosives are followed by H tone since they are non-depressors for H tone.

(26)	ka'dí	“cross pl.”	kwa'dí	“finish pl.”
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Now turning to roots with an initial depressor consonant, (27) shows that the underlying M is lowered after initial depressor. In these examples, the final H is unchanged because the preceding C is a non-depressor.

- |      |      |              |      |             |
|------|------|--------------|------|-------------|
| (27) | gàhí | “pour pl.”   | zàkí | “beat pl.”  |
|      | ’àkí | “snatch pl.” | wàcí | “leave pl.” |

Again, an implosive consonant in the final syllable does not function as a depressor of H.

- |      |       |              |       |            |
|------|-------|--------------|-------|------------|
| (28) | gà’bí | “answer pl.” | rà’dí | “pull pl.” |
|------|-------|--------------|-------|------------|

The data in (29) analogously illustrate lowering of the initial M to L (because of the initial depressor) as well as lowering of the final H to M, since there are depressors in both positions.

- |      |       |             |       |                  |
|------|-------|-------------|-------|------------------|
| (29) | ghàgi | “close pl.” | zàghi | “distribute pl.” |
|      | dùgwi | “help”      | ghèzi | “fall”           |
|      | zèbi  | “follow”    | zàli  | “send pl.”       |
|      | ghèli | “sing”      | wùrgi | “buy”            |
|      | wùri  | “weed”      | ràdi  | “tear”           |

We noted in (19), (22), (26) and (28) that implosives did not cause tone lowering — that is because in those examples, the tone in question is a H tone, and implosives do not lower H tone. As (30) shows, implosives do function as depressors of the initial tone in polysyllabic habitual verbs, since that tone is underlyingly M, which is subject to lowering by implosives.

- |      |       |              |       |           |
|------|-------|--------------|-------|-----------|
| (30) | ’dàhí | “inject pl.” | ’dàni | “tie pl.” |
|      | ’bàli | “dance pl.”  |       |           |

One final prediction can be verified here: in polysyllabic stems with an initial voiceless obstruent and a medial voiced obstruent, the first tone becomes L.

- |      |      |            |       |           |
|------|------|------------|-------|-----------|
| (31) | sàbi | “grow pl.” | sxàji | “be able” |
|------|------|------------|-------|-----------|

This is because Pre-Depressor Lowering applies to underlying /sábí/, where M comes before a voiced obstruent. As shown by *səmi* “hear”, a following sonorant does not condition lowering of the initial tone.

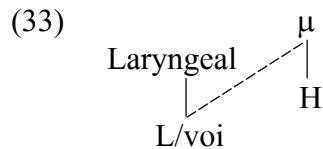
To summarize, the three consonantly-triggered tone rules of (32) are motivated in Kotoko.

- |      |                   |                 |   |
|------|-------------------|-----------------|---|
| (32) | <i>H-Lowering</i> | H → M / D ____  | (D = voiced consonants, ?)              |
|      | <i>M-Lowering</i> | M → L / D' ____ | (D' = voiced consonants, ?, implosives) |

*Pre-depressor lowering*       $M \rightarrow L / \text{---} \left[ \begin{array}{l} +\text{voice} \\ -\text{sonor} \end{array} \right]$

## 5. Theoretical Consequences

A number of points of theoretical interest have emerged from the investigation of consonant-tone interactions in Kotoko. The facts presented here broadly support the concept of a formal grammatical computation which is distinct from the extragrammatical causal principles influencing the shape of the raw data which grammars are induced from. More specifically, the Kotoko facts support a number of predictions in the model of consonant voicing and tone presented in Bradshaw 1999, regarding possible phonological computations. That model equates consonant voicing and L tone, identifying both as surface manifestations of a single feature L/voice with multiplanar linkages to the segmental laryngeal node and the prosodic tone node, analogous to the way in which Unified Features Theory unites coronal consonants and front vowels. This account is in some ways analogous to the use of [slack] in the Halle & Stevens 1971 account of voicing and tone features. Thus the change of a H tone to a rising tone after a voiced consonant formally represented as the spreading of L/voice from the consonant to the following vowel, at the prosodic level.



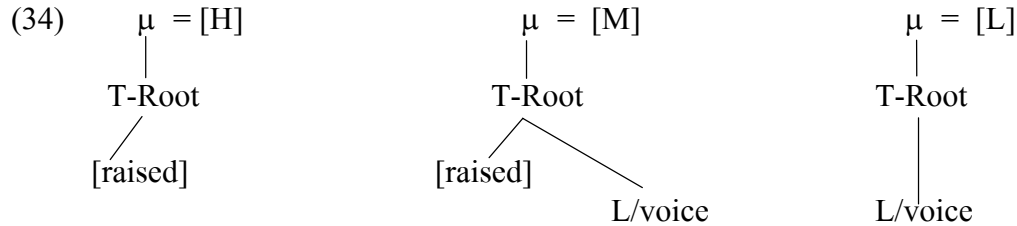
This theory makes a number of empirical predictions which have not previously been well documented or even verified at all, but which are verified by the data of Kotoko.

One interesting result of the study of Kotoko tone is that we see that sonorant consonants can function as tone depressors. While the patterning of sonorants with voiced obstruents is also attested in Ewe, Nupe and Ngizim, additional examples of this very rare phonological pattern are theoretically interesting when they involve new contexts for depressor behavior. Interestingly, the three previously known cases of sonorants exhibiting tone-depressor behavior discussed in Bradshaw 1999 all have similarity. In Ngizim, L spreads only through voiced consonants (including sonorants) to a H toned syllable followed by a H, hence /màrí báí/ → [màrì báí] “it’s not a beard”. Virtually the same rule exists in Nupe, except that no following H tone is required and the resulting tone is a rise rather than L (/èlélé/ → [èlě] “past”). And in Ewe, a floating L tone prefix in the imperative docks to an initial H only across a depressor, including a sonorant (/`ná/ → [nǎ] “give!”). These examples have in common the fact that sonorants can act with voiced obstruents in facilitating the spread of an existing L tone. The L/voice theory also predicts that L could spread directly from a sonorant, with no need for a pre-existing prosodic L tone — as we have seen here, such direct spreading from a sonorant is well-attested in Kotoko.

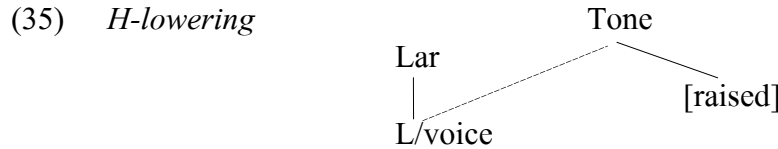
Another interesting fact emerging from this study is that we have seen that glottal stop can function as a depressor consonant. Previous studies have not established a clear phonological pattern for glottal stops in tone languages — for example, Bantu languages which have depressor effects do not have glottal stops. To the best of my knowledge, there are no clearly docu-

mented examples of glottal stops acting as phonological depressors or non-depressors in the literature, so the fact that they function as depressors in Kotoko provides interesting new information on the definition of depressor. In the context of the L/voice theory, we would conclude from the phonological patterning that they are specified L/voice.

The two most striking discoveries coming from Kotoko tone are that (a) a following consonant (other than a laryngeal glide) can be a depressor, contrary to the documented phonetic pattern and (b) implosive consonants can act as depressors. What is most striking is that even though these are phonetically unexpected processes, they are predicted from the perspective of a standard theory of phonological computation (rule-based theory), assuming the UFT model of tone and voicing. In that theory, the contrast between H, M and L can be represented as (34).

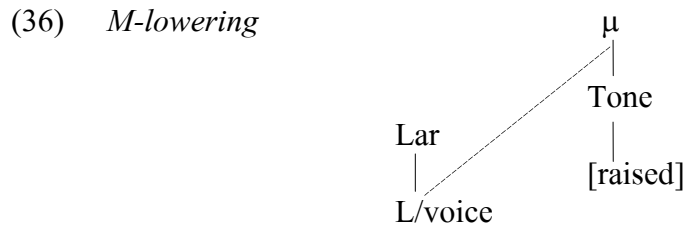


Since voiced consonants have the feature L/voice, as do M and L tones, the change of H to M reduces to autosegmental spreading of L/v to the H tone's Tone-root node

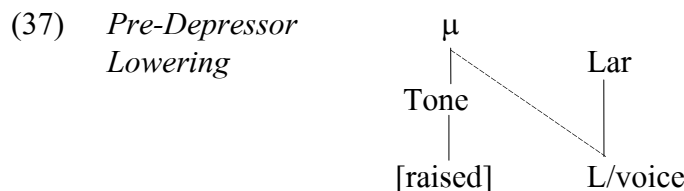


L/voice combined with [raised] under a single Tone node is phonetically realized as M tone.

The change of M to L tone after a depressor is described as spreading of L/voice as well, but in this case the spreading is at a level above the Tone Root node, so that the existing features of the M tone are entirely replaced by L/voice.



The predepressor lowering rule is simply the mirror image of M-lowering.



As to the mismatch between phonetic naturalness and phonological attestation regarding conditioning by a following depressor, phonological rules give no preference to triggering elements which stand before the target as opposed to those which stand after the target: “\_\_A” is no better or worse than “A\_\_” in rule formulation. It should therefore be possible for the trigger of a phonological depressor rule to follow the tone, just as the trigger of vowel nasalization sometimes precedes the vowel and sometimes follows. The attestation of such a rule in Kotoko verifies this basic prediction of autonomous phonology.

The differing definitions of “depressor” are also entirely within the descriptive purview of autonomous phonology, and as outlined in section 2, different classes of segments may be identified by the specification [L/voice], depending on the extent to which redundant features are specified. For Kotoko, only voiced obstruents have contrastive voicing: voicing of implosives and sonorants can be supplied by redundancy rule. If underlying forms can be unspecified at least for predictable feature values, then it is predicted that a language might treat just the voiced obstruents as depressors — as is the case for Pre-Depressor Lowering in Kotoko, and most cases of consonant-tone interaction documented in the literature. If sonorants are supplied with their redundant L/voice specification at some later stage, then we predict the situation where voiced obstruents and sonorants, but not implosives, act as depressors — this describes the situation with H-Lowering in Kotoko, also the relevant consonantly-triggered rules of Ngizim, Nupe and Ewe. And finally, if implosives are redundantly specified with L/voice, they too are included in the class of depressors — as is the case with M-lowering in Kotoko. These three different depressor effects within a single language makes it clear that the variation has to do with the organisation of grammar and the specific statements of rules, and not with peculiarities of how a given sound is pronounced in the language. Since voicing in implosives is predictable, there is no theoretical compulsion for them to be specified as having L/voice at all stages of the grammar, regardless of how they are pronounced; since they are phonologically voiced on the surface, L/voice will be present in their representation, and it is predicted that they could cause the same phonological lowering effect as voiced obstruents. This is true even when they *actually* have a standard surface phonetic F<sub>0</sub>-raising effect rather than a lowering effect, as observed in section 2.

An obvious question that should occur to the curious reader is, how does such a phonetically unmotivated situation arise. The answer is that at present, we do not know. The explanation lies somewhere in the history of the language — what sequence of events gave rise to the data which lead to the current form of the grammar. Since Chadic is the only branch of Afro-Asiatic with tone and most Chadic languages have only 2 levels of tone, it is fair to conclude that at least this dialect of Kotoko has undergone a tone split. We might conjecture that higher and lower allophones of basic H and L tones developed under the influence of the preceding consonant so that raised “H+”, “L+” variants might have appeared after voiceless consonants and implosives, and lowered “H-” “L-” variants might have appeared after voiced consonants. Phonemicization of some of these distinctions could have given rise to a 3-level system with tone distribution influenced by the consonant, but this does not make obvious how the implosives could have acquired a lowering effect for L tone but a raising effect for H tone. But relatively little tone-marked basic descriptive material is available for related languages, indeed for other so-called dialects of Kotoko, so any further speculation as to the historical causes of the phonetically non-intuitive grammar of Zina Kotoko must be a matter for future investigation.

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