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*The interaction between metrical structure and tone in Kera**

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This paper examines the cues for and interaction between the metrical and tonal systems of Kera. Kera has no word-level stress, but the heads of its quantity-sensitive iambic feet are cued by duration, intensity and vowel allophony; in addition, foot boundaries are identified by vowel-harmony and tone-spreading domains. The tonal system has three underlying tones, which are enhanced by differences in voice onset time (VOT). Kera demonstrates an interaction between the iambic foot and tone. Words have one or two tones. For words of three or more syllables the tone-bearing unit is the foot, but for shorter words it is the syllable. This dichotomy is accounted for by a faithfulness constraint requiring all tones to surface, which overrides a constraint limiting each foot to one tone. Kera shows that a tonal system can be sensitive to metrical structure, while maintaining a certain independence between the two systems.

1 Introduction

Kera is a tone language, with no clear unique metrical prominence in each word. I will argue that, despite this, Kera words are metrically parsed into feet, and that this foot structure interacts in complex ways with the tonal system. The traditional view of language categorisation involves a division into stress and tone languages, with pitch-accent languages occupying the middle ground, either as a third group or as a subset of tone languages (Inkelas & Zec 1988, Blevins 1993, Barreteau 1995, Hayes 1995, Zec 1999, De Dominicis 2003). But current thinking is moving away from such a broad categorisation to a more fine-grained approach. McCawley (1978), van der Hulst (1999), Hyman (2001, 2006) and Ewen & van der Hulst (2001) thoroughly investigate the middle ground, and show that

* This paper is based on Kera data mostly collected during a visit to Chad in January–March 2004, with a few references to field notes taken during 1992–2002. I wish to thank the Kera who enthusiastically provided recordings and to the other members of the Chad branch of SIL International for making these visits possible. I am grateful for the discussions on parts of this paper that I have had with members of the London Phonology Seminar at University College London, particularly the extended discussions with Moira Yip and John Harris, and for the help of Eric Carlson in using Praat. I would also like to thank the editors and anonymous reviewers for their helpful comments. Any errors are of course my own responsibility.

'pitch-accent' languages do not form a coherent group. Ewen & van der Hulst (2001: 203) claim that all languages have accent at the word level. Like many other tonal languages (including Hausa (Leben 1996), Hedʒe (Vaibra 2003, James Roberts, personal communication), Creek and Shingazidja (Kim 1999), Kirundi (Hayes 1995), Choctaw (Lombardi & McCarthy 1991), Ibibio, Owon-Afa and Yoruba (Orie 1997) and Igbo and Kuki-Thaadaw (Hyman 2006)), Kera seems to lack such word-level prominence, but the underlying metrical structure is nonetheless evidenced in multiple ways, including tonal interactions. It remains to be seen whether the same will turn out to be true for some of the other languages that are putative counterexamples to Ewen & van der Hulst's proposal.

Kera is an Afro-asiatic, Eastern Chadic language, with 50,000 speakers, spoken in Southern Chad and certain cities in Cameroon (Ebert 1979, Pearce 1998, 2003, 2005a, b). All of the forms cited in this paper were recorded from speakers of the standard Kera dialect who grew up in the main Kera-speaking area, south of Fianga in Southern Chad.

Kera has no obvious word-level phonetic stress, but we will see that there is clearly an active metrical structure which interacts with the tonal system. The placement of tone is partially dependent on metrical structure, although tone does not dictate the foot shape. When a word consists of exactly one foot, each syllable can carry a tone, but in words with two feet, each foot can only have one tone. This paper aims to present a description and a theoretical analysis within an Optimality Theory framework of the interaction between foot structure and lexical tone in Kera. This study is relevant to word-prosodic typology, as it presents a language in which the association of tones makes reference to within-word metrical structure, while there is no evidence of a word-level metrical head. A consideration of Kera will lead us to conclude that the fine-tuning of the categorisation of languages is indeed necessary, as even within 'tone languages' there is considerable variation in the way in which the metrical system and other prosodic phenomena, including tone, interact.

Across the world's languages, the tonal and metrical systems can interact in a number of ways, as listed below. Each of these is found to some extent in Kera or other Chadic languages.

(1) *Tonal and metrical interaction*

a. In the association of tones to heads: e.g. Winnebago (Hayes 1995), Digo (Kisseberth 1984), Creek (Kim 1999, Zec 1999), Seneca (Prince 1983).

b. In the deletion of tones on non-heads: e.g. Shanghai (Duanmu 1997, Yip 2002).

c. In the spreading of tones within the foot: e.g. Shanghai, Lhasa Tibetan (Duanmu 1992, 1993), Yoruba (Awoyale 2000).

d. In the preference for certain tones on heads and non-heads: e.g. Ayutla (de Lacy 2000, 2002), Fuqing (Jiang-King 1996, de Lacy 2000).
e. In associating certain melodies with certain foot types: e.g. Bole, Kanakuru, Hausa (Newman 1972, 2000, Leben 1997, 2001).

Winnebago (Hayes 1995) exemplifies the association of tones to heads (1a); tones are placed on the head of each iambic foot. In Digo (Kisseberth 1984), Setswana (Chebanne *et al*. 1997) and several other Bantu languages (Yip 2002), prominence is generally placed on the penult and is realised by H tone and increased length. This is usually explained in terms of tone being aligned with the head of the head foot.

For some of these languages (1b), the association of tones with the head is accompanied by a deletion of tones on the non-head. In Shanghai, for example, all the tones except the first are deleted in a disyllabic or trisyllabic left-headed foot (Duanmu 1997, Yip 2002).

When a tone is placed on the head of a foot, it is common for this tone to spread onto the non-head (1c). Examples include Shanghai and Lhasa Tibetan (Duanmu 1992, 1993). For these languages, we can say that the tone-bearing unit (TBU) is the foot.

De Lacy (1999, 2002) claims that prominence prefers H and avoids L, and that non-prominence prefers L and avoids H (1d). One consequence of this is that stress can be attracted to H-toned syllables and repelled from L-toned syllables, as in Ayutla and Fuqing (de Lacy 2002).

In (1e), some languages associate certain tone patterns to certain foot types. Newman (1972) notes this tendency in Bole verbs, where monosyllabic feet have low tone, while disyllabic iambic feet have H tone. Newman observes similar patterns in Kanakuru verbal nouns and Hausa plurals.

Apart from the cases of type (1e), there is a limited amount of data concerning metrical structure in Chadic. Previous work on Chadic occasionally refers to 'quantity-sensitivity' with respect to the placement of tones, as described for Bole above, but there are few references to foot structure, with only passing comments in Newman (1972, 1981) and Hyman (2002). It is possible that the foot structure does play a part in several Chadic languages, but that they are yet to be analysed in this way. Hedẽ (Vaibra 2003, James Roberts, personal communication), for example, has vowel alternations in verbs which depend on the foot structure. In Migaama (Roberts 2005), it is unclear whether a case can be made for foot structure, but some quantity-sensitivity is evident. In verbs, the H tone generally occurs on the first heavy syllable of the word. In long verbs, the placing of the H and L tones is predictable, suggesting that Migaama could be categorised as a pitch-accent language, but shorter verbs have contrastive tonal melodies, suggesting that it is in fact a tone language. Other Chadic languages have been described as pitch-accent languages, including Masa (Barreteau 1995, De Dominicis 2003), where the patterns

are largely predictable from the grammatical category and the voicing of the initial obstruent, Mofu (Barreteau 1995), with four melodies on the verbs, LLL, HLL, LHL and LLH, and Mukulu (Roberts 2000), which also has a limited selection of tone patterns in verbs. Roberts (2001) notes that most central Chadic languages have a simple system of two tones, which behave like pitch-accent systems. Linguists working on Chadic languages with three tones, such as Kera, Masa (De Dominicis 2003) and Podoko (Anderson & Swackhamer 1981), can usually account for at least one of the tones by claiming that the L tone developed from an exaggeration of the phonetic lowering of the fundamental frequency following voiced obstruents (known as depressor consonants).

This brief survey of Chadic languages shows that a number of them display signs of possible metrical and tonal interaction, and that further investigation of the phenomenon within this language family is merited.

In the rest of this paper, we will focus on Kera, beginning with the metrical system. We will establish evidence for the existence of the foot, despite the absence of realised word-level prominence or stress, with reference to CVCV sequences which undergo deletion or lengthening to avoid feet of the form (CVCV)[1] and to the phonetic cues of duration, allophony and intensity. In addition, we will see that vowel-harmony and tone-spreading domains mark the boundaries of the foot. In §3, we will investigate the tone system, looking at the evidence for tonal contrast and briefly considering the issues raised in the literature about Kera tone. The interaction of the Kera metrical and tonal systems will be discussed in detail in §4, and we will see that for longer verbs the TBU is the foot, while in shorter words the TBU is the syllable. I will claim that a small set of constraints is sufficient to account for this difference.

2 Metrical structure

To understand the foot structure of Kera, we first of all need to consider the syllable structure. The forms that are permitted in Kera are shown below. (Across the language there is no discernable difference in duration between lengthened vowels and lexically long vowels, so both are represented as VV.)

(2) *Possible syllable structures*

a. *light* ($\breve{\sigma}$)			
(C)V		[bàaŋ̱à]	‘elephant’
b. *heavy* ($\bar{\sigma}$)			
(C)VV	(vowel lengthened)	[ʧə́wáa̱] ← /ʧawa/	‘fire’
(C)VV	(lexically long vowel)	[kɔ̄ɔmɔ̄m]	‘rat’
(C)VC		[kān]	‘water’

[1] Foot boundaries are indicated by parentheses.

Kera has iambic feet constructed over light and heavy syllables: ($\breve{\sigma}\bar{\sigma}$) or ($\bar{\sigma}$). There are no ($\breve{\sigma}\breve{\sigma}$) feet. In (3), which shows the possible foot structures of Kera, heads are underlined.

(3) *Possible foot structures*

a. *monosyllabic*	(<u>CVV</u>)	(<u>CVC</u>)
b. *disyllabic*	(CV.<u>CVV</u>)	(CV.<u>CVC</u>)

In addition to the differences of quantity between head and non-head shown here, the head of the foot is cued by duration, allophony and intensity, as we will see below. The vowel-harmony and tonal systems, which are also described below, mark the foot boundary by using the foot as a domain for spreading.

Above the level of the foot, the other prosodic structures are the prosodic word, which contains the root and suffixes parsed into feet, and the phrase, which is made up of prosodic words, with the possibility of stray light syllables at the right edge.

Kera does not allow (CVCV) feet, so changes in quantity take place to avoid such feet. The example below illustrates how an underlying form undergoes changes to form an acceptable iambic foot (heavy or light–heavy). In this example, we consider a word of the form /CVCV/, which is parsed into one foot, either (CVC) or (CVCVV). Which of these is chosen depends on the position of the word in the phrase. There is a phonological distinction in quantity between the first and second syllables. The first (non-head) syllable is light, associated with one mora, while the second (head) syllable is heavy, with two moras. These quantity changes are discussed further in §2.1.1.

(4) /bɛ̀gɛ́/ 'cattle, animal'

a. *phrase-medial*
   → (bɛ̀g) Deletion of the final vowel, forming a (CVC) foot; *(CVCV)

b. *phrase-final*
   → (bégɛ́ɛ) A mora is added to the head, forming a (CVCVV) foot; *(CVCV)

The quality of the vowel in heads and non-heads is also different. In non-heads, the /ɛ/ vowel has the surface form of the [+ATR] vowel, [e]. We look at this further in §2.1.2.

In addition to changes in quantity and quality, there are further phonetic changes in duration and intensity which reinforce the asymmetry of the disyllabic foot. The non-head shortens and the head lengthens, while there is a considerable difference in intensity between heads and non-heads. In §2.2, we will discuss each of these in turn.

The foot structure is also indicated by the boundaries of the domains for vowel-fronting harmony and tone spreading. Vowel harmony will be discussed in §2.3 and tone in §3.

2.1 The phonemic realisation of foot structure

2.1.1 *Quantity*. (4) above shows that the repair strategies to avoid (CVCV) or (CV) feet include deletion and lengthening, both of which produce a well-formed iambic foot. A further strategy involves attachment to the following word. The choice of repair strategy depends on the position in the phrase. Phrase-medially, all syllables must be footed, and one of the three strategies is used. Phrase-finally, syllables may be left unfooted. Kera requires a heavy head in each foot, so the goal of each strategy is to ensure that the head of the foot is heavy. The Stress-to-Weight Principle (Crosswhite 1998) and the Weight-to-Stress Principle (Prince 1983) both apply, in that syllables are heavy if and only if they are heads of feet. So a (CVCV) foot is avoided in the example above, as the second syllable would be a light head. All three repair strategies used in Kera, deletion, lengthening or (in the case of stray CV syllables in phrase-medial position) combining the final syllable with the first syllable of the next word to form a foot, are thus motivated by the preference for well-formed feet.

(5) *Examples showing strategies for avoiding* (σ̆ σ̆) *feet*[2]

a. *deletion*

i. (σ̆ σ̆) # (σ̄) … → (σ̄)(σ̄) …

/bɛ̀gɛ́ nūutú/ → (bɛ̀g)(nūu)(túu)
animal his 'his animals'

ii. (σ̆ σ̆) # (σ̆ σ̄) → (σ̄)(σ̆ σ̄)

/ŋɛ̄mɛ́ hùlùm/ → (ŋɛ́m)(hùlùm)
choose man 'choose a man'

b. *lengthening*

i. (σ̄) σ̆ # (σ̆ σ̆) → (σ̄)(σ̄)(σ̆ σ̄)

/kúurí kájá/ → (kúu)(ríi)(kə́jáa)
their-neck there 'their necks there'

ii. (σ̄) σ̆ # (σ̆ σ̄) → (σ̄)(σ̄)(σ̆ σ̄)

/gùlnú ʧáwáŋ/ → (gùl)(núu)(ʧə́wáŋ)
looked-it the-sun 'saw the sun through it'

c. *attachment to the following word*

(σ̄) σ̆ # (σ̄) … → (σ̄)(σ̆ σ̄) …

/sáamá nɨ̄mtí/ → (sáa)(mə̄nɨ̄m)(tíi)
rope yours 'your rope'

d. *attachment and lengthening*

(σ̄) σ̆ # σ̆ # → (σ̄)(σ̆ σ̄) …

/bàaŋà bà/ → (bàa)(ŋə̀bàa)
elephant NEG 'not an elephant'

In the examples in (5a), the first two syllables are light. As a (CVCV) foot is not permitted in Kera, the preferred strategy for the construction of

[2] Taken from the folk story 'Squirrel tricks hyena'.

a well-formed foot is to delete the final vowel and form a (CVC) foot. This deletion applies to nouns such as /bègé/ and verbs such as /ŋɛ̄mé/. We can also observe in (5a.i) that the final syllable in /nūutú/ is lengthened.

The examples in (5b) have a CV syllable at the end of the first word. Deletion of the final vowel cannot be used to make a well-formed foot here, because these words begin with a heavy CVV or CVC syllable, so the result would be a superheavy syllable, which is not allowed in Kera. So the second strategy of lengthening the vowel is employed instead. This creates a (CVV) foot (underlined).

(5c) and (d) look superficially like the examples in (5b), but here the CV at the end of the first word is followed either by a heavy syllable in the next word or by a syllable that can be lengthened to make it heavy. This means that the CV syllable (underlined) can attach to the following word to form a disyllabic foot. We will see in §2.1.2 that vowel quality is also relevant to non-head status.

Word-final CV syllables in (5) are footed with a following syllable in the same phrase, to avoid leaving a stray CV syllable which cannot form the head of a foot. In phrase-final position, refooting across the phrase boundary is not allowed, and a CV syllable can remain unfooted. These syllables will be referred to as stray syllables, and will be discussed further in §2.2.1. Utterance-finally, they are lengthened, and become the head of a monosyllabic foot.

Other languages that undergo lengthening of the second vowel to form a ($\breve{\sigma}\bar{\sigma}$) foot are Choctaw (Lombardi & McCarthy 1991), Chickasaw (Hayes 1995), Hixkaryana (Derbyshire 1979), Yupic (Baković 1996) and Owon-Afa (Orie 1997). Lengthening also takes place in trochaic languages such as Ilokano, Icelandic, Italian and Tagalog (Gouskova 2005) and Yoruba (Orie 1997).

Fewer languages employ deletion to ensure well-formed feet, but notable examples include Palauan (Gouskova 2005). Ibibio (Akinlabi & Urua 1992, Orie 1997) uses both lengthening and shortening in negated verbs, but it appears that Kera is alone in applying both lengthening and deletion to the same underlying structure.

2.1.2 *Vowel quality*. The metrical structure is indicated not just by lengthening and deletion, as shown above, but also by vowel quality in heads and non-heads. Kera has six vowel phonemes, three of which have pairs of allophones, as shown in (6). The non-high allophones alternate in their ATR value roughly according to whether they occur in head or non-head position, although I will argue below that the relationship between the allophones is actually between quality and duration.

(6) *Allophones of Kera vowels conditioned by position in foot*

	/i/	/ɨ/	/u/	/ɛ/	/a/	/ɔ/
head [−ATR]	[i]	[ɨ]	[u]	[ɛ]	[a]	[ɔ]
non-head [+ATR]				[e]	[ə]	[o]

We know which vowels indicate heads, because lexical monosyllabic words always have one of [i ɨ u ɛ a ɔ]. As monosyllabic words must be feet, they are therefore also heads, and these vowels must be head vowels. In addition, all closed syllables have these vowels, and all closed syllables are heads.

[ɛ a ɔ] always have a duration greater than 50 ms, and are found in head position, underlined in (C<u>V</u>C), (CVC<u>VV</u>) and (CVC<u>V</u>C). The morphology of these words does not affect the choice of allophone.

(7)

	not phrase-final	*phrase-final*				
a.	[pɛ̱p]	[pépɛ̱ɛ̱]	‘god’	b.	[pépɛ̱ŋ]	‘God’
	[gɔ̀l]	[gòlɛ̀ɛ]	‘to look’		[gòlɔ̀ŋ]	‘looked’
	[tár]	[tərá̱a]	‘a run’		[fələ́ŋ]	‘found’

In contrast to this, [e ə o] are always of short duration (approximately 30 ms), and are found only in non-head position. They are never found in monosyllabic words or word-finally. So the only place in which these vowels are found is in the underlined position in the following feet: (C<u>V</u>CVV) and (C<u>V</u>CVC).

(8) *phrase-final*

a.	b.
[pépɛ́ɛ]	[pépɛ́ŋ]
[gòlɛ̀ɛ]	[gòlɔ̀ŋ]
[tərá̱a]	[fələ́ŋ]

The above examples suggest that the allophones are chosen according to the position in the foot.

(9) *Vowel quality in heads and non-heads*

non-head	*head*	
CV	CVC	CV<u>CVV</u>
[+ATR]	[−ATR]	[−ATR]
(pépɛ́ɛ)	(pɛ̱p)	(pépɛ̱ɛ̱)
(gòlɛ̀ɛ)	(gɔ̀l)	(gòlɛ̀ɛ)
(tərá̱a)	(tár)	(tərá̱a)

2.2 Acoustic measurements of foot structure

2.2.1 *Duration*.[3] In addition to the changes in duration that accompany an increase in weight, the two syllables in a disyllabic foot undergo further phonetic shortening and lengthening respectively, to accentuate the contrast between non-head and head. This is in keeping with the observation

[3] The Kera figures cited in this section give the average measurements of all words of the appropriate structure in two folk stories and a selection of sentences recorded in Chad between January and March 2004.

	non-head	head		
	CV	CVC	CVV	CVCVV
syllable duration	60·8 (s.d. 17·7)	156·0 (s.d. 25·7)	142·1 (s.d. 32·8)	150·4 (s.d. 24·8)
vowel duration	30·0 (s.d. 17·2)	62·0 (s.d. 10·8)	80·0 (s.d. 23·1)	108·0 (s.d. 24·7)
example	(tə́ráa)	(tár)	(bàa)ŋà	(tə́ráa)
number of tokens	18	51	40	14

Table I
Duration (ms) of head and non-head vowels.

of Hayes (1985) that the two syllables in disyllabic iambs will be as different in length as possible, to accentuate the head. To test this hypothesis, the vowel and syllable durations were measured in several words from two folk stories. 14 to 51 measurements were taken in each category, and all results (where a difference is claimed) are significant, with $p < 0{\cdot}05$.

Table I shows that there is a clear difference between both the syllable and the vowel durations of non-heads and heads. This is not simply a question of long and short vowels. Comparing the vowel durations in CV and CVC syllables (30·0 and 62·0 ms respectively), it looks as if shortening takes place in the non-head of disyllabic feet. Now comparing the head vowel in a (CVCVV) foot (108·0 ms) with a head vowel in a (CVV) foot (80·0 ms), it appears that extra lengthening takes place in the head of a disyllabic foot. The important measurement here is the ratio between the two syllables in a (CVCVV) foot. In Kera, the ratio is on average between 1 : 2·7 and 1 : 3·6, depending on the speaker. Over several examples of /bɛ̀gɛ́/ in a folk story, the average ratio is 1 : 2·7 between the duration of the non-head and head vowels. This is similar to the ratio of vowels between non-head and head in other iambic languages such as Ciyao (1 : 2·2) and Luganda (1 : 3·2) (Hubbard 1995a, b).

Several Chadic languages have similar relationships between ATR and duration, including Sokoro (Gordon Martin, personal communication) and Gœmai (Birgit Hellwig, personal communication). Hausa has a difference in vowel quality corresponding to length, but in this case the short vowel is found in both CV and CVC syllables (Carnochan 1988). Cantonese (Yip 1996) has a similar ATR/duration correspondence. English (Wells 1962) also has phonemic length differences between [±ATR] vowels, but [−ATR] vowels are shorter than [+ATR] vowels.

	non-head or stray		head		
	non-head CV	stray CV	head CVC	head CVV	head CVCVV
syllable duration	60·8 (s.d. 17·7)	78·5 (s.d. 12·0)	156·0 (s.d. 25·7)	142·1 (s.d. 32·8)	150·4 (s.d. 24·8)
vowel duration	30·0 (s.d. 17·2)	51·5 (s.d. 15·8)	62·0 (s.d. 10·8)	80·0 (s.d. 23·1)	108·0 (s.d. 24·7)
[ATR]	+	–	–	–	–
example	(tə̱ráa)	(bàa)ŋ̱à	(tá̱r)	(bà̱a)ŋà	(tə́rá̱a)
number of tokens	18	12	51	40	14

Table II
Comparison of duration (ms) and vowel quality.

The discussion on quality and duration has not yet considered stray syllables, which arise utterance-internally in phrase-final position. Up to this point, we have seen that a pattern emerges where [+ATR], short syllables and short vowel durations are seen in non-heads, while [−ATR], long syllables and long vowel durations are seen in heads. But stray syllables do not fit neatly into either of these categories. Stray syllables have the [−ATR] vowels [ɛ a ɔ], but they are not footed, and therefore cannot be heads, as in the following examples, where a foot is constructed at the left edge of the word, but the final stray syllable is too small to form a foot.

(10) (bàa)ŋ̱à ‘elephant’
(kín)tí̱ ‘monkey’
(gə̀dàa)mɔ̱̀ ‘horse’

Consider now Table II. To see that stray syllables are not CVV head syllables, we can compare the syllable duration of CV stray syllables (78·5 ms) to CV non-heads (60·8 ms) and CVV heads (142·1 ms). Their syllable duration is closer to non-heads than to heads, as shown by the light shading. On the other hand, their vowel duration is intermediate between that of non-head and head open syllables, as shown by the dark shading, and the ATR quality is like that of heads (unshaded). So it would seem that these syllables are not the same as non-head syllables either.

The [−ATR] quality also appears in light syllables which are vowel-initial, e.g. in (VCVC) words. So we get [ágàj] ‘hoe’, not *[ə́gàj]. In the absence of an onset, the initial vowel duration has a mean of 60·8 ms (s.d. 12·8; 20 tokens). This choice of allophone cannot be explained by its

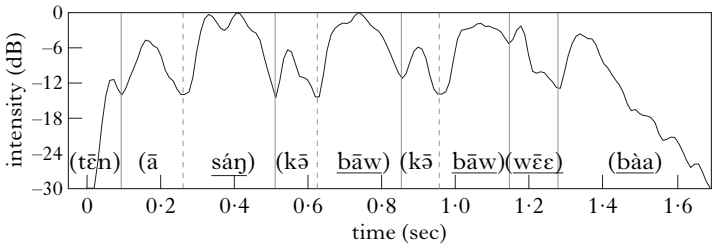


Figure 1

Intensity plot for [tɛ̄n āsáŋ kə̄bāwkə̄bāwwɛ̄ bà] 'I did not see a bat'.

position within the foot, but is consistent with the view that the allophones are related to the duration of the vowel.

The cases of stray syllables and vowel-initial words raise questions about the phonological and phonetic nature of the quality and duration differences between types of syllables. But we can still say that the allophone choice and the vowel and syllable duration indicate headship in general. [+ATR] still implies non-head, while a syllable duration of more than 110 ms indicates a head, and a vowel duration of less than 40 ms probably indicates a non-head.

2.2.2 *Intensity*. So far we have seen that vowel allophones, duration and quantity all indicate the difference between a head and non-head vowel in Kera. But we have not yet considered the property which was traditionally thought to be a major cue for word accent, namely intensity. In Kera, words do not generally exhibit a pattern where exactly one syllable is more intense than the others, so we cannot claim that intensity is used as a word accent. However, intensity is used at the level of the foot: intensity is greater for the head of the foot. For example, the average ratio of intensity for the examples of /bɛ̀gɛ́/ in a folk story is 8·5 dB louder for heads than for non-heads (s.d. 0·7; 5 tokens). Words with two feet have roughly the same intensity for the heads of both feet. Even at phrase level, there appears to be very little use of intensity unless a word is being particularly stressed for emphasis, but there is a consistent difference between heads and non-heads.

In Fig. 1, which is a representative plot of intensity, all heads apart from /tɛn/ have approximately the same intensity. The word /tɛn/ is a function word, and this may explain the low intensity. Other function words generally give a similar low intensity reading. All non-head syllables have a lower intensity, with a mean difference of 3·5 dB between each non-head and head (s.d. 2·7; 48 tokens). In Figs 1 and 2, heads are underlined. Solid lines indicate foot boundaries, while interrupted lines indicate a syllable boundary within a foot.

It is interesting to note in Fig. 1 that although the word [āsáŋ] has a [−ATR]-initial vowel, like all vowel-initial words (see §2.2.1), with

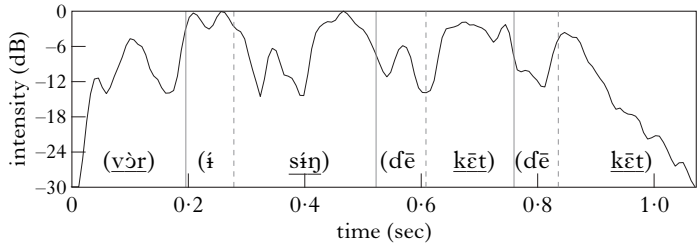


Figure 2

Intensity plot for [vɔ̀r ɨ́sɨ́ŋ ɗēkɛ̄t-ɗēkɛ̄t] 'The river stays calm'. [ɨ́sɨ́ŋ] has high tone on the non-head first syllable because the verb root, /ɨs/, has an underlying tone.

a longer duration than would normally be expected for a non-head, the intensity shows that the first syllable is not a head.

Figure 2 shows that the same patterns of intensity are found on a variety of vowels. Greater intensity is placed on both of the heads of the final word, which is an ideophone, for extra emphasis. The mean difference of intensity between non-heads and heads on emphasised words is 8·1 dB (s.d. 5·1; 39 tokens).

2.3 Foot boundaries marked by vowel harmony

In addition to the cues pointing to the head that we have already seen, there are two systems that interact with the foot, marking its boundary. Both the vowel-harmony and the tonal systems use the foot as a domain for spreading. The tonal system will be discussed later, but we will now look at the part of the vowel-harmony system that concerns the foot.

Kera has three types of vowel harmony, (a) total, (b) height and (c) fronting/rounding. Examples of these are shown in (11).

(11) a. *Total harmony*

(dɨ̀bɨɨ́)(bɨr)	'lizard'	(ʧ̄ēlɛ̄ɛ)(rɛ̄ɛ)	'commerce'
(kɛ̄f)(tɛ̄r)	'book'	(kúŋ)(kúrúŋ)	'bag'

b. *Height harmony*

/gùs-ɛ́/	gùzìi	'to buy'
/sɛ̄ɛn-ú/	síinú	'his brother'

c. *Fronting/rounding harmony*

/ʧ̄ɨ̄r-ī/	ʧ̄īirī	'your (FEM) head'
/ʧ̄ɨ̄r-ú/	ʧ̄úurú	'his head'
/vɨ̀ɨg-ɛ́/	vɨ̀ɨgì	'is emptying'

Total harmony, as illustrated in (11a), is found throughout monomorphemic words, with the possible exception of word-final vowels. The vowel quality alternates between [+ATR] in non-heads and [−ATR] in heads, as described in §2.1.2.

Height harmony, as illustrated in (11b), applies between the root and affixes, with [+high] spreading in both directions. Suffixes can cause root vowels to become high, and *vice versa*. The [+high] vowels are [i ɨ u].

Fronting and rounding harmony occurs in two situations. In the first, illustrated in (11c), the high central vowel [ɨ] in the root is fronted or rounded by the high suffixes [i] and [u] respectively. For this process to take place, both vowels must be underlyingly high.

The second situation for fronting and rounding is the one that concerns us most in this paper. All front suffixes cause central vowels in the same foot to front, so that /a ɨ/→/ɛ i/ before /i e ɛ/.[4] The examples in (12) illustrate this harmony. The imperative retains the underlying vowel, while in the imperfective fronting takes place, because of the /-ɛ/ suffix. For the verbs in (12a), the root vowel is already a front vowel, so no change takes place (apart from the [e] allophone). However in (12b), the underlying vowel is central, /a/ or /ɨ/, and both of these undergo fronting. (These examples also contain left-to-right height harmony /-ɛ/→/-i/ in the presence of a high vowel in the root, but this harmony is not restricted by the foot structure.)

(12)	CVC la (IMP)	CVC-ɛ́ (IMPERF)	
a.	(ʤɛ̀l) là	(ʤɛ̀lɛ̀ɛ)	'deviate'
	(dìg) là	(dìgíi)	'stop from leaving'
b.	(bàl) là	(bɛ̀lɛ̀ɛ)	'love'
	(bɨŋ) là	(bìŋìi)	'open'

In contrast, between feet the fronting does not take place. In both examples in (13), the central vowel is not fronted in the imperfective form, because the front suffix is not in the same foot as the root vowel.

(13)	(C)VXC la (IMP)	(C)VXC-ɛ́ (IMPERF)	
	(bàa)(d-ɨ làa)[5]	(bàa)dɛ̀	'wash'
	(ɨ̄s)(k-ɨ̄ láa)	(ɨ́s)kí	'understand'

This harmony clearly uses the foot as a domain for spreading and, in so doing, gives us an indication of the boundary of the foot.

[4] This is probably also matched with a similar rounding harmony within the foot, but the evidence for this is less clear.

[5] [laa] has a short vowel underlyingly, but in these examples [a] lengthens so as to avoid the badly formed foot *CVCV after the preceding syllable. Cf. (12), where the lengthening is not obligatory.

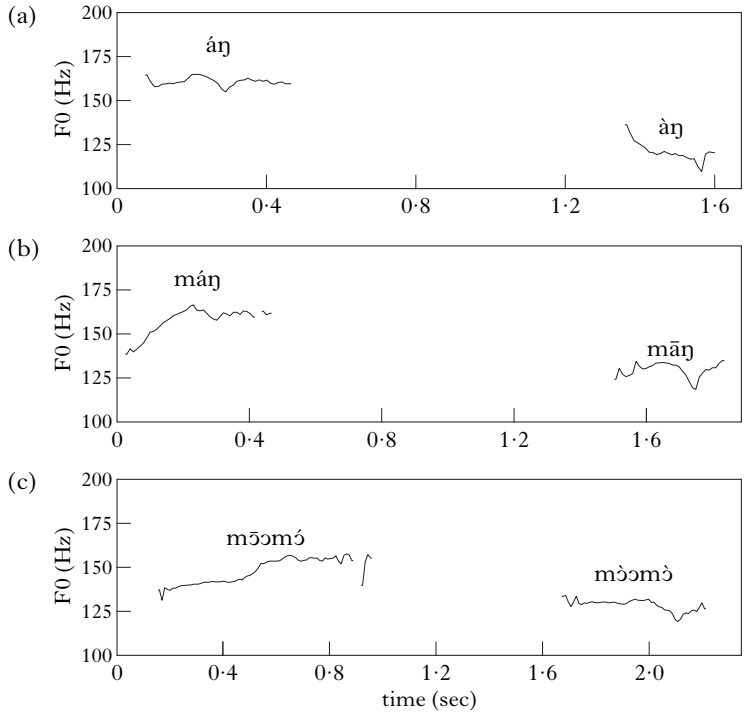


Figure 3

Pitch tracks for (a) H /áŋ/ 'us (INCL)' (163 Hz) and L /àŋ/ 'you (PL)' (119 Hz); (b) H /máŋ/ 'now' (163 Hz) and M /māŋ/ 'close by' (133 Hz); (c) MH /mɔ̄mɔ́/ 'grandmother' (141, 156 Hz) and LL /mɔ̀mɔ̀/ 'spirit' (130, 126 Hz). Frequency values are measured at the mid point of the vowel.

3 Tonal system

The final indication of the foot boundary is found in the tonal system.[6] Like all Chadic languages, Kera is tonal (Schuh 2003); its tonal system is comprised of the underlying tones /H/, /M/ and /L/. These can be seen clearly in the minimal pairs in Fig. 3.[7] The frequency value is measured at the mid point of the vowel.

In monosyllabic and disyllabic words, each syllable has a tone, regardless of the foot structure or syllable weight. This leads us to conclude that

[6] More information about the evidence for the Kera foot is given in Pearce (2005b, in press, b).

[7] The pitch tracks in this paper show the words recorded in isolation to emphasise the contrast, but they were also measured in tone frames, with similar results. The tone-frame results show that the fall in pitch is not due to list intonation. Minimal pairs with obstruent onsets show VOT differences in the onset as well as tone differences, e.g. /gè/ 'to throw', /ké/ 'to throw (ITERATIVE)'.

the tone-bearing unit is the syllable. One foot can have two tones which are both realised:

(14) a. (hùɗúm) 'hole' b. (kítīr) 'moon'

	L H	HM

In nouns, we find the following melodies.

(15)	[H]	máján	'river'	[L]	nàalà	'long grass'
	[M]	māanɨ	'co-wife'	[LH]	hùɗúm	'hole'
	[MH]	māahúr	'flute'	[HL]	mánhɔ̀r	'ten'
	[HM]	máalāŋ	'bird of prey'			

We might expect nine melodies, but the patterns [LM] and [ML] are absent. One possibility is that underlying /LM/ and /ML/ do exist, but are neutralised by the spreading of one or other of the two tones to produce surface [LL] or [MM]. Since these forms are monomorphemic, this hypothesis cannot be tested. Note that we must reject an analysis where non-heads are underspecified for tone, as this would generate only four patterns (where the head has H, M, L or ∅), rather than the seven patterns in (15), all of which can be found on disyllabic feet.

The above words contain only sonorants[8] and vowels, demonstrating a seven-way contrast. Some linguists have claimed that the tones exist in Kera through a development of the F0 perturbation that accompanied voiced or voiceless stops (Ebert 1979, Wolff 1987a, b, Pearce 1998), but these data show that the perturbation in F0 from voicing is no longer the only source of the distinction between tones.[9] Synchronically, voicing in stops is not distinctive independently; rather, it is part of the realisation of lexical tones. The same seven melodies occur in words with obstruents with an interaction between VOT and tone. Orthographic voiced stops appear with L tone (in the righthand column in (16)) and orthographic voiceless stops appear with M or H tone (although it turns out that there is no categorical distinction between voiced and voiceless obstruents, and VOT is linearly predictable from the tone; Pearce 2005a).

(16)	[H]	káasáw	'millet'	[L]	dàagà	'mat'
	[M]	pāatāl	'needle'	[LH]	ʤàká	'punting pole'
	[MH]	tāatá	'big jar'	[HL]	táabùl	'table'
	[HM]	táasā	'cup'			

[8] Implosives, glottal stop and [h] act in a similar manner to sonorants in Kera, as they do in most Chadic languages.

[9] The changing roles of VOT and F0 in Kera and the implications for claims of long-distance voicing spread (Odden 1994, Uffmann 2003, Rose & Walker 2004) are discussed further in Hansson (2004) and Pearce (2005a, in press, a).

There are no examples of words with three different tones within one monomorphemic word. This may be due to a constraint on the number and order of tones at word level, as Leben (1996) claims for Hausa in his discussion on tonal feet. On the other hand, it could be an accidental result of the fact that most Kera words are too short to have three tones. We will see later that words with three tones would need to contain three feet. There are probably only two or three monomorphemic, non-compound words of this length in Kera and they happen not to have three tones. Reduplicated words such as /ākólɓɔ̄jkólɓój/ 'grasshopper' suggest that it is possible to have more than two tones in a Kera word, and that the restriction is not on the tone melody, but rather on the normal length of a word.

We should also note that there are no contour tones in Kera, so when two tones arrive on one syllable, one of them is deleted. Examples from natural speech suggest that the second tone is deleted, although evidence is only available for the LH pattern at this stage:

(17)	*phrase-final*	*phrase-medial*	
	bègɛ́ɛ	bèg	'animal'
	hàgɛ́ɛ	hàg	'cry'
	gùníi	gùn	'wake'

So far we have established that there are three phonemic tones in Kera, and that the VOT of the onset is progressively smaller as the tone is lower. The examples above show tones on words of one or two syllables, and they could lead us to assume that the TBU is always the syllable. In the next section, we will see counterevidence to this assumption in words with more than one foot.

4 Interaction between the foot structure and the tonal system

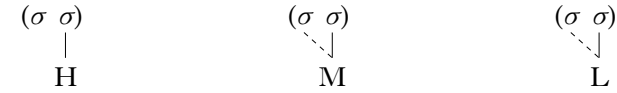
4.1 Metrical conditions on tone distribution

We have looked at the metrical structure and the tonal system of Kera separately. But in order to understand how tone assignment depends partially on the metrical structure, we now consider the relationship between them.

The metrical and tonal systems are independent in one- and two-syllable words, where the TBU is the syllable. However, in words of three or more syllables, the two systems interact. In these words, the foot is the TBU and tone is realised on the head.

If each foot has only one tone, the possible tone melodies on disyllabic feet in long words are /H/, /M/ and /L/. This tone links to the head. In /H/ and /M/ feet, the non-head has [M] tone. In /L/ feet, the non-head has [L] tone. I hypothesise that tone will spread onto the non-head if it can, but that non-heads avoid H-tone spreading, so the /H/ foot is realised as [MH] (unless preceded by /H/).

(18) a. /H/ → [M H] b. /M/ → [M M] c. /L/ → [L L]



The involvement of the foot is crucial in the analysis of long words. The boundary between tones in a word has to coincide with a foot boundary and each foot is associated with only one tone. The link between the possible tone patterns and syllable weight cannot otherwise be explained. For example, the pattern [LLH] is allowable on (σ̌σ̄)(σ̄), (gədàa)(mɔ́ɔ), but not on (σ̄)(σ̌σ̄), *(dàk)(tə̀láw).

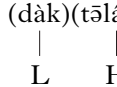
The possible metrical patterns for trisyllabic words are: (σ̌σ̄)(σ̄), (σ̄)(σ̌σ̄) and (σ̄)(σ̄)(σ̄). If these words have the same underlying melodies as disyllabic words, there are seven possibilities: L, H, M, LH, HL, MH and HM. Table III shows all the possible combinations of these. Where a combination exists, I give an example; — marks combinations that are not possible if the TBU is a foot. No examples of these combinations exist in Kera. Empty cells indicate combinations that could be possible given the analysis presented here, but for which I have found no examples. Note that disyllabic /H/ feet are realised as MH or HH, depending on the surrounding tonal context, so allotones are shown in the second column.

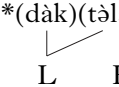
The examples in the last column are probably all compounds or loanwords, but no other examples of this length are available. Kera has very few words containing three feet or more than four syllables, apart from compounds. This may explain why there are no clear examples of words with three different tones except in compounds. Compounds and loans do not always follow the same rules for tone as monomorphemic words, but most of the examples here do fit the same pattern. /mājtɛ̄lfɔ́n/ and /ɗɛ́wmáatāa/ imply that there can be three underlying tones, but as these examples are compounds, and the first is a loan with the French final accent interpreted as H tone, they do not provide a strong case for the existence of three tones in a word. For this reason, we will focus on words with one or two tones.

Concentrating on the words with two feet where the data contain no compounds, we see from Table III that all tone melodies that would be expected do in fact occur. The table also shows that no tone patterns exist which would disprove the TBU being the foot.

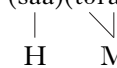
A small selection of these words are shown below, with the tone associations:

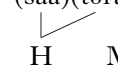
(19) a. (dàk)(tə̄láw) (type of bird) *(dàk)(tə̀láw)





b. (sáa)(tə̄rāw) 'cat' *(sáa)(tə́rāw)





		(σ́ σ̄)(σ̄)	(σ̄)(σ́ σ̄)	(σ̄)(σ̄)(σ̄)
/L/	LLL	(dɨmɨ̀ɨ̀)(mɨ̀ɨ̀) 'clothes'	(bɔ̀m)(bɔ̀rɔ̀ŋ) 'carp'	(jàm)(wàa)(lɛ̀ɛ) 'victory song'
/H/	HHH or MHH	(kə̄kám)(náa) 'chiefs'	(kúŋ)(kúrúŋ) 'skin bag'	(máj)(fáa)(táa) 'dried carp'
/M/	MMM	(ʧ̄ēlɛ̄ɛ)(rɛ̄ɛ) 'commerce'	(kāŋ)(kəlāŋ) 'hat'	(bāa)(sāj)(mɔ̄ɔ) (type of bird)
/LH/	LLH LHH or LMH	(gə̀dàa)(mɔ́ɔ) 'horse' —	— (dàk)(təláw) (type of bird)	 (hàm)(pɔ́r)(lɔ́ɔ) 'viper'
/HL/	HHL or MHL HLL	(kə̄sáa)(bɔ̀ɔ) 'cricket' —	— (mán)(də̀hàŋ) 'bag'	 (máa)(vɔ̀r)(gɔ̀ɔ) 'ulcer'
/MH/	MMH MHH or MMH	(tɨ̄lɨ̄ŋ)(kɨ́ɨ́) 'hole' —	— (tāa)(mə̄káa) 'sheep'	(māj)(tɛ̄l)(fɔ́n) 'tape recorder' (máj)(kɨ́f)(ríi) (type of tree)
/HM/	HHM or MHM HMM	(kūɓúr)(sīi) 'burning coal' —	— (sáa)(tərāw) 'cat'	(ɗɛ́w)(máa)(tāa) 'vegetable' (máj)(wāa)(rɛ̄ɛ) 'newly wed'

Table III
Potential tone patterns and foot structure in trisyllabic words.

c. (kūɓúr)(sīi) 'burning coal' *(kúɓūr)(sīi)

H M H M

d. (gə̀dàa)(mɔ́ɔ)[10] 'horse' *(gə̀dáa)(mɔ́ɔ)

L H L H

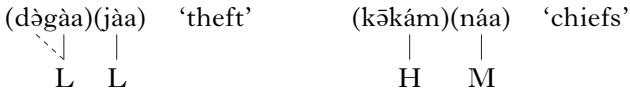
Note that in the first example, (dàk)(təláw), the L does not spread onto the middle syllable even though the non-head has the default M tone. It appears that the foot is limited to one tone and so the L tone cannot

[10] L spreads left onto M tones regardless of the foot structure.

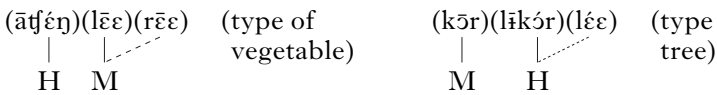
spread. We will look at this in more detail below, where we will develop an OT analysis of these facts.

We look first at the spreading processes in Kera. There are two main types of tone spreading:

(20) a. Within the foot, L tone spreads left from the head onto the non-head, but H does not appear to spread. We cannot be sure whether M spreads, as the default would also be M, but we will assume it does.

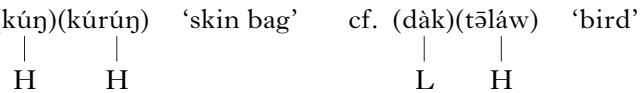


b. Tones spread to the right until they reach another tone, or a foot containing a tone. So the last tone in a word will spread to the end of the word. This applies to all three tones and involves all syllables including non-heads. Note that these are all monomorphemic words.



There are two more cases, demonstrated in (21) and (22), where phonological spreading of a H tone is a possibility, but these could equally be examples of phonetic interpolation. Further investigation would be necessary to decide between the two views, but this paper will assume that interpolation is taking place, and we will therefore not cover these facts in the OT analysis.

(21) Feet with H tone on the head are realised as [HH] if the previous tone is H.



When there are H tones on both sides of the non-head, as in (kúŋ)(kúrúŋ), the realisation of the tone on the non-head syllable is effectively H. But if the preceding tone is L, as in (dàk)(tə̄láw), the non-head tone is realised as M. This is consistent with an interpolation account, assuming that the non-head syllable does not carry a tone of its own in words with more than one foot.

(22) Words with a H-tone-initial foot are realised as [MH …] in isolation, but as [HH] if the previous word ends in a H tone. An interpolation account applies equally in this case.

kə̄táasāw	hār lā bɨ́ mántɛ́ kə́táasāw pá
'cups'	'Return to ask for the cups again.'

4.2 OT analysis

We now consider the facts of §4.1 within the framework of Optimality Theory, with the purpose of finding constraints that adequately account for the interaction between tones and feet and the difference in tonal specification, depending on the number of feet in the word.

The main point established in the previous section is that the syllable is the TBU for short words and the foot is the TBU for long words. To explain this change in the TBU we need to cover the following facts: (i) the foot is preferred as TBU; (ii) contour tones are not allowed, but all tones must be realised; (iii) possibly without exception, Kera monomorphemic words have a maximum of two underlying tones, so any word with two feet can realise all the tones on heads; (iv) however, in words containing only one foot, the non-heads may need to carry a separate tone in order for all the tones to be realised; (v) L and M tones spread left and right, and H spreads to the right, but H does not spread onto non-heads of a foot whose head is specified for tone. For this account, we will assume that a constraint which ensures that Kera has no tones on consonants is high-ranked.[11]

For several languages, including Chizigula, Zapotec, Kikuyu, Digo and Sukuma (Yip 2002), an OT account of tone involves mainly high-ranked constraints that align tones with word edges, but ALIGN constraints are not able to cover the Kera facts, because they do not make allowance for foot structure. Only one tone is allowed within the foot. So we need a constraint which defines the foot as TBU as in (23):

(23) NOCONTOUR-FT
The foot is only associated to one tone.[12]

But there is a need for a constraint to dominate this constraint. REALISE(T) makes sure that tones are realised, so that if there are more tones than feet, both tones associate to that foot, giving the appearance that the syllable is the TBU instead.

(24) REALISE(T)
All tones must be realised.

The tone is placed on the head of the foot, and there are no contour tones. These constraints, given in (25), are undominated:

(25) a. HD/SPECIFY
Heads must have a tone specified.
b. NOCONTOUR-σ
No contour tones.

[11] With the exception of approximately five words with a syllabic nasal which may carry a different tone: /dùugŋ́/ 'evening'.

[12] The default [M] tone can still surface on the non-head syllable in combination with a H tone on the head, but the foot cannot be associated to two specified tones.

Within a positional markedness schema (Zoll 1997, 2004), HD/SPECIFY is balanced by a lower-ranked SPECIFY. SPECIFY also encourages the spreading of M and L.

(26) SPECIFY
All syllables should be associated with a tone.

I now turn to spreading. Recall that M and L, but not H, spread onto non-heads in the same foot. The case for a constraint which avoids H tone on non-heads has been argued for several languages by de Lacy (1999, 2002). He claims that this is a universal constraint and proposes the ranking in (27):

(27) *NON-HD/H ≫ *NON-HD/M ≫ *NON-HD/L

In Kera, the constraint *NON-HD/H has to be placed carefully with respect to other constraints, because H tones are allowed on non-heads in disyllabic words with two underlying tones. *NON-HD/H blocks H from spreading onto non-heads.

(28) *NON-HD/H
Non-heads do not have high tone.

These are the key constraints that we need in our grammar. We will now go through each of these in more detail, with representative examples to demonstrate the motivation for each constraint and the ranking. We will see that the ranking we need to describe Kera is:

(29) HD/SPECIFY, NOCONTOUR-σ ≫ REALISE(T) ≫ *NON-HD/H, NOCONTOURFT ≫ SPECIFY[13]

Consider first the word /kəsaabɔɔ/ HL in (30).

(30) *Foot as TBU in a trisyllabic word*

(kəsaa)(bɔɔ) HL	HD/SPEC	*NON-HD/H	SPECIFY
☞ a. (kə̄sáa)(bɔ̀ɔ) H L			*
b. (kə́sàa)(bɔ̀ɔ) HL		*!	
c. (kə́sáa)(bɔ̀ɔ) H L		*!	
d. (kə́sāa)(bɔ̀ɔ) H L	*!	*	*

[13] All the constraints used in this grammar have a firm backing in the OT literature: NOCONTOUR, REALISE and SPECIFY in Yip (2002), *NON-HD/H in de Lacy (2002).

Candidate (30d) violates the constraint Hd/Spec by having no tone on the head of the foot. Candidates (b) and (c) are ruled out because a H tone is associated with a non-head. The ranking of the first two constraints is not yet established, but they must both be ranked higher than Specify in order for the correct winning candidate to emerge.

Turning now to a two-syllable word with the same tonal melody, we see the role played by the constraints NoContour-σ and Realise(T) in ensuring that each syllable is associated to a tone in the winning candidate. These two constraints must be ranked above *Non-Hd/H, to rule out the second and third candidates. This gives the positional markedness schema: Hd/Spec ≫ *Non-Hd/H ≫ Specify.

(31) *Syllable as TBU in a disyllabic word*

(kəbaŋ) HL	Hd/Spec	NoCont-σ	Realise(T)	*Non-Hd/H	Specify
☞ a. (kə́bàŋ) H L				*	
b. (kəbáŋ) H			*!		*
c. (kəbâŋ) H L		*!			*

To motivate the ranking NoContour-σ ≫ Realise(T), consider a monosyllabic word with two underlying tones. In the following example, the word /bɛgɛ/ is disyllabic underlyingly, and is pronounced with two vowels in phrase-final position. In phrase-medial position, the final vowel is deleted to create a monosyllabic iambic foot (see (4) above), with two underlying tones. For simplicity, the tableau below takes this monosyllabic form as its input. The winning candidate deletes the second tone, rather than keeping a contour.

(32) *No contour on the syllable as TBU in a phrase-medial monosyllabic word*

(bɛg) LH	Hd/Spec	NoCont-σ	Realise(T)	*Non-Hd/H	Specify
☞ a. (bɛ̀g) L			*		
b. (bɛ̌g) L H		*!			

To complete the grammar, we must motivate the constraint NoCont-Ft. The need for this constraint is seen in a trisyllabic word of the form ($\sigma\sigma$)(σ). In tableau (33), candidate (c) demonstrates that no contours in the foot are allowed, while candidate (b) also motivates the constraint Specify, which, although it is low-ranked, is still needed, to ensure that the L tone spreads to the left.

(33) *No contour on the foot as TBU in a trisyllabic word*

(dɨbɨŋ)(gaa) LH	Hd/ Spec	NoCont-σ	Realise (T)	*Non-Hd/ H	NoCont-Ft	Specify
☞ a. (dɨ̀bɨ̀ŋ)(gáa) L H						
b. (dɨ̄bɨ̀ŋ)(gáa) L H						*!
c. (dɨ̀bɨ́ŋ)(gáa) L H					*!	
d. (dɨ̀bɨ̄ŋ)(gáa) L H	*!					

This gives us the final grammar, as already shown in the ranking in (29).[14]

This grammar describes the key facts of Kera. Heads carry tones, no contour tones are allowed and all tones are realised. The foot is the preferred TBU, but the syllable becomes the TBU if there are not enough head syllables for all of the tones to be realised on the heads. Tones do not spread onto non-heads if the head has a tone specified.

5 Conclusion

We have seen that Kera exhibits the following interaction between the metrical system and tone:

(34) a. Tones are associated to heads.
b. Non-heads and heads within the same foot cannot be associated to different tones except in words of two syllables.
c. L tone spreads within the foot.
d. The placement of tone is partially dependent on metrical structure. Tone does not dictate the foot shape.
e. Non-heads prefer not to be associated with H tone, except in two syllable words where the association is needed to satisfy Realise(T).
f. The number of tones that can be associated with a root appears to be limited to two. This may be accidental, as most words are too short to have more than two tones, or it could be evidence for a restriction at word level for monomorphemic words.

In summary, there are four cues to metrical structure: weight, intensity, vowel harmony and duration. (Duration is in turn cued by ATR values.)

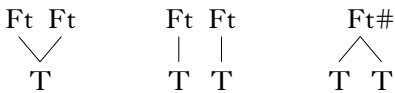
[14] There is still an unresolved issue as to why H spreads within the foot in a (σσ) word, but not in longer (σσ)(σ) or (σ)(σσ) words.

The tonal and vowel-harmony systems mark the boundary of the foot by using it as a spreading domain. Together, these cues give compelling evidence for the role of the foot in Kera. There are two cues to tone: F0 and VOT. The F0 value is evidently a stronger cue for the tone than the VOT, but the VOT still has a role to play in enhancing the perception of tone.

Between these two systems, the interaction comes from the use of the foot as a TBU in words which have enough syllables for all the tones to be realised. The interaction between metrical structure and tonal systems in Kera is adequately described by the grammar in (29).

In general, there are three possible situations with regard to the number of feet and the number of tones. If there are more feet than tones, the tone will spread, as shown by (ʤàm)(wàa)(lèɛ) in Table III. If there are the same number of feet as tones, there will be no spreading. If the number of tones is more than the number of feet, the two tones will both be realised on one foot, with the syllable becoming the TBU, as shown by /bègé/ in (4).

(35) *Foot level*



The same sorts of patterns are found at syllable level, but if there are two tones that could potentially be on the same syllable, Kera avoids contour tones by deleting one of the tones, as demonstrated in (17).

(36) *Syllable level*

In this paper, we have seen that Kera differs from typical syllable-tone languages such as Cantonese (Duanmu 1994), but that it also differs from typical word-tone systems such as Margi (Williams 1976). Kera represents a third type, a foot-tone language. Duanmu (1994) claims that the tonal domain for Shanghai is also a foot, suggesting that Shanghai should also be classified as a foot-tone language rather than a word-tone one. Kera and Shanghai are similar in that the heads of feet are associated with tones. But there is an important difference. In Kera, tones are underlyingly unassociated, and then migrate to foot heads. In Shanghai, each syllable has its own underlying tone, and there is no migration; instead, tones are only retained on foot heads. This means that even within the category of 'foot-tone language', there are still important differences in the details of the interaction between tone and feet. This is certainly an area of typology that merits further investigation.

In the previous section we arrived at a grammar which gives us the syllable as the TBU in two-syllable words and the foot as the TBU in three-syllable words. We did this without using any TBU constraints. The constraint NoContour-Ft is doing the same work that TBU = Ft would do. In fact TBU=Ft implies simply that there is only one tone per foot. This could be either NoContour-Ft or Agree-T-Ft, depending on whether there is spreading throughout the foot. These constraints could replace the TBU constraint.

	no spreading	spreading	result
TBU=μ	–	–	One tone per mora (contours possible on heavy σ)
TBU=σ	NoContour-σ	Agree-T-σ	One tone per syllable (unless there are more tones than syllables)[15]
TBU=Ft	NoContour-Ft	Agree-T-Ft	One tone per foot (unless there are more tones than feet)
word tone	NoContour-ω	Agree-T-ω	One tone per word (unless there are more tones than words)

Table IV
Alternative constraints for TBUs.

Kera illustrates that, even without stress at the word level, there are languages which have an interaction between the foot and a number of other phenomena, including tone. Although it should be possible for the tonal and metrical systems to be totally independent, Kera shows how a tonal system can be sensitive to metrical structure. In Kera, this relationship is partially hidden, because it surfaces only when the faithfulness condition of Realise(T) is satisfied. Nevertheless, Kera can be added to the list of languages that show that in tonal languages as well as in stress-accent languages we can find a robust metrical structure which interacts with the tonal system.

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[15] If there are more tones than syllables, the extra tones may appear at an edge or be deleted. The same is true for the other phonological categories.

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