*Kera tone and voicing**

MARY PEARCE

Abstract

Kera (a Chadic language) has been cited as one of a handful of languages which exhibit long distance voicing harmony between consonants (Rose and Walker 2001, Odden 1994). It has also been claimed that Kera voiced ('depressor') consonants lower the tone of the following syllable (Ebert 1979, Wolff 1987a, Pearce 1998). This paper addresses both of these claims, showing with recordings, pitch tracks and acoustic measurements that although the synchronic phonology includes consonant and tone interaction, it is the tones that are underlying and distinct. It also shows that the controversial account of *voice* spreading is no longer necessary as the facts can be adequately accounted for by *tone* spreading, and by voice onset times that correspond to the tone.

1 Introduction

Kera is a tone language with an apparent binary opposition between voiced and voiceless obstruents. This paper challenges this view of voicing contrast, suggesting instead that the effect of a contrast results from a gradient range of voice onset times (VOT) ranging from 0 ms to 70 ms. There is a correlation between the VOT and the fundamental frequency (F0) so that as the VOT is increased in length, the F0 is raised. But the VOT is not contrastive. Instead, the VOT cues enhance the tone cues which do have a three way phonological contrast. If this view is accepted, the implication is that the feature [voice] no longer has a role to play as one of the defining features of Kera. This raises serious questions about the claims of Rose and Walker (2001) and Odden (1994) that Kera exhibits long distance voice harmony. In response to these claims, I suggest that Kera exhibits tone spreading and a correlation between tone and VOT, but that [voice] is not a feature in Kera and therefore does not spread.

A number of Chadic linguists including Wolff (1987) would be concerned at any suggestion that tone is dominant and that voice agreement effects are caused by tone spreading. This is because a tonogenesis account is generally accepted for Chadic languages, where tones are introduced by an exaggeration of the F0

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perturbations that take place surrounding voiced and voiceless obstruents. Chadicists generally say that voicing affects tone, and not the reverse. This paper allows for the possibility that diachronically, tonogenesis has taken place in Kera so that voiced consonants have had the effect of lowering the F0 of the following syllable. But synchronically, the effect appears to be the reverse as tone is now phonemic while the VOT cues are secondary and phonetic. The reason for this change could well be that as the contrast in tone is used to distinguish between lexical items,the voicing contrast becomes redundant and the contrast is therefore reduced. There is still a correlation between VOT and tone, but the tone is the dominant factor in this interaction.

The interaction between consonants and tone has attracted wide interest among linguists, far beyond Chadicists. Many have tried to explain the possible phonetic motivation for a link between voicing and tone. Halle and Stevens (1971) and Ohala (1973) have explained the interaction as a variation in pitch that takes place around voiced consonants through changes in the vocal fold tension. This can be because the larynx is pulled by the tongue when producing high vowels, giving a higher pitch or through stiff or slack vocal folds when producing voiceless or voiced obstruents respectively. Other factors that may play a role are the raising of the larynx for the voiceless obstruent and the lowering of the larynx for the voiced obstruent. There is also a reduction of the tension of the vocal folds when breathy voiced stops are produced.

These types of pitch perturbations are typically small but in languages such as English and Russian, the pitch changes do provide perceptual cues for identifying voiced stops. Chistovich (1969) explains this as being due to increased air pressure in the upper cavities of the vocal tract causing a reduction in the pressure differential on the vocal folds.[1]

A number of linguists have claimed that once languages are using slight pitch changes as perceptual cues for voicing, it is a small step for listeners to consider the pitch change to be the major acoustic cue to differentiate words which are also differentiated by voicing or VOT. The language then becomes tonal as the pitch differences are produced intentionally.

Some languages go further than this in that the voicing contrasts are lost as the tone provides the necessary cues for distinguishing between lexical items and the voicing distinction becomes redundant. Lea (1973) claims that languages can move backwards and forwards between voicing and tone contrast. Other linguists would

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[1] Chistovich claims that the increase in pressure does not arise for sonorants, so sonorants do not produce a fluctuation in F0. Maddieson (1984) argues against this, showing from Burmese examples that sonorants act like voiced obstruents, but he acknowledges that in some Chadic languages such as Podoko (Anderson and Swachkamer 1981), Lame and Kera (Ebert 1977), sonorants have a different effect on the pitch track than voiced obstruents.

not claim a change in direction. Hyman (1973) for example states that 'Consonants affect tone, but tone does not affect consonants'. Kera would appear to be a counter example to this statement in that Kera has developed to the point where tones are contrastive and voicing appears to match the tone with high tones corresponding to voiceless onsets. The so-called 'voicing' is actually a short VOT. The voicing is no longer contrastive but VOTs do give enhancing cues to the tone.

Not all languages develop tones via voicing or VOT influences. Hombert et al (1979) shows that Yoruba has three tones, and for each tone, voiced and voiceless obstruents are permitted. For any one of the tones, there is a slight difference in the pitch track for voiced or voiceless obstruents, with the voiceless track higher, but after 40-60 ms, the two pitch tracks coincide. So it would appear that the three tones of Yoruba were not caused by such perturbations. Yip (2002) observes that tones have arisen from other laryngeal contrasts in consonants, such as aspiration and glottalization, but that these effects are not as consistent as those of voicing.

The picture that emerges from this quick language survey is that the changes in voicing, tone, VOT, quality etc. is more complex than first thought. All of these features can be present with a phonological constrast, but languages generally avoid redundant contrasts. So if a language develops tone from F0 perturbations surrounding voicing, at some point, the voicing contrast may become redundant and therefore be reduced. In this case, phonetic differences may remain to enhance the phonological tone contrasts, as we see in Kera. Vietnamese (Matisoff 1973) is an example of a language with both tone and voicing contrast. Before the sixth century there was voicing contrast but no noticeable tone. After the sixth century the tone perturbations surrounding voiced and voiceless consonants started to develop into tones which correlated with voiced and voiceless obstruents. Finally three tones developed. At present, the voicing contrast remains, but tone has become secondary to creaky voice cues. In Karen, a Tibeto-Burman language, Watkins (2001) tells us that several factors can play a part. Tone is only partially contrastive and several other factors such as duration, vowel quality, intensity, and spectral tilt play a role in providing contrasts. At the present stage in the development of Karen it is difficult to distinguish which of these features are phonologically contrastive and which are enhancing cues. Voicing does not appear to be important here, but voice quality needs to be taken into account. Maran (1973) suggests that Lisu, and Akha are examples of languages where the voicing contrast seems to be reduced now that the tone contrast is well established. Some of these developments are conjecture as it is difficult to get firm evidence of tone data from previous centuries, particularly if the language was not written down or if the tone differences were not part of the orthography (Yip 2002). However, it seems clear that a reduction in contrast is likely to result if some contrasts become redundant, and the hypothesis that an increasing tonal contrast reduces the voicing contrast seems reasonable as an explanation for the motivation behind language change in these languages.

In Kera then, it is probable that the voicing contrast motivated a tone contrast through a process of tonogenesis, but that the voicing contrast was then redundant and the voiced obstruents lost voicing, being realised instead as a short, positive VOT. Differences in VOT remain with a gradient of VOT values normally between 0 and 70 ms, but there is no longer a phonological contrast between VOT values. In phonetic terms, the VOT cues enhance the tone contrasts with a correlation between the length of VOT and the height of F0. A short VOT corresponds to a low F0 value. The present situation is that tone is contrastive, but voicing and VOT are no longer phonologically contrastive.

In §2 we will consider the basic tone and voicing facts for Kera, and the way the consonants have been categorised in the literature into groups according to their effect on tone. In §3, we will discuss the data which have been cited to support the long distance voice harmony claim for Kera, and we will see that in fact there are data that cannot be accounted for under this theory and that the evidence is more compelling in support of a theory of tone spreading. We will conclude that Kera must be removed from the short list of languages that have been claimed to exhibit long distance voicing harmony and that this should lead us to reconsider the evidence of the other languages that apparently support the claim.

2 Kera tone and voicing facts

Kera has three distinct surface tones, H, M, and L, which in general correspond to the three underlying tones /H/, /M/, and /L/. All three surface tones appear in the tone patterns of nouns. In order to show that the interaction between obstruent voicing and tone has no synchronic effect over these tone patterns, the examples below (as much as possible) contain only sonorants.

(1) *Tone patterns in nouns containing only sonorants*

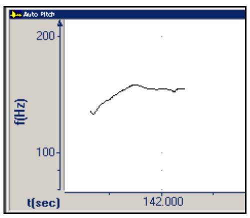
[H]	mə́yán	'river'	[L]	mòlɔ̀ɔrɔ̀	'saliva'
[M]	māanɨ̄	'co-wife'	[LH]	hùlúm	'man'
[MH]	māahúr	'flute'	[HL]	mánhɔ̀r	'ten'
[HM]	máalāŋ	'bird of prey'			

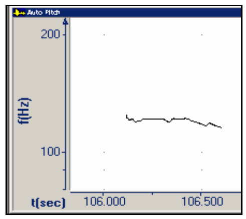
Below, I give the pitch tracks for these nouns showing the contrast between the surface tones. As these examples were pronounced as isolated words, the absolute difference in F0 between different items cannot be used as proof of contrast, but in the words with more than one tone, the relative difference between tones is clear.

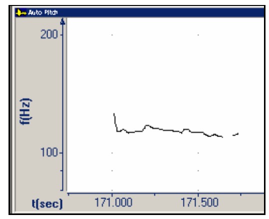
(2) *Examples of pitch tracks for nouns*

[H] mə́yán 'river' [M] māanɨ̄ 'co-wife' [L] mòlɔ̀ɔrɔ̀ 'saliva'

141 146 Hz 121 120 Hz 113 114 113 Hz

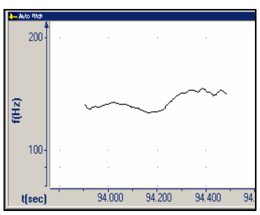


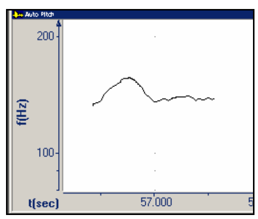




[MH] māahúr 'flute' [HM] máalāŋ 'bird'

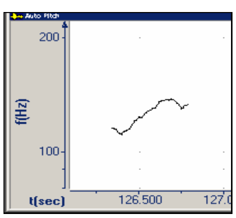
129 145 Hz 157 136 Hz

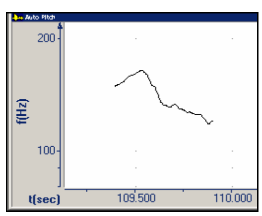




[LH] hùlúm 'man' [HL] mánhɔ̀ŋ 'ten'

111 137 Hz 163 127





2.1 Consonant groups

Kera consonants are traditionally placed into three groups according to the tones found on the following vowel.

(3) Never with high tone: b, d, j, g, v, z
('depressor consonants' in Ebert 1979, Pearce 1998)
Never with low tone: p, t, c, k, f, s
('raiser consonants' in Pearce 1998)
With all three tones: m, n, ŋ, l, r, ɓ, ɗ, h, ʔ
('neutral consonants' in Pearce 1998)[2]

In this paper, I will suggest that this may not be the best way of viewing the consonants from a synchronic point of view. This categorisation is still helpful however when considering the tonogenesis account of the development of tone in Kera, where it is claimed that the depressor consonants produced a slight lowering of the F0 value surrounding the consonant and the raiser consonants had the reverse effect. It is claimed that these slight perturbations became exaggerated and formed tones. This paper does not contradict this view for the development of tone, but it suggests that the synchronic situation implies further changes since this process took place.

In (1), we saw that seven tone patterns are possible in nouns with sonorants. The same seven patterns are evident in nouns which also include obstruents. The fact that the inventory of patterns is the same for obstruents and sonorants shows that the tonogenesis view does not account for all of the facts. This view would predict a much smaller selection of tone patterns for words beginning with sonorants as the neutral consonants should not perturb the tone towards H or L. Clearly other factors have come into play. The examples below demonstrate (in the right hand column) that L correlates with the voiced obstruent. This fact is compatible with all of the theories presented in this paper.

(4) *Noun tone patterns including obstruents*

[H]	káasáw	'millet'	[L]	dàagà	'mat'
[M]	pāatāl	'needle'	[LH]	d̲àktə́láw	'bird'
[MH]	tāatá	'big jar'	[HL]	táab̲ùl	'table'
[HM]	táasā	'cup'			

The correlation between voicing and tone applies equally to verbs, which have the surface melodies H, M, L, and LH. The following examples illustrate each tone

[2] Implosives and fricatives have sometimes been placed in different groups in the literature, but the grouping here reflects the correlation between tone and consonants in the data used for this paper, including a vocabulary list of over 4000 words.

pattern with sonorants and obstruents. As with the nouns, all four melodies are attested for both sonorants and obstruents and the voiced obstruents correlate with L. (<j> is pronounced as a voiced affricate [dʒ].)

(5) *Verb tone patterns*

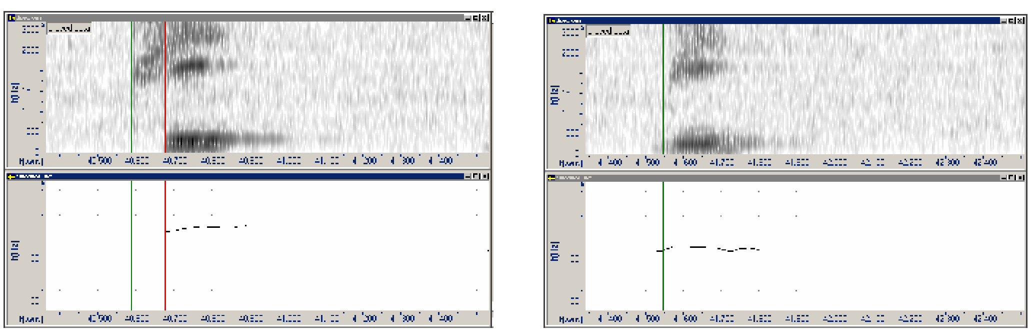
[HH]	lúɓúy	'convince them'	[LL]	nìlì	'surprise them'
	fɨ̂lɨ̂y	'find them'		jìirì	'write to them'
[MM]	nɨ̄ɨl̄ɨy	'chat to them'	[LH]	lùɓúy	'fatten them'
	kɨ̄yɨ̄y	'help them'		jìɓrí	'listen to them'

2.2 Voicing or VOT?

Up to this point, we have been talking about voiced and voiceless obstruents. But if the spectrograms of these consonants are studied, we find that all the VOT values are positive and that the obstruents which we have been calling voiced, actually have a short, positive VOT. This means that the correlation with tone is actually between L and a short VOT.

(6) *Analogous pair showing the correlation between F0 and VOT*

pí	'to lift'	bì	'to come'
VOT 91 ms, 165 Hz		VOT 10 ms, 120 Hz	



Kera is by no means the only language where some sort of pitch perturbation takes place. The same effect occurs to a lesser extent in English. But the changes in pitch are much smaller and less predictable than in Kera, with a maximum difference of around 14 Hz (Hombert 1978). We can compare this with the 45 Hz difference in Kera, shown in the example above. In English, the slight F0 differences have not developed into a phonological tone, but in Kera, the F0 differences do represent a difference of tone.

2.3 Apparent voicing spread

We have seen that a correlation exists between short VOT and L tone in noun and verb roots. But this correlation is most clearly demonstrated in changes in affixes. A K- prefix is added to certain nouns to form the plural. The examples below show that the VOT of the prefix alternates according to the tone of the first syllable. A long VOT is represented by k- while a short VOT is represented by g-. The VOT of the prefix is written in brackets (ms).

(7) *K- plural prefix on nouns with (VOT)*

sg.	VOT	pl.	
kúmná	(28)	kɨ̄kámnɨ̂	'chief' (H does not spread left)
tāatá	(36)	kɨ̄tāatáw	'big pot'
táasā	(32)	kə̄táasāw	'cup'
bɨ̀rwá	(16)	gɨ̀bɨ̀rwáŋ	'white' (L spreads left and so does voicing)
dàarà	(0)	gə̀dàarà	'friend'
àzrá	(14)	gàzráw	'gazelle'

These examples could also be demonstrating voicing spread as the voicing of the initial consonant agrees with the other obstruents in the word. However, a further example demonstrates the problem with this claim:

(8) ágày (67) k-ágày → kə́gày 'hoe'

The change in vowel does not concern us here, but the choice of k- rather than g- is important. If voice spreading is taking place, we would expect *gə̀gày with the k-prefix appearing as g- and a possible change of tone on the first syllable to correspond to the 'voiced' obstruent. We find instead that the tone remains and the consonant is voiceless, corresponding to the H tone. From this example, we would have to say that rather than voicing spreading onto the prefix, we have a H tone affecting the VOT of the prefix. We will return to this example below.[3]

[3] Adjectives with a k-prefix also suggest a correlation between tone and VOT, for example k-maörwaàñ → kéðmaðrwaàñ 'new pl.' (VOT of prefix: 43 ms). This is interesting because the first consonant of the root is a sonorant. We can see from this that the sonorant does not spread

Other examples of correlation between VOT and tone include the -T habitual suffix which is placed on verbs. A few examples are given below.

(9) *-T habitual suffix on verbs*

fal-T-i	fɨ̄ltɨ̄y	'find them repeatedly'
kay-T-i	kɨ̄ytɨ̄y	'help them repeatedly'
jɛɛr-T-m	jɛ̀rdɛ̀m	'write repeatedly to him'

Those who claim long distance harmony (Rose and Walker 2001, Odden 1994) justify this by the K- prefix facts shown above and also by examples which appear to show voicing agreement among obstruents throughout the word as shown below.

(10) agònɔ̀gi *grudge,* gùjùglùgi *granary cover,* bɛ̀zɛ̀rnɛ̀gi *fox*

In favour of this argument, approximately 80% of words do seem to demonstrate voicing agreement, but that still leaves a number that do not. For example in words of the form CVNCV, such as [kinti] 'monkey', a measurement of observed/expected tokens for 103 words gives a highly significant result for the agreement of voicing between the two consonants. But this test does not measure the cause of the correlation, nor does it explain why there is a lack of agreement in some words.

(11) CVNCV (103 words)

O/E	b	p
b	2.5	0.3
p	0.3	1.3

(p stands for all voiceless obstruents, b stands for all 'voiced' obstruents.)

The examples given in this section suggest that rather than 'long distance voicing spread', we are actually dealing with tone spreading. In the next section, we will examine the evidence for this claim and the claim that VOT values are secondary to tone, that they enhance the tone and that they increase with a gradient slope.

voicing leftwards. Unfortunately no example has yet come to light with a prefix before a sonorant in a low tone syllable. I would predict that in this case the prefix would be g-.

3 Voice/ Tone Interaction
3.1 Current view in literature

Concerning Kera tone, there are three views expressed in the literature. i) Ebert (1979), Wolff (1987a, b), and Pearce (1998) all follow the tonogenesis approach in saying that depressor consonants lower the tone. This implies that the voicing is dominant and that the tone follows the voicing. ii) The second view is that of Bradshaw (1999, 2000a, b, p.c.) who has noted that in many languages, there is a close correlation between low tone and voicing. She suggests that low tone and voice are actually one feature: [L/+voice]. On a consonant, this is realised as voicing and on a vowel, this is realised as tone. Bradshaw does not cite Kera in these papers, but she has expressed the view verbally that Kera has this feature. iii) The third view is expressed by Hansson (2004, p.c.). He has observed the problems in claiming that voicing is directing the tone synchronically. He also has reservations with Bradshaw's view. Instead, he suggests that synchronically, tone may affect voicing. This paper follows the third of these views.

As already mentioned, the literature refers to the idea of long distance voicing harmony in Kera. This is analysed as spreading (Odden 1994) or correspondence (Rose and Walker 2001). Uffmann (2003, p.c.) also claims voice spreading, but he puts limits on how far the spreading can go. The examples below show the arguments for long distance voice harmony. In these examples, the tones and vowel quality are written as cited in the literature. In some cases they conflict with my data.

(12) *Kera examples cited by Ebert, Rose and Walker, Odden and Uffmann*[4]

kV-kámná-w	kə̄kámnáw	'chief (pl)'
kV-tāatá-w	kə̄tāatáw	'pot (pl)'
kV-màanə̀	kə̄màanə̀	'co-wives'
kV-sár-káŋ	kə̄sárkáŋ	'black (col)'
kV-sír-kí	kīsírkí	'black (m)'
sár-ká	sárká	'black (f)'

[4] I have not been able to elicit the words for 'colourful', and I cannot confirm the -ka/-ki suffix in these words. I also question the tones on the words for 'colourful' and 'co-wives' (the latter has M tone in my data). If these data are correct, there are exceptions to the correlation between voicing and tone, but I have not seen any exceptions in my data.

kV-gə̀r	gə̀gə̀r	'knee'
kV-dàarə̀	gə̀dàarə̀	'friend'
kV-jàr-káŋ	gə̀jàrgàŋ	'colourful (col)'
kV-jìr-kí	gìjìrgí	'colourful (m)'
jàr-ká	jàrgá	'colourful (f)'
kV-dàygá-w	gèdàygáw	'jug (pl)'

Rose and Walker claim that fricatives can disagree in voicing. To show this, they give two examples from Ebert (1979). In actual fact, fricatives agree in voicing as much as obstruents do, but in both cases there are some exceptions where voicing agreement does not occur.

(13) *Examples cited by Rose and Walker*

fèrgé	'to itch'	(correct form: [vɛ̀rgɛ̄])
dèfé	'to make sauce'	

(14) *Uffmann's examples of apparent voicing spread*
(tones are omitted by Uffmann)

dəbərgə	'chicken'	dege	'to stomp'
kupurki	'billy goat'	tepe	'to gather'

These words are all monomorphemic, so they don't actually show voicing spread, but the voicing agreement shown here is typical. Uffmann suggests that there might be long distance spreading as seen in the example below, but he remains tentative.

(15) t-rəŋ-ga   tərəŋka   'old (f)'

There is actually no evidence that the suffix is -ga in this example. Having offered this example, he acknowledges that certain words present a problem to his theory:

(16) gogloki   'rooster'   kəgay   'hoes'

Although a theory of voice spreading or correspondence would fit with most Kera words, there are a number of words where it does not hold. We cannot explain these words without considering tone.

Instead of accepting this voice spreading hypothesis, I suggest that we view tones as discrete phonological features, and that the 'voicing' effect is a gradient change in VOT which enhances the cues from the tones. In the next section, we will summarise the evidence for this.

3.2 Evidence for tone spreading hypothesis

I give five bits of evidence as reasons to reject the voice spreading hypothesis and to replace this by a hypothesis of tone spreading.

a. Depressor consonants do not appear to be the sole source of L tone, as words containing no obstruents exhibit all the possible melodies:

(17) [H] mə́yán 'river' [M] maāwāy 'gold'
[L] mòlɔ̀ɔrɔ̀ 'saliva'
(More examples above in (1))

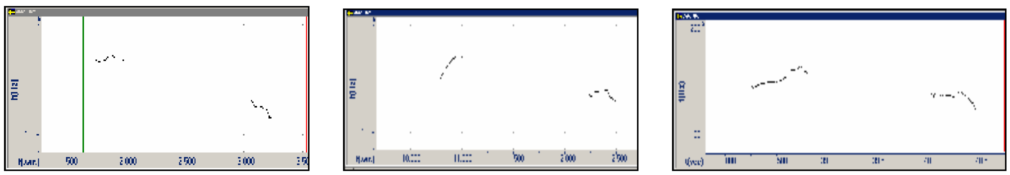
b. We have seen that L tone spreads onto prefixes, and tones that are already placed on a syllable remain. If we were to say that the voice spreads, the k- prefix ought to match the voice (and the tone should match the voice too). But we have already seen the example below where this does not happen.

(18) ágày → kə́gày 'hoe/ hoes ' *gə́gày

In this example, the VOT for g in both words is 0 ms whereas the VOT for k is 39 ms. Clearly the H tone remains, and the k- prefix corresponds to the H tone.

c. All the examples of supposed 'minimal pairs' with a difference in voicing (such as pí and bì in (6), also have a difference in tone. This is to be expected with any of the hypotheses presented in this paper. However, real minimal pairs do exist between words where only the tone changes. If voicing is causing tone, these should not exist.

(19) áŋ 'us (inc)' máŋ 'now' mɔ̄ɔmɔ́ 'grandmother'
àŋ 'you (pl)' māŋ 'close by' mɔ̀ɔmɔ̀ 'spirit (type)'
163 Hz, 119 Hz 163 Hz 133 Hz 141, 156 Hz; 130, 126 Hz



d. Stevens (2003) claims that defining features tend to be quantal while supporting features are gradient. In Kera, tone is contrastive while VOT values increase in a gradient with no obvious breaks between any contrastive groups. This implies that tone is a defining feature and the VOT is a supporting feature.

Languages rarely have two defining gestures with the same force within one feature. Examples of this include Vietnamese, where creaky voice is contrastive while tone acts as a supporting gesture (Pham 2003) and Mandarin, where tone is contrastive and creaky voice acts as a supporting gesture (Xu p.c.).

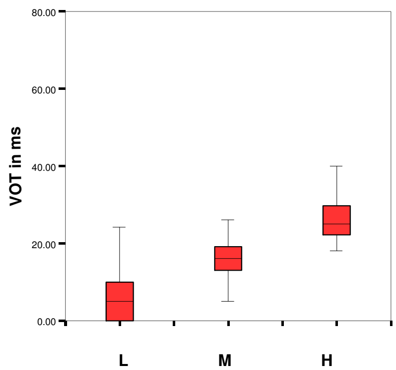
e. Kera 'voiced' consonants are rarely truly voiced. The 'voiced' and 'voiceless' differences are actually a difference in VOT. These VOTs vary considerably between speakers and between tokens for the same speaker. The variation is gradient and a longer VOT correlates with a higher F0.

I have claimed that the VOT values are gradient, but we need to look at this in more detail. Below, I give examples of the VOT values for each of the obstruents, showing the range when followed by each of the tones. The measurements were taken over 300 words for each speaker.

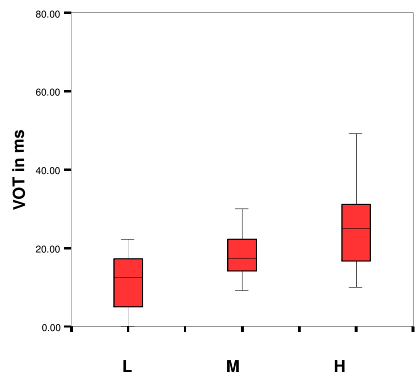
(20) *VOT for P, T, K in onset position with the tone of the following vowel*

Speaker M (bass voice) (All results are significant, p = 0.001 or less)

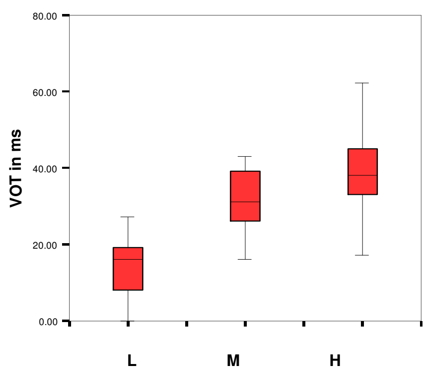
P



T

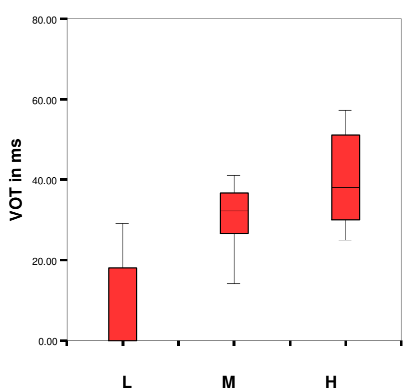


K

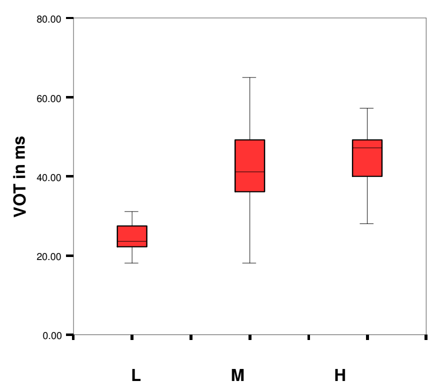


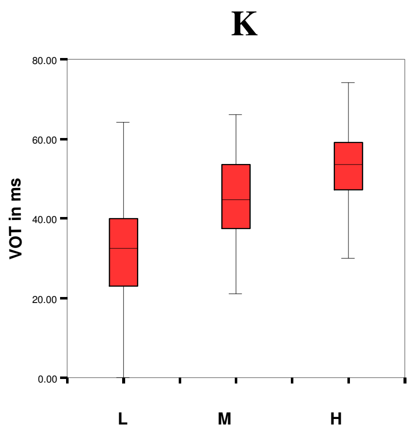
Speaker A (tenor voice) (All results are significant, p < 0.05, most <0.001)

P



T





In these graphs, the difference in voicing is clearly not a binary distinction. VOTs do correlate with tone, but there is no bi-modal split between "voiced" and "voiceless". There is also no clear cut off point for consonant tokens to be classified as "depressors". It is therefore hard to argue that so-called depressor consonants are affecting the tone synchronically. This does not rule out the possibility of this process happening in the past, but voicing cannot be the dominant feature over tone for current speakers of Kera.

3.3 Comparison with other languages:

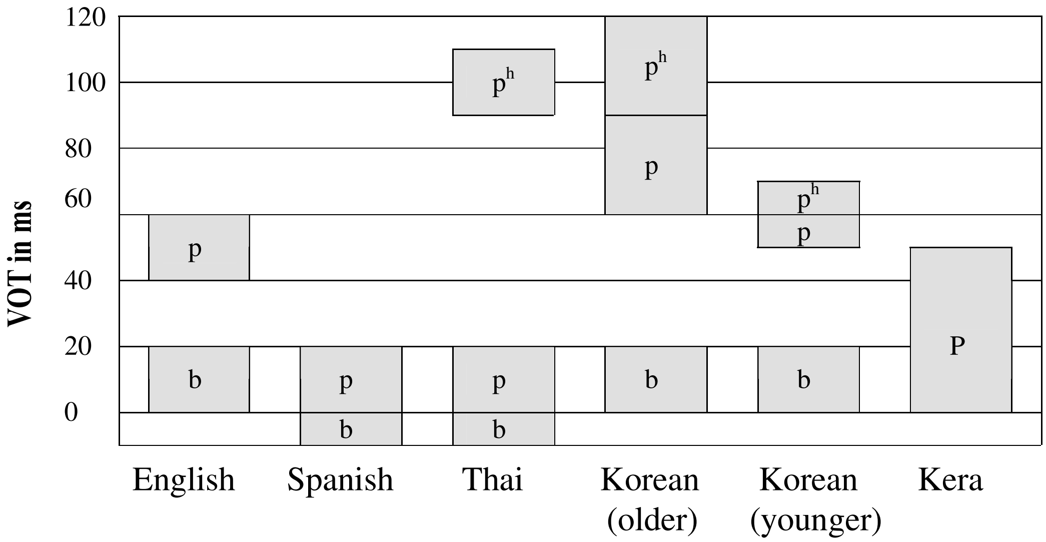
The following table gives a comparison of VOT ranges in various languages including Kera. The same information is given in graph form below.

(21)

English VOTs: (*and Germanic*)	k t, p	50-70 ms 40-60 ms	aspirated
	b, d, g	0-20 ms	
Spanish VOTs: (*and Romance*)	k p, t	20 ms 0-20 ms	unaspirated
	b, d, g	negative VOT	
Thai VOTs:	b	negative VOT	
	p	0-20 ms	unaspirated
	p^h	100 ms	aspirated
Korean VOTs:	b, d, g	10 ms	
	p, t, k	80 ms 55 ms	older speakers younger speakers
	p^h, t^h, k^h	120 ms 65 ms	older speakers younger speakers
Kera VOTs: (archiphonemes)	K T P	10-70 ms 5-60 ms 0-50 ms	some aspiration with higher VOTs

(Ladefoged 2001, Ohala 1995, Silva 2005)

(22) *Comparison of VOTs for p/b consonants*



3.4 VOT corresponds to surface pitch

The examples above imply that the VOT corresponds to the phonological tone. In fact, the correspondence is more likely to be between VOT and F0. This is what gives the VOT a more gradient slope. (If it corresponded to tone, we would expect three distinct groups.) The following examples show that VOT corresponds to F0. In some of the following phrases, F0 is lowered or raised due to interaction on a phrase level. So the same word, which in theory retains the same phonological tone, can be realised with a different apparent tone because of phrasal intonation. The tone marks in this example refer to the surface tone (with a subjective judgement as to whether it is high or low) rather than the phonological tone. Two speakers (A and M) are involved and this also affects the height of F0. Note that the VOT changes with the changes in F0.

(23) /k̲ólɔ́r/ 'tree' hàa k̲ólɔ́r 'that is a tree' k̲ə́ná k̲ōlɔ̄r 'here is a tree' (M)
/agɔ̀lká/ 'palm' hàa àgɔ̄lkā 'that is a palm' k̲ə́ná āgɔ̄lká 'here is a palm' (A)
/gɔ̀ɔrɔ̀/ 'cola' hàa gɔ̄ɔrɔ̀ 'that is a cola' k̲ə́ná gɔ̄ɔ̀rɔ̀ 'here is a cola' (A)

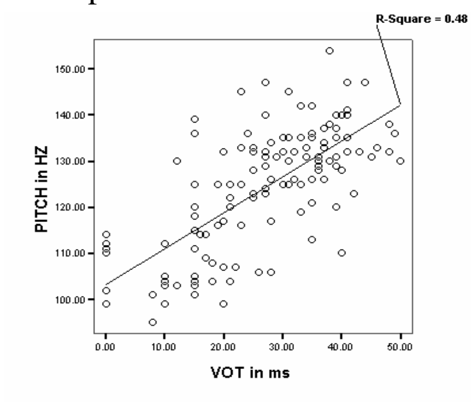
average VOT values in ms:

	H	M	L	Speaker (both male)
k̲olɔr	42	22	-	M (bass voice)
agɔlka	-	39	21	A (tenor voice)
gɔɔrɔ	-	45	28	A

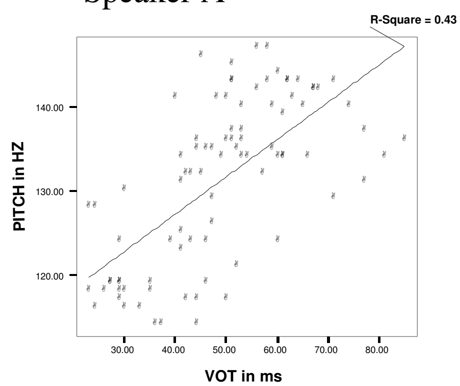
The table above gives a subjective view of how the VOT corresponds to FO. In the following graphs, we consider the correspondence between F0 and VOT with no reference to phonemic tones. We find no clear boundary between voiced and voiceless consonants.

(24) *K consonant VOT and pitch correlation*

Speaker M



Speaker A

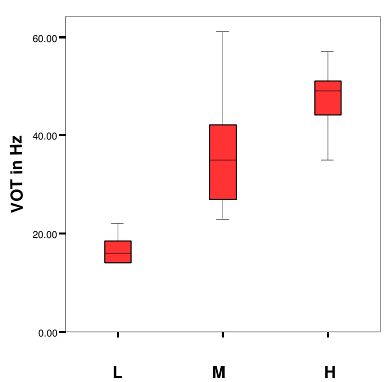


We can see that the F0 and VOT ranges are different for the two speakers, but that the line of best fit gives a similar slope of correlation.

3.5 Affixes

The same gradient changes can be seen in words with a K- prefix:

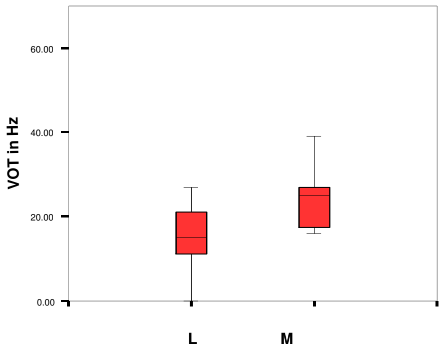
(25) *VOT measurements for 33 K-prefixes separated according to tone*



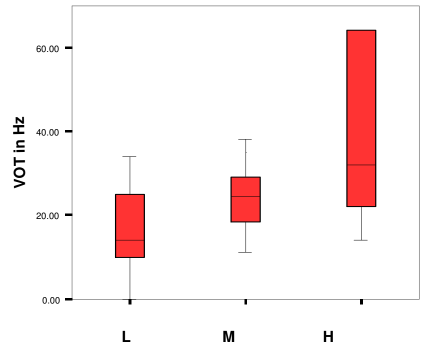
The habitual -T suffix (surface form -t or -d) has a similar VOT and F0 correlation. Generally, -T is contiguous to a preceding consonant, which affects the VOT length. There are several factors to be taken into account, but each consonant type appears to move the VOT range up or down by a fixed amount while retaining the same slope for the increase in VOT as the tone increases.

(26) *VOT Measurements of T in CVC-T-V* *(Speaker A)*

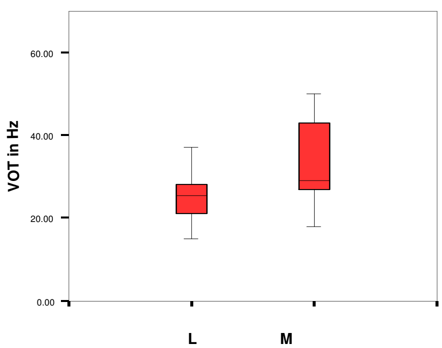
1. CVNTV (N, nasal)



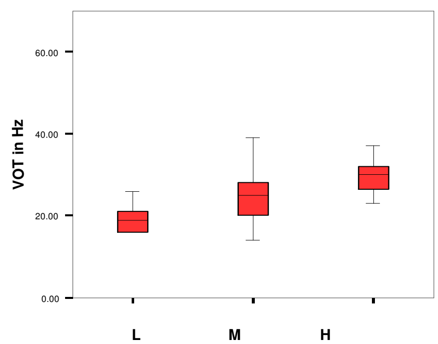
2. CVRTV (R, liquid)



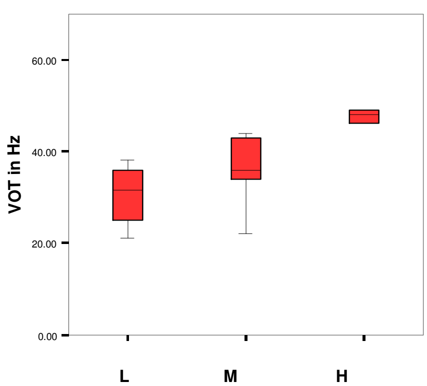
3. CVKTV (K, obstruent)



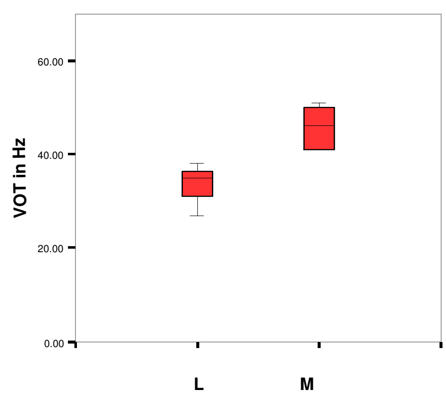
4. CVƁTV (Ɓ, implosive)



5. CVYTV (Y, glide)



6. CVSTV (S, fricative)



All results are significant with $p < 0.05$ except Y: L, M and Ɓ: M, H. From the above graphs we can see that if we were to claim that voice influences tone, we would get a confusing picture. There is no clear binary split between the features [+voice] and [-voice] and there is no true voicing, so the phonetic motivation for this claim is weak. Historically, it is possible that voicing meant a negative VOT, but this is no longer the case. Instead we conclude that tone is the main gesture, and that VOT changes give support.

The changes in VOT are less critical than the changes in tone, so an amount of variation in VOT can take place without affecting the comprehension of the lexical item, whereas the same amount of variation in the tone might confuse the hearer. It is clear that we are not dealing with a [+/- voice] feature, but rather a gesture that accompanies the tone. We conclude that the feature [voice] no longer has a role to play as one of the defining features in Kera.

4 Conclusion

Our conclusion is that Kera has a system where the tone is phonemic, with three distinct tones, and a correlation between the VOT and F0, where a higher tone means a higher VOT. The VOT changes enhance the tone cues.

Diachronically, we accept that it is possible that the tone system was introduced into Kera through voicing and that over time, once the tone system was established, there was a decrease in voicing. This then developed till the tone became the main defining gesture while the VOTs became supporting cues. This means that a synchronic description of the language should conclude that the tone is phonemic while the VOT cues enhance the tone.

We have rejected the long distance spreading arguments for Kera because we have found counter arguments to the claims made and because the tone spreading account covers the data. Obstruent 'voicing' (realised in terms of long or short VOT) is dependent on the tone of the syllable. Tone does spread in certain cases, but it does not skip syllables. It should be noted that Rose and Walker (2001) claim that the long distance harmony comes about through correspondence rather than spreading. This paper does not argue against the theory of correspondence, but it does show that Kera cannot be used to provide evidence for the theory. Those who claim that the harmony comes about through spreading (Odden 1994 and Uffmann 2003 for Kera and Mester 1988 in general) face opposition from several linguists. Clements (1985), Archangeli and Pulleyblank (1994) and Gafos (1995) suggest that the spreading of a segment over a vowel is universally prohibited and Gafos (1996, 1998) suggests that apart from within coronals (Shaw 1991) there is very little long distance spreading of any segmental feature. The argument is that spreading must be local and that spreading can only be long distance if the feature is carried through the intervening segment. The only features which can spread from consonant to consonant in a CVC sequence are those which can be carried through the vowel without significantly affecting its acoustic quality. So [voice] would be excluded as [-voice] could not be carried through the vowel. Tone on the other hand can spread from vowel to vowel because the setting of the vocal folds can be carried through the consonant even if there is no voicing. Kera therefore supports the views of Gafos that spreading only occurs long distance if the feature can be carried through all segments.

In the light of these conclusions, there is a need to reconsider the claim of long distance voicing harmony in Chaha, Amharic, Ngizim, Hausa, Ijo, Aymara, Yabem and Zulu (Rose and Walker 2001). Hansson (2004) has begun to do this, arguing that for the Chadic languages (Kera, Ngizim and Hausa), the voicing agreement is likely to be an indirect result of the interaction between tone and the laryngeal features of obstruents. His argument is based on the implosives which act like voiceless obstruents. A voice spreading account would predict that they behave like voiced obstruents. I have not used this argument in this paper because in my data, Kera implosives can be followed by any tone. However, Hansson's arguments do show that there are alternative approaches for at least some of the languages cited by Rose and Walker. This paper supports his reservations about the long distance voice spreading claims. Equally, there is a need to reassess other Chadic languages which claim to have depressor consonants. It is possible that they too have gone through a process of tonogenesis followed by an added contrast in tones and a reduced voicing contrast, leaving the tonal contrast to take the dominant role in distinguishing between lexical items.

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