Peak Delay and Tonal Noniterativity*

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1 Tone Spreading and Shifting

There are many claims for many languages to the effect that a tone spreads or moves by one syllable, typically to the right (Hyman & Schuh 1974). To pick just one example, Myers (1987) explicitly uses both iterative and noniterative rules to account for various tone spread phenomena in Shona. But as Kisseberth (2007:663) states in his recent review of Yip (2002), "the proper way to get at [noniterative tone shift] is a significant issue in OT." But This paper adds to research in this area by building on findings about the phonetic properties of tone spread and shift as elucidated by Myers (1999, 2003).

The reason noniterative tone shift and spread are difficult issues for OT is that, as Kisseberth (2007) points out, to determine whether or not a tone as spread or shifted noniteratively, a constraint must compare the output to the input. This is exactly what Myers's (1997) LOCAL, which I discuss below, does. But a constraint enforcing noniterative spread/shift must be a markedness constraint (since spreading and shifting are clearly not the product of faithfulness), and markedness constraints are barred from accessing the input.

Noniterative tone shift/spread therefore forces a choice for OT: Either the ban on accessing the input must be relaxed, or an alternative approach to these phenomena that does not explicitly invoke noniterativity must be proposed. In light of evidence from segmental phenomena showing that OT is better off for not permitting explicit noniterativity (Kaplan 2008a, to appear), I take the latter option here.

Philippson (1998) explicitly argues for a conceptual dichotomy between iterative ("unbounded") tone spread/shift and noniterative but otherwise identical phenomena. For an example of the latter, in Kikuyu, tones appear one syllable to the right of their underlying hosts (Clements 1984, Clements & Ford 1979; data from Clements 1984). The data in (1) show this for verbs.

(1) to rɔr aɣ a — 'we look at'
    to mo rɔr aɣ a — 'we look at him/her'

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to ma rɔ́r aɣ a	‘we look at them’
má rɔ́r aɣ a	‘they look at’
má mó rɔr aɣ a	‘they look at him/her’
má má rɔ́r aɣ a	‘they look at them’

The first two forms establish that the root *-rɔr-* ‘look at’ and the object prefix *mo-* ‘him/her’ are low-toned morphemes. In the third form, the introduction of the object prefix *ma-* ‘them’ causes a high tone to appear on the root. The conclusion we’re led to is that this H is part of the object prefix and shifts to the following morpheme. Similarly, when the subject prefix *ma-* ‘they’ appears instead of *to-* ‘we’ in the last three forms, the following morpheme surfaces with a high tone. Again, since we’ve already seen that *-rɔr-* and *mo-* are low-toned, the obvious conclusion is that the subject prefix supplies the H, which links not to the subject prefix but to the following morpheme (and then, in Clements & Ford’s (1979) and Clements’s (1984) analyses, spreads leftward back to the subject prefix so that this morpheme isn’t left toneless). In the last form, both high-toned *ma-* prefixes are present (one the subject, the other the object), and H appears on the morpheme following each prefix.

Similarly, a high-toned root such as *-tom-* ‘send’ causes the following morpheme to surface with H. The data in (2) show this. Whereas the habitual suffix *-aɣ-* was low-toned throughout (1), here it is high-toned because the preceding morpheme now contributes a high tone.

(2)	to tom áɣ a	‘we send’
	to mo tom áɣ a	‘we send him/her’
	to ma tóm áɣ a	‘we send them’
	má tóm áɣ a	‘they send’
	má mó tom áɣ a	‘they send him/her’
	má má tóm áɣ a	‘they send them’

Both Clements & Ford (1979) and Clements (1984) account for this pattern by positing an early rule that associates the first tone, whether H or L, to the second tone-bearing unit (TBU). The normal tone association conventions subsequently apply, with the second tone associating to the third TBU, etc. Then, since the first TBU was skipped, a repair rule spreads the first tone leftward back to this TBU.

The same thing occurs in nouns. For example, the root in *mo-ɣatě* ‘bread’ (where the root is preceded by a noun-class prefix) belongs to the tone class LH. But instead of associating with the first root syllable, L associates with the second syllable along with H. Clements’s account for this form works as follows: The prefix (like all noun-class prefixes) contributes a low tone of its own. As with verbs, the first tone–here the prefix’s L–associates with the second TBU. This means that the first root syllable bears the L of the prefix, and the root’s final syllable bears the root’s LH. The first L then spreads leftward to the prefix.

Similarly, in Chichewa (Hyman & Mtenje 1999, Kanerva 1990, Moto 1983, Mtenje 1987, Myers 1999, Myers & Carleton 1996, Peterson 1987), it is claimed that “a high tone spreads rightward onto the following syllable *only if the high tone is not in the last three syllables of* *a phrase*" (Myers 1999:215; emphasis original). Mtenje (1987:174) specifically identifies this as a noniterative rule. Compare the pairs of examples in (3). In each pair, the first item has a high tone in the antepenultimate syllable of the phrase, and the tone does not spread. But when the phrase or word is lengthened, as in the second items, the high tone is no longer in the phrase's last three syllables, so it spreads to the following syllable:

(3)	a.	mtsíkaana	'girl'
		mtsíkána uuyu	'this girl'
	b.	zidzábeera	'they will steal x for/with you'
		zidzábéraana	'they will steal x for each other'

It is reasonably common to encounter diachronic explanations for this kind of phenomenon (e.g. Schuh 2007, Silverman 1997) grounded in "peak delay" (e.g. Myers 1999, Silverman & Pierrehumbert 1990). Spreading and shifting begin, as the claim goes, with tones spilling over into adjacent syllables. For shifting, eventually this leads to the pitch target being reached only in the adjacent syllable. A generation of learners encounters this situation and mistakenly assumes that these tones are actually moving or spreading, when they are actually simply not being articulated strictly within the boundaries of their host units. This is a straightforward and appealing explanation, but it leaves an important question unanswered: When these learners assume that they've encountered spreading or shifting, what exactly do they add to their grammars? That is, there may be clear diachronic reasons for these phenomena, but it remains a fact that speakers have some way of producing them in their synchronic grammars.

The most obvious solution is to posit a noniterative rule or other mechanism that produces the shifted tone.[1] But if noniterative mechanisms are unavailable to phonological grammars, as OT claims, this cannot be the correct solution. In this paper I argue that phenomena like Kikuyu's tone shift are phonetic at root. There is no active phonological process in Kikuyu that results in tones being associated one syllable to the right of their expected hosts. Rather, the phonetic pitch correlate of a tone is delayed, resulting in the pitch peak being realized on the following syllable.[2] This is the conclusion that Myers (1999) draws,

[1]However, if tone shift involves the lexical tone pattern in monomorphemic contexts (or solely within morphemes) in a language being shifted one syllable (or other unit) to the right compared to related languages, analysis is trivial. This is part of the situation in Kikuyu (Schuh 2007):

(i)	Mwimbi:	mòté	'tree'
	Kikuyu:	mòtě	'tree'

Compared to Mwimbi, it appears that the whole tone pattern in Kikuyu is shifted to the right. In languages where this is the entire story, the solution is rather simple: Lexical representations are simply different, and the surface forms reflect this. Unfortunately, this is not the entire story in Kikuyu, as the discussion above makes clear. Schuh (2007), in contrast, argues that a tone-shift pattern in Ngamo that is very similar to Kikuyu's pattern is purely a diachronic effect, in which case it is subject to this simple analysis.

[2]While I focus mainly on pitch peaks throughout this paper, the same goes for low-tones' pitch troughs, for languages that have phonological low tones. The analysis is easily extendable to other tone levels.

based on phonetic data, for Chichewa: The spreading illustrated in (3) is not phonological spreading, but rather phonetic encroachment of one syllable's H onto the next syllable.

However, while it might be tempting to chalk up tone shift to peak delay entirely and absolve phonologists from any analytical responsibility, there is evidence that peak delay is at least somewhat phonologically controlled. For example, while a historically final H in Kikuyu docks onto the word-final syllable to create a rising contour tone with the preceding shifted (and historically penultimate) L as in (4a), a historically final L does not appear on the final syllable. Instead, as (4b) shows, this displaced L remains afloat, as evidenced by the downstep it induces on the following word. The forms in (4c) verify that the initial words in in (4b) are responsible for the downsteps.

(4)	a.	moɣatɛ̌	'bread'
		némátɛ́ŋɛraɣǎ	'they run'
		némátómírɛ̌	'they sent'
	b.	moaɣáhiɲá ꜝné moɛɣá	'the weakling is good'
		kariokí ꜝné moɛɣá	'Kariũki is good'
		keaɣáraro ꜝné keɛɣá	'the stile is good'
		βiriβiri ꜝné ɲjɛɣá	'chillies are good'
	c.	moβake né moɛɣá	'the tobacco-plant is good'
		βaŋgírí né ɲjɛɣá	'bangles are good'

The downstep indicates that there is phonologically a floating L, and in fact this L is quite mobile under certain conditions (Clements & Ford 1981, Clements 1984, Clements & Ford 1979). For example, as Clements & Ford (1981) describe it, the downstep operator (which they do not explicitly identify as L, although other research cited in this paragraph makes this connection) may move from the right edge of a [+assertive] verb to the right edge of the verb's complement. This is illustrated in (5) with examples drawn from Clements & Ford (1981). In (5a), the matrix verb lacks a complement, so it induces downstep on the immediately following word. The verb in (5b) has a complement (*móɣɛraniá* 'examiner'), and its downstep operator moves to the other side of this complement and triggers downstep on the word after the complement. The same verb appears in (5c), but here it is not [+assertive]. Its downstep operator cannot move across the NP complement and therefore stays on the verb.

(5)	a.	nderáːkamírɛ	ꜝkiɲa	áꜝkéꜝrúɣá	mbɔ́ːcɔ́
		I-milked	until	he-cooked	beans

	b.	ndɔːnirɛ́	móɣɛraniá	ꜝðeíne	oá	ɲómba
		I-saw	examiner	inside		house

c. ndiɔní^{!}rɛ móɣɛraniá ðeíne oá ɲómba
I-didn't-see examiner inside house

Were the downstep-inducing L formally linked to the verb-final syllable in (5b), it would be expected to be bound to this word and unable to travel across the NP complement. It is therefore not tenable to claim that this L is phonologically associated with the word-final syllable while its associated pitch trough is simply unrealized by the phonetic component since there's no following syllable in the word. We must derive a phonological representation that includes a floating L.

Consequently, the analysis developed in this paper attributes what has been called tone shift to peak delay, but this peak delay is itself controlled by the grammar. This approach is very similar to the one taken by Gafos (1999), who uses formal constraints on articulatory gestures to produce phonological phenomena. An even closer predecessor is Xu & Wang (2001). The analysis below also builds on Morén & Zsiga (2006) and Zsiga & Nitisaroj (2007), who seek to transparently connect the seemingly complex pitch patterns in Thai to simple phonological representations, and especially Li (2003), who adopts constraints on phonetic implementation (as distinct from formal tone association) in an OT analysis of Mandarin tones. The upshot of the current analysis, with respect to (4b), is that the grammar blocks an L whose associated pitch contour will not be realized from being associated with any TBU. On the other hand, a high-ranking constraint banning floating high tones requires the creation of a contour in (4a).

Of course, the claim that Kikuyu's tone shift is inherently phonetic is subject to experimental verification. One interesting consequence of placing peak delay in the grammar is that a simple reranking of constraints can produce phonological tone shift under pressure from the constraints responsible for peak delay. This means that whether or not tone shift is purely phonetic, an analysis that treats it as driven by phonetic considerations can account for it.

I do not claim that this paper resolves the issue of noniterativity in tone once and for all, and certainly not for every language exhibiting a relevant phenomenon. Rather, this paper adds to research in this area by building on work suggesting that these phenomena reflect facts about phonetic implementation and not the languages' phonological grammars. The evidence for this view from two languages, Chichewa (Myers 1999) and Kinyarwanda (Myers 2003), is compelling. The analyses in this paper argue that it is worth viewing all noniterative tonal phenomena in this light, although whether all relevant cases are actually inherently phonetic remains an open question that can only be answered by future experimental work.

It is also worth emphasizing that I do not claim that all cases of tone spread/shift—bounded or not—fall under the purview of the PDT analysis developed below. Many phenomena submit to wholly different analyses, and I discuss some salient examples in §5 below. For example, tones are often attracted to specific position in a word such as the stem-initial or -penultimate syllable. Rather than coopting the analysis developed here for such phenomena, and it seems better to account for them with constraints requiring edge-alignment or coincidence with specific positions. PDT may eventually prove applicable to (some of) these cases, but here I wish to pursue the more modest hypothesis that they're relevant to phenomena for which one might be tempted to write a noniterative rule.

The paper is organized as follows: In §2, I discuss the existing research that establishes the reality of peak delay. In §2.2, I develop an analysis of Chichewa tone spread. In §3, this analysis is extended to Kikuyu. §4 addresses other proposed OT analyses of tonal noniterativity.

2 Peak Delay

2.1 Phonetic Delay of Pitch Targets

Peak delay is a phenomenon whereby the f_0 target for a tone is reached some time after the beginning of the syllable with which that tone is associated. The peak may appear sometime late in the host syllable, or it may appear in the following syllable—i.e., the f_0 target for a high tone need not fall within the (phonologically) high-toned syllable. (All studies of peak delay that I am aware of focus on high tones.) Both patterns may occur in a language. As I describe below, in both English and Chichewa, a high tone's peak by default appears in the syllable after the stressed or high-toned syllable, but under certain circumstances, it falls within that syllable.

Peak delay has been reported for a variety of languages, including English (Silverman & Pierrehumbert 1990, Steele 1986), Danish (Thorsen 1978), Navajo (deJong & McDonough 1993), Spanish (Prieto et al. 1995), Mandarin (Li 2003), and Chichewa (Myers 1999). Morén & Zsiga (2006) find perseverative coarticulation of tones in Thai that resembles peak delay, although they argue against peak delay as an explanation for that particular phenomenon. In this section I discuss the English and Greek cases. Chichewa is discussed in §2.2.

Silverman & Pierrehumbert (1990) investigate the timing of prenuclear H accents in English. They find that the corresponding f_0 peak appears at some regular interval after the beginning the stressed syllable (or more accurately, the beginning of the rime) with which the H is associated. The precise length of the delay depends on various factors. First, speech rate affects peak delay: When the stressed syllable is shortened in fast speech, peak delay is also shortened. Likewise, when slow speech increases the syllable's length, peak delay is also increased.

Second, word boundaries and stress clash affect peak delay. Word-final syllables are systematically lengthened, as are syllables at other syntactic and prosodic boundaries (e.g. Horne et al. 1995, Lehiste 1972, Lehiste et al. 1976, Lunden 2006, Oller 1973, Wightman et al. 1992), and a stressed syllable that immediately precedes another stressed syllable is lengthened. But whereas lengthening caused by speech rate increases peak delay, lengthening caused by word boundary-adjacency and clash result in a proportionally shorter delay. While the reason for word-final peak delay reduction is not immediately clear, reduction due to clash is plausibly a result of the need to articulate two pitch targets in close succession. This can be facilitated if the first of these targets is shifted leftward. (This explanation, called "tonal crowding" by Myers (1999), is among the ones that Silverman & Pierrehumbert accept as a possible model of their findings.) One of the two subjects in this study showed a gradient effect of clash: The closer the following stressed syllable is, the greater the reduction in peak delay.

If the stressed syllable is neither word-final nor subject to clash, the f_0 peak typically falls in the syllable after the stressed syllable. Both word boundaries and clash can push the peak leftward, back into the stressed syllable.

Arvaniti et al. (1998) find that the high-tone target of Greek's prenuclear accent, which they conclude is best represented as L+H*, "is very precisely aligned just after the beginning of the first postaccentual vowel" (23). They argue that peak timing is correlated with the duration of the interval from the onset of the accented syllable to the beginning of postaccentual vowel. That is, in ... [CV́C]V..., where V́ is the accentual vowel, the peak's timing is correlated with the bracketed interval. Arvaniti et al. argue this this model is better than a model that ties peak timing to the duration of the postaccentual vowel itself. The superiority of the first model over the second indicates that even though the tone's peak appears after the accented syllable, it is still timed with respect to (and perhaps associated with) that syllable. That is, we have a case of peak delay. Arvaniti et al. also argue that the peak's "alignment is probably phonologically, rather than phonetically, conditioned" (17) since it is aligned with respect to a phonological unit (the accented syllable) rather than a phonetic property of the utterance.

They also find tonal crowding for some speakers, whereby the prenuclear H is articulated earlier or with an attenuated pitch rise when another accent follows closely. Closeness of the following accent is determined by the number of intervening unaccented syllables, not a phonetic temporal measurement. Arvaniti et al. again point out that articulation of the prenuclear H is affected by phonological, not phonetic, factors. Their results are important for the analyses presented below because they establish that attributes that might be extra-grammatical artifacts of phonetic implementation (a lag in producing the target pitch, adjusting the articulation of one pitch target to facilitate articulation of the following target) are sensitive to phonological properties and may therefore be governed by the phonology itself. This is the position I take later in this paper.

Why does peak delay occur? Articulatory and perceptual answers are found in the literature. Myers (1999:224) speculates that "the vocal fold adjustments that determine f_0 modulation are more sluggish than the supralaryngeal gestures that define the syllable." In other words, executing a high tone's f_0 rise is inherently harder (as measured by the time required for gesture) than gestures associated with other phonological units. Other researchers (Ohala & Ewan 1973, Sundberg 1979) offer similar physiological explanations.

Myers also cites work showing that the rise in pitch, as opposed to the f_0 peak itself, is an important perceptual cue to the presence of a high tone. He notes that "f_0 cues are more easily perceived in regions of relative spectral stability, as in the midpoint of a vowel" (Myers 1999:224). Coordinating the f_0 rise with the end of the syllable places an important perceptual cue in a position that maximizes its perceptual salience. A side effect of this alignment is that the f_0 peak occurs late in the syllable or even in the next syllable.[3]

[3]Evidence, perhaps weak, for this hypothesis comes from the observation in Prieto et al. (1995) that when factors like clash and word or phrase boundaries trigger a reduction of peak delay in Spanish, rather than

If either hypothesis is correct, we have an answer to a puzzle: Why are apparently noniterative processes particularly common for tone compared to other domains? That is, why do we find many cases of tone shift/spread by one syllable, but so few cases in which, say, vowel height spreads or moves by just one syllable? If noniterative tone spread/shift is a consequence of peak delay, then the answer is that only tone is subject to the articulatory or perceptual factors that give rise to a lag in timing, or at least that these factors are greater for tone than for other phonological entities. The hypotheses sketched above predict either that the articulators that control pitch are more sluggish than those that control vowel height, or that perception of vowel height is less dependent upon alignment with some other acoustic unit.

2.2 Peak Delay in Chichewa

2.2.1 Tone Spread as Peak Delay

Myers (1999) applies the findings summarized in the previous section to purported tone spread in Chichewa. This language has a privative tonal contrast between H and ∅ (Kanerva 1990, Myers 1999); Myers (1999) notes that non-high-toned syllables have no pitch target, and instead acquire their pitch properties through interpolation from surrounding high-tone targets.

Both Kanerva (1990) and Myers (1999) take the tone-bearing unit of Chichewa to be the mora, yet the latter showed that tones are most reliably timed with respect to syllables. Mtenje (1987) adopts syllables or vowels as the TBU. I will adopt a compromise: The mora is the TBU, but constraints can make demands about tones' (and their corresponding phonetic implementations') syllabic constituency—i.e., constraints can require or prevent association with (moras in) particular syllables. Also, throughout the analysis, I distinguish abstract tones (H, L, M, etc.) with formal autosegmental associations to TBUs from their phonetic pitch implementations, which have no formal autosegmental associations (although the "belong" to particular tones, of course) but merely temporally coincide with other elements such as syllables (see also Xu & Wang 2001).

The data from (3), repeated and expanded in (6), illustrates how high tones spread one syllable rightward from a syllable that is not one of the last three syllables in a phrase.

(6) a. mtsíkaana — 'girl'
mtsíkána uuyu — 'this girl'

b. chigawée^{n}ga — 'terrorist'
chigawé^{n}gá iichi — 'this terrorist'

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the whole f_0 articulation being shifted leftward, the beginning of the pitch rise is held constant and the rising slope becomes steeper. This means that under pressure, the f_0 rise executed more quickly, showing that the normal, unshifted peak delay doesn't represent the speaker's fastest possible f_0 rise. However, this could also mean only that the default tonal articulation is comparatively sluggish but, like other gestures, can be sped up if necessary (e.g. under fast speech).

c. zidzábeera — ‘they will steal x for/with you’
zidzábéraana — ‘they will steal x for each other’

d. mte^{n}go wá dee^{n}gu — ‘price of basket’
mte^{n}go wá dé^{n}gu iili — ‘price of this basket’
mte^{n}go wá ^{n}thíwatiiwa — ‘price of ostrich’

e. tinabá dee^{n}gu — ‘We stole the basket.’
tinabá dé^{n}gu iili — ‘We stole this basket.’
tinabá ^{n}thíwatiiwa — ‘We stole the ostrich.’

The data in (7) further illustrate the lack of spreading from the last three syllables in a phrase:[4]

(7) dzíina — ‘name’
mtée^{n}go — ‘tree’

My understanding is that Kanerva’s (1990) Focal Phrase is the relevant phrasal category. Aside from the lack of tone spread, two processes are characteristic of the right edge of this phrase. First, phrase-penultimate vowels are lengthened, as can be seen in the data above. Second, phrase-final tones are retracted to the penultimate syllable:

(8) a. mle^{n}dó uuyu — ‘this visitor’
mleé^{n}do — ‘visitor’

b. pezá nyaama — ‘find the meat!’
peéza — ‘find!’

Both Myers (1999) and Kanerva (1990) transcribe retracted tones over the second half of (lengthened) penultimate vowels as in (8). Kanerva explicitly claims that this is the position to which tones retract (as opposed to the first half of the vowel), but Myers mentions some variability. He notes that two of his subjects produced retracted tones early in the penultimate syllable and thus exhibited neutralization with lexical penultimate tones such as those in (7). The third subject’s retracted tones were instead articulated later in the penultimate syllable. Myers suggests that the third subject retracted tones to the penultimate syllable’s second mora, which would motivate his and Kanerva’s transcriptions. The issue makes little difference for the analysis developed here, and I give transcriptions as they are provided by each author. But for simplicity, I adopt in my analysis the timing of Myers’s first two subjects with retraction to the first half of the long vowel. I will note analytical adjustments that are required by the other pattern (which I assume is a different dialect) where applicable. (See also Hyman & Mtenje (1999). While silent on the specific question at hand, they note that at least one dialect of Chichewa lacks retraction altogether.)

[4] No examples of phrase-final tones are available because such tones retract to the penultimate syllable.

Myers's experimental data suggest that "high tone spread" is better characterized as peak delay.[5] For high-toned medial syllables (i.e. those from which H can spread), the tone's peak is regularly achieved only in the following syllable (i.e. the target of spreading). But the timing of the peak is still correlated with properties of the first syllable, primarily that syllable's duration. Furthermore, if Chichewa has genuine (phonological) tone spread, we might expect peak duration to be longer in spreading contexts than in non-spreading contexts since tones in the former context are, by hypothesis, linked to two syllables while that latter are linked to just one. Myers points out that while one of his two subjects show this pattern, the difference in duration (26.2ms in spreading contexts, 21.3ms in non-spreading contexts) does not approach the 2:1 ratio that would be naively expected of H linked to two TBUs versus H linked to one TBU. For the other subject, these tones' durations were 23.0ms in spreading contexts and 25.1ms in non-spreading contexts. This difference trends in the wrong direction, but it is not statistically significant. The importance of the second subject's data is that it does not remotely exhibit the expected timing difference.

From these data, Myers concludes that H does not in fact spread. It is formally associated only with its original host syllable, but phonetic implementation of the H leads to the impression that spreading has occurred.

Myers also has explanations for the lack of (supposed) spreading from the final three syllables in a phrase. First, spreading from phrase-penultimate syllables is not reported by transcribers because these syllables are lengthened. This means that even with peak delay, a penultimate high tone's peak is contained within its host syllable. That is, with penultimate lengthening, peak delay does not result in the peak falling in the following syllable. Furthermore, both Silverman & Pierrehumbert (1990) and Myers (1999) found a reduction of peak delay in lengthened syllables, a pattern which would increase the likelihood that a penultimate H's peak would appear in that syllable.[6]

Spreading from phrase-final syllables is unattested because H in this position is retracted to the penultimate syllable (see (8) above). An explanation of these tones reduces to the explanation given in the previous paragraph. (The same sort of measurements that lead Myers to conclude that spreading doesn't occur leads him to the conclusion that retraction is a real phonological process: Phrase-final H is timed with respect to the penult.)

Finally, Myers (1999) speculates that the lack of spreading from antepenultimate syllables is due to "tonal crowding." Other researchers (Arvaniti et al. 1998, Silverman & Pierrehumbert 1990) have found that "peak delay is reduced if another f_0 target immediately follows" (Myers 1999:225). Boundary tones at the end of the phrase could lead to a reduction of peak delay in nearby syllables. Since Silverman & Pierrehumbert (1990) observed tonal crowding even when the two high tones were not syllable-adjacent, it is not unreasonable to think that it is applicable to Chichewa's antepenultimate syllables. See Myers (2004) for discussion of the long-distance effects of boundary tones. Tonal crowding may also contribute to the lack of spreading from penultimate syllables.

[5] DeJong & McDonough (1993) make the same conjecture about Navajo.

[6] For the dialect with retraction to the penultimate syllable's second mora, the lack of spreading can be attributed to tonal crowding (see below) and the reduction of peak delay in lengthened syllables.

Another factor that Myers doesn't consider is the phrase boundary itself. Prieto et al. (1995) report that in Spanish, the closer a stressed syllable is to the end of a phrase, the shorter the observed peak delay becomes. This may also help explain the lack of spreading in the last three syllables of a phrase in Chichewa.

2.2.2 Peak Delay in the Phonology

If the conclusions Myers draws are accurate, we can eliminate spreading from phonological analyses of Chichewa and let phonetic implementation produce peak delay. But as I noted above, there is evidence from Kikuyu that the phonological grammar is sensitive to peak delay: In that language, when tone shift leaves a final L with no TBU, that L floats, creating a downstep on the following word. If tone shift in Kikuyu were merely peak delay with unshifted tones, there would be no reason for this L to float, and therefore no explanation for downstep. Instead, I argue in the next section that Kikuyu's grammar prevents tones from associating with TBUs if peak delay would leave that tone unpronounced. The "shifted" pattern in Kikuyu involves unshifted tones with peak delay, but if peak delay is to trigger floating low tones in certain environments, then peak delay must be phonologically active.

Since we need to implement peak delay formally for Kikuyu, there is no reason we cannot do the same for Chichewa. To begin, let's adopt a constraint that requires peak delay in the first place:

(9) PEAK DELAY (PD): The f_0 rise for a high tone must be allotted an adequate duration.

This constraint ensures that an output allots enough time for the rise in pitch to be successfully executed; an effect of this constraint is that the onset of the pitch excursion (the point at which the rise—or fall, in the case of low tones—in f_0 begins) and the f_0 peak are sufficiently separated. If the onset is anchored to the tone's host syllable, this produces peak delay because the f_0 peak must be held back until PEAK DELAY is satisfied. Li's (2003) RISETIME and FALLTIME families of constraints are similar to PEAK DELAY in that they favor the allotment of certain durations for phonetic rises and falls. In some respects, PEAK DELAY is a more nuanced version of Hyman's (2005) LAG, which requires a tone's target to be reached in the syllable after the tone's host; see §4.2.

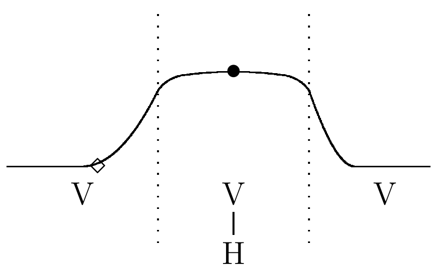
What is "an adequate duration?" Myers (1999:222) states that peak delay "varies systematically as a function of syllable duration," and he gives linear regression models that formalize this function. The model in (10), for example, is the model that (according to Myers) best accounts for the data from his subject SM.

(10) Peak delay $= (((-.88P) + 1.43) * S) - 3.89$
where $P =$ syllable position (0 for medial, 1 for penult) and $S =$ syllable duration

I'll assume that PEAK DELAY references a function such as this one and assigns violations to candidates whose peak delay is not within some window around this function's output. For a more nuanced view of how this sort of timing requirement might be modeled, see Byrd (1996) and Browman & Goldstein (1986). It might also be possible to build the timing specifications directly into the constraints themselves, as Li (2003) does.[7] To simplify Tableaux, I will make the idealistic assumption that a violation is incurred when the peak and onset are contained within the same light syllable or the same half of a heavy syllable. Equivalently, the onset and peak must not coincide with the same mora.

Peak Delay says nothing about where the pitch excursion occurs with respect to the larger phonological structure. There are a number of imaginable strategies that would or would not satisfy this constraint. For example, the peak could overlap with the tone's host syllable, forcing the pitch excursion's onset leftward into the preceding syllable to comply with Peak Delay. This is illustrated schematically in (11), where dotted lines represent syllable boundaries and curves represent idealized pitch tracks. To aid interpretation of the pitch tracks, the symbol $\diamond$ marks approximate onset locations and $\bullet$ marks approximate peak locations. These markers are merely an expository convenience and should not be interpreted as formal claims about where tonal articulations begin and end.

(11)



(It's important to note that this diagram and the ones below are merely idealizations that illustrate only the possible relative timing of peaks, onsets, and TBUs in a coarse way. I abstract away from factors like downdrift (Hyman & Schuh 1974). See, e.g., Myers (1999, 2003) for actual pitch tracks whose details I abstract away from here.)

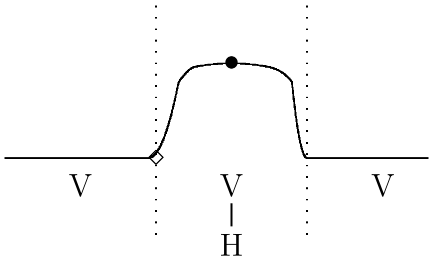
This is not such an outlandish proposition. Myers (2003) shows that this is exactly what happens in Kinyarwanda, which has traditionally been analyzed as having (typologically unusual) leftward tone spread. As with Chichewa, Myers argues instead that the peak of a supposedly spread tone is timed with respect to the original host syllable. He further finds that peaks in Kinyarwanda appear quite early in their host syllables (earlier than is shown in (11)), often even before the vowel begins. This means that the pitch excursion's onset must overlap with the preceding syllable, giving transcribers the impression of spreading.[8]

Another option is that the peak and the corresponding onset could both appear in the host syllable, as in (12). This is presumably the situation in languages that have neither Chichewa/Kikuyu-style peak delay nor Kinyarwanda's onset anticipation—that is, languages

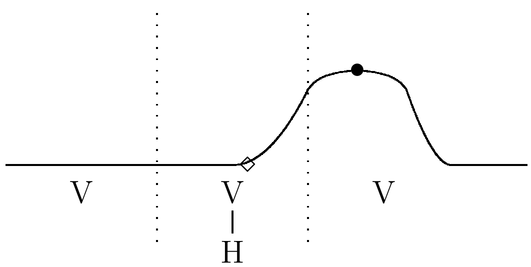
[7] However, Li's constraints, which mention specific intervals such as 120ms, lose the connection that peak delay has to factors such as syllable duration. And since those constraints specify minimum durations, another constraint is needed to prevent excessively long rises and falls. The windowed approach of Peak Delay simplifies matters by building maximum and minimum durations into one constraint.

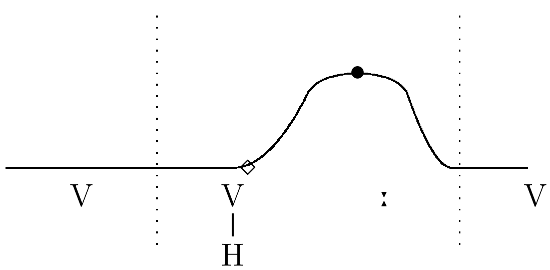
[8] Although this paragraph—and Myers's research—suggests a close connection between leftward and rightward tone spread, others, such as Hyman (2004), argue that these processes result from quite different factors.

in which (in traditional terminology) tones neither spread nor shift. This configuration violates PEAK DELAY.

(12) 

Finally, the onset itself could be aligned with the host syllable with PEAK DELAY bumping the peak into the following syllable if the host syllable is too short. This is what happens in Chichewa. The onset occurs in the host syllable, and the peak falls some time after that. If the syllable is short, the peak appears in the following syllable (13a), but if the syllable is long, the peak appears in the host syllable (13b).

(13) a. 

b. 

To produce this variety of timing patterns, I adopt the Coincide constraints in (14) (Zoll 1998, 2003).

(14) a. COINCIDE(Peak, $\acute{\sigma}$): Every f_0 target coincides with a syllable with which the target's tone is associated.

b. COINCIDE(Onset, $\acute{\sigma}$): Every pitch excursion's onset coincides with a syllable that hosts the target peak's tone.

What is the justification for these constraints? COINCIDE(Peak) ensures that phonetic implementations of phonological tonal representations closely mirror those representations: An association between a syllable and a high tone is most transparent when that syllable is articulated with a high f_0. See also Li (2003), whose Align-Lo and Align-Hi align tones' articulations with one or another syllable edge or contrast preservation purposes.

On the other hand, Myers (1999) and Zsiga & Nitisaroj (2007) cite work (such as House (1990)) showing that the transition leading to the high f_0 is an important cue to the presence of a high tone. It is therefore perceptually beneficial for the onset fall saliently within the high-toned syllable, as Coincide(Onset) requires, because this is a good signal that a high tone is present. Similarly, Morén & Zsiga (2006) argue that tones' pitch peaks in Thai are aligned with the right edges of moras. One way to produce this pattern (although Morén & Zsiga propose no formal account themselves) is to require onsets to appear within the time span that corresponds to each mora.

More generally, Zsiga & Nitisaroj (2007) show that the timing of various pitch landmarks with respect to (sub)syllabic landmarks affects listeners' perceptions of tones in Thai. It is therefore important that speakers achieve the correct alignment, and the constraints in (14) are two of the constraints that can ensure proper placement of pitch landmarks within syllables.

The Chichewa pattern, with the peak surfacing on the syllable after the one associated with H, is produced with Coincide(Onset) and Peak Delay outranking Coincide(Peak). This is shown in (15). Underlining marks the extent of the phonetic implementation of the tone from onset to peak, with the peak marked by double underlining.

(15)

/zidzáberaana/	Ident-T	PD	Coincide(Onset)	Coincide(Peak)
☞ a. zidzáberaana				*
b. zidzáberaana		*!		
c. zidzáberaana			*!	
d. zidzábéraana	*!			

A couple notes: I make the simplifying assumption that tones are underlyingly specified on their original hosts, i.e. their hosts before (what is traditionally called) tone spread occurs and, in other Tableaux below, before retraction from a phrase-final syllable occurs. Maintenance of these underlying associations is enforced by Ident-T, which is really a cover constraint for whatever system is responsible for this initial tone assignment. See Peterson (1987) for a rule-based analysis of tone assignment in Chichewa's verbal system. Also, since the claim advanced here is that high-tone spread is really just peak delay, the optimal form in this and subsequent Tableaux has a high-tone diacritic over just one vowel, contrary to the traditional transcriptions in (3).

Candidate (a) is the winner: The H stays put on the second syllable (Ident-T is satisfied), and articulation of the tone is initiated in that syllable; i.e. the onset occurs in that syllable as required by Coincide(Onset). But the peak occurs in the following syllable, satisfying Peak Delay and violating Coincide(Peak). In candidate (b), the entire articulation of the tone is contained within the high-toned syllable. This satisfies the Coincide constraints but fatally violates Peak Delay. Candidate (c) satisfies both Peak Delay and Coincide(Peak) by shifting the tone's onset into the preceding syllable. But since Coincide(Onset) outranks Coincide(Peak), this is a losing strategy. Finally, candidate (d) satisfies Peak Delay and the Coincide constraints by adding an association between H and the syllable after its underlying host. With this configuration, the onset and peak can be in separate syllables while each component still appears on a syllable formally linked to H. Unfortunately, this runs afoul of the highly ranked Ident-T, which penalizes the new association.

When the tone's host syllable is long, as in (16), there is no conflict between Peak Delay and the Coincide constraints. With a long syllable, both the peak and the onset may appear in the host syllable and still be sufficiently separated to satisfy Peak Delay. (16) illustrates this with a lexical—i.e. non-retracted—penultimate H:

(16)

/kuɲéeɲa/	Ident-T	PD	Coincide(Onset)	Coincide(Peak)
☞ a. kuɲéeɲa				
b. kuɲéːɲa				*!
c. kuɲéeɲa			*!	
d. kuɲéeɲá	*!			

To prevent the peak for an antepenultimate high tone from landing in the penultimate syllable (*mtsíkaana* 'girl'), we need an additional constraint. Recall Myers's (1999) suggestion that "spreading" in this situation is blocked by tonal crowding: The phrase ends with a boundary tone (%H for questions and nonfinal phrases and %L for utterance-final phrases, both represented as %T below), and to keep the lexical tone and the boundary tone from being too close, the lexical tone fails to spread. More accurately, under the current analysis, a smaller peak delay than normal is used. This is straightforwardly captured with the constraint in (17):

(17) *Crowding: The peak of a lexical tone cannot occur within a syllable that is adjacent to a syllable in the same Focal Phrase that hosts a boundary tone.

If we assume (uncontroversially?) that boundary tones are associated with phrase-final syllables, then *Crowding will affect only tones on the last three syllables of a phrase. Normal peak delay with an antepenultimate tone is blocked because this would place the tone's peak in the penult, which is of course adjacent to the phrase-final syllable.

It is important to note that *Crowding is not an OCP constraint. It does not militate against adjacent identical phonological units. Instead, it makes demands of a lexical tone's phonetic implementation in the environment of a boundary tone, without regard for where the lexical tone is formally associated. Also, H is repulsed by both H% and L%—this is not an OCP-like effect because the OCP bans adjacent *identical* elements. The OCP appears elsewhere in Chichewa's tonology, as I discuss in §2.2.3 below.

*Crowding, Ident-T, and Coincide(Onset) must all outrank Peak Delay because together they conspire to eliminate the normal delayed peaks with antepenultimate tones. *Crowding blocks peak delay in this position, and Ident-T prevents these tones from relocating to an earlier position where *Crowding won't penalize a delayed peak. Coincide(Onset) prevents onsets for antepenultimate tones from being shifted leftward, a strategy that would satisfy both Peak Delay and *Crowding. This is illustrated in (18).

(18)

/zidzábeera %T/	Id-T	Coincide(Onset)	*Crowd	PD	Coincide(Peak)
a. zidzábeera %T			*!		*
☞ b. zidzábeera %T				*	
c. zidzábeera %T		*!			
d. zídzabeera %T	*!				*

The ranking Ident-T, Coincide(Onset) ≫*Crowd is justified immediately below. Candidate (a) is the normal peak delay candidate, but with the boundary tone looming, *Crowding eliminates this form: The peak cannot be postponed to the following syllable. Candidate (c) obeys this requirement by shifting the onset to the left. This only violates Coincide(Onset), but this violation is fatal. Compare this form to the winner, candidate (b). Whereas candidate (c) opts to satisfy *Crowding at the expense of Coincide(Onset), candidate (b) does so at the expense of Peak Delay. Since candidate (b) is the correct form, we must have the ranking Coincide(Onset) ≫Peak delay. Finally, candidate (d) shifts the high tone left one syllable, where *Crowding cannot block the normal peak delay. This strategy is ruled out by Ident-T.

*Crowding has no effect on the outcome of (15) because the tone's host syllable is not within three syllables of the phrase-final boundary tone. This constraint also doesn't affect (16): With Ident-T and Coincide(Onset) outranking *Crowding, H on the penultimate syllable cannot be shifted leftward without violating Ident-T, and its phonetic implementation cannot be adjusted without violating Coincide(Onset).[9]

There is one more piece to the analysis. Recall that a phrase-final H retracts to the previous syllable. Myers (1999) argues that this is a genuine phonological operation rather than phonetic manipulation of f_0 timing. Like Myers (1999), I account for this with a NonFinality constraint:

(19) NonFinality: H may not occur on the phrase-final syllable.

It's possible that retraction is just a more drastic product of tonal crowding whereby the affected tone actually moves instead of having its associated peak delay shortened. Philipp-

[9]It is likely that tonal crowding has some effect on penultimate tones, reducing their peak delay somewhat if not actually changing which syllable hosts the f_0 peak. This can be accounted for by fine-tuning *Crowding so that it assigns gradient violations depending on just how close the lexical and boundary tones are.

son (1998) argues that retraction is actually attraction of the H to the penultimate stressed syllable. The desired result could also be produced by banning H from phrase-final moras instead of syllables. As the precise nature of retraction is inconsequential for the analysis developed here, I adopt the NonFinality approach while acknowledging the plausibility of competing analyses.

NonFinality must outrank Ident-T since, unlike *Crowding, NonFinality induces changes to a tone's formal associations. I also assume a high-ranking Max-Tone, which prevents satisfaction of NonFinality through deletion of the offending H. The Tableau in (20) shows the effect of NonFinality.

(20)

/peezá/	NonFin	Ident	Coin(Onset)	*Crowd	PD	Coin(Peak)
a. peezá	*!			*	*	
b. peezá	*!		*	*		
☞ c. péeza		*		*		

Candidates (a) and (b) both fatally violate NonFinality because the high tone is formally associated with the final syllable in these forms. As these candidates demonstrate, it doesn't matter how the peak and onset are aligned; phrase-final high tones are disallowed. The only solution is to retract the H to the preceding syllable, where the timing of the peak and onset proceeds exactly as in (16) as if the H were underlyingly penultimate.[10]

The ranking arrived at in this section produces the range of facts relevant to alleged tone spread in Chichewa. Rather than generating phonological spreading, this analysis derives the peak delay uncovered by Myers's (1999) phonetic studies. Whereas Chichewa is traditionally described as having noniterative tone spread, careful phonetic study reveals that "spreading" is really peak delay that places the tone's f_0 peak in the following syllable. (However, for expository convenience, I will continue to refer to Chichewa's peak-delay phenomenon as tone spread.)

The next section presents additional evidence in favor of the peak-delay approach.

2.2.3 Peak Delay and the OCP

Evidence that Chichewa's tone spread is phonetic comes from its interaction with the OCP (Leben 1973). As Kanerva (1990) shows, adjacent high tones are generally not permitted in Chichewa. Like many other Bantu languages, Chichewa has a process, known as meeussen's Rule, by which the second of two high tones that are linked to adjacent TBUs is deleted.[11]

[10] Retraction to the syllable's second mora can be produced with constraints requiring minimal displacement of the tone. Alternatively, following Myers (1999), we can take this dialect to represent minimal satisfaction of NonFinality and adopt constraints against $\emptyset$H syllables (i.e. rising tones) for the dialect with retraction to the first mora.

[11] In certain conditions, the second H instead shifts rightward. I do not discuss this process here; see Chapter 6 of Kanerva (1990).

This (as Kanerva points out) is probably best understood as an effect of the OCP. (21) illustrates the deletion pattern.[12]

(21)	a.	on-aan-a	‘see each other’
		on-aán-e	‘see each other (subjunctive)’
	b.	^{n}d-aa-dya	‘I-Perf-eat’
		^{n}d-a-líi-dya	‘I-Perf-5OM-eat’
	c.	^{n}di-líi-dy-e	‘I-5OM-eat-subjunctive’

The data in (21a) show that the subjunctive *-é* is high-toned. (Since these are citation forms and hence phrase-final, this H retracts.) Next, (21b) shows that the object marker *-lí* is also high-toned. But when these morphemes appear in adjacent syllables, as in (21c), only the object marker's H surfaces. We might expect a form like **^{n}di-líí-dy-e*, where the subjunctive morpheme's tone retracts to the penultimate vowel, but since this results in two high tones on adjacent moras, the second one deletes.

As another example, (22a) shows that the reflexive object marker *-dzi-* carries a high tone (which undergoes the expected spreading) and assigns another high tone to the stem-penultimate syllable. But as (22b) shows, when the verb stem is monosyllabic, only the morpheme's own H surfaces. The one it assigns to the stem deletes because it is adjacent to the first H, either before penultimate lengthening (/y-a-dzí-dyá/) or after retraction (/y-a-dzíí-dya/). Kanerva (1990:§2.2.4) provides ample additional evidence for OCP-induced deletion.

(22)	a.	l-a-lemekeeza	‘5-Perf-respect’
		l-a-dzí-lémekéeza	‘5-Perf-Refl-respect’
	b.	y-a-dzíi-dya	‘9-Perf-Refl-eat’
		z-a-dzíi-pha	‘10-Perf-Refl-kill’
		u-ka-dzíi-^{m}va	‘3-Cond-Refl-hear’

However, when two high tones occupy adjacent TBUs as a consequence of tone spread, no deletion occurs:

(23)	a.	/bírimá^{n}khwi/	→ bírímáa^{n}khwi	‘chameleon’
	b.	/^{n}dí-ta-phíka/	→ ^{n}dí-tá-phíika	‘I-sequence perf.-cook’
	c.	/ch-a-dzí-sekétsa/	→ ch-a-dzí-sékéetsa	‘7-Perf-Refl-laugh.Caus’
	d.	/mte^{n}go wá galú uuyu/	→ mte^{n}go wá gálú uuyu	‘price of this dog’
	e.	/y-á-i-kúlu/	→ y-á-í-kúulu	‘4-Asc-4-big’

The noun in (23a) has underlying initial and penultimate high tones. In (23b), the tense marker *ta* assigns Hs to both the preceding and following syllables (indicated above as underlying tones). In (23c) the reflexive morpheme *-dzí-* bears H itself and assigns another H

[12]Glosses follow those in Kanerva (1990). Numerals represent subject or object noun classes. For example, the morpheme *lí* ‘5OM’ (which undergoes penultimate lengthening) is the noun-class 5 object marker.

to the verb stem's penultimate syllable. In (23d), the associative marker *wá* and the following noun each has a lexical H. Finally, (23e) is an adjective, and I have been unable to find the details of its derivation or a full explanation of its gloss in Kanerva (1990), from which this form is taken. Nonetheless, Kanerva gives *y-á-i-kúlu* as the form's representation before spreading and penultimate lengthening occur. In all of these examples, the first H spreads to the syllable immediately before the second H. The resulting ostensible OCP violation is not rectified.

The analysis of tone spread adopted here predicts these facts. Rather than exhibiting (formal, phonological) tone spread, the examples in (23) display peak delay: The peak of the first high tone has been pushed into the syllable preceding the second high tone. The first high tone is not formally associated with the syllable before the second high tone, so there is no OCP violation, and deletion is not motivated. The representations in (24) show the forms in (23) as they are produced by the peak delay analysis. As above, underlining represents the alignment of various pitch landmarks.

(24)
- a. bírimáa^{n}khwi
- b. ^{n}dí-ta-phíika
- c. ch-a-dzí-sekéetsa
- d. mte^{n}go wá galú uuyu
- e. y-á-i-kúulu

In a derivational approach, the correct tone patterns can be produced by ordering meeussen's Rule before tone spread (i.e. in a counterfeeding relationship). But this ordering is arbitrary[13]—the tone retraction rule could just as well be ordered after meeussen's Rule instead, and we'd find forms like **y-a-dzí́í-dya* instead of (22b). For the peak delay approach, there is a principled reason that tone spread doesn't trigger meeussen's Rule while tone retraction does: Only the latter actually manipulates tones' associations, so of the two processes, it is the only one that might produce a configuration with two high tones formally associated with adjacent syllables.

Kanerva (1990) posits another rule that is puzzling from the point of view of the OCP. When two high tones are separated by one mora, the first spreads to the intervening mora to create a plateau. In support of this, Kanerva (1990:65) gives data such as the following:

(25)	a.	/mte^{n}go wá galú/	→ mte^{n}go wá gáálu	'price of the dog'
	b.	/tinabá galú/	→ tinabá gáálu	'We stole the dog.'
	c.	/ti-dzá-pezá/	→ ti-dzá-pééza	'we-Fut-find'

In each case, the final H retracts to the penultimate mora, and the first H spreads. This is not the same as the tone spread phenomenon considered above. The plateau process occurs even in the final three syllables of a phrase, and it requires an H after the spreading tone. Its effect is to create two high tones that are associated with adjacent TBUs, in direct contravention of the OCP. We seem to have a contradiction: Chichewa schizophrenically

[13]It is also opaque, making it a marked ordering under the assumptions of Kiparsky (1971, 1973).

both actively eliminates such configurations (via meeussen's Rule) and actively produces them (via plateau).

Myers (1999) notes, however, that there are no low-pitch targets in Chichewa (hence the H vs. ∅ rather than H vs. L tonal distinction). Syllables that are not specified as high-toned acquire their pitch values through interpolation. A toneless syllable between high tones will not have a pitch trough that is as pronounced as the trough in a similar syllable that is between other toneless syllables. In fact, one interpretation of the data in (25) is that a toneless syllable between two high-toned syllables shows sufficiently little pitch decrease as to be (impressionistically?) indistinguishable from a high-toned syllable. That is, the two high-pitch targets are not sufficiently separated to permit a noticeable descent toward neutral pitch. The plateau phenomenon is not a phonological rule, but a product of interpolation caused by two nearly adjacent high-tone targets and no intervening low pitch target. This interpretation resolves the conflict mentioned in the previous paragraph by relegating the apparently OCP-flouting tone spread process to a non-phonological status; that is, by invoking interpolation, we can eliminate the rule that creates configurations that the language otherwise avoids. The forms in (25) comply with the OCP because there is in fact a mora separating the two high tones.

This is not the only possible characterization of plateau, of course. The OCP violation may be resolved by fusing the two high tones (as suggested by the lack of downstep between them; (Bickmore 2000, Odden 1982)), although it is not clear why plateau induces fusion but other OCP violations trigger deletion. In other languages such as certain dialects of Emakhuwa (Cassimjee & Kisseberth 1999a,b), plateau effects are sensitive to morphological and moraic structure, and they can trigger or block other phonological processes. Such behavior points strongly toward a phonological plateau and away from interpolation.

In any case, the interest of these plateaus in the present context is that they do not surface when the configuration that triggers them is produced by tone spread. That is, high-tone spreading could in principle feed plateau creation, but it does not (cf. Lukhayo (M. Marlo p.c.), where such feeding does occur). This is shown in (26).

(26)	a.	/tinabá kalulú/	→ tinabá káluúlu	'We stole the hare.'
	b.	/mu-ná-lemerá/	→ mu-ná-lémeéra	'you.pl-past-be heavy'

Even though tone spread and retraction create two high-toned syllables that are separated by just one toneless mora, no plateau appears. This is not unexpected if both spreading operations involve manipulations of pitch contours rather than formal tone associations. If tone spread is just peak delay, then the two high-pitch targets are separated by two syllables. This means that pitch interpolation will not give rise to the appearance of a plateau: With more than one syllable between the two pitch targets, there is time for the pitch to drift toward the neutral position between these targets.

A derivational approach can account for (26) by ordering tone spread after creation of the plateau. But once again, this ordering is arbitrary and opaque, whereas no comparable arbitrary assumptions are needed under the peak delay analysis.

The next section addresses the other timing patterns discussed above: the lack of tone spread (12) and Kinyarwanda's (supposed) rightward spread (11). Reranking the constraints adopted for Chichewa produces these patterns.

2.3 Other Timing Patterns

Languages with no tone spread or shift—the situation represented by (12)—are produced with the ranking in (27).[14] This example, from Ruciga (Cassimjee & Kisseberth 1998), contains one high tone. There is no spreading or shifting of this tone. (Cassimjee & Kisseberth (1998:16) state that the output in (27) is correct when this word stands in "medial position before a toneless modifier.") The onset and peak are once again indicated with underlining.

(27)

/e-ságama/ 'blood'	IDENT-T	COINCIDE(Onset)	COINCIDE(Peak)	PD
a. eságama			*!	
☞ b. eságama				*
c. eságama		*!		
d. eságáma	*!			

This time, it is more important for the onset and peak to be contained within the host syllable than to have an adequate peak delay. Another way to produce this pattern would be to make the plausible assumption that the function that informs PEAK DELAY is determined on a language-particular basis. This means that PEAK DELAY might be less stringent in other languages so that it is satisfied by configurations in which the onset and peak are tautosyllabic, so even a language with a highly ranked PEAK DELAY might exhibit no spreading or shifting.

For Kinyarwanda (11), where a tone's onset appears in the syllable before the one with which the tone is associated, COINCIDE(Peak) and PEAK DELAY must outrank COINCIDE(Onset) (this example is from Myers (2003)):

(28)

/umusóre/ 'youth'	IDENT-T	COINCIDE(Peak)	PD	COINCIDE(Onset)
a. umusóre		*!		
b. umusóre			*!	
☞ c. umusóre				*
d. umúsóre	*!			

[14]This is not to deny that a language may have "faithful" tone in general with specific movement, shifting, etc., operations in particular contexts. In such languages, the ranking in (27) holds, but higher constraints can subvert the faithfulness that this ranking promotes.

To reiterate, the pitch tracks in (11) and (12) are broad templates. Other factors surely influence the specific realization of these onset and peak alignments so that two languages with the same alignment pattern may show rather different phonetic properties.

2.4 Summary

This section has demonstrated how an analysis whose constraints manipulate the phonetic implementations of tones can generate what has been called tone spread in Chichewa. The crucial constraint is Peak Delay, which produces the relatively late attainment of the tone's f_0 target that, according to Myers (1999), has misled researchers to posit tone spread in this language. The significance of this analysis is that it produces the correct forms without recourse to a noniterative spreading rule or constraint. In fact, the analysis developed here follows Myers (1999) in denying that tones spread in Chichewa, whether noniteratively or not. This analysis also follows Morén & Zsiga (2006) and Li (2003) in that it proposes a phonological account of what is, at heart, a phonetic phenomenon. In Morén & Zsiga's (2006) analysis of Thai, they argue that pitch peaks are right-aligned with moras and develop an OT account that positions tones on the moras with which their peaks are aligned. Like Li (2003), the analysis developed here takes this a step farther by adding the alignment of pitch landmarks to the phonology.

The Chichewa facts could be produced without building peak delay into the phonological grammar and instead attributing it to the automatic translation of phonological forms into articulatory gestures. But the next section, which discusses tone shift in Kikuyu, reveals the necessity of placing peak delay within the phonology.

3 Kikuyu

Recall that a pervasive characteristic of Kikuyu is the shifting of tones one syllable to the right of their underlying hosts. The data from (1) and (2) are repeated below. The tone of each morpheme varies according to the identity of the preceding morpheme. We can tell that morphemes such has *-ma-* and *-tom-* are lexically specified with high tones, even though *-ma-* and *-tom-* may themselves surface low-toned, because when these morphemes appear, the following morpheme is always high-toned.

(29)	a.	to rɔr aɣ a	'we look at'
		to mo rɔr aɣ a	'we look at him/her'
		to ma rɔ́r aɣ a	'we look at them'
		má rɔ́r aɣ a	'they look at'
		má mó rɔr aɣ a	'they look at him/her'
		má má rɔ́r aɣ a	'they look at them'
	b.	to tom áɣ a	'we send'
		to mo tom áɣ a	'we send him/her'

to ma tóm áɣ a	'we send them'
má tóm áɣ a	'they send'
má mó tom áɣ a	'they send him/her'
má má tóm áɣ a	'they send them'

This is simple enough to account for in rule-based terms. The analyses of Clements & Ford (1979) and Clements (1984) are grounded in a rule whose effect is shown in (30), where 'τ' represents TBUs and 'T' represents tones.

(30) $\left[\begin{array}{l} \tau\ \ \tau \\ \mathrm{T} \end{array}\right.$

This rule, which is the first tone rule that applies in their derivations, links the first tone to the second TBU. As subsequent tones link to available TBUs to the right of the second TBU, the eventual effect of (30) is to link tone n to TBU $n+1$; That is, each tone appears one TBU to the right of its expected placement.

But we cannot easily translate (30) into an OT constraint. The constraint producing tone shift must be a markedness constraint (since tone shift is clearly not the exponent of some faithfulness imperative), but there is no obvious markedness consideration that would motivate the first tone associating with the second TBU.

Fortunately, the peak delay facts discussed in §2 afford a solution. Without detailed phonetic information for Kikuyu of the sort that Myers (1999, 2003) provides for Chichewa and Kinyarwanda, it is impossible to know whether Kikuyu's tone shift is phonetic or phonological in nature. Consequently, this section develops two analyses of Kikuyu tone shift, one that takes shifting to reflect peak delay, and another that produces phonological shifting of tones from one TBU to the next. Both are driven by Peak Delay. In the first, the analysis claims that Kikuyu's tone shift is identical to Chichewa's tone spread. The reason one is characterized as shift and the other as spread is due to Kikuyu having the phonologically active low tone that Chichewa lacks. The second minimally alters the ranking of the first analysis so that tones' formal associations follow their delayed peaks.

The section proceeds as follows: §3.1 presents additional data to be accounted for. §3.2 presents the phonetic analysis, and §3.2.2 shows how this analysis can produce the downstep facts illustrated in (4). §3.3 presents the analysis that takes tone shift to be phonological. §3.4 discusses how long vowels interact with tone shift.

3.1 Tone Shift in Kikuyu

Unlike Chichewa, Kikuyu has a phonological low tone: H contrasts with L rather than with the absence of tone. (Not every morpheme contributes a tone, so there are still toneless morphemes. But every syllable surfaces with some tonal specification.) The data below are taken from Clements & Ford (1981, 1979) and Clements (1984). For simplicity, I only indicate high tones except where this would create ambiguity.

Clements & Ford (1979) and Clements (1984) develop rule-based analyses of tone assignment in Kikuyu that are centered around tone shift. In this section I follow the latter's discussion of the data. I also follow Clements (1984) in adopting the syllable as the TBU (see also Kaplan (2007)).

The verbs in (29) illustrate tone shift, as do the nouns below:[15]

(31)	a.	LL	kemore	'torch'
	b.	LH	moɣatɛ̌	'bread'
	c.	HL	moɣɛká	'rug'
	d.	HH	maɣɔkɔ́	'bark'
	e.	LHL	kaɲamǒ	'small animal'
	f.	HLHL	karání́	'clerk'

Each noun stem contributes a specific tone pattern (indicated in the leftmost column in (31)), and the noun-class prefix—the initial CV sequence in these examples—contributes an additional low tone. Tone assignment proceeds as follows: The first tone—the L of the noun-class prefix—associates with the second syllable of the noun as required by (30). Subsequent tones associate to each of the following TBUs in a one-to-one, left-to-right fashion, with the last tone spreading to excess TBUs. The first tone spreads leftward, back to the word-initial syllable that was originally skipped. If there is a free H after all TBUs have been assigned a tone, this H docks on the final syllable, creating a contour as in (31b) and (31e). Free low tones remain floating and induce downstep, as was shown in (4) above. See also §3.2.2. To illustrate the tone-assignment schema, these rules yield the structure in (32) for (31e).

(32) ka ɲa mo

L L H L

The exceptional behavior of *karání́*, which we would expect to be (something like) **karaní́*, comes from an underlying association between the second H and the final syllable. Therefore, after the noun-class marker's L associates with the second syllable and spreads back to the first, we have the representation in (33).

(33) ka ra ni

L H L H L

The first H then links to the second syllable by the same rule that creates a contour in (31b). This triggers delinking of the initial L from this syllable because contours are not allowed word-internally. Thus we end up with (34). As a full analysis of Kikuyu's tonal system would stray too far from the goals of this paper, I will not consider exceptional cases

[15] Clements (1984:284) states that the tone patterns illustrated in (31) "appear sentence-finally after affirmative verb forms that do not induce H Tone Spread upon following words." Some of these patterns are changed in other contexts by rules that are not relevant here.

like *karáni̋* any further.

(34)
```
ka    ra    ni
  \    |     |
   L H L H L
```

The verbal system is similar to the nominal system in terms of peak delay, but there are additional complexities: More morphemes are involved, and not all morphemes contribute a tone. The clearest evidence for tone shift was already presented in (29a) and (29b), and I will not recapitulate that here. The same principles are at work: The first TBU is skipped and is subsequently the target of leftward spreading, and other TBUs receive their tones via standard association rules. Excess low tones float, but excess high tones do not.

Before beginning the peak delay analysis, some technical issues must be dealt with. Since the analysis below takes tone shift to reflect peak delay, an unshifted representation is adopted for each form. For example, *kaɲamǒ* is assumed to have the structure in (35) instead of (32). Because of peak delay, though, it appears that the first two low tones are associated one syllable rightward.

(35)
```
ka    ɲa    mo
 |     |     |
 L     L     H     L
```

If peak delay is to affect the low tones in this form, the definition of Peak Delay must be amended. The definition given in (9) refers only to high tones. Even with a high-ranking Peak Delay, low tones' troughs are free to surface on the syllables that host the low tones. This accords with my understanding of peak delay generally. To my knowledge there are no studies that have found "trough delay" for low tones comparable to peak delay.

But to produce trough delay in (35), we need the constraint in (36). There are several potential justifications for broadening Peak Delay in this way. First, the same perceptual justification for peak delay given at the end of §2.1 holds here: with the f_0 fall occurring late in the syllable, it is more likely to be reliably heard. Articulatorily, we can also suppose that if articulation of pitch excursions is sluggish for pitch rises, it may also be sluggish for pitch falls, although this sluggishness may be different for rises and falls.

(36) Peak Delay (PD): The f_0 rise or fall for a tone must be allotted an adequate duration.

Alternatively, if learners encounter a language that has peak delay for just high tones, they may extrapolate to all tones and thus posit a constraint like the one in (36).

This change does not affect the analysis of Chichewa because that language lacks phonological low tones. (It is also possible that the Chichewa and Kikuyu simply require different constraints.)

It is probably necessary to modify the function that informs Peak Delay since the one given in (10) is specific to Chichewa. But to my knowledge no appropriate phonetic studies have been conducted on Kikuyu, so there is no way to know what the new function should look like. It also seems reasonable to suppose that pitch rises and falls might be subject to different functions; again, I know of no relevant data, but Ohala & Ewan (1973) and Sundberg (1979) report that pitch rises take longer to execute than equivalent falls. To assess violations of this constraint, the same simplifying rubric that was used for Chichewa will be adopted here: PEAK DELAY is violated when the onset and peak appear on the same mora.

The studies cited above that investigate peak delay report that the the f_0 peak is delayed with respect to some prosodic landmark such as the beginning of the tone's host syllable or a segmental landmark like the onset or nucleus of some syllable. But the definition of PEAK DELAY used here takes peak delay to be timed with respect to the beginning of the articulation of the tone, i.e. the onset. This discrepancy might be explained by a high ranking of COINCIDE(Onset) in the languages for which peak delay has been investigated. With the tone's onset fixed with respect to prosodic and segmental landmarks, it is no surprise that the tone's peak is timed with respect to these landmarks, even if PEAK DELAY is defined as in (36). This line of reasoning predicts that in other languages, the location of a tone's peak can vary with respect to prosodic and segmental material even while obeying PEAK DELAY if COINCIDE(Onset) is ranked low enough. If the analysis developed below is correct, Kikuyu is such a language.

Finally, I assume that a tone's phonetic onset begins as soon as the preceding tone's peak or trough is reached and thus coincides with the same mora that the preceding peak/trough coincides with. This is obviously an idealization since f_0 targets can be maintained for some duration, but this assumption will streamline the analysis below and is necessary because of the lack of phonetic data about Kikuyu.

3.2 Tone Shift as a Phonetic Phenomenon

The goal of this section is to present an analysis of Kikuyu tone shift under the assumption that this is a phonetic phenomenon in which the peak or trough of each tone appears on the syllable to the right of the one that hosts the corresponding H or L. Tones themselves do not shift. This can be accomplished the same way that tone spread in Chichewa was produced above. PEAK DELAY pushes each tone's peak or trough into the syllable after the one associated with the tone. Obviously the viability of this analysis is contingent on verification of the phonetic nature of tone shift.

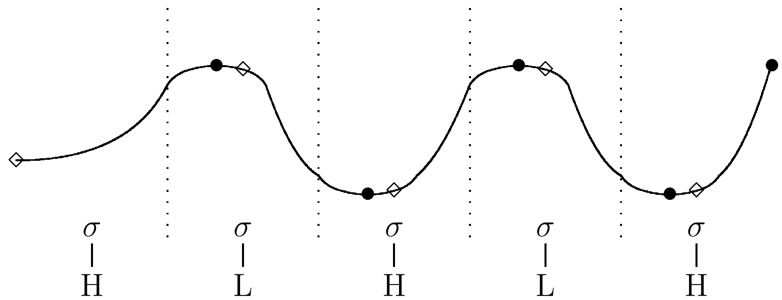
3.2.1 Peak Delay and Tone Shift

The claim advanced here is that what has been called tone shift in Kikuyu is really the same as tone spreading in Chichewa. From a theoretical basis, Philippson (1998), e.g., argues that tone shift is just tone spread with an extra step: After a tone spreads to the adjacent TBU, its original association line is delinked. Beyond this representational connection, evidence that spreading and not shifting occurs in Kikuyu comes from word-initial syllables. In all of the examples given above in (29) and (31), the first syllable has the same tonal specification as the second syllable. This is expected under a spreading approach: The first syllable simply spreads its tone to the second syllable. But under a tone shift approach, where the first syllable is skipped altogether, this first syllable should surface either with an invariant default tone (if shifting is phonological; i.e. driven by (30)) or some neutral pitch level (if shifting involves displacement of the peak belonging to the first syllable's tone). That Kikuyu exhibits spreading is revealed by Clements's (1984) rule that spreads the initial tone leftward back to the syllable that was originally skipped (see (32)). This rule undoes the effect of tone shift: We might as well associate the first tone to the first TBU and then spread that tone instead.

Under the analysis developed here, the details of the first two syllables of a word in Kikuyu are identical to the characterization of Chichewa's tone spread. The tone's onset appears on the first syllable, and Peak Delay requires the peak to be postponed until the next syllable.

Why, then, don't we find (reports of) spreading with all tones in Kikuyu? The answer has two parts. First, as I argue below, whereas in Chichewa Coincide(Onset) outranked Coincide(Peak), the opposite ranking holds here. This seems unintuitive at first, since the hallmark of Kikuyu's tonology is displaced peaks, but I will give evidence for this ranking in §3.4.1. Second, since Kikuyu has phonological low tones, there are increased pressures in this language to avoid stretching out a tone's articulation for too long. Overextended articulations encroach upon neighboring tones and their own requirements for implementation.

To elaborate on the last point, consider the diagram in (37), which is a schematic representation of the pitch track for a Kikuyu word. In the first syllable, which is formally associated with a high tone, the onset for the tone begins in that syllable. Peak Delay ensures that the peak is not reached until the second syllable. Once the peak is reached, the articulation for the low tone can begin immediately. The onset for the second syllable's low tone appears in that syllable, just after the first H's peak. This means that to obey Peak Delay, the trough associated with this L must appear in the third syllable. Articulation of the third syllable's H cannot be begun until this trough is reached. This means that the onset for the H occurs in the third syllable, but again Peak Delay forces the peak into the fourth syllable. In the fourth syllable, the onset for the tone associated with this syllable again cannot begin until the peak from the first tone is reached. Peak Delay forces the trough for the fourth syllable's L into the fifth syllable. In this syllable, which is the last in the form, the high tone's onset begins once the preceding L's trough is reached, at which point a steep rise is required: With no following syllable to host the H's peak, Peak Delay must be violated if the H's peak is to be articulated.

(37) 

Except for the first and last syllables, two important events occur in each syllable: the peak for the tone of the preceding syllable, and the onset for that syllable's own tone. The final syllable must also host its own tone's peak since there is no following syllable in which this peak can appear. These properties give the impression of tone shift on each non-initial syllable, the appearance of a contour tone on the last syllable, and the impression of tone spread in the first syllable.

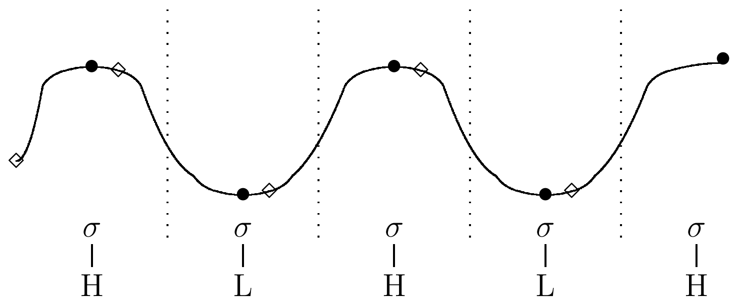
The first syllable is not preceded by another syllable, so it doesn't host a preceding tone's peak. In this way it is comparable to tones' host syllables in Chichewa, where the OCP and lack of a phonological L ensure that tone-bearing syllables are never adjacent. This means that the entire duration of each tone-bearing syllable in Chichewa is available for the onset of that syllable's tone. Similarly, the first syllable of Kikuyu word isn't preceded by another tone-bearing syllable and therefore can devote its entire duration to its tone's onset. In Chichewa and word-initial syllables in Kikuyu, similar tonal environments lead to impressionistic tone spread.

Non-initial syllables in Kikuyu cannot make their whole durations available to the onsets of their tones because they must also cope with peaks from tones of preceding syllables. It is not surprising that this situation has been identified by transcribers and analysts as tone shift instead of tone spread. Since each tone's onset is necessarily relegated to some rightward portion of a syllable, it can reasonably be interpreted as anticipatory coarticulation (the speaker is preparing for the tone that has shifted to the next syllable) rather than an indication that the onset's tone has simply spread to the next syllable.

(It is tempting to suggest that this is case for all languages: When there's an H/∅ contrast we find spreading, and when there's an H/L contrast we find shifting. But there is no such cross-linguistic correlation. Jita, for example, has a H/∅ contrast with tone shift (Downing 1996). Perhaps for Jita it would be more accurate to claim that tone shift involves alignment of the tone's onset with the end of the high-toned syllable. I won't make this move for Kikuyu, however: Word-initial syllables are described as having the same tonal specification as the following syllable, so it is necessary to have some part of the high tone on the initial syllable.)

Two other conceivable f_0 configurations are shown in (38) and (39). The configuration in (38) is suboptimal because, while each peak/trough appears on the syllable with which the appropriate tone is associated, Peak Delay is violated by the first tone's implementation. While the other tones' onsets can appear in the syllable before the corresponding peak/trough, there is no syllable before the first syllable, and both the onset and the peak for the first H must fit into this syllable.

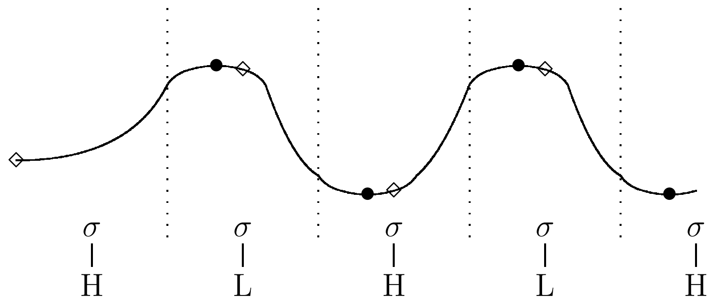
(38)



Both (37) and (38) have one violation of PEAK DELAY. How are we to distinguish them? That is, what makes a peak delay violation at the end of the word better than one at the beginning? The answer, I think, lies in final syllable lengthening. Syllables that are final in various domains (word, utterance, etc.) tend to be longer than their medial counterparts (e.g. Horne et al. 1995, Lehiste 1972, Lehiste et al. 1976, Lunden 2006, Oller 1973, Wightman et al. 1992). Phonologies are sensitive to this lengthening in various ways. Most relevant is Zhang's (2001) argument that phonetically long syllables are cross-linguistically better contour tone hosts than phonetically short syllables. While Zhang focuses on phonological contours (i.e. multiple tones linked to one syllable), his reasoning also applies to phonetic implementation of tones: Just as all parts of a contour tone have better chance of being implemented if they're associated with a long syllable, the articulation of multiple f_0 landmarks in one syllable is easier if the syllable is longer.[16]

The question now becomes one of representing this asymmetry in a Tableau. The most obvious solution is to adopt a constraint that penalizes multiple phonetic peaks on a non-final syllable. But since the effect of final lengthening is to ameliorate the severity of a PEAK DELAY violation, I will simply not record violations of PEAK DELAY that are incurred on word-final syllables. This amounts to the hypothesis that a phonetically lengthened final syllable provides enough duration for appropriately delayed peaks to be articulated on that syllable, and in the absence of phonetic data about peak delay in Kikuyu, I adopt this hypothesis.

[16]Reasoning from the perceptual side works as well. Since final syllables are longer, there's a greater duration of the spectral stability that Myers (1999) identifies as crucial to tone perception. Thus the prime real estate in a final syllable is longer than in a short syllable, making it more likely that multiple f_0 landmarks can fit into this window.

(39) 

The problem with (39) is that the last tone's peak (and perhaps onset?) is not present. This fixes the logjam in the last syllable of (37) because we don't have an onset and peak for the same tone in the same syllable. This configuration deftly manages the demands of PEAK DELAY by reducing the number of landmarks it must accommodate. Of course, it does no good to have a phonological tone that doesn't get a phonetic realization; the constraint in (40) (which is related to but crucially different from Morén & Zsiga's (2006) REALIZETONE) encodes this fact.[17]

(40) *UNPRONOUNCED-T: The f_0 target for every tone associated with some TBU must be reached.

*UNPRONOUNCED-T outranks PEAK DELAY since it favors the correct crowding configuration in (37) over the PEAK DELAY-obeying (39).

We also need constraints that produce one-to-one, left-to-right mapping of tones to TBUs. The constraints in (41) do this. SPECIFY ensures that no TBU is left without a tone, and *FLOAT ensures that every tone docks somewhere. ALIGN-L is responsible for the left-to-right order of association. (For more discussion of these constraints and their responsibilities, see, e.g., Yip (2002) and Zhang (2000).)

(41) a. SPECIFY: Every TBU is associated with some tone.
b. ALIGN-L: The left edge of every tonal domain is aligned with the left edge of some word.
c. *FLOAT: Floating tones are disallowed.

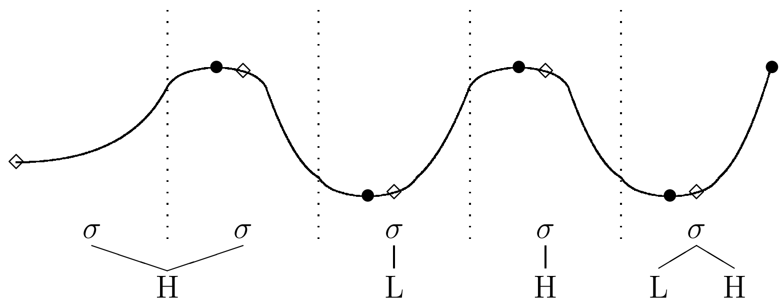
ALIGN-L assigns one violation for every syllable between a tone and the left edge of the word. *FLOAT must outrank ALIGN-L, otherwise the best strategy would be to associate just one tone to all TBUs so that there are no tonal domains not left-aligned. I will assume that SPECIFY is ranked above all other constraints, and neither this constraint nor candidates

[17]This constraint seems to preclude the possibility of phonetic undershoot, but it can be outranked by additional constraints that favor undershoot, or violations of *UNPRONOUNCED-T can be assessed gradiently. It is also possible to view the depressed peak that is reached in undershoot as the f_0 target in such cases, in which case *UNPRONOUNCED-T is not violated. Yet another option is to revise *UNPRONOUNCED-T so that is merely requires *some* phonetic implementation of a tone, not necessarily one that reaches the pitch target.

that violate it will be shown in Tableaux. Other constraints are necessary to prevent tones from piling up at the left edge of a word at the behest of Align-L; I won't consider this sort of candidate either.

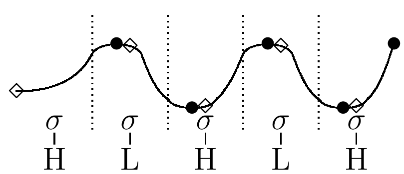
The traditional tone-shift form has yet to be considered. It is given in (42). The pitch profile is same as (37), but tones' formal associations match the alignment of their peaks. Align-L disprefers this form because the non-initial tones are not as far to the left as possible.

(42)

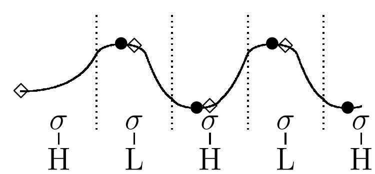


The Tableau in (44) shows how (37) can be selected over the competitors in (38) and (39), plus a modified version of (39) and a new candidate given in (42), which is the traditional tone-shift form. The diagrams from (37)–(42) are repeated in (43) for ease of reference.

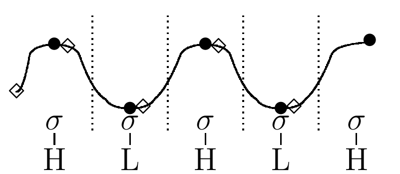
(43) a.



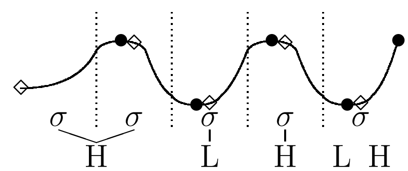
c.



b.



d.



(44)

/σσσσσ HLHLH/	*Unp	*Float	PD	Al-L	Coin(Pk)	Coin(Ons)
☞ a. (43a)				10	****	
b. (43b)			*!	10		****
c. (43c)	*!			10	****	
d. (43c), last H delinked		*!		6	****	
e. (43d)				13!		***

Candidate (b) loses because the violation of Peak Delay in this candidate occurs on a non-final syllable. Candidate (c) avoids problems with Peak Delay by failing to implement a phonetic realization of the final H. It therefore fatally violates *Unpronounced-T. Candidate (d) avoids violating both Peak Delay and *Unpronounced-T by leaving the final H floating. Since this tone floats, *Unpronounced-T does not require an f_0 target for this tone. But this strategy fatally violates *Float. Candidate (e), which is the traditional representation of tone shift with rule (30) applying, loses because of excessive Align-L violations. This means that candidate (a) wins. All tones are associated with TBUs and Peak Delay is satisfied. With the lengthened final syllable hosting the most phonetically crowded part of the configuration (as opposed to the first syllable, in candidate (b)), this form is optimal.

Now let's consider an actual example such as *moɣatɛ̌* 'bread.' Recall that this form has two low tones (one from the noun-class prefix, the other from the noun root) and a high tone. The structure assigned to it under traditional analyses is given in (45a). The structure assumed here is given in (45b).

(45) a. mo ɣa tɛ
L L H

b. mo ɣa tɛ
L L H

The Tableau for this form is given in (46). The following notation is used. Association lines mark formal phonological associations. Diacritics mark the location of each tone's peak. For clarity, indices identify which low tone's peak is hosted by which syllable. Onsets are not marked explicitly, but they should be assumed to appear in the most advantageous location immediately after the previous tone's peak. Since Peak Delay outranks Coincide(Onset), this means wherever possible, an onset appears in the syllable before its corresponding peak. Of course, if a peak is in the initial syllable, its onset must also be in that syllable. Likewise, when two peaks share a syllable, the onset for the second peak must of course also be in that syllable.

(46)

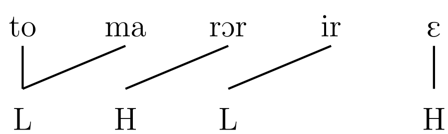
/mo-ɣatɛ LLH/	*Unp-T	*Float	PD	Al-L	Coin(Pk)	Coin(Ons)
☞ a. mo ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H				***	**	
b. mò$_{(1)}$ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H			(*!)	****!		*
c. mò$_1$ɣà$_2$ tɛ́ L$_1$ L$_2$ H			*!*	****		**

Candidate (a) violates Coincide(Peak) twice because neither low tone's peak appears on the syllable with which that tone is associated. This form wins because it assigns tones to TBUs according to standard association conventions and obeys Peak Delay. Candidate (b), which is the traditionally correct form, fatally violates Align-L because tones are not assigned to TBUs one-to-one and left-to-right. Since the first L is associated with more than one syllable, there is some leeway in where that tone's peak appears. If it appears in the first syllable, a violation of Peak Delay is incurred. This form also violates Coincide(Onset) because the onset of the second L is not on the final syllable.

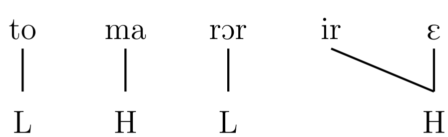
Candidate (c) assigns tones to TBUs in a one-to-one manner, just like the winner. But this form does not obey Peak Delay: While the second and third tones' onsets can be placed in the syllables before their peaks, the first tone's onset cannot. This is of course because the first tone's peak appears on the initial syllable.

As another example, consider the verb *tomarɔ́rirɛ́* 'we looked at them.' This verb is composed of the morphemes in (47). Each morpheme contributes a lexical tone except for the the tense/aspect marker *-ir-*. In Clements's (1984) analysis, the first tone, which is the subject marker's L, associates with the second syllable of the word, which contains the object marker. Association then proceeds one-to-one, left-to-right, with the subject marker's H associating with the verb root, the verb root's L associating with the tense/aspect marker, and the final vowel surfacing with its own H. The first tone spreads leftward to the syllable that was skipped. The result is shown in (48).

(47)	a.	to-, L	'we'
	b.	-ma-, H	'them'
	c.	-rɔr-, L	'look'
	d.	-ir-	'Current Past Completive'
	e.	-ɛ, H	final vowel

(48)


Under the peak delay analysis, though, the first syllable isn't skipped by the tone association algorithm. After all tones have been associated, we have the configuration in (49): tones are matched to TBUs in a one-to-one, left-to-right fashion. Since there are more TBUs than tones, the last tone spreads to the extra syllable (as required by Specify). The phonetic implementation places the pitch or trough of each tone on the following syllable to create an acoustic configuration that is comparable to the one produced by the standard tone-shift analysis.

(49)


The Tableau in (50) shows the evaluation of *tomarɔ́rirɛ́*.

(50)

/to ma rɔr ir ɛ LHLH/	*Unp	*Float	PD	Al-L	Coin(Pk)	Coin(Ons)
☞ a. to mà$_1$rɔ́$_2$r ì$_3$r ɛ́$_4$ L$_1$ H$_2$ L$_3$ H$_4$				6	***	
b. to mà$_1$rɔ́$_2$r ì$_3$r ɛ́$_4$ L$_1$ H$_2$ L$_3$ H$_4$				9!		***
c. tò$_1$ má$_2$rɔ̀$_3$r ir ɛ́$_4$ L$_1$ H$_2$ L$_3$ H$_4$			*!**	6		**(*)

Candidate (b) is the traditional tone shift form. It is ruled out by Align-L. It does not violate Peak Delay because although each tone's peak falls on the syllable that hosts the tone, the corresponding onsets can appear in the previous syllable.

Candidate (a), which is the optimal form, has the fewest possible Align-L violations under the assumptions stated above (see discussion below (41)). It has zero violations of Peak Delay because each tone's onset falls in the (leftmost) syllable that hosts the tone, and each peak/trough falls in the subsequent syllable. This results in three violations of Coincide(Peak) because for all but the last tone, the peak does not occur in the syllable that hosts the corresponding tone.

Candidate (c) is similar to the winner in terms of formal tone associations. In this form, however, peaks are not displaced from their tones' host syllables. This results in just one violation of Peak Delay because every onset except the first one can be shifted to the preceding syllable. This lone violation is fatal. (The parenthesized violation of Coincide(Onset) is for the final H's onset, which may be placed either in the antepenultimate syllable or in the penultimate syllable without violating Peak Delay. The former placement violates Coincide(Onset) while the latter does not.)

The three Tableaux in (44), (46), and (50) illustrate the core of the peak delay analysis as it pertains to tone shift. The analysis is largely the same as that presented above for Chichewa in that misalignment of tones and their implementations is driven by a requirement that onsets and peaks be sufficiently separated. Peak delay in Kikuyu is somewhat more complicated than peak delay in Chichewa because Chichewa lacks Kikuyu's phonological low tones. It is this difference that leads to the appearance of spreading in Chichewa versus the appearance of shift in Kikuyu. The distinction between the two phenomena boils down to whether or not the syllable that hosts a tone's onset must also host a preceding tone's peak. In Kikuyu, the higher density of phonological tones gives the auditory impression of tone shift. But in Chichewa, syllables that host a tone's onset need not worry about a preceding tone's peak, and this means that the onset has a whole syllable to itself, giving the impression that each tone is associated with two syllables.

It is also worth noting that the analysis presented here aligns tones' onsets with the syllables that the tones are associated with. This happens despite Coincide(Onset) being ranked below the other constraints considered here, and it is caused by the word-initial syllable and its tone. With no preceding syllable for the onset to fall on, the initial tone's onset must appear in the initial syllable. Because of Peak Delay, this triggers postponement of the tone's peak until the second syllable, at which point the process starts over: The second syllable's tone can't appear earlier than the second syllable because the first syllable is occupied by the implementation of the first tone, and therefore the second tone's peak must appear in the third syllable, etc. Proper alignment of onsets is a byproduct of other considerations (such as the demands of Peak Delay on the initial syllable), not the high ranking of Coincide(Onset). This means that if these other considerations do not hold in some instance, onsets might not be so aligned. We will see a case of this in §3.4.1.

So far it would be possible to ignore peak delay in the phonological grammar and let the (non-grammatical) phonetic implementation mechanism deal with it. The next section addresses downstep in Kikuyu, and it is this phenomenon that highlights the need for the phonology to be sensitive to peak delay.

3.2.2 Tone Shift and Downstep

Certain words in Kikuyu trigger downstep on the following word. Examples of this were given in (4), repeated in (51).[18]

(51)	moaɣáhiɲá ꜜné moɛɣá	'the weakling is good'
	karioḱı́ ꜜné moɛɣá	'Kariũki is good'
	keaɣárarɔ ꜜné keɛɣá	'the stile is good'
	βiriβiri ꜜné ɲjɛɣá	'chillies are good'

Clements & Ford (1979) and Clements (1984) explicitly connect these downsteps to the presence of a floating low tone. In each form, the result of tone shift is that after each TBU has been assigned a tone, there is a low tone left over that cannot be assigned to an unoccupied TBU, and this floating tone triggers downstep.

There is other evidence that this L floats and survives stray erasure. The downstep displacement illustrated in (5) indicate the survival of this L. As another example, a process called tonal flattening by Clements & Ford (1981) lowers a sentence-final H to L. The process holds for citation forms and certain kinds of sentences. Flattening is illustrated in (52). In each pair, the first form is a sentence type that is not subject to flattening. The final noun in each case ends with a high tone. But when this noun is in isolation, the high tone disappears.

(52)	a.	nderaːrɔ́rirɛ keŋaŋı́́	'I watched the crocodile'
		keŋaŋi	'crocodile'

[18]This downstep may be displaced to the right in certain contexts such as the one illustrated in (5); see Clements & Ford (1981) for a detailed discussion.

b.	nderaːrɔ́rirɛ ŋgiŋgɔ́	‘I watched a neck’
	ŋgiŋgɔ	‘neck’
c.	nderaːrɔ́rirɛ moβakě	‘I watched the tobacco-plant’
	moβake	‘tobacco-plant’
d.	nderaːrɔ́rirɛ moɣɛraniá	‘I watched the examiner’
	moɣɛrania	‘examiner’

Contrast these examples with those in (53). In these cases, the sentence-final nouns come from the set of nouns that induce downstep as in (51). Flattening does not affect their citation forms.

(53)	a.	nderaːrɔ́rirɛ moaɣáhiɲá	‘I watched the weakling’
		moaɣáhiɲá	‘weakling’
	b.	nderaːrɔ́rirɛ kariokǐ	‘I watched Kariũki’
		kariokǐ	‘Kariũki’
	c.	nderaːrɔ́rirɛ ihóá	‘I watched the flower’
		ihóá	‘flower’
	d.	nderaːrɔ́rirɛ ŋgǒ	‘I watched the firewood (pl.)’
		ŋgǒ	‘firewood’

The reason these nouns are impervious to flattening is that the final high tones are not in fact final: The same floating L that caused downstep in (51) protects the words in (53) from flattening. Both downstep and flattening are explained if certain words possess floating low tones at their right edges.

Along the same lines, Clements & Ford (1981) argue on the basis of the mobility of the downstep operator that this operator must be an abstract entity rather than a diacritic on a vowel because the diacritic would not be expected to move around in a construction. Their argument supports the point made here in that the simplest conclusion about the identity of this abstract entity is that it is a floating autosegment such as a low tone.

Producing these floating tones seems to crucially rely on the tone shift rule in (30). For example, according to Clements (1984), the noun *moɣɛká* ‘rug’ contains a stem characterized by the tonal pattern HL. Adding the noun-class prefix’s L, we have LHL, and applying the normal tone-association conventions without (30) yields (54).

(54) mo ɣɛ ka
L H L

There is no floating L in this structure and therefore no indication that this form induces downstep and blocks flattening. With the tone-shift rule added, we get (55), which does have a floating low tone because, once it comes time to associate the rightmost L, all TBUs are already occupied.[19]

[19] The rule that associates floating tones to already occupied TBUs as in (32) doesn’t apply here because that rule is specific to floating H.

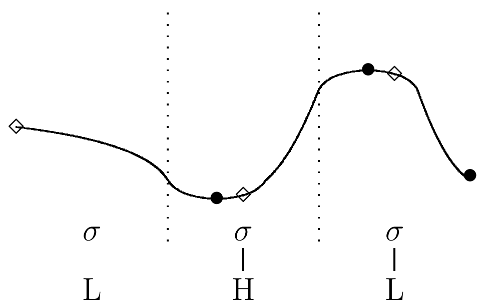
(55) mo ɣɛ ka

L H L

From this point of view it seems as though the traditional tone shift analysis is superior to the peak delay approach since the latter is committed to the structure in (54). But it is simple enough to amend the peak delay analysis to account for these floating low tones.

The schematic pitch track for (54) as predicted by the peak delay approach is given in (56), with each tone's peak/trough appearing in the syllable after the one the tone is associated with, except for the last tone.

(56)



This configuration incorrectly predicts a falling pitch on the last syllable: **moɣɛkâ*. In fact, to my knowledge, falling contours do not appear in Kikuyu at all. Under the peak delay approach, this means that Kikuyu does not allow a high pitch target to be followed by a low pitch target in one syllable. We could adopt a constraint banning such configurations outright while still allowing rising contours, but this would contradict other research showing that rising contours are more marked than falling contours (e.g. Zhang 2001). Instead, I adopt the constraint in (57), which bans all phonetic contours (on the grounds that they're more marked than level pitch specifications).

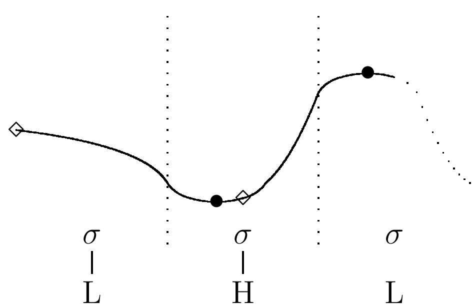
(57) *MULTI-PEAK: Multiple pitch targets on one syllable are disallowed.

Although this constraint may seem to duplicate the effect of PEAK DELAY in that both constraints favor greater spacing between f_0 landmarks, the two constraints are quite different. PEAK DELAY requires sufficient space between onsets and their corresponding peaks, no matter where they fall with respect to syllable boundaries.[20] *MULTI-PEAK is more like a constraint against contour tones (although I do not use *CONTOUR for reasons that will become clear below): It penalizes multiple peaks/troughs on one syllable, no matter how far apart they are. Whereas PEAK DELAY cares about timing but not coincidence with prosodic elements, *MULTI-PEAK cares about prosodic coincidence and not phonetic timing.

[20] Recall that the practice adopted here of assessing violations of PEAK DELAY according to whether or not the onset and peak are on the same syllable is just a convenient shortcut.

Given free rein, this constraint would correctly ban the falling contour in **moɣεkâ* but also incorrectly ban the rising one in *moɣatε̌* 'bread.' The difference between these forms, in terms of the tone shift analysis, is that whereas the leftover H from *moɣatε̌* associates with the already occupied final syllable as in (45a), the same does not happen when a low tone is leftover. Although I adopt a different configuration here, the insight that this analysis reveals is worth retaining: Kikuyu allows floating L but not floating H. This means that *FLOAT must be decomposed into two constraints, one for H and one for L. *FLOAT-H outranks *MULTI-PEAK, but *FLOAT-L does not.[21]

Now with the correct ranking we can produce both *moɣεká* and *moɣatε̌*. When *MULTI-PEAK eliminates the low tone's trough from (56), a violation of *UNPRONOUNCED-T is triggered. To avoid violating both of these constraints, the low tone must also be set afloat. Now there is neither an unpronounced docked tone nor a pitch contour on the last syllable. This is shown in (58), where the dotted part of the curve is the implementation of the low tone from (56) that is now absent.

(58)


On the other hand, *FLOAT-H prevents the final H in *moɣatε̌* from floating. Since it must be associated with some TBU, its peak must be realized as per *UNPRONOUNCED-T, and a violation of *MULTI-PEAK is necessary. The Tableaux for *moɣεká* (59) and *moɣatε̌* (61) are given below. To save space, COINCIDE(Peak) and COINCIDE(Onset) are omitted.

[21]Splitting *FLOAT in this way might also shed light on *karáni͂* 'clerk' (31f), which was labeled exceptional above because although the root's lexical tones are HLHL, the first L is skipped by the tone mapping system. Notice that skipping this L ensures that both Hs can be associated, leaving only Ls floating. This state of affairs is favored by the ranking *FLOAT-H ≫*FLOAT-L.

(59) /mo-ɣɛka LHL/	*Unp-T	*Float-H	PD	*Multi	*Float-L	Align-L
a. mo ɣɛ̀ kâ L H L				*!		***
b. mò ɣɛ̀ kâ L H L			(*!)	*!		****
c. mò ɣɛ́ kà L H L			*!			****
☞ d. mo ɣɛ̀ ká L H L					*	*
e. mo ɣɛ̀ ká L H L	*!					***
f. mo ɣɛ̀ ká L H L					*	**!

In (59), the expected peak delay candidate—candidate (a)—loses because of the illicit multiple f_0 targets on the final syllable. *Contour, which is typically invoked to prevent multiple tones from being linked to one syllable, would not penalize this candidate because each syllable is formally linked to just one tone. Consequently, a constraint like *Multi-Peak, which deals with tones' phonetic implementations rather than their formal associations, is required.

Candidate (b) loses either because the trough of the first low tone appears in the first syllable (as indicated by the diacrtic on this syllable) and thereby violates Peak Delay, or (with the diacritic removed) because of the same violation of *Multi-Peak that doomed the first candidate. Candidate (c) loses because of a Peak Delay violation: Each peak is on the syllable associated with the peak's tone, and each onset can appear in the preceding syllable except for the first onset. Candidate (d) wins because by setting the L afloat, it can avoid violating both Peak Delay and *Multi-Peak. Candidate (e) also avoids violating these two constraints, but it does so by failing to articulate the final L. This fatally violates *Unpronounced-T. Finally, candidate (f) is the traditional tone shift form. This candidate has the same phonetic profile as the winner, but its formal tonal configuration incurs an extra violation of Align-L.

We still need a way to rule out the form in (60), which so far harmonically bounds the winning candidate. Why is it better to leave the second L unassociated rather than the first? I have no simple answer to this question, but I suspect the reason might be related to a prominence asymmetry between the first and last syllables, with the former being more prominent than the latter: since final elements (segments, syllables, etc.) are less salient than initial elements, setting a final tone afloat is a more faithful move from a perceptual standpoint than setting an initial tone afloat. Perhaps as Kikuyu's tone shift developed and the penultimate tone encroached on the last tone's syllable, the last tone's perceptibility was reduced, and speakers eventually concluded that this tone was actually unassociated. Synchronically, this state of affairs could be enforced by constraints favoring association of initial (i.e. prominent) elements over final (less prominent) elements. The issue of how to rule out (60) is not specific to the current analysis—it arises in any non-derivational approach to Kikuyu. Whatever the correct solution is, I assume that constraints penalizing (60) are highly ranked in Kikuyu, and I will not consider candidates like (60) further.[22]

(60) mo ɣέ kà

L H L

The upshot of (59) is that a low tone can float if doing so alleviates pressure on the phonetic implementation. The next Tableau shows that the same is not true of high tones.

[22] Anchoring is an appealing place to look for help, but such an approach would require tones to be associated with TBUs underlyingly.

(61)

/mo-ɣatɛ LLH/	*Unp-T	*Float-H	PD	*Multi	*Float-L	Align-L
☞ a. mo ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H				*		***
b. mò$_{(1)}$ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H			(*!)	*		****!
c. mò$_1$ ɣà$_2$ tɛ́ L$_1$ L$_2$ H			*!			****
d. mo ɣà$_1$ tɛ̀$_2$ L$_1$ L$_2$ H		*!				*
e. mo ɣà$_1$ tɛ̀$_2$ L$_1$ L$_2$ H	*!					***

The highest ranked constraint that candidate (a) violates is *Multi-Peak, and higher constraints make this violation unavoidable. Candidate (b) loses either because of a violation of Peak Delay (depending on where the first tone's peak begins) or excessive violations of Align-L. Candidate (c) incurs a fatal violation of Peak Delay because the first L's onset cannot begin in a syllable before the one its onset appears in. Candidate (d) avoids violating *Multi-Span by setting the H afloat. This is ruled out by *Float-H.[23] Finally, candidate (e) doesn't have a floating H, and it avoids violating *Multi-Peak by not pronouncing the H's peak. This fatally violates *Unpronounced-T.

As this Tableau shows, *Unpronounced-T, *Float-H, and Peak Delay can conspire to force a phonetic pitch contour when the only viable alternatives involve not realizing a tone's peak phonetically, setting a high tone afloat, or failing to allot enough time between a tone's onset and its peak. The difference between this Tableau and (59) lies in the rankings of *Float-H and *Float-L. With *Float-H above *Multi-Peak, high tones cannot float, even if this means assigning multiple f_0 targets to some syllable. But since *Multi-Peak outranks *Float-L, *Float-L cannot force a similar phonetic contour when the alternative is setting afloat a low tone.

To summarize this section, the peak delay analysis, which does away with the noniterative tone shift rule that previous analyses have adopted, can produce the same floating low tones that tone shift accounts for. This section also demonstrates the importance of placing peak

[23] I assume that candidates in which one of the low tones floats instead of the high tone are eliminated by the same constraint that rules out (60).

delay in the phonology. If the phonology is ignorant of phonetic considerations, there is no motivation for the floating tone in *moɣɛká* 'rug.' Since the peak delay approach does not involve assigning the first tone to the second TBU, each tone in this form can be linked to its own TBU, and candidate (d) from (59) should lose because it does not follow the normal association conventions. It is only once the phonetic implementation of a form with no floating tones is considered that the correct form becomes superior. Therefore, the phonology must have access to at least some details of phonetic implementation.

3.3 Tone Shift as a Phonological Phenomenon

This section shows how the PEAK DELAY analysis developed in the previous section can be amended to produce phonological tone shift. Here I discard the assumption that tone shift is purely phonetic, and in this section I will treat it as a genuine phonological phenomenon in which each tone associates with the syllable to the right of the one it would be expected to associate with under normal tone association conventions. I will call this analysis the phonological analysis and the analysis from the previous section the phonetic analysis.

The constraint ranking adopted in §3.2.1 is repeated in (62).

(62) *UNPRONOUNCED-T, *FLOAT-H, PEAK DELAY $\gg$*MULTI-PEAK $\gg$*FLOAT-L, ALIGN-L $\gg$COINCIDE(Peak), COINCIDE(Onset)

By reranking ALIGN-L and COINCIDE(Peak), we can produce a grammar that values coincidence between pitch peaks and their associated tones over left alignment. PEAK DELAY is still ranked high enough to produce the pitch contours generated by the phonetic analysis, but now COINCIDE(Peak) ensures that tones' formal associations follow these delayed peaks.

This is illustrated in (63). Compare this Tableau with (44) above. (Some irrelevant constraints have been removed to make the comparison easier.) As in (44), candidates (b) through (d) are eliminated by the first block of constraints. But whereas the choice between candidates (a) and (e) was made above by ALIGN-L, COINCIDE(Peak) now gets to make that choice, and it prefers candidate (e) because, while the tones do not obey the normal left-to-right association conventions, they achieve better alignment with their associated pitch peaks.[24]

[24] I assume that the first tone associates with the first syllable—and not just the second—to satisfy SPECIFY.

(63)

/σσσσσ HLHLH/	*Unp-T	*Fl-H	PD	Coin(Pk)	Al-L	Coin(Ons)
a. σ σ́ σ̀ σ́ σ̌ H L H L H				****!	10	
b. σ́ σ̀ σ́ σ̀ σ́ H L H L H			*!		10	****
c. σ σ́ σ̀ σ́ σ̀ H L H L H	*!			****	10	
d. σ σ́ σ̀ σ́ σ̀ H L H L H		*!		****	6	
☞ e. σ σ́ σ̀ σ́ σ̌ H L HL H					13	***

This result is important: We saw above for both Chichewa and Kikuyu that Peak Delay can cause mismatches between tones' formal associations and their phonetic implementations, and now we see that a high-ranking Peak Delay does not necessarily require such mismatches. With Peak Delay and Coincide(Peak) outranking Align-L, the normal tone association desiderata take a back seat to pitch timing requirements so that the formal tone configuration takes its cues from the pitch profile. The interaction between tones and their phonetic implementations is a two-way street: Tones affect a form's phonetic pitch, but pitch considerations can also influence the tonal configuration.

A real example from Kikuyu is shown in (64) (cf. (46)). The new ranking between Coincide(Peak) and Align-L means that when Peak Delay shifts each tone's peak, the tone must follow. The winner in this Tableau is the traditional form, with the first tone associating with the second syllable, etc. Crucially, the pitch profile of the winner is identical to that of candidate (a), the winner under the phonetic analysis. The two analyses produce the same phonetic forms (ignoring the small timing differences that one might use to differentiate the analyses in a Myers (1999)-style study), but they differ in terms of the phonological form that underlies the acoustic signal.[25]

[25]The status of the first syllable in terms of the phonetic pitch implementation is unclear. According to the assumptions of the peak delay analysis, this syllable should host the first tone's onset, and thus we might expect this syllable to be transcribed with a falling pitch. That it is transcribed with a low pitch has three possible explanations: (i) Word-initially, the onset for a low tone might be a low pitch; (ii) A low pitch is reached sufficiently quickly for transcribers to hear it as low; or (iii) the fall is interpreted by transcribers as a low tone. The last option is appealing in light of Myers's (2003) finding that the anticipatory pitch rise before a high-toned syllable in Kinyarwanda has been misidentified as reflecting spreading of the tone itself.

(64)

/mo-ɣatɛ LLH/	*Unp-T	*Fl-H	PD	Coin(Pk)	Al-L	Coin(Ons)
a. mo ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H				*!*	***	
☞ b. mo ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H					****	*
c. mò$_1$ ɣà$_2$ tɛ́ L$_1$ L$_2$ H			*!		****	**

Consider next the Tableau in (65) (cf. (50)). Once again, Peak Delay requires the first tone's peak to appear in the second syllable, and this bumps the other peaks rightward, just as in the phonetic analysis. But here, Coincide(Peak) rules out candidate (a) and selects candidate (b) as the winner. This constraint requires each tone to be associated with the one that hosts its peak. With Peak Delay requiring rightward movement of the peaks, satisfying Coincide(Peak) means (minimally) abandoning the one-to-one, left-to-right tone assignment algorithm. As in (64), the traditional tone-shift form is a byproduct of phonetic peak delay.

(65)

/to ma rɔr ir ɛ LHLH/	*Unp	*Fl-H	PD	Coin(Pk)	Al-L	Coin(Ons)
a. to mà$_1$rɔ́$_2$r ı̀$_3$r ɛ́$_4$ L$_1$ H$_2$ L$_3$ H$_4$				*!**	6	
☞ b. to mà$_1$rɔ́$_2$r ı̀$_3$r ɛ́$_4$ L$_1$ H$_2$ L$_3$ H$_4$					9	***
c. tò$_1$ má$_2$rɔ̀$_3$r ir ɛ́$_4$ L$_1$ H$_2$ L$_3$ H$_4$			*!		6	**(*)

The floating low tones can be produced by the phonological analysis, too, as shown in (66) (cf. (59)). As in (59), a phonetic or phonological contour—candidates (a) and (b)—on the last syllable is ruled out by *Multi-Peak. Since this constraint outranks *Float-L, it has the power to block the final low tone's association, just as before. The difference between (59) and (66) is that in the latter, the higher ranking of Coincide(Peak) prefers the middle syllable to be associated with the first low tone because that is the tone whose peak appears on that syllable. Hence candidate (d), which better satisfies Align-L and was the winner in (59), loses to candidate (f).

(66)

/mo-ɣɛka LHL/	*Unp	*Fl-H	PD	*Multi	*Fl-L	Coin(Pk)	Al-L
a. mo ɣὲ kâ L H L				*!		**	***
b. mo ɣὲ kâ L H L				*!			****
c. mò ɣέ kà L H L			*!				****
d. mo ɣὲ ká L H L					*	*!	*
e. mo ɣὲ ká L H L	*!					***	***
☞ f. mo ɣὲ ká L H L					*		**

Finally, for completeness, the analog of (61) is given in (67). Whereas candidate (a) won above, now candidate (b) wins. Again, this is the traditional representation, and the deviation from the standard association conventions is driven by Peak Delay and Coincide(Peak).

(67)

/mo-ɣatɛ LLH/	*Unp-T	*Fl-H	PD	*Multi	*Fl-L	Coin(Pk)	Al-L
a. mo ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H				*		*!*	***
☞ b. mo ɣà$_1$ tɛ̌$_2$ L$_1$ L$_2$ H				*			****
c. mò$_1$ ɣà$_2$ tɛ́ L$_1$ L$_2$ H			*!				****
d. mo ɣà$_1$ tɛ̀$_2$ L$_1$ L$_2$ H		*!				*	*
e. mo ɣà$_1$ tɛ̀$_2$ L$_1$ L$_2$ H	*!					***	***

To summarize this section, we've seen that just one modification of the ranking developed for the phonetic analysis of Kikuyu is sufficient to produce a system in which tones shift one syllable rightward. Exactly as in the other peak delay analyses presented in this paper, Peak Delay drives rightward displacement of each tone's peak, but here, with Coincide(Peak) outranking the normal tone association conventions, the tones' formal associations are, to a greater extent than before, controlled by the pitch profile of each form.

To reiterate, more research is needed to determine whether or not Kikuyu's tone shift is phonological. Either way, the peak delay analysis can account for it. It is worth noting two appealing aspects of the two analyses of Kikuyu developed here. First, discussions of tone shift/spread often suggest an origin for the process along these lines (e.g. Myers 1999): The muscles responsible for executing a tone rise lag behind other relevant muscles so that the peak for a high tone appears after the high toned syllable. In contrast with rules or constraints that could be devised to move tones one syllable rightward—such as the one in (30)—the constraint Peak Delay captures the proposed impetus directly.

Second, the fact that the two analyses of Kikuyu presented here differ in the ranking of just one constraint suggests that they are on the right track. If tone shift is phonological in the modern language (as in the phonological analysis), it is reasonable to assume that it evolved from a stage with just phonetic peak delay (as in the phonetic analysis). Under the analyses presented here, this means that the grammar changed from one in which Align-L outranked Coincide(Peak) to a grammar with the opposite ranking. Such a simple grammatical change is clearly superior to the wholesale introduction of constraints or rules that the language's evolution would require in an analysis that takes the earlier stage and the phonetic peak delay it entails to be outside the grammar.

3.4 Long Vowels

Clements (1984) notes two interesting ways in which long vowels interact with tone shift in Kikuyu. One falls out automatically from his rule-based approach, and the other is problematic without an additional representational assumption. The peak delay approach already predicts the data that cause problems for the rule-based approach, and the phonological analysis from §3.3 can be amended to account for the other data that Clements considers. Thus data concerning long vowels lend credence to the peak delay approach, and the phonological peak delay analysis in particular. I address the two kinds of data separately, first the facts that are already predicted by the peak delay analysis and then the facts that require a minor revision.

3.4.1 Long Vowels in Verbs

Clements (1984:294) notes that the data in (68) do not show the expected tone shift pattern. (Glosses are extrapolated from Clements (1984:292). Although I use past tense in the glosses, Clements identifies the tense as immediate perfect.)

(68)	to a rɔ́r a	'we looked at'
	to a mó rɔr a	'we looked at him/her'
	to a má rɔ́r a	'we looked at them'
	to a tóm á	'we sent'
	to a mó tom á	'we sent him/her'
	to a má tóm á	'we sent them'

Consecutive vowels are typically fused into a single syllable, so the space between the subject marker *to-* and the tense marker *-a-* is misleading. Transcriptions that note syllable boundaries instead of morpheme boundaries are given in (69).

(69)	toa.rɔ́.ra	'we looked at'
	toa.mó.rɔ.ra	'we looked at him/her'
	toa.má.rɔ́.ra	'we looked at them'
	toa.tó.má	'we sent'
	toa.mó.to.má	'we sent him/her'
	toa.má.tó.má	'we sent them'

According to the rule in (30), the first two syllables of any word should be tonally identical. In (69), the low tone of the subject marker should appear on the first two syllables of each word. Instead, it looks as though tone shift has failed to apply. Clements accounts for this by suggesting that the initial domain of tone assignment is the morpheme, not the syllable. Thus when tone shift applies, the initial L skips the subject morpheme and lands on the tense marker. Later, when the two morphemes merge into one syllable, -*a*-, which was originally the second TBU, now becomes part of the first TBU.

But under the peak delay approach, these data are expected, under the assumption that the diphthongs are bimoraic, i.e. long. If the diphthongs are monomoraic, then the peak delay analysis would have to adopt an approach similar to the one Clements proposes. I have found no information on the moraic or length status of these diphthongs, so it appears that more work is needed on this point. The discussion below proceeds under the assumption that the diphthongs are long.

If the first syllable is bimoraic, it is long enough to host the first tone's onset and peak without violating Peak Delay. This is exactly like the penultimate lengthened syllables in Chichewa. Clements's assumption about the TBU initially being the morpheme is unnecessary. We can instead retain the syllable as the TBU at all levels. Since peak delay handles these data better than one that ignores the relevant timing issues, we have reason to believe the former is superior to the latter.

Before going on, it's worth noting that these data present an argument for the ranking Coincide(Peak) $\gg$Coincide(Onset)—these constraints went unranked in the phonetic analysis, and the phonological analysis posited exactly this ranking: The reason peaks were pushed into the syllable after the one to which their tones were associated in the data considered in previous sections is that the first tone didn't have the luxury of putting its onset into a preceding syllable. This meant that the first tone's peak had to appear in the second syllable, and this started a sequence in which each peak bumped the following peak into the next syllable. But in the data in this section, the initial syllable is long, so the first tone's peak isn't pushed into the second syllable. This means that the second tone gets to decide what to do with its onset and peak without pressure from the implementational requirements of the first tone. There are two choices: (i) place the second tone's onset in the second syllable and let the peak fall in the third syllable, or (ii) place the second tone's onset in the first syllable and let the peak appear in the second syllable. Option (i) obeys Coincide(Onset) but not Coincide(Peak), while option (ii) satisfies Coincide(Peak) but not Coincide(Onset). Since option (ii) is the one that is actually chosen, Coincide(Peak) must be ranked above Coincide(Onset).

3.4.2 Long Vowels in Nouns

Unfortunately, long vowels in nouns are not so easily accommodated by peak delay. Consider the nouns in (70).

(70)	LLH	keroomǐ	'cheetah'
	LHL	moraatá	'friend'
	LLHL	kariokí	(man's name)

In the leftmost column is the tonal pattern that accompanies each word, including the noun-class prefix's L. If we ignore the fact that these words contain long syllable nuclei, these forms are completely ordinary. The first tone appears on the first two syllables, and from there association proceeds as normal. The final L in the last two forms cannot associate with an unoccupied TBU, and becomes a downstep operator. Clements uses this reasoning to argue for the syllable as the TBU—as opposed to the mora—since it appears that syllable length plays no role in tone mapping.

But under the peak delay approach, syllable length is an irrepressible factor. Although we've been counting violations of PEAK DELAY by asking whether a tone's onset and peak are in the same syllable, this constraint actually measures the time allotted for the f_0 rise or fall. If a syllable is long enough to host the entire rise/fall, then PEAK DELAY doesn't care that the onset and peak are in the same syllable. We saw immediately above that long syllables are in fact long enough to host a tone's onset and peak. Now we see evidence that contradicts this.

To be more explicit, the peak delay analysis predicts the following for the word *keroomǐ* 'cheetah': The first L's onset appears in the first syllable, and its trough is relegated to the second syllable. The onset for the second L accompanies this trough in the second syllable. Since the peak/trough of one syllable and the onset of the next usually coopt the entirety a single short syllable, we can suppose that the second half of the (long) second syllable is still available for the second L's trough. (This seems especially reasonable considering that it is following a low tone and thus needs little if any time to reach a low pitch target.) The onset of the H can immediately follow this second trough, letting the H's peak occupy the last syllable all by itself. Thus we end up with **keròòmí*, and the rising tone in the actual form is unexpected.

(It is worth noting that the contrast between long vowels in verbs and those in nouns from the peak delay point of view is actually unrelated to morphological category. Rather, the long vowels in (68) are in word-initial syllables, whereas those in (70) are in word-medial syllables. Word-initially, the first tone can claim the whole syllable for itself, but medially, the peak delay analysis predicts that the long vowel should be divided between multiple tones.)

A simple solution is available within the phonological peak delay analysis in which the traditional shifted forms are produced. Recall the under this analysis, the ranking COINCIDE(Peak) ≫ALIGN-L results in each tone being associated with the syllable that hosts its phonetic peak. The expected **keròòmí* therefore has the structure in (71).

(71) *ke rò$_1$ò$_2$mí

L$_1$ L$_2$ H

The correct form, *keroomǐ*, under this analysis, would have to look like (72), again with tones following their peaks.

(72) ke rò$_1$o mǐ

L$_1$ L H

To produce (72) instead of (71), we need a new constraint that favors the former over the latter. An obvious way to distinguish these forms is in terms of the tones that are associated with the medial syllable in each form. Kikuyu permits each non-final syllable to be associated with at most one tone; i.e., contour tones are found only word-finally. See Zhang (2000, 2001) for a functional explanation of the cross-linguistic tendency to avoid medial contours. But in (71), two tones are associated with the medial syllable. This is not a contour per se since both tones are L, but this configuration still violates the ban on non-final syllables with multiple tonal associations. In contrast, (72) avoids this problem by relegating the second L to the final syllable, where it creates a permissible contour with the high tone.

Two sorts of constraints are conceivable for ruling out (71). The first, in (73a), militates against multiply linked non-final syllables. The other, the OCP constraint in (73b), bans configurations with two identical tones linked to the same syllable. The structure in (71) violates both constraints, while (72) violates neither. I arbitrarily adopt *Medial Contour for purposes of illustration. It is important to note that neither of these constraints duplicates the effect of *Multi-Peak. The constraints in (73) are concerned with formal, abstract tonal representations, and *Multi-Peak deals with phonetic facts. What all three constraints have in common is a preference for candidates that avoid assigning too much material to one syllable.

(73) a. *Medial Contour: Non-final syllables may not be linked to multiple tones.
b. OCP-σ: Adjacent identical tones are prohibited within the same syllable.

Adding one of these constraints to the top of the ranking (since, to my knowledge, they are never violated in Kikuyu, although ranking them above just Align-L is sufficient) is enough to produce the correct form:

(74)

/mo-ɣatɛ LLH/	*Med Cont	PD	*Multi	*Fl-L	Coin(Pk)	Align-L
a. kerò$_1$ò$_2$mí L$_1$ L$_2$ H	*!		*			***
b. kerò$_1$ò$_2$mí L$_1$ L$_2$ H			*		*!	***
c. kè$_1$rò$_2$o mí L$_1$ L$_2$ H		*!	*			***
☞ d. ke rò$_1$o mǐ L$_1$ L H			*			****

Some irrelevant constraints are omitted. Candidate (a), which is the form that the peak delay analysis predicts without *MEDIAL CONTOUR, violates the low-ranked ALIGN-L and COINCIDE(Onset), the latter of which is not shown here. It also fatally violates *MEDIAL CONTOUR because of the tonal configuration of the medial syllable, and, like all of its competitors, it violates *MULTI-PEAK because one of its syllables hosts two phonetic pitch peaks.

The remaining candidates show various ways of avoiding violations of *MEDIAL CONTOUR. Candidate (b) is identical to candidate (a) except that the first L is not associated with the second syllable. *MEDIAL CONTOUR is no longer violated because each syllable has just one tonal association. But candidate (b) incurs a fatal violation of COINCIDE(Peak) because the first L's peak is on the second syllable, but the L is not associated with this syllable. Candidate (c) fixes this problem by retracting the first L's peak to the initial syllable. While COINCIDE(Peak) is now satisfied, PEAK DELAY eliminates this form because the first tone's onset and peak are both on the initial syllable.

Finally, candidate (d) relocates the second L to the final syllable along with its peak. *MEDIAL CONTOUR is satisfied, and since this L's peak is on the last syllable, COINCIDE(Peak) is also satisfied. Recall also that PEAK DELAY does not assign violations when a tone's onset and peak are both in the word-final syllable. This candidate wins because it avoids placing two tones on the medial syllable at the cost of only an extra violation of the low-ranked ALIGN-L.

Candidates that leave one of the low tones floating can be ruled out by a constraint that prevents skipping a tone as they are assigned to TBUs. Such a constraint is needed anyway for Kikuyu; see the discussion above (60) in §3.2.2. *FLOAT-L is ranked too low to serve this purpose, but *FLOAT-H is ranked high enough to block another candidate that declines to associate the H.

In sum, *MEDIAL CONTOUR gives the phonological peak delay analysis of Kikuyu the power to account for long vowels in nouns. Unfortunately, this constraint is much less helpful in the phonetic analysis. Recall that there, ALIGN-L outranks COINCIDE(Peak). This means that candidate (d) from (74) loses in favor of candidate (b) because the former violates ALIGN-L more than the latter. This is shown in (75).

(75)

/mo-ɣatɛ LLH/	*Med Cont	PD	*Multi	*Fl-L	Align-L	Coin(Pk)
a. kerò$_1$ò$_2$mí L$_1$ L$_2$ H	*!		*		***	
(☞) b. ke rò$_1$o mǐ L$_1$ L H			*		****!	
☹ c. kerò$_1$ò$_2$mí L$_1$ L$_2$ H			*		***	*
d. kè$_1$rò$_2$o mí L$_1$ L$_2$ H		*!	*		***	
(☞) e. ke rò$_1$o mǐ L$_1$ L H			*		***	**!

The two candidates marked with (☞) represent possible desired outcomes: low tones and/or pitches on the first two syllables and a rising tone/pitch on the last. Candidate (b), the winner from the previous Tableau, violates Align-L too many times to be viable. Candidate (e) is more similar to other outputs under this analysis, with normal tone assignment and delayed peaks. This form runs into the problem noted at the beginning of this section: The medial long syllable provides a landing site for two peaks so that violations of Coincide(Peak) can be minimized without running afoul of Peak Delay. Candidate (c) takes advantage of this opportunity, but candidate (e) does not. Under the phonetic analysis, then, phonetic implementations and formal tone associations are too loosely connected for *Medial Contour to be of any use.

Instead, the phonetic analysis needs a specific version of *Multi-Peak that bans medial syllables that host multiple peaks. Such a constraint will rule out candidates (a) and (c) in (75):

(76)

/mo-ɣatɛ LLH/	*Med Multi	PD	*Multi	*Fl-L	Align-L	Coin(Pk)
a. kerò$_1$ò$_2$mí L$_1$ L$_2$ H	*!		*		***	
b. ke rò$_1$o mǐ L$_1$ L H			*		****!	
c. kerò$_1$ò$_2$mí L$_1$ L$_2$ H	*!		*		***	*
d. kè$_1$rò$_2$o mí L$_1$ L$_2$ H		*!	*		***	
☞ e. ke rò$_1$o mǐ L$_1$ L H			*		***	**

There are reasons to be skeptical of this amendment. *Medial Multi-Peak duplicates the effect of *Multi-Peak in a way that *Medial Contour doesn't, although we could view *Medial Multi-Peak as a positional markedness (Lombardi 1995) version of *Multi-Peak that bans a particularly bad kind subset of the configurations that *Multi-Peak rules out.

Worse, though, is this: It would be surprising from an articulatory perspective if a low-low sequence of pitch were really bad enough to avoid. One motivation for *Multi-Peak is that it militates against configurations that require too many articulatory gestures within one syllable. But candidate (c) in (76) has consecutive identical targets, so the second target should not be too hard to reach because it is the same as the first one. Articulatorily, the LH contours that Kikuyu allows word-finally are worse than the LL sequences that are banned internally.

Despite these drawbacks, there is a perceptual justification for banning tautosyllabic LL sequences. While LL has articulatory simplicity, it plausibly creates perceptual problems. Since no change in pitch level is necessary, listeners may be in danger of misperceiving the consecutive low targets as one long low tone. This line of reasoning seems more like a traditional OCP account, although we're dealing with a constraint against adjacent identical phonetic elements, not phonological units.

Perhaps the contrast between the phonetic and phonological analyses in terms of the usefulness of *Medial Contour indicates that the phonological analysis is superior, and therefore its assumption about the phonological nature of tone shift in Kikuyu is correct.

In any case, we've seen that the peak delay analysis can be modified to account for the behavior of all long vowels in Kikuyu. The necessary modification involved adding *MEDIAL CONTOUR, a constraint that has independent motivations in the absence of non-word-final contour tones in Kikuyu and the articulatory difficulty such tones would create. This modification compares favorably to the assumption that Clements (1984) makes concerning morphemes being the TBU at the initial stage in the derivation. That assumption has no independent justification.

More phonetic research is needed to shore up some questions about (potential) long vowels in Kikuyu. I noted in the previous section that the diphthongs in verbs are unproblematic for the peak delay analysis only if they are long. Here, too, questions remain. Perhaps the long vowels in this section are not really long enough to host two tones' peaks. If this is the case, the problems these long vowels pose for the peak delay analysis disappear because there is no practical difference between long and short vowels as far as tone articulation is concerned. The problematic form in (71) would incur a fatal violation of PEAK DELAY, and both the phonetic and phonological peak delay analyses could produce the correct form without *MEDIAL CONTOUR.

3.5 Summary

This section has applied the peak delay analysis to tone shift in Kikuyu. Because of the lack of relevant phonetic studies on Kikuyu, two analyses were developed, one that takes tone shift to be purely phonetic and another that does not. The argument presented in the first analysis was that Kikuyu is identical to Chichewa in terms of the misalignment of tones and their corresponding peaks. Since tones appear in greater density in Kikuyu, this state of affairs gives the impression of tone shift instead of Chichewa's tone spread. In the phonological analysis, the same constraints that drive misalignment in Chichewa still require sufficient space between pitch landmarks, but this time tones' formal associations follow these landmarks.

The analyses of Chichewa and Kikuyu are built on the interaction of three forces: Tone association conventions, tone/pitch alignment requirements, and phonetic implementation desiderata. As in basic OT analyses, when these forces are in conflict, the one that is represented by the lowest constraint is the one that yields to the others. In Chichewa and the phonetic analysis of Kikuyu, a constraint requiring tone/pitch alignment (COINCIDE(Peak)) is low-ranked, and therefore the association conventions (IDENT or ALIGN-L) and the phonetic implementation considerations (PEAK DELAY) are satisfied by abandoning a close alignment between tones and their peaks. In the phonological analysis of Kikuyu, ALIGN-L is ranked lowest, and the tone association conventions are ignored so that tones can align with their delayed peaks. Finally, if PEAK DELAY is demoted, then the requirements concerning phonetic implementation are ignored in favor of adhering to the tone association conventions and ensuring a close match between formal and phonetic representations. This last system is represented by the many languages with no Chichewa- or Kikuyu-style tone shift/spread (see also (27) in §2.3). Broadly speaking, then, the constraint system proposed here predicts three kinds of languages, and each is attested.

So far in this paper, I have shown that phenomena reportedly exhibiting noniterative tone spread and shift can be accounted for without recourse to noniterativity. If this result can be maintained in the face of other potentially noniterative tonal phenomena, then it goes a long way toward supporting OT's prohibition on access to the input by markedness constraints.

4 Other Analyses of Noniterativity in Tone

In this section I discuss competing OT analyses of noniterative tone spreading phenomena. I argue that they are inferior to the peak delay framework developed above on conceptual and empirical grounds.

4.1 Local

Myers (1997) adopts the constraint LOCAL to account for noniterative tone shift in Rimi. I give Yip's (2002) definition in (77) because this version is also capable of producing noniterative tone spread.

(77) LOCAL: An output tone cannot be linked to a TBU that is not adjacent to its host.

This constraint penalizes candidates whose high tones stray too far from their input hosts. But Kisseberth (2007:663) notes that:

> The problem, however, is that in current OT, a phonological constraint such as Local can access only the output candidates to see whether they violate the constraint. However, one cannot determine whether Local is satisfied in a given output candidate ... because one cannot see which mora is the host of the H tone in the input.

Kisseberth goes on to note that faithfulness constraints *are* allowed to access the input, but LOCAL is clearly not a faithfulness constraint. Adopting LOCAL amounts to the sort of modification of OT's architecture that the peak delay analysis avoids.

4.2 Lag

Hyman (2005) adopts the constraint LAG (78) to account for tone spreading. Developing and defending an account of noniterative tonal phenomena is not Hyman's central goal, so the defects of LAG discussed below reflect the preliminary nature of the proposal. Nonetheless, LAG represents a tempting analytical approach, and examining it is instructive in the present context.

(78) LAG(αT): An input tone should reach its target on the following output TBU.

We might interpret the reference to targets to mean that this constraint cares about how tones are articulated, but Hyman's subsequent examples and discussion make clear that LAG is satisfied when an output tone is linked to the TBU after its input host. So this constraint concerns phonological representations, not their phonetic implementations.

LAG creates tone shift, but it is not a sound account. Hyman apparently means for this to be a faithfulness constraint since the definition refers to input tones, and because he attaches '-IO' to it in specific instances (e.g. LAG-IO(H)). But LAG does not maintain faithfulness. It states a fact about markedness instead. We can't reinterpret it as a markedness constraint because markedness constraints are barred from access to the input, and LAG clearly requires this access.[26] Emphasizing the mention of the tone's *target* in the constraint definition, we might interpret LAG as a markedness constraint that requires a mismatch between tones and their phonetic implementations. But in this case, LAG reduces to (something like) PEAK DELAY.

One objection to the above argument is that if our theoretical assumptions render us unable to account for certain phenomena, we should modify our assumptions rather than shoehorn the phenomenon into an awkward analysis. Our theory should adapt to new phenomena, not the other way around. Perhaps the tonal phenomena considered in this paper indicate that markedness constraints should have access to the input after all. This would mean we can adopt LAG, which would provide us with a simple account of noniterative tonal phenomena that doesn't require a theory of peak delay.

The problem with this move is that it admits the possibility of noniteratively oriented constraints for other phenomena. If we can posit LAG constraints for non-tonal elements like, say, vowel height, noniterative height harmony should be as common as iterative iterative harmony: just as many grammars with a highly ranked LAG-height are possible as grammars with a highly ranked SPREAD-height, for example, are. Yet noniterative harmony is vanishingly rare, if existent at all, suggesting that constraints like LAG are superfluous. See Kaplan (2008a,b, to appear) for discussions of this point. Even though LAG lets us sidestep issues like peak delay and gives us a simple account of noniterative tonal phenomena (at the cost of abandoning what might be a trivial and pedantic theoretical tenet), it sets the stage for massive overproduction for OT. Since an analysis that does not require accessing the input is available, we should be hesitant to adopt constraints like LAG.

Of course, we can conclude that tone is simply different from other phonological entities in that it alone is governed by markedness constraints that can see inputs. This would be a disappointing result: As Autosegmental Phonology (Goldsmith 1976) developed, tones came to be viewed as rather closely related to segmental features in that, as autosegments, both tones and features can behave as autonomous units that are independent of the timing units that host them. It might be a step backward to conclude now that tones and features really are formally different entities after all. This move would also lead us to ask why tone should be exempt from the ban on access to the input. What makes tone so special that it can do what featural assimilation, foot assignment, syllable construction, etc., cannot? No obvious

[26] Even if we remove the reference to inputs tones, LAG can't tell whether or not a tone appears "on the following TBU" without seeing what the original TBU was in the input.

answer presents itself, so we are left no more enlightened (and actually significantly less enlightened, I would argue) than we are if we assume that tonal constraints are subject to the same restrictions that govern other markedness constraints.

Both LOCAL and LAG are unsatisfactory because they take noniterative tone spread/shift to be purely phonological processes that involve adding exactly one association line between a tone and a TBU. Consequently, when these constraints evaluate candidates, they must know which association lines are new and which are underlying, and this is what leads to the conflict with the ban on access to the input. On the other hand, the peak delay account proposed here does not have this problem. Peak delay takes these noniterative phenomena to reflect articulatorily motivated mismatches between phonological representations and phonetic implementations, and it doesn't need to manipulate association lines.

4.3 Optimal Domains Theory: *MonoHD, Minimality

Cassimjee & Kisseberth (1998) develop an Optimal Domains Theory (Cole & Kisseberth 1994, 1997, 1995, Cassimjee 1998) analysis of tone spread. In this analysis, the constraint *MONOHD (79) produces minimal tone spread or shift. (Although *MONOHD refers to high tones specifically, it can be extended to other tone levels in obvious ways, and I assume this extended version in the following discussion.)

(79) *MONOHD: A high-tone domain should not be monomoraic/monosyllabic.

This constraint is virtually identical to the constraint MULTI-TBU SPAN used in Kaplan (2007). In practice, *MONOHD produces disyllabic or bimoraic tonal domains because such domains satisfy *MONOHD while minimally violating faithfulness constraints. Spreading occurs when constraints require all syllables/moras in the domain to express the high tone, and shifting results from limiting the tone's expression to just one syllable/mora.

Zerbian (2006), in an analysis of various languages in the Sotho family of Bantu, uses MINIMALITY (80) to similar effect. It ensures that spreading by even just one syllable occurs in (almost) all cases, even when high-ranking constraints block the usual long-distance spreading.

(80) MINIMALITY: Tone domains are minimally disyllabic.

*MONOHD and MINIMALITY produce noniterative tone spread without the conceptual problems of LOCAL and LAG, and the claim behind them is intriguing: Tonal structure prefers binary (or non-unary) groupings on analogy with metrical structure. But there is no clear reason why tone but not, say, vowel height tends toward binary groupings. This means that *MONOHD and MINIMALITY gives no answer to the question addressed at the end of §2.1: Why are virtually no apparent cases of noniterativity found in phonology except in tonal phenomena? For peak delay, this is explained if the articulatory or perceptual factors that give rise to peak delay asymmetrically affect to tone as compared to other phonological units. But for MINIMALITY, the answer must be that there is no MINIMALITY constraint for other phonological entities. But since MINIMALITY is grounded in abstract an notion like the desirability of binarity, which cannot be independently verified, there is no obvious explanation for why this state of affairs should hold.

Kikuyu poses a particularly difficult challenge for *MonoHD and Minimality because, beyond the first two syllables of a Kikuyu word, there is no evidence for the binary domains required by these constraints. Consider *totomáɣa* 'we send.' *MonoHD and Minimality can correctly require the first two syllables to be parsed into a low-tone domain, but they will also penalize the monosyllabic high and low tones on the final two syllables. These constraints therefore predict an output like **(tòtò)(máɣá)*.

Perhaps the effect of *MonoHD and Minimality in non-initial domains is suppressed because **(tòtò)(máɣá)* fails to preserve the second underlying L. We need unary domains in order to preserve all tones. The constraint used by Cassimjee & Kisseberth (1998) to require one domain for each underlying feature is Domain Correspondence. This constraint must outrank *MonoHD because it is responsible for the lack of non-initial binary domains:

(81)

/totomaɣa LHL/	Dom Cor	*MonoHD
a. (tòtò)(maɣá)	*!	
☞ b. (tòtò)(má)(ɣà)		**

Another option is to invoke overlapping binary domains (Key 2007).

The floating low tones still must be accounted for. Recall that in the rule-based analysis, tone shift bumps these tones off the final TBU. In ODT, this means *MonoHD (which replicates tone shift) forces a violation of Dom Cor:

(82)

/mo-ɣɛka LHL/	*MonoHD	Dom Cor
☞ a. (mòɣɛ̀)(ká) L		*
b. (mò)(ɣɛ́)(kà)	*!	

We have a ranking paradox. The problem, it seems, is that *MonoHD requires binary domains for every tone, but the actual forms have binary domains only for initial tones. A scaled-back version of *MonoHD is needed, one that requires a non-unary domain for the leftmost tone. The justification for this constraint is not obvious, though. I am aware of no evidence outside of the tone-shift facts suggesting that the first syllable or pair of syllables in Kikuyu is special, so the revised *MonoHD arbitrarily singles out these syllables. (The same comments apply to Minimality.)

More generally, the status of the unpronounced tones in ODT is difficult to determine. ODT rejects autosegments, so it seems that an L is simply deleted if it doesn't have a domain in the output. But this is problematic because the downstep facts of Kikuyu point strongly toward the survival of this L, which means this tone must be an autosegment: It is a phonological object that is formally distinct from its host. Furthermore, it is clear that tones in Kikuyu are not underlyingly associated with their hosts, which also points to autosegmentalism.

There is also little evidence for the domains posited by ODT In Chichewa and Kikuyu, this is not a significant issue since tones are expressed throughout each domain, but in languages with tone shift over longer distances, ODT posits domains that encompass large amounts of a form even though the tone is expressed on only one syllable in that domain. Cassimjee & Kisseberth (1998) offer some evidence for these domains based on what appear to be long-distance OCP effects in Isixhosa: A high tone at the right edge of a verb stem affects the realization of a prefix high tone. In ODT, this is because the left edge of the stem tone's domain abuts the prefix tone's domain. To give just one example, in *(bá)ya(boníí)sa* 'they show,' the prefix *bá*-'s high tone is prevented from shifting rightward because this would create adjacent domain edges: **(bayá)(boníí)sa*. But it is equally plausible to suppose that an OCP constraint prohibits multiple high tones within a verb stem (a morphological category that excludes subject prefixes). Verb stems in Isixhosa seem to be restricted to hosting at most one high tone anyway, so the ODT prohibition on adjacent domain edges does not achieve better empirical coverage than a non-ODT account. Better evidence for ODT's domains is desirable.

In short, an ODT analysis of noniterative tonal phenomena avoids the problems of LOCAL and LAG, but it does so at the cost of new deficiencies that are not encountered in the peak delay analysis.

5 Other Tonal Phenomena

The PDT analysis takes many tonal phenomena to be artifacts of timing discrepancies between f_0 and other articulations. But this does not mean the proponent of PDT is committed to the position that all tonal phenomena are phonetic in nature. For example, in Chichewa, the infinitive/progressive marker *-ku-* induces a high tone on the following syllable. The transcriptions below follow Kanerva (1990).

(83)	ku-phíika	'I am cooking'
	ku-lémeera	'I am rich'
	ku-fótókooza	'I am explaning'

The lack of spreading in the second example indicates that the tone is associated with the first stem syllable, rather than this being a case of Kikuyu-style peak delay. Furthermore, if the tone shift in (83) were merely the phonetic result of peak delay, we'd expect to see this kind of shift everywhere in the language. Also, along with the last example from (83), the data below, from Moto (1983) (who doesn't transcribe penultimate lengthening), show that the shifted tone undergoes the usual spreading that was discussed in §2.2:

(84)	kuphíká ndíwo	'to cook relish'
	kulírá maliro	'to mourn'
	kupémpá ndaláma	'to ask for money'
	kusámála mkázi	'to care for a woman'

Since the tones in (84) are transcribed over the first two stem syllables, the reasonable conclusion is that the tone has shifted to the first stem syllable and then spread from that syllable. If H remained associated with the prefix, we'd expect transcriptions like **kúlíra maliro* and **kúpémpha*. Instead, the transcriptions are consistent with the assumption that these tones are underlyingly associated with the stem-initial vowel.

The tones in these examples phonologically shift—H is formally associated with the stem-initial syllable. Once this shift is produced, the spreading facts fall out from the analysis in §2.2. How are we to produce tone shift? Since the shift seen here is confined to specific contexts (words with the *-ku-* prefix, and also the recent past *-na-* and habitual *-ma-*) in contrast with the pervasive tone shift from Kikuyu, we could adopt a morpheme selection constraint like the one in (85).

(85) H ON *-ku-* STEM: *-ku-* must affix to an H-initial stem.

This constraint encodes the observation that *-ku-* selects a high-toned stem allomorph. Since the prefix itself supplies a high tone, we don't have to lexically list each verb stem with a high-toned variant. Instead, the prefix's H docks onto the stem—the prefix provides the means for satisfying its own selectional requirements.

Alternatively, we could adopt an Alignment constraint like the one in (86). This requires high tones affiliated with the infinitive prefix to be left-aligned within a verb stem. Ranked over IDENT-T, this will correctly place a high tone on the stem-initial syllable.

(86) ALIGN-L(H_{Inf}, Stem): The left edge of every high tone from an infinitive morpheme is aligned with the left edge of some verb stem.

Similar constraints could be adopted for other verbal prefixes in the language, such as the present habitual *-ma-*, which requires two high tones, one on the preceding syllable and another on the stem-penultimate syllable.

These solutions are workable here because of the limited scope of Chichewa's tone shift. Since the prefix's H always lands in the same position in the same morphological unit, we can posit a specific constraint that produces this state of affairs. Compare this to the sweeping constraint or army of specific constraints that would be necessary under approaches based on (85) or (86) for Kikuyu.

A Positional Licensing constraint (in the style of Crosswhite (2001)) would even work. By declaring that *-ku-*'s H is licensed only in the stem, we can achieve tone shift similar to the way spreading to the root is produced for various phenomena in Kaplan (2008b).

Other cases of tone shift involve high tones moving to specific position in a word or phrase. The target syllable is often a final syllable in some domain. For example, in Digo, the last H of a word moves to the final syllable (Kisseberth 1984). Kisseberth also argues that the rightmost H in a phrase moves to the phrase-final syllable in Digo. Tone shift can also reflect the pressure of a NONFINALITY constraint: in Nkore (Odden 2005) and Somali (Saeed 1999), H moves from the phrase-final syllable to the penultimate syllable. Also relevant is the retraction phenomenon in Chichewa discussed above and similar cases that are noted in Myers (1999).

Similarly, many researchers (e.g. de Lacy 1999, 2002, Downing 2003, Peterson 1987) have noted that high tones often gravitate toward prosodically prominent positions. Digo's shift-to-final-syllable phenomenon may involve attraction to prominence or simply right-alignment, and Philippson (1998) argues that retraction in Chichewa is really attraction of the phrase-final H to the stressed penultimate syllable. Downing (2003), who points out many similarities between accentual systems and the tonal systems of Chichewa and Xhosa, argues that in Chichewa, when a prefix's H moves to the stem-penultimate syllable in a way comparable to *-ku-*'s placement of a stem-initial H, this is attraction to prominence. Peterson (1987), also working with Chichewa, adopts essentially the same analysis: Extra prominence (via grid marks) is assigned to certain syllables, and a rule or well-formedness principle requires tones to associate with these prominent syllables. Since specific positions are targeted in these cases, straightforward accounts that do not run afoul of the ban on markedness constraints accessing the input are available. This is even true of certain cases that involve shifting to an adjacent position, such as movement from the final to the penultimate syllable in Chichewa. Simply put, tone shift of this nature is not noniterative, so it is not problematic for existing OT constraints.

Shona has a particularly interesting tone spread phenomenon (Myers 1987, 1997, Odden 1981). High tones in this language can engage in unbounded rightward spreading as long as every pair of adjacent syllables in the spreading domain belongs to different morphemes. (This is far from the whole story about tone spread in Shona—see the work cited immediately above for more comprehensive discussion.) Thus we have (87a), where the high tone on the first morpheme spreads all the way to the penultimate syllable. It can reach this position because each spreading "step" crosses a morpheme boundary. Compare this to *ma-zi-mi-chero* 'Big ugly fruits,' which shows that the non-initial morphemes in (87a) contribute no high tones themselves. On the other hand, in (87b), spreading just to the antepenultimate syllable is allowed because spreading to the penultimate syllable would involve spreading within the morpheme *ðambudziko* (cf. (87c), which shows that the root has no high tone of its own).

(87) a. *Vá-Má-zí-mí-chéro*
2a-6-21-4-fruit
'Mr. Big-ugly-fruits' (Odden 1981:77, gloss from Myers 1997:862)

b. *Vá-Dámbudziko*
honorific-Dambudziko
'Mr. Dambudziko' (Odden 1981:76)

c. Dambudziko (proper name) (Odden 1981:76)

Myers (1997) accounts for this pattern by positing unbounded rightward tone spread that is reined in by a constraint requiring successive high-toned syllables to be in different prosodic or morphological domains. Although examples like (87b) seem to show noniterative spreading, forms such as (87a) reveal this noniterativity to be a happenstance of the morphological configuration.

PDT can also interact with some of these other analytical approaches. Michael Marlo (p.c.) provides the data in (88) from Lukhayo and Lutura. In these languages, H spreads leftward to the peninitial stem syllable (stems are marked with square brackets). That is, the stem-initial syllable is off limits for spreading. But if the stem is disyllabic, the initial syllable *is* targeted. The generalization is this: spreading by one syllable is mandated, and then if there are other stem syllables available besides the initial syllable, further spreading occurs.

(88)	Lukhayo	Lutura	Gloss
	a-li[fw-á]	a-li-[fw-á]	'he will die'
	a-li[xín-á]	a-li[xín-á]	'he will dance'
	a-li[reéβ-á]	a-li[rééβ-á]	'he will ask'
	a-li[βukúl-á]	a-li[βukúl-á]	'he will take'
	a-li[siindíx-á]	a-li[siindíx-á]	'he will push'
	βa-li[karaáng-ír-án-á]	βa-li[karááng-ír-án-á]	'they will fry for each other'

Some constraint—call it ALIGN-L—motivates spreading to the stem-initial syllable, and another constraint (say, NONINITIALITY (Bickmore 2000)) outranks ALIGN-L and prevents complete satisfaction of ALIGN-L. PEAK DELAY, when it outranks NONFINALITY, effectively produces the minimal-spreading requirement by encouraging the tone's onset and peak to appear in separate syllables. When the stem is trisyllabic, satisfaction of ALIGN-L (to the extent possible) entails the satisfaction PEAK DELAY. E.g., in *βa-li[karááng-ír-án-á]*, the high tone's domain is long enough for the peak and onset to appear in separate syllables without either one falling outside the tone's formal, phonological domain. But when the stem is disyllabic, PEAK DELAY motivates the otherwise banned spreading to the initial syllable.

We've seen in this section that there are phenomena that need not (and probably should not) be accounted for under the peak delay umbrella. Peak delay is just one of many factors that can leave their mark on tonal systems.

6 Conclusion

This paper has argued that it is worth viewing noniterative tonal phenomena as the product of constraints on phonetic implementation. It would of course be premature to suppose that the analyses developed here resolve the question of how to account for these phenomena once and for all, and certainly not for every language exhibiting noniterative tonal phenomena. Only a broader examination of tonal processes will determine if the peak delay framework can account for every case of noniterativity. Peak delay is just one of the many tools available to grammars, and it would not be surprising to find that a variety of approaches are needed.

Giving control of peak delay to the phonological grammar results in a theory in which phonetics and phonology are not wholly distinct. Much recent work (such as Dispersion Theory (e.g. Flemming 2002, Padgett 2003)) has argued for a phonetically sophisticated phonological grammar in which acoustic, articulatory, and perceptual factors play direct roles in the formal phonology. In a similar vein, Li (2003:165) notes a "strong parallelism between phonology and phonetic implementation in that both domains can be modeled as systems of constraint interaction." The analyses proposed here obviously support this view, but they are not incompatible with the view that "phonological constraints must in some cases operate at a level distinct from the phonetics" (Morén & Zsiga 2006:172). I have argued here that separate, independent constraints may exist for phonological elements and their phonetic exponents. In this way, phonetics and phonology interact but are not conflated.

This paper began with the observation that noniterative tonal phenomena put OT in a bind. Like opacity and the too-many-solutions problem, noniterativity is something that OT is not equipped to cope with easily. Without granting markedness constraints access to inputs, OT cannot require a process to apply exactly once. I've argued here that taking noniterative tonal phenomena to reflect peak delay solves this conundrum: Noniterativity is not a defining characteristic of these phenomena, but is instead a byproduct of the interaction between phonetic implementation and constraints on phonological well-formedness. In this light, the current investigation builds on other work (Kaplan 2008a,b, to appear) that argues that, in contrast with opacity, noniterativity is one phenomenon that OT is better off for not permitting.

Finally, it should be noted that a theory that includes peak delay is not committed to the position that all tonal phenomena are phonetic in nature. Traditional (OT or rule-based) phonological analyses of tonal phenomena are compatible with the peak delay framework—we saw an example of this in the analysis of Chichewa, where NonFinality was used. It is far too premature—and perhaps absurd—to claim that all tonal phenomena involve manipulating pitch targets instead of phonological representations. The claim developed here is simply that peak delay plays a role in some phenomena, and it can elucidate the principles behind a particularly interesting and difficult type of phenomenon.

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