

Effects of tonal distance and speech rate in the phonetic realization of Kinande H tones *

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Cho, Hyesun. 2013. Effects of tonal distance and speech rate in the phonetic realization of Kinande H tones. *Studies in Phonetics, Phonology and Morphology* 19.3. 501-527. The effects of time pressure in the realization of the fall and the rise between H tones in Kinande are examined, through a production study of one Kinande speaker. Phonetic realization of tonal languages such as Kinande is relatively less studied, though their phonological patterns have been more studied. Two types of time pressure of different nature are tested: tonal distance (phonological) and speech rate (phonetic). For the former, the number of syllables between two H tones is varied from zero to three. For the latter, speech rate is varied among fast, normal, and slow rates. The two types of time pressure showed similar effects in some respects, e.g., reduction in pitch magnitude under time pressure, relatively consistent slope of the fall. There were also differences in the effects of two types of pressure: the slope of the rise becomes steeper in closer tonal distance, but it becomes shallower in faster speech. Overall, alignment is less affected than pitch magnitude, under both types of time pressure. This suggests that in a tonal language such as Kinande, where tones are contrastive, tonal alignment is important to maintain than pitch magnitude. (Seoul National University)

Keywords: Tonal distance, speech rate, tonal anticipation, Kinande

1. Introduction

This study investigates the phonetic realization of tones in Kinande, varying two types of time pressure: tonal distance and speech rate. Kinande is a Bantu language (Guthrie code, JD42 (Maho 2009)), spoken in Eastern Congo by 1.5 million people. Tonal distance and speech rate are two of the most-studied factors that impose time pressure on the phonetic realization of tones or pitch accents: (i) tonal distance (or ‘tonal crowding’): Dutch (Caspers and van Heuven 1993), English (Silverman and Pierrehumbert 1990), Spanish (Prieto et al. 1995), Greek (Arvaniti and Ladd 1995), Kinyarwanda (Myers 2003), (ii) speech rate: English (Ladd et al. 1999), French (Fougeron and Jun 1998), Mandarin (Xu 1998), Spanish (Prieto and Torreira 2007). Time pressure that is imposed by the two is different in nature. Time pressure imposed by tonal distance is phonological, in that it depends on phonological context (e.g., the number of syllables between tones, phonological vowel length, syllable structure), whereas speech rate

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imposes purely phonetic time pressure. The distinction of phonological/phonetic time pressure is not clear-cut, since phonological time pressure in effect induces absolute, phonetic time pressure. In the present study I selected two types of time pressure, whose nature is relatively distinct enough from each other: the number of intervening syllables *vs.* speech rate.

The current study aims at examining the effects of time pressure of different nature on the phonetic realization of tones in Kinande. If some patterns of phonetic realization turn out to be different under different types of time pressure, it would arise from different nature of time pressure. Patterns that are robust regardless of time pressure types can be considered as fairly stable properties of phonetic realization of Kinande.

Previous studies on the effects of time pressure have mostly dealt with non-tonal languages, as cited above. Relatively less work has been done on the phonetic realization of tonal languages such as Kinande, while its phonological/morphological characteristics are mainly studied (Mutaka 1989, 1990, Hyman 1990, Downing 2000, Akinlabi and Mutaka 2001, Kenstowicz 2008, Jones 2010; but Kenstowicz (2009) on Kinande vowel harmony using phonetic measures). It is a contribution of the current paper to provide a detailed phonetic characterization of Kinande. The effects of time pressure are carefully examined in three dimensions: pitch magnitude, slope, and tone-segment alignment. In my knowledge this is the first work on tonal alignment of Kinande.

However, as a limitation of this study, it should be noted that there was only one speaker for the production experiment. Thus the results presented here should be considered as a pattern that *can* be observed in Kinande, rather than a pattern of Kinande in general. Individual differences are quite likely, e.g., Myers (2003) experimented with four speakers of Kinyarwanda, another related Bantu language (Guthrie code, JD61), showing individual differences in the patterns of F0 timing, though the overall patterns are shared.

1.1 Previous studies

Caspers and van Heuven (1993) examined effects of time pressure in Dutch prominence-lending pitch accents. They varied speech rate, phonological vowel length, and distance between a rising and a falling pitch movement (occurring in the same syllable, one or two syllables away, or occurring alone in the utterance). The onset of the rise in Dutch was synchronized with the syllable onset, regardless of various types of time pressure, i.e., speech rate as well as tonal context (distance from the following tone). The slope of the rise increased in fast speech, and when the upcoming tone was nearer. On the other hand, the slope of the fall was not much affected by speech rate and tonal distance, but remained relatively consistent. However, the beginning of the fall was delayed when

the preceding rise is closer (i.e., in the same syllable). In the present paper, I will examine two types of pressure, tonal distance and speech rate, in Kinande and see whether different types of pressure have different effects on phonetic realization of tones.

A study of phonetic realization of tones in a language related to Kinande is found in Myers (2003). Myers examined F0 timing of Kinyarwanda (Bantu, Rwanda) with varying phrasal position, word position, and distance to a following tone (no following H tone, or H tone after 0-3 toneless syllables). He found the effects of tonal distance on the timing of H tone: the closer the next tone, the earlier the H tone. He also examined the phenomenon known as ‘tone anticipation’ (Kimenyi 1976), i.e., pitch of a syllable preceding a high tone is raised. In Kinyarwanda the syllable preceding a H tone is raised in pitch. The nature of this pitch raising has been a puzzle to many scholars (Sibomana 1974, Overdulse 1975, Jouannet 1989). The question was whether the pre-H pitch raising is categorical (phonological) tone spreading or phonetic anticipatory coarticulation. Myers examined F0 timing of Kinyarwanda in order to find the nature of this pitch rise preceding a H tone. His hypothesis was that if a H tone phonologically spreads onto the preceding syllable, then the best predictor of the timing of H tone will be the preceding one, not the syllable which the H tone is underlyingly associated with. It turns out that the preceding syllable is not a better predictor than the original syllable. Thus, he concluded that the pitch rise in the syllable preceding a H tone is anticipatory coarticulation, rather than categorical H tone spreading. In the current study, Kinande also shows a pitch increase before a H tone. The nature of this pitch raising will be examined following Myers’ method just described.

1.2 Basic properties of Kinande tones

In Kinande, tones are contrastive in lexical meaning as well as in grammatical function. Kinande has two basic tones (High and Low) and a Falling tone, and the rising tone is very rare (Mutaka 1990, 2007). It is also suggested that Kinande has High, Low, and toneless contrasts underlyingly on the final syllable of disyllabic nouns (Hyman 1990, Kenstowicz 2008). In this paper I will consider only surface tones (except in this section). Following the convention, high tone will be marked with [^h], falling tone [^f]. Low tone is considered as default, so conventionally it is unmarked (e.g., Akinlabi and Mutaka 2001).

Kinande has phrasal H tone and intonational H tone, in addition to lexical H tone (Hyman 1990, Akinlabi and Mutaka 2001, Jones 2010). Phrasal H tone appears usually on the penultimate syllable, e.g., in the case of a toneless verb root /-hum/ ‘to hit’, (1) is the infinitive forms of this verb (-*ri*- is the infinitive marker). The H tone in (1a) is a phrasal tone (Mutaka 1989: 78, Akinlabi and Mutaka 2001: 335ff.). When there is an object

following the verb, the phrasal H tone moves to the penultimate syllable of the last word, showing that the H tone in (1a) is not a lexical H tone but a phrasal tone¹.

- | | | | |
|--------|----------------|-----------------|-----------------|
| (1) a. | erihúma | ‘to hit’ | /ɛ-ri-hum-a/ |
| | erimuhúma | ‘to hit him’ | /ɛ-ri-mu-hum-a/ |
| b. | erihuma Magúlu | ‘to hit Magulu’ | |

The final syllables in (1) carry a L tone (indicated by the absence of tone symbol). The H tone on the penultimate syllable is a phrasal tone, and the L tone on the final syllable is an intonational tone, according to Hyman (1990). Phrasal tone is always H tone, and intonational tone can be L or H. Intonational tone always appears in the final vowel. The phrasal H tone can occur on the penult (as in (1)), but it can also occur on the final syllable if a verb appears in the sentential subject position, as in (2a), or if a verb is conjoined with another verb (2b) (Akinlabi and Mutaka 2001: 336-7).

- | | | |
|--------|--------------------------------|-------------------------------------|
| (2) a. | erihumá sítyowéne | ‘to hit is not good’ |
| b. | erihumá n’ erihumirá sítyowéne | ‘to hit and to hit for is not good’ |

Kinande places a boundary (phrasal) tone at the right edge of phonological phrase when a phonological phrase occurs within an intonational phrase (Hyman 1990), and even in word-internal domain such as stem (Black 1995). It seems that in (2) the subject (a) and the conjunct (b) are also a phonological phrase, so the final vowel has phrasal H tone.

Kinande lexical H tone does not appear on the syllable where it is associated in the underlying representation, but one syllable ahead of its underlying tone bearing unit, known as ‘High Tone Anticipation (HTA)’ (Hyman and Valinande 1985, Mutaka 1989: 77, Mutaka 1990, Akinlabi and Mutaka 2001: 338). Both verbs and nouns undergo HTA. Consider a H tone verb /-túm-/ ‘to send’ in (3).

- | | | | |
|-----|-----------|------------------|-----------------|
| (3) | erítúma | ‘to send’ | /ɛ-ri-túm-a/ |
| | erinátúma | ‘to send indeed’ | /ɛ-ri-na-túm-a/ |

The H tone on the penult is phrasal, rather than lexical tone, just as in (1). The other H tone on the syllable preceding the root /-túm-/ is the realization of the lexical H tone of the root. Lexical H tone in Kinande is always anticipated and never appears on its underlying position (except for

¹ I omitted vowel length notations, which indicate penultimate lengthening, from the original text in Akinlabi and Mutaka (2001), because they are not shown in most literature and are irrelevant in this paper. According to Mutaka (2014), penultimate lengthening in Kinande is “a manifestation of a metrical representation of stress”, due to a rule turning a short light penult into a heavy syllable, which occurs at the end of an intonation phrasal domain. Nouns and the majority of verbs undergo penultimate vowel lengthening.

vowel-initial root, e.g., eryómbola /-ómbol-/ ‘to filch’, Jones (2010)).

HTA examples from nouns are shown in (4) (Mutaka 2007). The word for ‘woman’ is [o-mú-kalɪ], where the root is /-káɪ/. The H tone in the root is not realized on the root, but on the prefix (C1, C3 indicates noun class).

- (4) a. o-mú-kalɪ ‘woman’ root: /-káɪ/
Aug-C1-woman
b. o-mú-sanga ‘flower’ root: /-sánga/
Aug-C3-flower

Some grammatical words do not undergo HTA. In Kinande, subject marker, object marker, and verbal suffix is underlyingly toneless, whereas roots and tense markers can be either H or toneless (Black 1995: 5-7). In (5), H tone in [ká] is not due to HTA, but is H-toned underlyingly. Also note that in (5b) a phrasal H tone occurs at the end of the subject (magulú ‘Magulu’) indicating that the subject and the verb are separate phonological phrases (Black 1995: 14).

- (5) a. tu-ká-mu-hum-a-a ‘We are hitting him’
SM-TM-OM-hit-PF-FV
b. magulú a-ká-ndi-mu-sond-ír-a ‘Magulu will look for him’
SM-TM-TM-OM-look for-EX-FV
SM: subject marker, TM: tense marker, OM: object marker, PF: prefinal, EX: extension, FV: final vowel

In our speech materials presented in the Appendix, I showed only the surface tones, not the underlying tones.

This paper presents results of two experiments: one manipulating tonal distance between two H tones (Experiment 1), the other varying speech rate (Experiment 2). Section 2 shows the procedure and results of Experiment 1. Section 3 illustrates Experiment 2. Section 4 is the discussion, and section 5 is the conclusion.

2. Experiment 1: effects of tonal distance

The purpose of experiment 1 is to examine the effects of distance between two H tones on the timing and scaling of the F0 movements in Kinande.

2.1 Speech materials and recording procedure

A target word contains exactly two H tones, one on the last syllable in the target word and the other on one of the preceding syllables. The first H (‘H1’) tone is lexical, and the second H tone (‘H2’) is phrasal. H2 in the target word always falls on the word-final syllable and H1 is separated from the second H by 0, 1, 2, or 3 syllables. In this paper, ‘distance’ means

the number of syllables intervening between the first H tone and the second (word-final) H tone. For example, distance is 0 when there is no intervening syllable between the two H's, e.g., *ekitábú* 'book'. Distance is 1 when there is only one intervening syllable. The distance of 0 and 1 syllables comes from nouns, and the distance of 2 and 3 syllables comes from SVO phrases, as will be described shortly. Except for distance-0 words, the target words have a LHL(..)H tonal sequence (the tones will be referred to as L1, H1, L2, H2; the F0 minimum point between H1 and H2 is referred to as L2). Our analysis will mainly focus on the fall from H1 to L2 and the rise from L2 to H2.

There were eight target words for distance 0, nine target words for distance 1, and six target words for distance 2 and 3 respectively (total of 29). The target words/phrases were spoken in a carrier sentence, as shown in (6).

- (6) Mó-ngá-bw'-in-di _____ munábwíre. (Consonant-initial target word)
 Mó-ngá-bw'-in-dy' _____ munábwíre. (Vowel-initial target word)
 Tense-I-say-AGR-that _____ today²
 'I said _____ today'
 /mó/ recent past, /ng/ I, /-búir-/ to tell, /indi/ I say that...

In the present speech materials, the verbs in the embedded clause always carry a H tone on its final vowel, as in (7). This final H is a phrasal tone, as in (2). The verbs (*bakítirirá*, *bakítiririrá*) are inflected for 3rd person plural subject, and *Tsongó* is its object. That is, the verb is in the subject position in the subordinate clause, so a phonological-phrase boundary tone (H) is placed on the final vowel.

- (7) a. Móngábw'indi *bakítirirá Tsongó* munábwíre.
 'I said 'They reveal a bad secret of Tsongo' today'
 b. Móngábw'indi *bakítiririrá Tsongó* munábwíre.
 'I said 'They kill Tsongo' today'

/ba/ they, /k/ Tense marker, /-jt-/ kill, /irir/, /iririr/ Aspect marker (purposive, Jones 2010: 5), /a/ final vowel

Not only verbs, but also nouns end with a final H, which is a phrasal tone.

² A reviewer wondered whether 'today' is a part of the subordinate clause rather than the matrix sentence, because the matrix clause is recent past whereas the target phrase is present. However, 'today' can be used with recent past as well. For example, there are many other sentences (distance of zero and one syllable in Experiment 1, and all the sentences in Experiment 2) which have nominal objects (as in (6)). In such cases, 'today' is unambiguously used with recent past. When the matrix verb takes a sentential object in present tense as in (5), 'today' can be ambiguous. In the experiment the speaker repeated the word 'today' in all sentences, so it seems more likely that he understood 'today' as part of the matrix sentence.

The dictionary entry for ‘woman’ is [omúkalɪ] (cf. (4)), but when it is embedded in a sentence, the final syllable is produced with a H tone, as in (8).

- (8) Móngábw’indy’ *omúkalɪ* múnábwǵre.
 ‘I said ‘woman’ today’

Thus, all the target words in the speech materials end with a H tone. For the reasons above, the first H tone is lexical, and the second H tone is phrasal in all the target words. See the Appendix for the full list of the sentences. The transcription follows a Kinande dictionary by Mutaka and Kavutirwaki (2008). The order of the sentences was randomized, and the entire list was repeated three times (29×3 repetitions=87 tokens in total). Sometimes there were two instances of same types next to each other in the randomized order, but no more two instances of same types were next to each other.

The subject was a male native Kinande speaker. He was also a fluent or near-native French speaker, who is an author of several novels and plays published in France. The instructions during the experiment were given in English. The speech materials were given on a sheet of paper, in English letters. He read the speech materials three times (the whole list read at each time) at a normal speech rate. The speaker was not aware of the purpose of the study. The recording was made in a sound-attenuated recording booth in the phonetics lab. The speaker wore a head mounted microphone (Shure SM10A). Speech signals were directly digitized using Amadeus II (version 3.8.4, HairerSoft) on an iMac. Sampling rate was 44.1kHz, and sampling size was 16 bit.

The recording was manually labeled for segment boundaries using Praat. F0 turning points (minimum and maximum) are located. Due to pitch perturbation some F0 turning points were not measurable (this was the source of differences in the degrees of freedom between rise and fall in the result section). The results were analyzed using a statistical software package R (ver. 2.15.1, R Core Team 2012). Since there was only one speaker, a simple linear regression was fitted to the data, using the *lm* function. When assessing random effects of vowels (Section 2.3.1, 3.2.1), the package *lme4* was used for mixed linear regression analyses. The magnitude of the fall (H1 to L2) was measured as the difference between H1 and L2 pitch levels, and the magnitude of the rise (L2 to H2) the difference between L2 and H2 pitch levels. The slope of the fall (or the rise) was computed by dividing the magnitude by the duration of the fall (or the rise), i.e., mean slope (in Hz).

2.2 Hypothesis

The effects of time pressure can be found in various aspects of phonetic

realization: magnitude, alignment, and slope. Some or all of these properties will be changed under time pressure to realize a tonal contour in limited time, and there are various strategies that can be imagined. The magnitude of the fall from H1 to L2 and the rise from L2 to H2 can be reduced under pressure because there is less time for pitch movement. The slope of the fall and the rise can also be affected by intervening syllables. Slope has to become steeper under pressure if to maintain the same F0 peak level or magnitude. This is called ‘time-compressed’ (Caspers and van Heuven 1993), because in that case the magnitude is not affected but the temporal dimension is compressed. Yet there are other possible strategies to accommodate tones in a limited time span than adjusting slopes, e.g., the magnitude of pitch rise or fall can decrease under time pressure. In French for example, pitch range is reduced in fast speech than in normal speech for all the three speakers tested (Fougeron and Jun 1998: 53). This kind of change is called ‘frequency-compressed’ because the F0 magnitude/level is affected by time pressure. We will see in this paper which strategy the Kinande speaker adopts.

2.3 Results and analysis

2.3.1 Magnitude of the fall and the rise

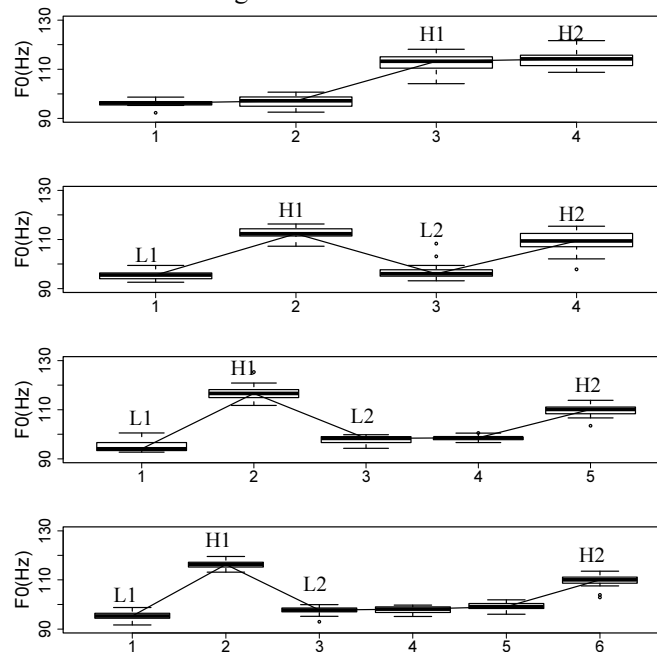


Figure 1. Mean F0 values for syllables, according to the number of intervening syllables (distance 0 to 3 from top to bottom). The numbers on the x-axis indicate each syllable.

To overview, Figure 1 shows mean F0 values for each syllable, depending on the number of intervening syllables. The first panel shows when there is no intervening syllable. As expected, there is no fall between the two H tones when distance is zero, so distance 0 data will be excluded in the following analyses. Figure 1 also suggests that there is an L tone target immediately following H1, confirming the existence of L2, since otherwise there should be a gradual decline of pitch after H2. Also note that this is a figure with mean values. For L2, the absolute F0 minimum point between two peaks was taken. So, sometimes L2 was found on the syllable after the third one.

It is noteworthy that, as in Kinyarwanda (Myers 2003), an F0 curve that looks like an anticipatory rise is found in the syllable(s) that precede(s) the final H tone. Figure 2 shows pitch tracks of two examples, one with the distance of one syllable, the other with the distance of two syllables. In (a), there is no room for anticipatory rise because there are only four syllables that are associated with each of the four tones. When there is more than one intervening syllables between two H tones, as in (b), there is a small rise in pitch in the syllable preceding the final H. A local F0 minimum (L2) is found at the beginning of the penultimate syllable 'ri'. Pitch rises from this point to the final F0 maximum (H2).

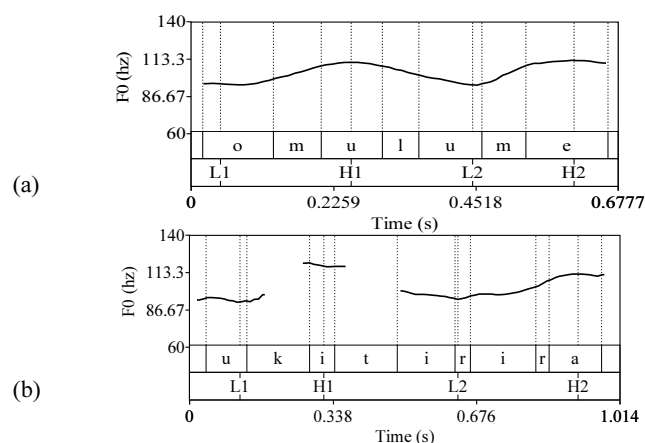


Figure 2. Pitch tracks of (a) distance of one syllable (omulumé 'man') (b) distance of two syllables. In (b) (ukítirirá 'You (sg.) reveal a bad secret of Tsongo'), an anticipatory rise is found on the syllable ('ri') which precedes the final syllable carrying the final H. (No words have only sonorants in the distance of two or three, so a discontinuous pitch track is shown here in (b))

One might wonder the nature of this rise, whether it is anticipatory coarticulation or categorical H2 spreading onto the preceding syllable. As

mentioned at the end of section 1.1, we also test this by looking at which is the best predictor of H2 alignment (following Myers (2003)). If the best alignment point remains within the final syllable, it would mean that the preceding pitch rise is gradual, anticipatory coarticulation. The best alignment point of H2 will be shown in section 2.3.3.2 below.

Figure 3 shows the magnitude of the fall and the rise by the number of syllables. As shown, the magnitude of the fall (H1 to L2) and the second rise (L2 to H2) was partly affected by the number of intervening syllables between H1 and H2.

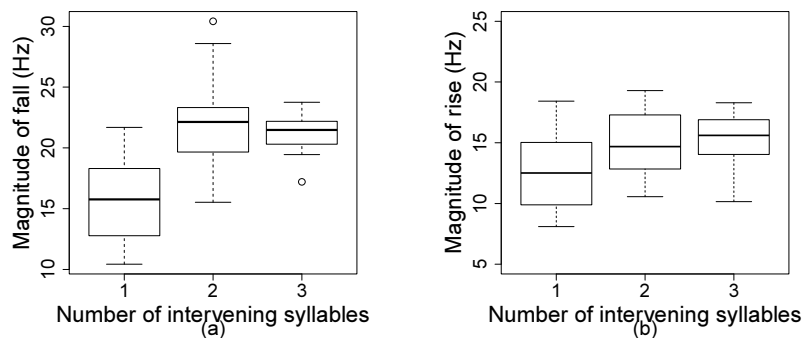


Figure 3. Magnitude of the fall (a) and the rise (b) depending on the number of intervening syllables

To test significance of the differences, a linear regression model was fitted to the data, with PITCH MAGNITUDE dependent variable and NUMBER OF SYLLABLES independent variable. The magnitude of the fall was significantly affected by the number of intervening syllables when comparing distance 1 and 2 (coefficient=6.34, $t(53)=6.5$, $p<0.001$). The magnitude of the fall was greater if there were more intervening syllables. However, the difference between distance 2 and 3 was not significant (coefficient=0.94, $t(53)=0.7$, $p=0.49$). This means that the effect of tonal distance is significant if the number of syllables increases from 1 to 2, but beyond 2, the effect does not significantly increase.

The magnitude of the rise (Figure 3(b)) was also affected by the number of intervening syllables when comparing distance 1 and 2 (coefficient=1.86, $t(58)=2.12$, $p<0.05$). The difference between 2 and 3 was not significant (coefficient=0.42, $t(58)=-0.3$, $p=0.73$), as in the case of the magnitude of the fall. In sum, the effect of distance was greater for the magnitude of the fall than that of the rise, and the effect does not linearly increase depending on the time available, but is limited only between distance 1 and 2.

We will examine another factor that affects pitch – intrinsic pitch of vowels. That is, high vowels tend to have higher pitch than low vowels if other things being equal (Ohala and Eukel 1987). This is considered to be

universal, since it has been found in many languages (31 languages, 11 major language families) (Whalen and Levitt 1995). We will test whether the present result actually comes from vowel height in the speech materials that are randomly selected. Usually speakers and items are treated as random effects in mixed models (Baayen et al. 2008). In our experiment there was only one speaker, but the speech materials (items) are randomly selected, so items are random effects. I treat vowel height in the words as random effects, instead of actual vowel identity, because intrinsic pitch concerns vowel height. To test the effects of vowel height, mixed-effects linear regression is fitted to the data. For the fall, the dependent variable is FALL MAGNITUDE, the fixed effect is NUMBER OF SYLLABLE (as in the simple regression), and random effects are VOWEL HEIGHT (HIGH, MID, LOW) of the two syllables (the second and the third syllable) where H1 and L2 is associated.

For the fall magnitude, the number of syllable show the same effect in the mixed-effects regression as in the previous simple linear regression (distance 1 vs. 2: coefficient=5.3, $t(56)=4.80$, $p<0.0001$; distance 1 vs. 3: coefficient=4.37, $t(56)=4.05$, $p<0.001$; distance 2 vs. 3: $t(56)=0.61$, $p=0.54$). That is, the reported pattern is valid when intrinsic vowel pitch is factored out. For the rise magnitude, a difference arises in the comparison of distance of one and two syllables, but other results are the same as before (distance 1 vs. 2: coefficient=1.86, $t(61)=0.98$, $p=0.06$; distance 1 vs. 3: coefficient=2.28, $t(61)=0.98$, $p<0.05$; distance 2 vs. 3: $t(61)=0.31$, $p=0.67$). That is, distance 1 vs. 2 is now not significantly different, after factoring out vowel height effects, whose difference was not that great anyway. In summary, the effects of vowel height partly exist, but the overall pattern is not much changed by including vowel height in the model.

2.3.2 Slope of the fall and the rise

The slope of the fall and the rise shows clearly different patterns, as Figure 4 shows. The slope of the fall was not affected by the number of intervening syllables under any condition (distance 1 vs. 2: coefficient=0.007, $t(53)=1.73$, $p=0.09$; distance 2 vs. 3: coefficient=-0.0011, $t(53)=0.21$, $p=0.83$, distance 1 vs. 3: coefficient=0.006, $t(53)=1.5$, $p=0.14$). On the other hand, the slope of the rise was affected by the number of syllables under all conditions (distance 1 vs. 2: coefficient=-0.033, $t(58)=-6.88$, $p<0.001$; distance 2 vs. 3: coefficient=-0.019, $t(58)=2.97$, $p<0.01$; distance 1 vs. 3: coefficient=-0.052, $t(58)=-11.2$, $p<0.001$). The coefficients indicate that rising slope decreases when there are more syllables. Given enough time, the slope does not have to be steep in order to reach a target peak level, whereas under time pressure rise slope must increase.

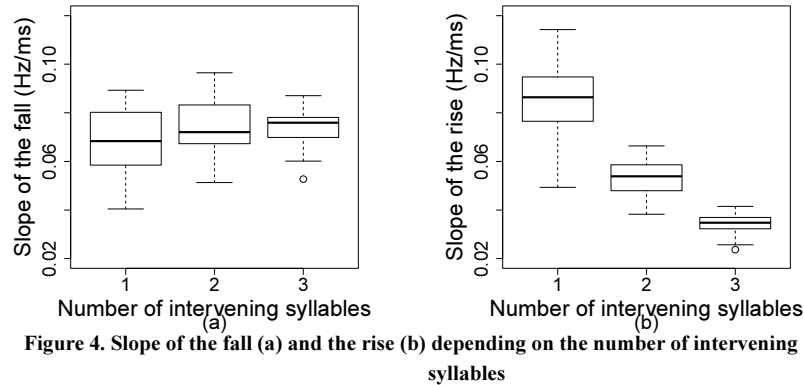


Figure 4. Slope of the fall (a) and the rise (b) depending on the number of intervening syllables

2.3.3 Alignment

2.3.3.1 H1 Alignment

For the analysis of alignment, it is necessary to locate a reference point with respect to which a F0 turning point occurs. This point is often referred to a segmental ‘anchor’ (Ladd et al. 1999). In this paper a segmental anchor is selected as the point that has the highest correlation in the vicinity of the syllable that the tone is phonologically associated with.

H1 is usually associated with the second syllable (except a few initial H tones), so the alignment of H1 is shown with respect to the end of the second syllable (‘Syllable2 end’) in Figure 5(a). H1 and Syllable2 end are highly correlated ($R^2=0.77$) so this point can be considered as a segmental anchor for H1. To see whether alignment of H is affected by tonal distance, deviation from the anchor (H1 to Syllable2 end) is plotted against the number of intervening syllables in Figure 5(b). There is a systematic deviation of H1 from c3, depending on the number of syllables following the H1 (distance 1 vs. 2: coefficient = 33.4, $t(42)=3.77$, $p<0.001$; distance 2 vs. 3: coefficient = 50.7, $t(42)=5.96$, $p<0.001$). That is, the more the following syllables the later the H1 occurs relative to the end of the second syllable. In other words, when there is more pressure from the next tone (such as distance-1 condition), H1 shifts leftward. This is the same direction of shift as in Kinyarwanda (Myers 2003) where a tone occurred earlier if a following tone is closer.

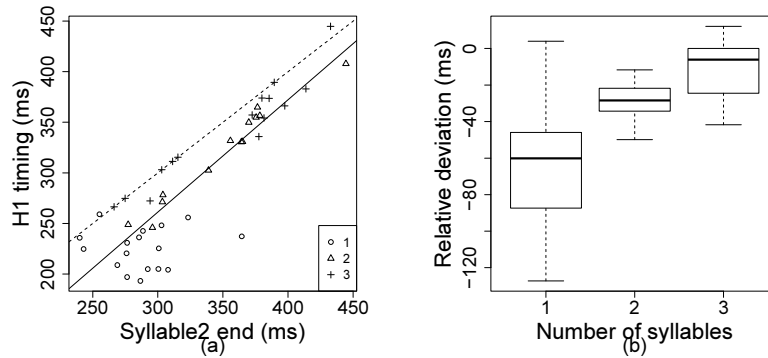


Figure 5. Alignment of H1 with respect to the end of the second syllable. In (a), the solid line is the regression line, and the dotted line is $y=x$ line, that is, the tone falls exactly on the segmental anchor (here and subsequent similar figures as well). (b) shows relative deviation of H1 from the anchor point (zero = Syllable2 end).

2.3.3.2 H2 Alignment

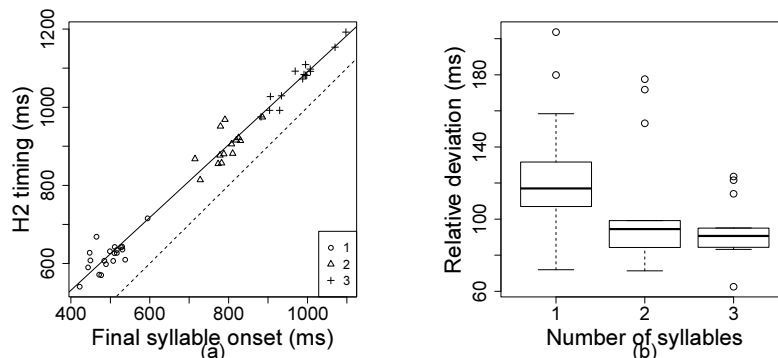


Figure 6. Alignment of H2 with respect to the onset of the final syllable

H2 is always associated with the final syllable of a target word. Figure 6(a) shows the alignment of H2 with respect to the onset of the final syllable. H2 and this point are highly correlated ($R^2=0.98$) so this point can be considered as a segmental anchor for H2. H2 is earlier when there are more intervening syllables, as shown in Figure 6(b). This is a mirror image of the H1 alignment, shown above in Figure 5(b). H2 occurs earlier when there is less time pressure, and shifts rightward when there is more pressure, though the effect is much weaker than in H1. Distance 3 was different from distance 1 (coefficient=-29.91, $t(46)=-3.1$, $p<0.01$). Distance 2 was not significantly different from distance 1 (coefficient = -17.9, $t(46)=-1.8$, $p=0.075$), and distance 2 vs. 3 conditions were not different from each other (coefficient=-12, $t(46)=0.87$, $p=0.38$), but the direction of shift is in

the same trend.

It should also be noted that the best predictor of H2 remains in the final syllable. Returning to our question in section 2.3.1, we can thus say that the small pitch rise in the syllable preceding the final syllable is phonetic coarticulation, rather than phonological spreading.

2.3.3.3 L1 Alignment

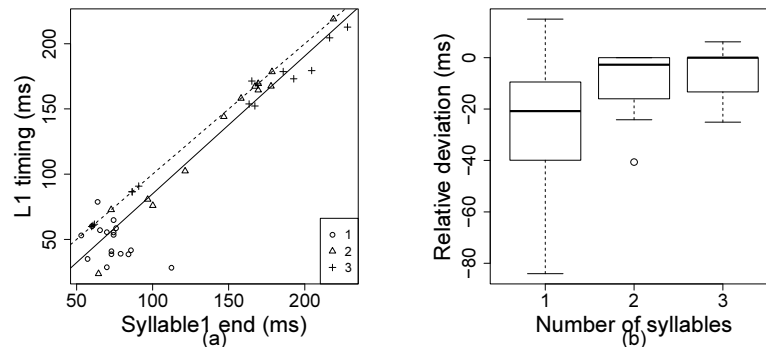


Figure 7. Alignment of L1 with respect to the end of the first syllable

L1 and the end of the first syllable ('Syllable1 end') are highly correlated ($R^2=0.91$), as shown in Figure 7(a). There is a systematic deviation of L1 from this point, depending on the number of syllables following the H1 (distance 1 vs. 2: coefficient = 15.5, $t(42)=6.12$, $p<0.05$; distance 1 vs. 3: coefficient = 18.04, $t(42)=5.89$, $p<0.01$) (Figure 7(b)). Distance 2 vs. 3 conditions were not significantly different from each other (coefficient=2.57, $t(42)=-0.30$, $p=0.76$). This means that L1 is aligned significantly earlier in the distance-1 condition only.

2.3.3.4 L2 Alignment

The anchoring point for L2 alignment is chosen as the end of the third syllable ('Syllable3 end'), which shows the highest correlation with L2 ($R^2=0.94$). As shown in Figure 8(b), L2 was earlier in distance-1 condition than in distance-2 condition (coefficient=28.71, $t(47)=4.64$, $p<0.001$) and distance-3 condition as well (coefficient=31.56, $t(47)=5.21$, $p<0.001$). Distance 2 vs. 3 are not different from each other (coefficient=2.85, $t(47)=-0.33$, $p=0.74$).

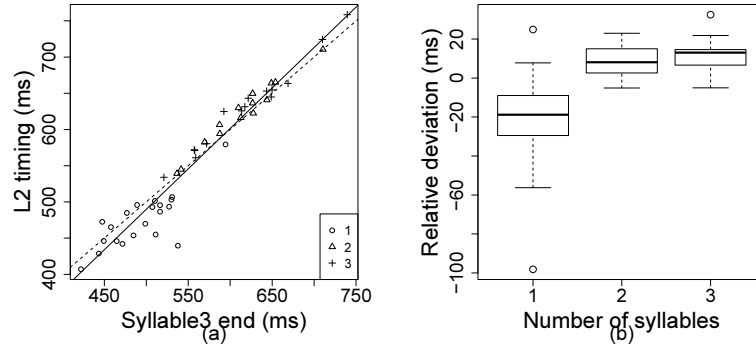


Figure 8. Alignment of L2 with respect to the end of the third syllable

3. Experiment 2: effects of speech rate

3.1 Speech materials and experimental methods

In Experiment 2, the second type of time pressure, speech rate, was varied. All the target words were four-syllable words with LHLH tonal specifications (e.g., amábugú ‘banana’ (again, first H is lexical, and final H is phrasal)). As before each tone will be referred to as L1, H1, L2, H2. There were six target words, embedded in the same carrier sentence as in Experiment 1. The same speaker read the speech materials at fast, normal, slow speech rates. He was first asked to read the speech materials naturally, without any instructions about speech rate. After this, he was asked to read as fast as possible, and then to read slowly but naturally. There were three repetitions of the whole list in each speech rate (6 words \times 3 rates \times 3 repetitions = 54 tokens in total). The recording procedure was the same as before. In the analysis of alignment (Section 3.2.3), utterances in the three speech rates are normalized (dividing each utterance by the length of the target words) in order to show the relative degree of the deviation from the segmental anchors across speech rate.

3.2 Results and analysis

3.2.1 Magnitude of the fall and the rise

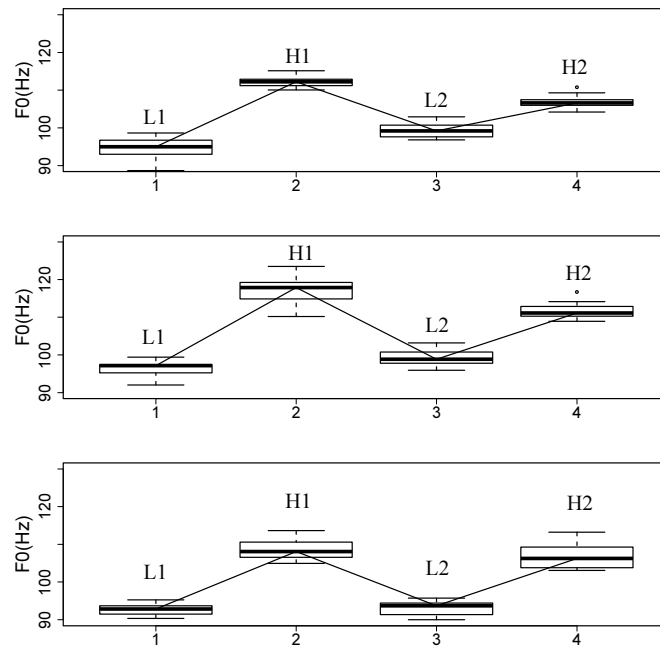


Figure 9. Mean F0 values for syllables, depending on speech rate (fast, normal, slow from top to bottom). The x-axis indicates each syllable (syllable 1 to 4).

Figure 9 shows the overall F0 means for each syllable, depending on speech rate. It is noticeable that the amount of the fall and the subsequent rise is smallest in fast speech. Also noticeable is that the magnitude of the first rise is the greatest in fast speech ($t(39)=2.05$, $p<0.05$), which is somewhat counterintuitive given that the speaker will have more time for a greater rise in slow speech. Similarly, the magnitude of the fall (H1 to L2) is smaller in slow speech than in normal speech, contrary to expectation. Figure 10 shows the magnitude of the fall (H1 to L2) and the second rise (L2 to H2) depending on speech rate.

As Figure 10 shows, magnitude of the fall is greater in normal and slow speech than in fast speech (normal speech: coefficient=4.88, $t(42)=4.21$, $p<0.001$; slow speech: coefficient=2.43, $t(42)=2.02$, $p<0.05$). Magnitude tends to be smaller in slow speech than in normal speech, according to the figure, though the difference was not significant (coefficient=-2.4, $t(42)=1.46$, $p=0.15$). The reason why the fall magnitude is not the greatest

in slow speech is unclear, but the way the speaker produces slow speech seems, or sounds like, that slow speech is less effortful than fast or normal speech, and such lethargic articulation would result in small magnitude. Not just speech rate, but also other conditions in the vocal organs (such as style, effort) may affect pitch movements, resulting in somewhat counterintuitive result. Caspers and van Heuven (1993: 170) reports a similar phenomenon: “The rise and fall are steeper in short vowels than in long vowels... The increased steepness may lead to an overshoot of the target, resulting in the counterintuitive finding the excursion size of the movement is increased a little (under time pressure)” (the phrase in the parentheses added by the present author). Conversely, the decreased steepness in slow speech may lead to smaller movements in our experiment.

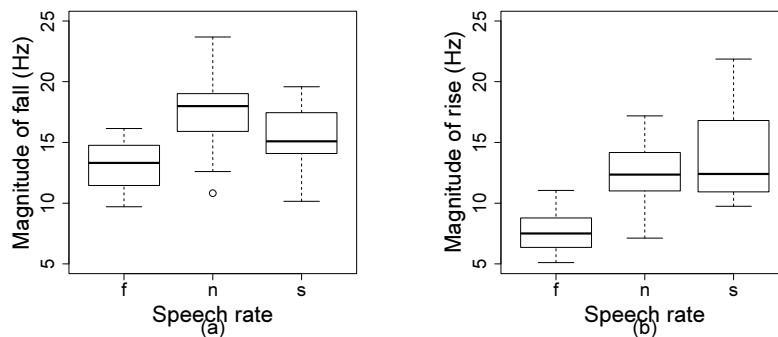


Figure 10. Magnitude of the fall (a) and the rise (b) depending on speech rate

As for the rise, normal and slow speaking rates show a greater rise magnitude than fast rate (normal speech: coefficient=4.71, $t(48)=4.89$, $p<0.0001$; slow speech: coefficient=6.07, $t(48)=2.0$, $p<0.05$). Figure 10(b) shows a tendency for greater magnitude in slow speech than in normal speech. However, the difference was not significant between normal and slow speech (coefficient=1.35, $t(48)=-0.97$, $p=0.33$), probably for the same reason above.

To test possible effects of vowel height, a mixed-effects linear regression was fitted to the data. For the fall, the dependent variable was FALL MAGNITUDE, the fixed effect was SPEECH RATE, and random effects were VOWEL HEIGHT of the second and third syllables. For the rise, the dependent variable was RISE MAGNITUDE, the fixed effect was SPEECH RATE, and random effects were VOWEL HEIGHT of the third and fourth syllables.

For both fall and rise, the effects of speech rate showed exactly the same pattern in the mixed-effects regression as in the previous simple linear regression. For the fall, fast vs. normal: coefficient=4.8, $t(45)=4.22$,

$p < 0.001$; fast vs. slow: coefficient=2.42, $t(45)=2.03$, $p < 0.05$; normal vs. slow: $t(45)=1.46$, $p=0.15$. That is, the reported pattern is valid when intrinsic vowel pitch is factored out. For the rise magnitude, fast vs. normal: coefficient=4.72, $t(51)=4.89$, $p < 0.0001$; fast vs. slow: coefficient=6.07, $t(51)=6.10$, $p < 0.0001$; normal vs. slow: $t(51)=0.31$, $p=0.33$). In summary, the overall pattern and statistical significance remain unchanged by including vowel height in the model.

3.2.2 Slope of the fall and the rise

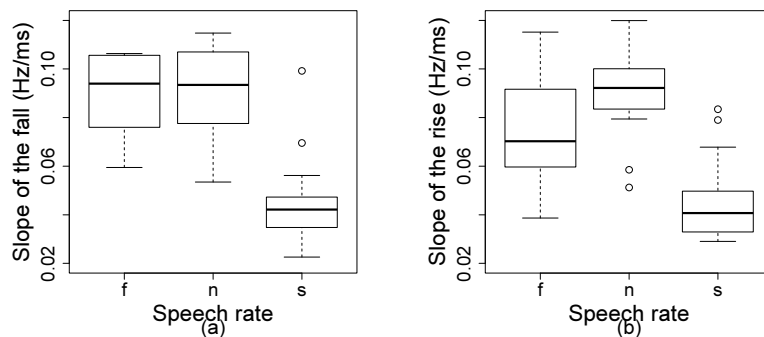


Figure 11. Slope of the fall (a) and the rise (b) depending on speech rate

The slope of the fall was not significantly different in fast and normal speech (coefficient=0.001, $t(42)=0.27$, $p=0.79$) (the slope in the slow speech is lower probably for the reasons mentioned above). Putting aside the slow speech, it is noteworthy that slope is not affected by changes in speech rate. This is a similar result as in Experiment 1, Figure 4(a). That is, the slope of the fall is not significantly affected regardless of the types of time pressure. On the other hand, the slope of the rise was significantly steeper in normal speech than in fast speech (coefficient=0.02, $t(48)=2.75$, $p < 0.001$). This seems to be due to the smaller magnitude of the rise in fast speech. The speaker reduces the magnitude of the rise under time pressure, so the slope of the rise does not have to be steeper. Pitch peak was also lower in fast speech than in normal speech (coefficient=4.81, $t(49)=5.78$, $p < 0.0001$). In both the rise and the fall, slope is the smallest in slow speech. This again suggests that slow speech was sluggish, so the vocal folds must have been less stiff. This lack of stiffness probably caused flatter slope in slow speech.

In summary, under time pressure the speaker reduces both the magnitude and the slope of the rise, i.e., ‘frequency-compressed’. Notice that this is a different result from tonal distance manipulation, where the slope of the rise becomes steeper under time pressure (recall Figure 4(b)). Magnitude of the rise was reduced both in tonal distance manipulation and in speech rate

manipulation.

3.2.3 Alignment

Figure 12 shows alignment of the four tones with their respective anchors. The segmental anchor was selected as the point that has the highest correlation in the vicinity of the syllable that the tone is phonologically associated with. The highest correlation points were found at the end of each syllable that a tone is associated with. The tone and its respective anchor is as follows: L1 with 'Syllable1 end' ($R^2=0.86$), H1 with 'Syllable2 end' ($R^2=0.95$), L2 with 'Syllable3 end' ($R^2=0.97$), and H2 with the end of the final syllable ($R^2=0.98$).

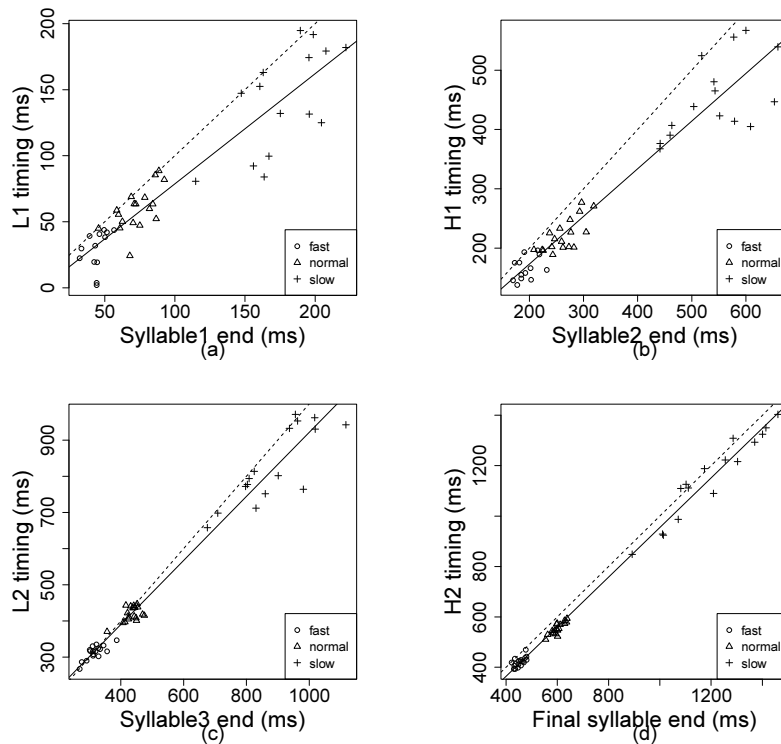


Figure 12. Alignment of each tone (L1, H1, L2, H2) with segmental anchors, depending on speech rate. The solid line is the regression line. The dotted line is $y=x$ line, i.e., the line where the tone falls on the anchor exactly.

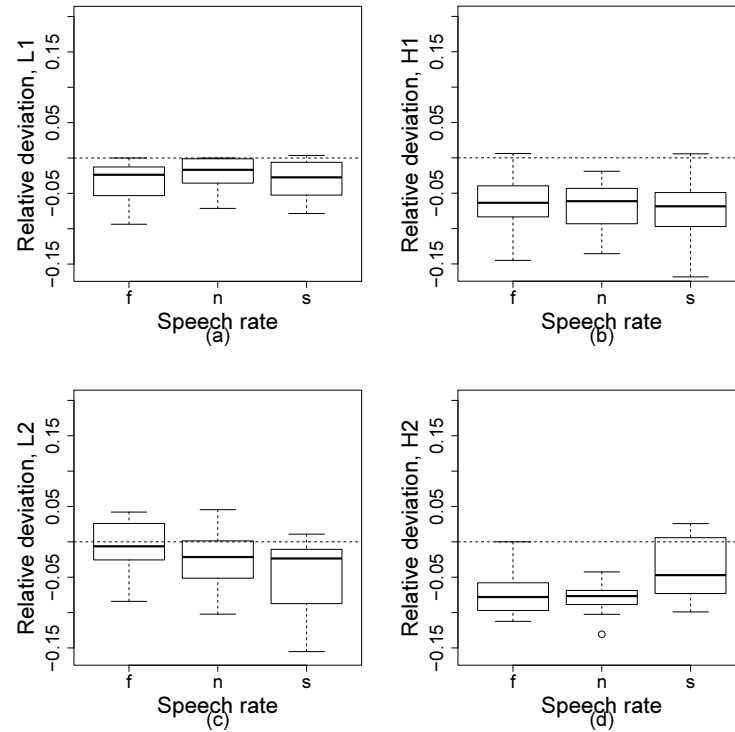


Figure 13. Relative deviation of tones from anchors depending on speech rate. The deviation values are normalized across speech rate, by dividing the target words by the word duration. The dotted line at zero indicates the anchoring point for each tone.

Using the segmental anchors obtained above, Figure 13 shows how much a tone is deviated from its anchor, depending on speech rate. The dotted vertical line shows the location of the anchor (deviation=0). Deviation is computed by subtracting the timing of the anchor from the timing of a tone. The negative values mean a tone appears before its anchor; the positive values mean a tone appears after its anchor. The deviation value is divided by the length of the whole phrase for normalization, so that different speech rates can be comparable.

Overall, alignment was not as much affected by speech rate as scaling. As can be seen, alignment of L1 and H1 was not much affected by speech rate. Alignment of L2 was affected, i.e., the faster the speech, the later the L2, but only fast and slow rates were significantly different (coefficient=-0.04, $t(48)=-2.65$, $p<0.05$). Alignment of H2 was delayed in slow speech. The difference between normal and slow speech was significant (coefficient=0.039, $t(49)=-2.51$, $p<0.05$), but fast and normal rates were

not significantly different (coefficient=-0.006, $t(49)=-0.58$, $p=0.56$).

4. Discussion

4.1 A tendency toward frequency-compressing and its phonological implications

In the case of tonal distance manipulation, magnitude of both the fall and the rise was reduced as tonal distance decreased – a characteristic of a ‘frequency-compressed’ language. The effect was significantly different between distance 1 and 2, but not between distance 2 and 3. Thus we can say that pitch range reduction occurred only in the presence of time pressure, and the range did not expand much even if there was extra time³. In speech rate variation, we also see a frequency-compressing pattern, i.e., the magnitude of the rise and the fall was reduced in fast speech. Thus this Kinande speaker showed a pattern similar to French (pitch reduction in fast speech, Fougeron and Jun 1998), rather than time-compressed languages such as Dutch (Caspers and van Heuven 1993) or English (Ladd et al. 1999)⁴.

Note that phonetic adjustment of tones is mainly achieved by adjusting scaling of tones, instead of alignment. This is evident in speech rate variation (Figure 13). Alignment is not systematically affected speech rate. In terms of Caspers and van Heuven (1993), the tones are frequency-compressed, rather than time-compressed, under fast speech. In tonal languages such as Kinande, tones are contrastive in lexical and grammatical meanings, so it is very important to realize a tone within the phonologically-associated syllable, for clear comprehension. Thus, under time pressure, alignment is preserved at the expense of pitch magnitude.

Yet, tonal alignment is systematically affected by tonal distance variation. As the number of intervening syllables between H1 and H2 decreased (increasing time pressure), the two peaks shifted in the opposite directions (H1 leftward, H2 rightward), relatively to their respective anchors. Thus we cannot say that alignment is invariant. The divergence in the effects on alignment between the two types of time pressure may come from different nature of time pressure. It may be suggested that the time pressure caused by speech rate is greater, or more ‘urgent’. The time pressure caused by proximity to the following tone is less urgent (note that the subject was

³ However, this has to be taken with a grain of salt: with more speakers, the effects may have been monotonically increasing. E.g. some Kinyarwanda speakers (Myers 2003: 84) showed monotonically increasing effects of time pressure depending on the distance to the next F0 peak, ranging from 1 to 3 intervening syllables.

⁴ Recall that the speaker is highly fluent in French. Though it is far beyond the scope of this paper to prove the transfer of tonal phonetic realization patterns from one’s second language to the first language, it has been observed that alignment patterns of one’s native language are carried over to the pronunciation of the second language (German speaker’s pronunciation of English, Atterer and Ladd (2004)).

speaking at a normal rate for all the tonal-distance conditions). Since there can be more than one syllable between H tones, the speaker had more room for deviation from anchoring points, whereas there was only one syllable between H tones in speech rate variation. The upshot is that under greatest time pressure, alignment is not affected, but adjustments in other dimensions take place. I suggest that such patterns are related to the language's phonological nature, the requirement that alignment of lexical tones must be stable.

4.2 Stability of the slope of the fall

It is noteworthy that slope of the fall was not affected by tonal distance nor speech rate. Slope of the fall remained relatively stable regardless of the type of time pressure. This conforms to a cross-linguistic tendency (Dutch, Caspers and van Heuven 1993; Finnish, Suomi 2007; Danish, Thorsen 1984). The asymmetry between rise and fall is found in a language such as Dutch. In Dutch, rise becomes steeper under time pressure (for two types of time pressure: speech rate as well as distance to adjacent accents) whereas the slope of the fall was consistent under changes in time pressure (Caspers and van Heuven 1993).

Alternatively, this stability of the slope of the fall in Kinande may be the result of the presence of phonological tone target L2 following H1. If there is no L tone after H1, there should be a gradual decline of pitch after H1, which is not the case (Figure 1). The stability of the slope of the fall seems to reflect the presence of the L tone on the syllable following H1. This justifies the existence of the L tone in Kinande.

4.3 Anticipatory rise

Anticipatory rise is observed in Kinande, as in Kinyarwanda. Following Myers (2003), we attempted to answer to the question of whether it is phonetic (gradual) or phonological (categorical) by examining which is the best predictor of H2. If categorical spreading had taken place, the best predictor of the timing of H2 would be somewhere in the preceding syllable. However, we have seen that it was the end of the final syllable that had the highest correlation with H2 (Section 2.3.3.2), not any points earlier in the preceding syllable. Thus we concluded that anticipatory rise in Kinande is phonetic, gradual coarticulation, as in Kinyarwanda. An interesting question remains whether this kind of anticipatory rise might have been a precursor to a categorical shift such as HTA in Kinande. Kinyarwanda, which is shown to have anticipatory rise, has also a process of HTA (Kimenyi 1976).

5. Conclusion

In this paper, phonetic realization of tones in Kinande has been examined varying two types of time pressure: tonal distance and speech rate. The two types of time pressure showed similar effects in some respects, e.g., pitch reduction in the fall and the rise, consistent falling slope, but differences were also observed in the slope of the rise and tonal alignment. In particular, two H peaks shifted from each other relative to their respective segmental anchors, as the number of intervening syllables decreased. On the other hand, alignment was not affected by speech rate changes. This suggests that as a lexical tone language, tone-segmental alignment remains stable despite time pressure.

The Kinande speaker in the present experiment showed a ‘frequency-compressing’ pattern, reducing pitch magnitude under pressure, and this pattern is even stronger in speech rate variation where there is little room for alignment adjustments. The current work has limitation that there was only one speaker. Whether the current result is a pattern of one individual or of Kinande in general should be examined with experiments with more speakers of this language. Also note that different methods of measurement may yield different results. For example, there are other methods of measuring slope, such as taking the velocity maxima (the first derivative of the F0 curve, Xu (1998)), or mean slope in semitone (Caspers and van Heuven 1993), whereas I used mean slope in Hz in this paper.

Despite the limitation of the study, it may be suggested that the frequency-compressed pattern observed in the Kinande speaker can be considered as a natural consequence of the fact that Kinande is a tonal language, where tones are contrastive. It is likely that in a tonal language, the alignment between tones and their associated segments is rather strong, so under time pressure it is important to keep tonal alignment stable. As a result it is pitch magnitude that undergoes greater changes than alignment under phonetic pressure. The present results show that phonetic realization of tones is affected by phonological nature of a language.

Appendix. Speech materials

The final column shows the citation form of the word as appears in Mutaka and Kavutirwaki (2008).

<Experiment 1>

1. Distance: 0 syllable

Móngábw’indy’ekítábú múnábwíre.	‘book’	[ekítábu]
Móngábw’indy’akapúsú múnábwíre.	‘cat’	[akapúsú]
Móngábw’indy’obühótí múnábwíre.	‘beans’	[obühótí]
Móngábw’indy’akalási múnábwíre.	‘class’	not listed

Móngábw'indy'eβikúsá múnábwíre.	'corn'	[ekikúsá]
Móngábw'indy'embĩrĩkĩ múnábwíre.	'brick'	[embĩrĩkĩ]
Móngábw'indy'émbwá múnábwíre.	'dog'	[émbwâ]
Móngábw'indy'erĩbyá múnábwíre.	'to be'	[erĩbyâ]

2. Distance: 1 syllable

Móngábw'indy'ekíkobá múnábwíre.	'rope'	[ekíkoba]
Móngábw'indy'omúlumé múnábwíre.	'man'	[omúlúme]
Móngábw'indy'omũkalĩ múnábwíre.	'woman'	[omũkalĩ]
Móngábw'indy'amábugú múnábwíre.	'banana'	[amábugu]
Móngábw'indy'akálumé múnábwíre.	'small man'	[aká-]
Móngábw'indy'akákalĩ múnábwíre.	'small woman'	[aká-]
Móngábw'indy'omũngyakyá múnábwíre.	'tomorrow'	[omũgyakyâ]
Móngábw'indy'ómwaná múnábwíre.	'child'	[ómwána]
Móngábw'indy'ómũnyũ múnábwíre.	'salt'	[ómũnyũ]

3. Distance: 2 syllables

'_____ reveal a bad secret of Tsongo'		
Móngábw'indi bakítirirá Tsongó múnábwíre.	'They _____'	
Móngábw'indi tukítirirá Tsongó múnábwíre.	'We _____'	
Móngábw'indi ngítirirá Tsongó múnábwíre.	'I _____'	
Móngábw'indy'ukítirirá Tsongó múnábwíre.	'You(sg.) _____'	
Móngábw'indi mukítirirá Tsongó múnábwíre.	'You(pl.) _____'	
Móngábw'indy'akítirirá Tsongó múnábwíre.	'He/she _____'	

4. Distance: 3 syllables

'_____ kill Tsongo on purpose'		
Móngábw'indi bakítirirá Tsongó múnábwíre.	'They _____'	
Móngábw'indi tukítirirá Tsongó múnábwíre.	'We _____'	
Móngábw'indi ngítirirá Tsongó múnábwíre.	'I _____'	
Móngábw'indy'ukítirirá Tsongó múnábwíre.	'You(sg.) _____'	
Móngábw'indi mukítirirá Tsongó múnábwíre.	'You(pl.) _____'	
Móngábw'indy'akítirirá Tsongó múnábwíre.	'He/she _____'	

<Experiment 2>

Móngábw'indy'amábugú múnábwíre.	'banana'	[amábugu]
Móngábw'indy'ekĩrĩmũ múnábwíre.	'spirit'	[ekĩrĩmũ]
Móngábw'indy'omúlumé múnábwíre.	'man'	[omúlúme]
Móngábw'indy'omũkalĩ múnábwíre.	'woman'	[omũkalĩ]
Móngábw'indy'akálumé múnábwíre.	'small man'	[aká-]
Móngábw'indy'ekíkobá múnábwíre.	'rope'	[ekíkoba]

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