Contour Tone Distribution in Luganda

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1. Introduction

The traditional model of contour tone distribution (see, e.g., Hyman 2003) uses phonological units to describe which syllable types can bear rising or falling tones (see Zhang 2004 for an overview). A common pattern is one in which contour tones are permitted on long vowels but not on short vowels; this is explained in the traditional model by assuming that the mora is the tone-bearing unit (TBU) and there is a one-tone-per-mora restriction that prohibits contour tones on short vowels.

An alternative to the phonological approach is one in which contour tone distribution is phonetically based (see, e.g., Gordon 2001, 2006, Zhang 2001, 2004). In the phonetic model, there is no role for the mora in determining contour tone distribution; instead, it is duration and/or sonority that determine whether a contour can occur on a given syllable.

In this paper, we show how Luganda bears on the choice between the two models, favoring the phonological approach over the phonetic one. As we will show, the mora is crucial to explaining contour tone distribution in Luganda, and the duration-based phonetic model makes incorrect predictions for this language.

2. Two competing approaches

In the phonetic approach proposed by Zhang (2001), contour tones need a minimum sonorous rime duration (SRD) in order to be realized on a given syllable. SRD is defined as the duration of the syllable nucleus plus any sonorant consonant(s) in the coda, but crucially *not* including any obstruent coda consonants. A variant on the SRD-based model is Gordon's (2001) proposal that contour tones require the host syllable to have a certain amount of 'overall sonorous energy'. Under either version of the phonetic model, if contour tones can occur on a syllable with a given SRD/sonorous energy, then they must also be permitted on syllables with a greater SRD/sonorous energy. This yields an implicational hierarchy of syllable types in terms of their phonetic suitability to bear a contour tone, which in most languages is as shown in (1).

(1)   **CVV   >   CVR   >   CV   (>)   CVO**

Note that the relative position of CV and CVO in the hierarchy varies depending on the SRD/sonorous energy of these two syllable types on a language-by-language basis.

The phonological approach to contour tone distribution most often involves a constraint requiring that each mora may bear only one tone. The result is that contours are permitted on syllables of type CVX (2a) (X is a moraic segment, i.e., a vowel or a coda consonant) but not on syllables of type CV (2b).

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(2) a. ✓CVX   b. * CV

              | | |

             μ μ   μ

             | | / \

            H L   H L
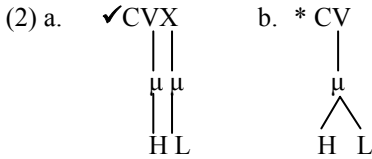
Since the status of coda consonants as moraic vs. non-moraic appears to be language-specific, it follows that "CVX" as a bearer of contour tones may need to be broken down futher for some languages. If Language X does not have codas, or if codas are non-moraic in Language X, then CVV may be the only syllable type that can bear a contour tone in Language X. If all syllables in Language Y are of type CV, then there may be no contour tones at all in Language Y. If Language Z assigns a mora to sonorant codas (R) but not obstruent codas (O), then contours should be allowed on CVV and CVR syllables, but not CVO or CV. A language where all codas are moraic and there is a one-tone-per-mora constraint should have the following hierarchy of phonological suitability to bear a contour tone:

(3)   **CVV, CVR, CVO**   **>**   **CV**
        Able to bear a contour   **Unable to bear a contour**

One major difference between the phonetic and phonological approaches is in the position of CVO syllables, as can be seen in comparing the phonetic hierarchy in (1) with the phonological hierarchy in (3). CVO syllables are phonetically ill-suited to bear contours since they tend to have a short SRD, but they are phonologically eligible to bear contours because they have two moras (in languages where obstruent codas are moraic). This difference in the predictions of the two models allows us to distinguish between them empirically in languages that allow only one tone per mora. The discovery of a language where CVO syllables are bimoraic but have a short SRD and cannot bear contour tones would support the phonetic model; the discovery of a language where CVO syllables are bimoraic and have a short SRD but can still bear contour tones would support the phonological model. We will argue that Luganda is the latter type of language, providing support for the phonological model.

3. Contour tone distribution in Luganda

3.1. Background on Luganda

Luganda is a good language in which to test the predictions of the competing models of contour tone distribution because it has both contour tones and closed syllables, including CVO syllables. The existence of CVO syllables is crucial to testing the models, and these are absent in most Bantu languages. In Luganda, CVO syllables result from the fact that the language has developed geminates; all CVO syllables in Luganda are closed by the first half of a geminate.

In Luganda, coda consonants are moraic, a fact that has been demonstrated independently of the tone distribution facts by Clements (1986). The language has high (H) and low (L) tones as well as falling (H͡L) tones (Hyman 2003). There are no rising tones.

Disyllabic verb stems in Luganda have the shape /-CVC-a/, /-CVCC-a/, or /-CVVC-a/. There are no /-CVVCC-a/ verbs. The /-a/ at the end of each stem is the so-called 'Final Vowel' (FV) that occurs at the end of verbs in most environments. Because all verb stems end in a vowel, the possible stem-initial syllable types are CV, CVC (including CVR and CVO), and CVV. It has been claimed that in Luganda, H͡L falling tones can occur on CVV, CVR, and CVO, but not on CV. As will be shown below, our study confirms this generalization.

3.2. Predictions of the competing approaches for Luganda

Before presenting the results of our study, we will lay out the specific predictions that are made by the two competing models for contour tone distribution in Luganda. The phonetic approach (whether

based on SRD or on sonorous energy) makes the following predictions. In order for the phonetic model to be upheld in Luganda, at least one of the predictions must be correct. The first is that an underlying $\widehat{HL}$ contour on a CVO syllable will be realized as level H with lowering of a following H. That is, the L will be delinked from the TBU, becoming a floating tone which will be manifested as a downstep on a following H tone. In his Introduction to Snoxall 1967, A.N. Tucker claims that this is, in fact, the way that underlying falling tones are manifested on CVO syllables. This claim is subsequently repeated by Gordon (2001, 2006) and Blevins (2004); we test the claim phonetically in our study, to be discussed below.

If falling tones really are phonetically manifested on CVO syllables in Luganda, contrary to the first prediction of the phonetic model, there is a second way in which the model may work for Luganda: CVO syllables should have a longer SRD or more sonorous energy than CV syllables, which do not bear falling tones.[1] In section 3.3, we test this second prediction by measuring the SRD of CVO vs. CV syllables in Luganda.

If both the first and second predictions fail, then in order for the phonetic model to be maintained for Luganda, the following must be true: CVO syllables with $\widehat{HL}$ must have a lengthened SRD (or more sonorous energy) in comparison with level-toned CVO syllables; this would most likely be manifested via vowel lengthening in CVO syllables with a falling tone. As pointed out by Gordon (2001: 442), the existence of such a lengthening process in Luganda would be facilitated by the fact that there is no vowel length distinction in closed syllables; this means that if the vowel of a CVO syllable lengthens, there is no danger of neutralizing a contrast with CVVO since the latter does not exist underlyingly. We test this prediction by measuring the SRD of CVO syllables with level vs. falling tones.

The phonological approach makes a contrasting prediction for Luganda, which is that falling tones will occur on syllable types with two moras (i.e., CVV, CVR, and CVO) but not on those with one mora (CV). In our study, we consider both the phonological tone distribution (based on our transcriptions) as well as the phonetics of contour tone realization in evaluating the competing models.

3.3. Luganda contour tone data

Phonologically, the distribution of tones in Luganda is as follows. H and L level tones surface on all syllable types (CV, CVO, CVR, CVV). $\widehat{HL}$ falling tones surface on CVV, CVR, and CVO syllables, but not on CV. Falling tones are observed on CVO syllables with voiced codas (CVD) and voiceless codas (CVT).

The distribution of tones on verb stems is slightly more restricted because there is only a two-way tonal distinction on verb stems. The distribution of tones on the initial syllable of disyllabic verb stems (in isolation in their infinitive forms) is as follows.[2]

(4) Verb tones by stem-initial syll. type (note: [ó] = H tone; [ò] = L tone; [ô] = short falling tone)

	CV		CVT		CVD		CVV	
L	òkù-tòkà	'be enraged'	òkù-kòkkà	'ask riddles'	òkù-kòggà	'get thin'	òkù-kòòtà	'choke'
H	òkù-kókà	'clean out'	——		———		———	
$\widehat{HL}$	——		òkù-côppà	'become poor'	òkù-bôbbà	'throb'	òkù-kóòkà	'cry'

As seen in (4), all syllable types can be toneless, but only CV has level H, while as discussed above, CV does not have falling tones. We can explain this distribution and collapse the two 'defective' tone types into a single category by assuming (following Hyman and Katamba (1993)) that there is a underlying two-way tone contrast between $\widehat{HL}$ and Ø (toneless) on verb roots. The surface forms in (4) result from this as follows.

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[1] There is one environment in which CV syllables can bear a falling tone, namely in word-final position. The study of word-final falling tones is outside the scope of this paper, but see Hyman and Katamba 1990 for discussion and for an analysis that reconciles the existence of falling tones on word-final CV syllables with the one-tone-per-mora restriction assumed here.

[2] For the remainder of the paper, we will ignore CVR syllables since they behave just like CVV syllables.

Toneless stems get L tone by default; this occurs straightforwardly on all verb types regardless of syllable type.

On $\widehat{HL}$ stems, the underlying tone sequence is associated with the first stem mora, and the L portion of the contour shifts onto the second mora of the stem due to the 'one tone per mora' restriction.[3] For a /-CVC-a/ stem, where the stem-initial syllable has only one mora, the result is a level H on the first stem syllable, followed by a level L tone on the FV (5a). For a /-CVVC-a/ or /-CVCC-a/ stem, this results in a $\widehat{HL}$ contour on the stem-initial syllable, as shown in (5b).

(5) a. -CVC- a   b. -CVCC- a

It is important to point out that this is a claim only about the output of the phonology, not the precise phonetic manifestation of the tones. This is especially important for CVT syllables. In our analysis, the phonology will produce outputs where there is a H on the vowel of CVT and a L tone on the voiceless coda. In reality this would be impossible to produce since a voiceless obstruent has no vocal fold vibration to be manipulated in order to produce a low pitch, so we assume that the phonetic component is responsible for interpreting the output of the phonology in such a way so as to make it pronounceable. Therefore, we do assume a role for phonetics in contour tone manifestation. But what is crucially different between this approach and the pure phonetic approach is that we are assuming that the phonetics operates only on the *output* of the phonology and does not affect the phonological distribution of contour tones.

Now that we have described the phonological distribution of tones and provided a phonological account for this, we move to the phonetics of contour tone realization. The phonetic distribution of contour tones can be summarized as follows. First, unsurprisingly, H and L level tones surface on all syllable types. However, when the syllable in question is stem-initial in an infinitive verb form with no grammatically imposed tone changes, true level H tones do not surface on CVV or CVD syllables and only variably on CVT. $\widehat{HL}$ never surfaces on CV syllables, but it does surface consistently on CVV syllables. $\widehat{HL}$ also surfaces consistently on CVD and variably on CVT, contradicting Gordon's claim (2006: 93, 101) that falling tones do not surface on CVO syllables in Luganda. This is, however, fully consistent with an earlier claim made by Gordon (2001: 442):

> 'Although CVO ending in a voiced obstruent and carrying a contour tone regularly realizes its contour tone, CVO ending in a voiceless obstruent and carrying a phonological falling tone… are reported to often carry only a "psychological low tone"… *though it should be pointed out that the vowel in CVO ending in a voiceless obstruent can realize the contour tone itself.*' [italics ours]

Below we provide some representative spectrograms and pitch contours to illustrate the phonetic generalizations given above. The first example, shown in (6), is a typical falling tone on a stem-initial CVV syllable. The arrow indicates the location of the fall, whose size is 39 Hz from its highest to lowest point.

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[3] Alternatively, the underlying H and L tones could be associated directly to their ultimate host moras rather than being associated to a single mora and then undergoing readjustment. We have opted for the readjustment approach based on Hyman and Katamba's (1993) arguments that the underlying tone is a true $\widehat{HL}$ contour rather than a HL sequence.

(6)   CVV syllable: [òkùlóòt ènnyò] 'to dream excessively' (speaker LY)
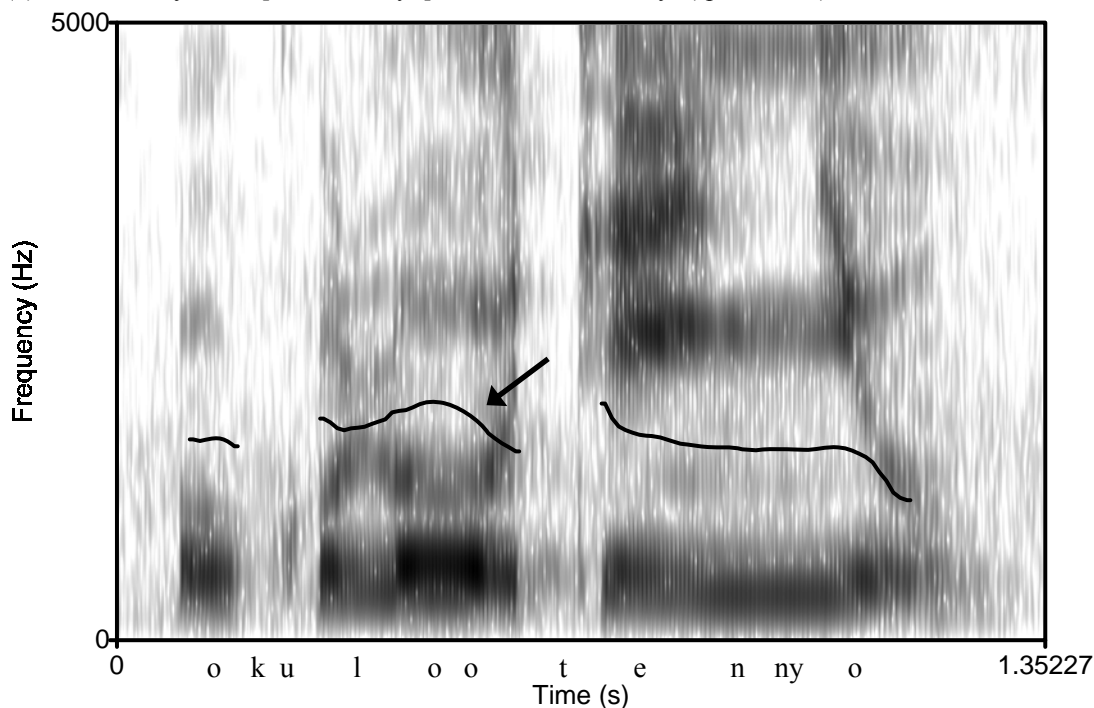
The second spectrogram, in (7), shows a falling tone on a stem-initial CVD syllable. The location of the fall is again indicated by an arrow. Note that the fall begins before the end of the vowel, but continues into the stop closure. The fall in this example totals 51 Hz, but part of this may be attributed to the inherent low pitch of the voiced obstruent coda. We therefore assume that the fall is not actually significantly larger in magnitude than the 39 Hz fall on CVV that was seen in the previous example.

(7)   CVD syllable: [òkùbôbb éddà] 'to throb later' (speaker PK)
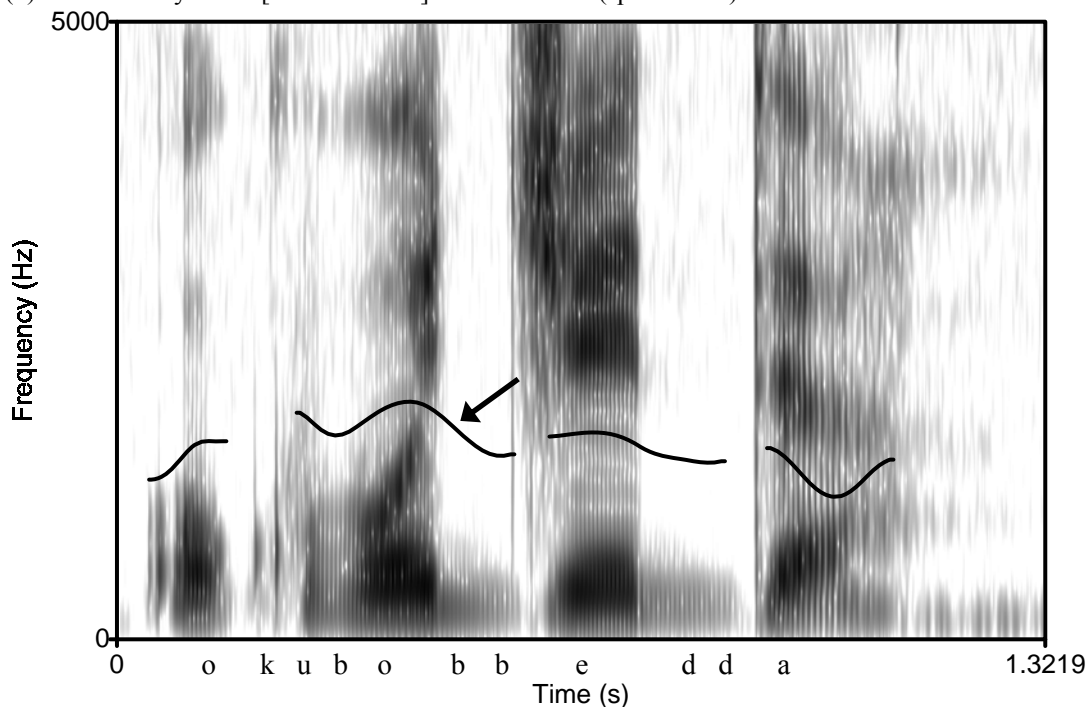
Our third spectrogram, in (8), shows a falling tone on a CVT syllable. The fall here is only 17 Hz and takes place fully within the duration of the vowel. Hence, the fall appears to be compressed and reduced. Nonetheless, we take this (and other similar examples) to represent true falling tones for two reasons. First, a 17 Hz pitch drop is perceptible to us and, presumably, to native speakers. Second, there is no logical source for a falling pitch of this magnitude, other than the phonological falling tone.

(8)   CVT syllable: [òkùlâtt ènnyò] 'to ignore (someone) excessively' (speaker LY)
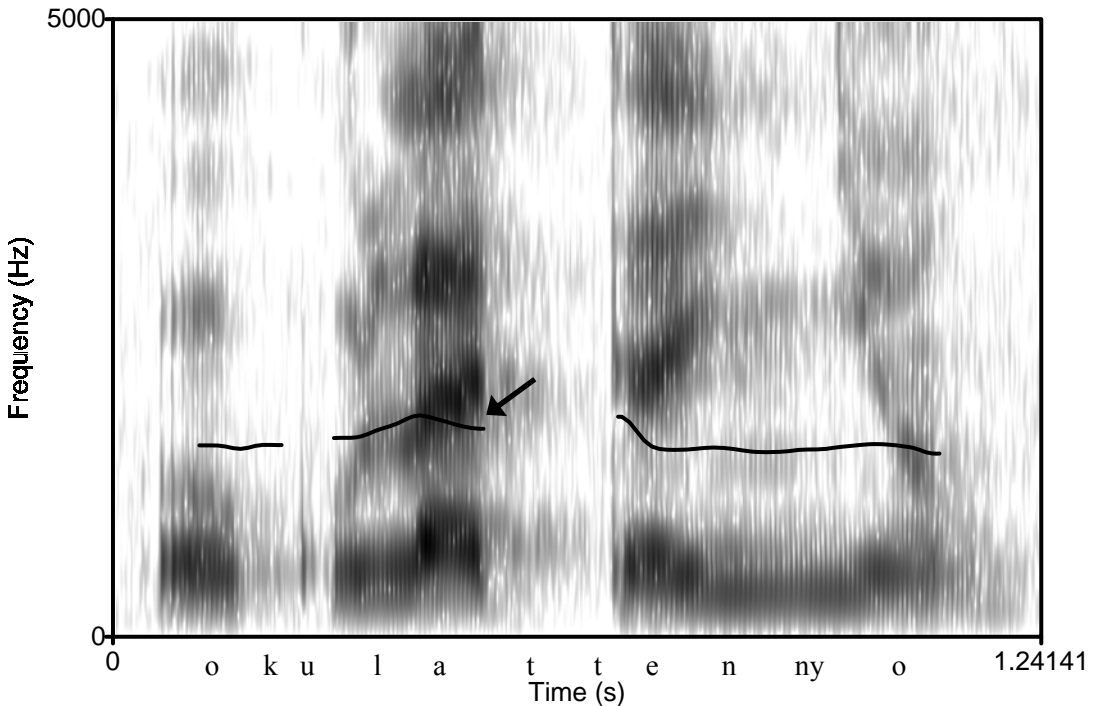
Thus, the phonetic distribution of contour tones supports the mora-based account: CVO can bear a falling tone (always on CVD, and variably on CVT), patterning with the other bimoraic syllable types (CVR and CVV). Monomoraic syllables (CV), on the other hand, do not bear falling tones.

These facts also contradict the first prediction of the phonetic model discussed above, that underlying falling tones should be manifested on CVO not as true falling tones but as a H tone followed by a floating L tone that causes a downstep on a following H tone. However, the phonetic account can still be upheld if CVD and CVT syllables turn out have a longer SRD (or more sonorous energy) than CV, and/or if CVO syllables are lengthened when they bear a falling tone.[4]

We consider first the relative SRD of CV, CVD, and CVT syllables. (9) shows the mean SRD for level-toned syllables by syllable type and stem vowel, along with the number of tokens for each.

(9)   Level-toned syllable mean SRD (msec) for speaker PK

	CV	CVD	CVT
/a/	106 (n=18)	107 (n=6)	
/e/	123 (n=12)	130 (n=6)	106 (n=12)
/o/	106 (n=6)	107 (n=6)	107 (n=6)
/i/	91 (n=12)		83.7 (n=6)
/u/	94.2 (n=9)		

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[4] In what follows, we are specifically testing the SRD-based phonetic model, rather than a version based on sonorous energy. The predictions made by each version of the phonetic model are roughly the same, and we argue in section 3.4 that measuring sonorous energy rather than SRD would not change the overall result of our study.

The inherent duration differences among vowels turned out to be too great for us to pool the results for each syllable type across vowels, but some generalizations emerge in comparing the SRD of each syllable type for each vowel (statistical significance values can be found in Appendix II). For /a/, we find that there is no significant difference in the SRD of CV vs. CVD syllables. For /e/, we find that CVD syllables have a statistically significantly longer SRD than CV syllables, and CV syllables have a significantly longer SRD than CVT syllables. For /o/, we find no significant differences among CV, CVD, and CVT. For /i/, we find no significant difference between CV and CVT. Overall, we can conclude that CV, CVT, and CVD are not reliably different from each other across vowels. If we pool the non-high vowels (since it is high vowels in particular that exhibit a variable and usually very short duration), we obtain a mean SRD of 112 msec for CV, 107 msec for CVT, and 115 msec for CVD; this yields no statistically significant SRD differences among the three syllable types.

Since CVO syllables are do not have a longer SRD than CV syllables, the only remaining hope for the phonetic model is that CVO syllables with a falling tone are lengthened. (10) compares the mean SRD of CVD syllables with level vs. falling tones (with all non-high vowels pooled).[5]

(10)   Mean SRD (msec) of level- vs. falling-toned CVD syllables for speaker PK
         CVD /∅/   **CVD /H͡L/**
         115 (n=18)   105 (n=6)

We find no evidence here for CVO syllables lengthening when they bear a contour tone. In fact, strangely, the level-toned CVD syllables have a slightly *longer* mean SRD than H͡L, not shorter, as would be expected. But it is important to note that this difference is *not* statistically significant. This small difference could be attributed to the unexpectedly high SRD values of the underlyingly toneless CVD syllables with /e/; excluding /e/, the mean SRD for this syllable type is 107 msec.

Following our study with speaker PK, we ran a more carefully controlled version of the study with speaker LY looking only at syllables with /o/, since this vowel occurred in the largest number of syllable and tone types in the dictionary. We first considered the mean SRD across syllable types.

(11)   Level-toned syllable mean SRD (msec) in syllables with /o/ for speaker LY
         CV   **CVT**   **CVD**
         120 (n=14)   91.2 (n=16)   119 (n=7)

As seen in (11), CV and CVD syllables have a longer SRD than CVT syllables; this difference is statistically significant. CV and CVD, however, are not significantly different.

As with speaker PK, we also compared the SRD of level- vs. falling-toned CVD syllables to see whether CVO syllables are lengthened when they bear a falling tone.

(12)   Mean SRD (msec) of level- vs. falling-toned CVO syllables with /o/ for speaker LY
         CVD /∅/   **CVD /H͡L/**
         119 (n=7)   101 (n=6)

As shown in (12), level-toned CVD syllables have *longer* SRD than falling-toned CVD syllables, and in this case the difference is statistically significant. We presently have no explanation for why level-toned syllables are longer than falling-toned syllables; we leave this question for future consideration.

3.4. Summary of the study results

We now summarize the results of our studies of speakers PK and LY. We found that the syllable types that cannot bear contours (CV syllables) have a mean SRD that is equal to (or, in some cases,

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[5] We did not have enough tokens of speaker PK pronouncing CVT syllables with non-high vowels for each tone type to run this comparison for CVT syllables, so only CVD syllables are shown here to represent CVO. But we have no reason to expect that CVT would behave differently from CVD with respect to any possible lengthening process, nor do measurements of our few relevant tokens suggest the existence of such a process.

greater than) that of CVO syllables, which can bear contours. Furthermore, there is no evidence for vowel lengthening in CVO syllables to accommodate falling tones; CVO syllables with falling tones have an SRD that is equal to (or, in some cases greater than) that of CVO syllables with level tones. Therefore, we conclude that SRD is not a predictor of contour tone distribution in Luganda.

This raises the question of whether a measure of sonorous energy would fare any better than SRD. The relevant difference between SRD and sonorous energy for our purposes is that SRD does not include any part of an obstruent coda, even if it is voiced and allows for some measure (and percept) of fundamental frequency. Sonorous energy, on the other hand, can include part of a voiced obstruent if the voicing is robust enough to manifest a pitch (see Gordon 2001 for the details of one method of measuring sonorous energy). Therefore, measuring sonorous energy rather than SRD could possibly account for why CVD syllables can bear falling tones but CV syllables cannot, if SRD systematically underestimates the ability of obstruent codas to bear tone relative to CV syllables. However, measuring sonorous energy would still not help with CVT syllables, since this measure does not include any portion of a voiceless coda. Therefore, the phonetic account still fails to account for contour tone distribution in Luganda, while the phonological account does accurately capture the empirical facts described above.

3.5. Phonetic factors in Luganda contour tone distribution

Our conclusions above may suggest that we deny a role for phonetics in contour tone distribution in Luganda. But this is false; we do believe that SRD/sonorous energy can help explain the surface realization of contours. For example, phonetic factors are likely responsible for the variable manifestation of $\widehat{HL}$ as a (phonetically) level vs. falling tone on CVT syllables. But in our analysis, the $\widehat{HL}$ tone is associated to moras in the phonology *prior* to phonetic realization, which is where duration comes in. We therefore distinguish between phonological tone assignment and phonetic surface tone manifestation. This allows us to explain why CVT syllables sometimes bear falling tones but CV syllables never do, even when they have an equal SRD. A CVT syllable can have a $\widehat{HL}$ contour since it is bimoraic; this contour will necessarily be phonetically reduced and contracted, which in some tokens will result in a level high pitch but in other tokens (such as the one represented in (8)) will result in a small falling pitch contour. A (non-final) CV syllable in a $\widehat{HL}$ verb, on the other hand, will always have its L reassigned to the FV phonologically, and therefore the CV syllable will never bear even a reduced falling tone, despite having an SRD that is as long as or longer than that of CVT.

Another way in which phonetics influences contour tone distribution is in the diachronic domain. In Luganda, as mentioned earlier, CVO syllables are always closed by the first half of a geminate. The geminates in Luganda arose historically from VC sequences where the vowel is a super-high front vowel (Blevins 2004: 172; see also Clements 1986), e.g., *-dduka-* < *-*ji̧duk-* 'run'. This allows a phonetically natural explanation for why CVO syllables are allowed to bear falling tones. Since the first half of every geminate was historically a vowel, it would have been able to bear tone. Then the vowel became a consonant, but its tone-bearing ability was retained; in phonological terms, the mora was preserved. Therefore, contour tone distribution was likely phonetically natural at an earlier stage in Luganda, when the only mora-bearing segments would have been sonorants. But because of the emergence of geminate obstruents, the synchronic grammar now has a mora-based restriction, and the distribution is now phonetically somewhat unnatural in that it is not predictable from SRD, according to our study. Blevins (2004) discusses this and many other cases in which a phonetically natural pattern becomes unnatural due to sound changes that obscure the original motivation for the pattern.

4. Conclusion

In conclusion, we have shown that phonetics alone cannot account for contour tone distribution in Luganda. We need a phonological restriction (one tone per mora) to account for why CVO patterns with CVV and CVR to the exclusion of CV in allowing falling tones, regardless of SRD. With this mora-based restriction, the role for the SRD in Luganda contour tone distribution is in determining the surface realization of tones *already assigned in the phonology*. Our view is similar to one expressed by Gordon (2001: 441, referring to Hausa):

'It is possible that tone bearing ability in certain languages… is sensitive to structural length lexically and that phonetic considerations remedy any deficiencies in the ability of a syllable carrying a lexical contour tone to realize the contour on the surface. Pursuing this approach, contour tones could thus be assigned to CVO lexically… because the rime in CVO contains two segments and is thus "phonologically" as long as CVR and CVV. However, because CVO is ill-suited to support a contour tone phonetically, steps must be taken to ensure that the latter half of the contour tone is properly realized on the surface.'

Hence, our approach does not deny a role for phonetics; it allows for phonetic influences on sound patterns without assuming that phonetics must drive *synchronic* phonological processes.

5. Appendices

5.1. Appendix I: Methodology for duration study

Participants were two female native speakers of Luganda. Target words were chosen based on Snoxall 1967 and were elicited in advance to determine which words were familiar to the speaker. Only those that were familiar were added to the wordlist. For speaker PK, the list included disyllabic verb stems with each of the five vowels. For speaker LY, the list included only disyllabic verbs with /o/.

We attempted to control for the type of consonant occurring before and after the vowel in the target syllable. In some cases this was impossible due to lack of verbs with certain syllable types. This does not seem to have affected our data except possibly in the case of toneless CVD syllables with [e], where the values were higher than expected, perhaps related to the fact that the only verbs of this type that we were able to elicit had /j/ after the target V.

In the citation form of verbs, Ø vs. $\widehat{HL}$ is hard to distinguish, so forms were elicited with an adverb following the verb. Tokens were recorded from a wordlist directly onto a PC using PRAAT. We controlled for list intonation by asking for each token separately.

Sonorous rime duration (SRD) was measured manually using visual segmentation and confirmed auditorily. Segment boundaries were marked at the nearest zero-crossing to each point of rapid change in period shape and/or amplitude in the waveform, and intensity of formants in the spectrogram. SRD on a syllable with a voiceless stop onset was measured beginning at the offset of the stop closure, i.e., including the burst.

5.2. Appendix II: Statistical significance values

For speaker PK, syllables with [e]: CVD>CV (t=-2.15, p=.047)   CV>CVT (t=3.55, p=.002)
For speaker LY, syllables with [o]: CV>CVT (t=8.60, p=.000)   CVD>CVT (t=6.09, p=.000)
                                      CVD L > CVD $\widehat{HL}$ (t=3.23, p=.008)

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