ATR allophones or undershoot in Kera?

MARY PEARCE

Abstract

Kera (a Chadic language) has 6 vowels, 3 of which have +/-ATR allophones. [+ATR] vowels appear in non-heads of feet and [-ATR] vowels in heads and elsewhere. This binary classification is sufficient until we examine the acoustic measurements of F1, F2 and duration in footed and non-footed syllables. These results suggest that the variation in quality relates to the duration of the vowel rather than directly to the foot structure. We will consider the evidence for claiming that there is a gradient relationship between the F1 value and the duration. The key data for this claim come from vowels in non-footed syllables at the right edges of phrases and vowel initial syllables. In non-footed syllables the duration of the vowel is longer than a non-head vowel, but shorter than a head vowel. The F1 value for these vowels is equally between the average head and non-head values. Gendrot and Adda-Decker (2006) have demonstrated similar patterns in other languages where a shorter duration means a more centralised vowel. Their results could lead us to suppose that the reason for this gradient is articulatory, due to the need of a certain amount of time for articulators to arrive at the target position, and that all languages may exhibit a similar phonetic pattern. A few counter-examples suggest that this pattern can be over-ridden by phonological factors. In the case of Kera we may well be seeing a process that began as a gradient phonetic change but which is now in the process of being phonologized. Therefore the use of the term 'allophone' correctly describes the phonology, but the phonetics also has a role to play in the quality of the vowel.

1 Introduction

Kera has been analysed in the literature (Ebert 1974, 1979, Pearce 2003) as having 6 vowels, 3 of which have +/-ATR allophones based on the position of the syllable in the iambic foot. [+ATR] vowels appear in non-heads of feet and [-ATR] vowels in heads and elsewhere. Up to now this binary classification has been generally accepted. However, a closer inspection using acoustic measurements of F1, F2 and duration reveals that the variation in quality may be due principally to duration rather than foot structure (although the foot structure affects duration). This would lead us to suppose that rather than a categorical distinction between the allophones associated with head and non-head syllables, we may have a gradient relationship between the F1 value and the duration. Both increase together until the target F1 value is reached, at which point a further increase in duration no longer affects the quality. The key data for this claim come from vowels in non-footed syllables at the right edges of phrases and vowel initial syllables. In both of these cases, the duration of the vowel is longer than a non-head vowel, but shorter than a head vowel. The F1 value for these vowels is equally between the average head and non-head values. Neither of these cases fits neatly into a binary division of allophones.

A useful comparison can be made with French. Gendrot and Adda-Decker (2006) have measured F1, F2 and duration in corpuses from several languages including French, and conclude that in each language the F1 and F2 values appear to vary with duration in a gradient relationship, particularly in non-high vowels. They observe that the polygons made by the vowel space in an F1/F2 plot converge as the duration decreases towards a schwa like vowel. Kera shows a similar convergence, but towards a horizontal line rather than a point. For a full understanding of the Kera facts, we need to combine an undershoot account with a consideration of the effects of the metrical structure on duration and the contribution made by the rich vowel harmony system, which may be constraining the variation in F1 and F2.

This paper begins by looking at the case for allophones and the case for undershoot. We then move to consider other languages as mapped out by Gendrot and Adda-Decker, and we compare the Kera results with these languages. Finally, we will discuss whether the Kera facts are best considered as a categorical split between allophones or a gradient of qualities that vary with duration.

2 The case for allophones

Kera is typical of a number of Chadic languages in having a symmetrical system of vowels which can be paired into high and non-high vowels. Kera has 6 vowels, and the three high vowels do not differ much in quality regardless of the duration or position of the vowel in the foot. But the 3 non-high –ATR vowels have +ATR allophones in non-heads of iambic feet[1]. This binary analysis of these vowels gives us [+ATR] vowels in non-heads of feet and [-ATR] vowels in heads and elsewhere[2].

[1] More information on iambicity in Kera is available in Pearce (2006).

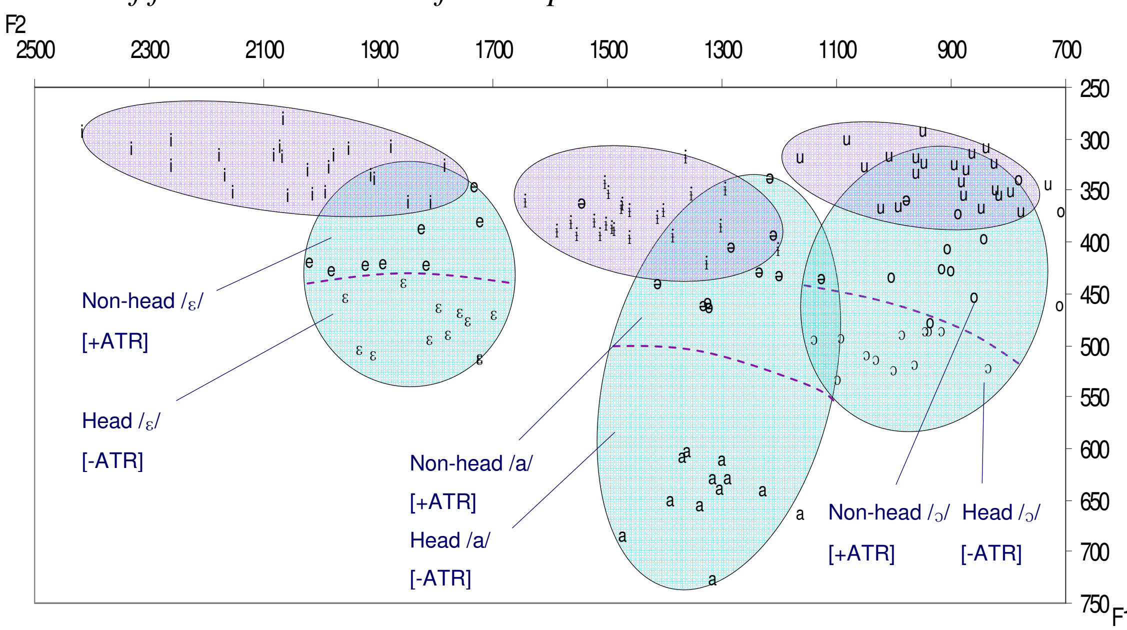
[2] The use of [ATR] rather than [tense/lax] is not meant to be significant. Either could be used in Kera. It is important however that this feature is differentiated from the high/non-high distinction which is contrastive, playing a role in height harmony. Casali (2001) supports the use of the [ATR] feature in this case even if the action of the tongue root is not proven, but it should be noted that in most African languages when [ATR] is involved, it is used to mark contrasts in an ATR harmony system.

(1) *Allophones in Kera vowels*

Phonemes:	/i/	/ɨ/	/u/	/ɛ/	/a/	/ɔ/
Head (-ATR)	[i]	[ɨ]	[u]	[ɛ]	[a]	[ɔ]
Non-head (+ATR)				[e]	[ə]	[o]

In (2), the three non-high vowels are split by a dotted line separating the allophones.

(2) *Means of footed Kera vowels for 12 speakers*



Because the ə/a alternation involves two allophones that are phonetically much further apart than the others, Ebert (1979) treated this alternation as a special case of a process of dissimilation which changed every other /a/ into [ə]. This alternating pattern was actually the result of the metrical structure which prefers disyllabic feet where non-heads and heads will be alternating. Unfortunately the apparent special case for the low vowel /a/ has led several linguists including Buckley (1997), Suzuki (1998), de Lacy (2004) and Archangeli and Pulleyblank (2007) to give this Kera example as support for theories of dissimilation processes involving low vowels, although all of these authors cite other languages as well as Kera. But this alternation behaves exactly like the alternation for o/ɔ and e/ɛ, and the three pairs should be treated in the same way.

Examples of the allophones can be seen in the following words where feet are indicated by parentheses and head vowels are underlined. In these examples, there is total vowel harmony, so any change in quality is due to the choice of allophone for the position within the foot.

(3) *Allophones chosen by the position in the foot (head vowels underlined)*

(gəda̲a̲)(ya̲w)	‘pots’
(da̲k)(təla̲w)	‘bird’
(sε̲ε̲)(renε̲n)	‘rescued me’
(gɔ̲l)(donɔ̲n)	‘searched for me’

Kera is not alone in having such alternations between stressed and unstressed syllables. Among Chadic languages, Pearce (2007) notes that Hausa (Newman 2000), Sokoro, Goemai, Bade and Ngizim show a similar pattern. Beyond Chadic, there are languages such as Catalan (Harrison 1997) which has a 7 vowel system /i, e, ε, a, ɔ, o, u/ which reduces to 5 vowels. [ε] and [ɔ] ([-ATR]) appear only in stressed syllables.

Returning to Kera, as long as we consider only the vowels contained within feet, this analysis appears to be perfectly adequate and the case for a binary choice between allophones seems solid. However, if we look at vowels that are either unfooted or epenthetic, the case becomes less clear.

3 The case for gradiency

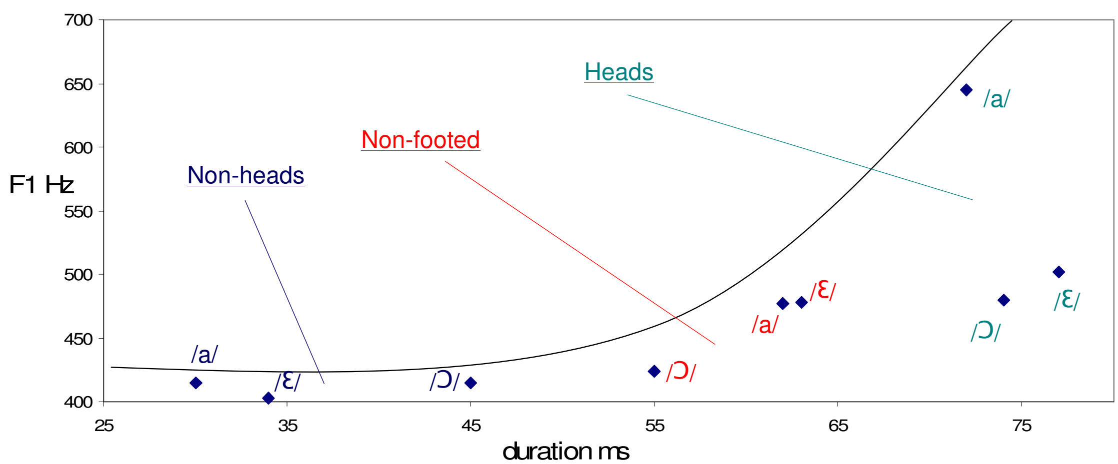
Our key evidence for gradiency is that non-footed vowels have a duration and F1 value between head and non-head vowels. They do not fit neatly into either of the two categories. Non-footed syllables are found at the right edges of phrases and in vowel initial words where the syllable is made up of just the vowel. These vowels do not behave like the vowels in footed syllables. The table in (4) demonstrates this, also including epenthetic vowels which equally do not fit well in a categorical system. The quality that we previously called +/-ATR does not seem to vary according to inclusion in a foot or headedness. It does however appear to relate to the duration of the vowel. The shortest vowels are closer to a [+ATR] category and the longest vowels are closer to a [-ATR] category. There is the temptation to argue that this is still a categorical distinction between short and long vowels, but all the vowels in (4) are phonologically short. Kera has a phonologically long vowel which has not been mentioned. This vowel typically has a duration of around 110 ms with a quality in keeping with the feature [+ATR]. But the difference in quality in (4) appears to occur at around 50 ms which is not the same place as the phonological boundary between short and long.

(4) *The correlation between quality, duration and position*

	Head V	Not a Head V		
	Head V (ta̲r) ‘run’	Non-head V (cə̲wa:) ‘sun’	Epenthetic V (gɔl)do̲(to̲nɔn)	Non-footed V (baa)ŋa̲ ‘elephant’
Footed	✓	✓	?	
Duration	70ms	30ms	30ms	50ms
+ATR		✓	✓	?

So instead of a categorical distinction between the allophones associated with head and non-head syllables, we might find that positing a gradient relationship will suit us better. As the phonological feature [ATR] is categorical, it does not lend itself to being treated as a gradient. Instead, we will consider the gradient in terms of the F1 value. In (5), the non-high vowels are plotted on a graph with F1 against duration. The mean values for vowels in each category are shown. Non-heads are short and the F1 value is also low. Heads on the other hand have a much greater duration and a much higher F1. The non-footed vowels have a duration between the footed vowels already considered, and likewise the F1 value is between that of the others.

(5) *A gradient change in duration and F1 (diagram in Pearce forthcoming)*



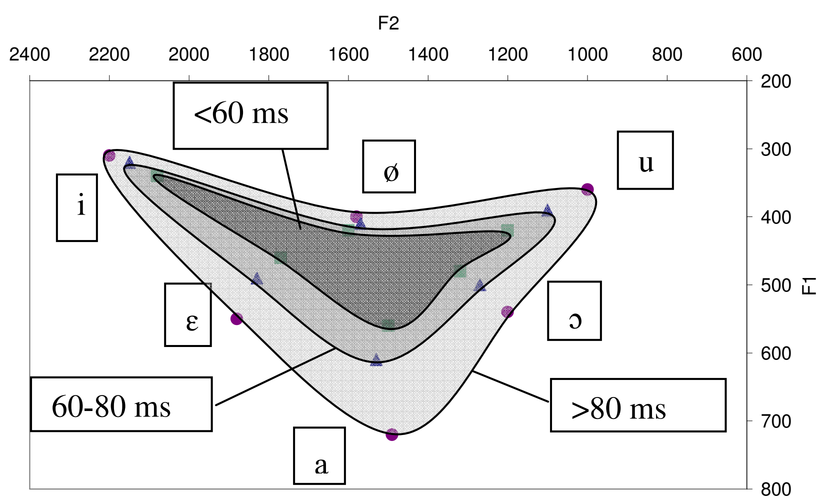
It seems that duration and the F1 value increase together until the target F1 value is reached, at which point a further increase in duration no longer affects the quality. The curved line in (5) is there as an indication of the gradient nature of the curve. These data are not enough to give any precise equations for this line, but the implication is that the vowel has to be of a certain duration before the F1 target can be reached and that if it is shorter than this, the vowel will have a reduced quality. The reason for this could well be that the articulators do not have enough time to reach the target.

So the analysis of a gradient curve rather than an allophonic split now seems the better option. We now consider other languages to see if there is evidence for a similar gradient curve there.

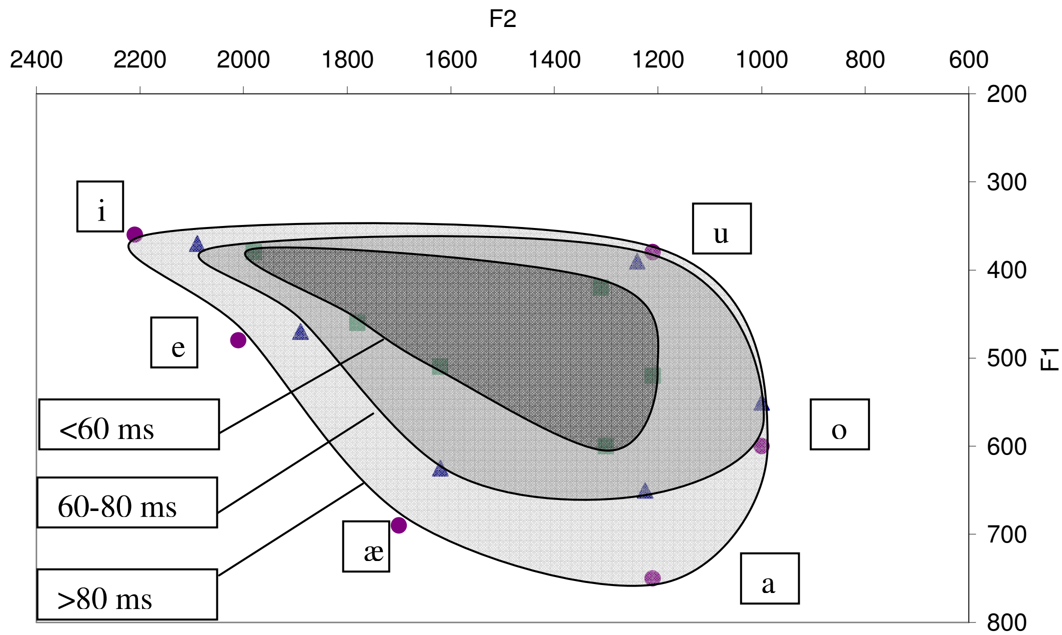
4 Convergence in other languages

For this section, we will make use of the work of Gendrot and Adda-Decker (2005, 2006). They have studied eight languages, using a large corpus for each, and they have found similar results in each language. In the diagrams below, I include only the vowels which bear some correspondence with the Kera vowels, but the results with all of the vowels in each language are available in the original papers. My purpose here is to demonstrate the trend that appears to be present in all of the languages studied. For each language, a plot of F1 and F2 is made with different polygons according to the duration of the vowel. The results show clearly that F1 and F2 values vary with duration in a gradient relationship, particularly in non-high vowels. The polygons made by the vowel space in an F1/F2 plot converge as the duration decreases. Gendrot and Adda-Decker suggest that the explanation for the convergence effect might be partly articulatory. This view would be supported if all languages converge in the same way. This is true in their data. Four language plots are given here.

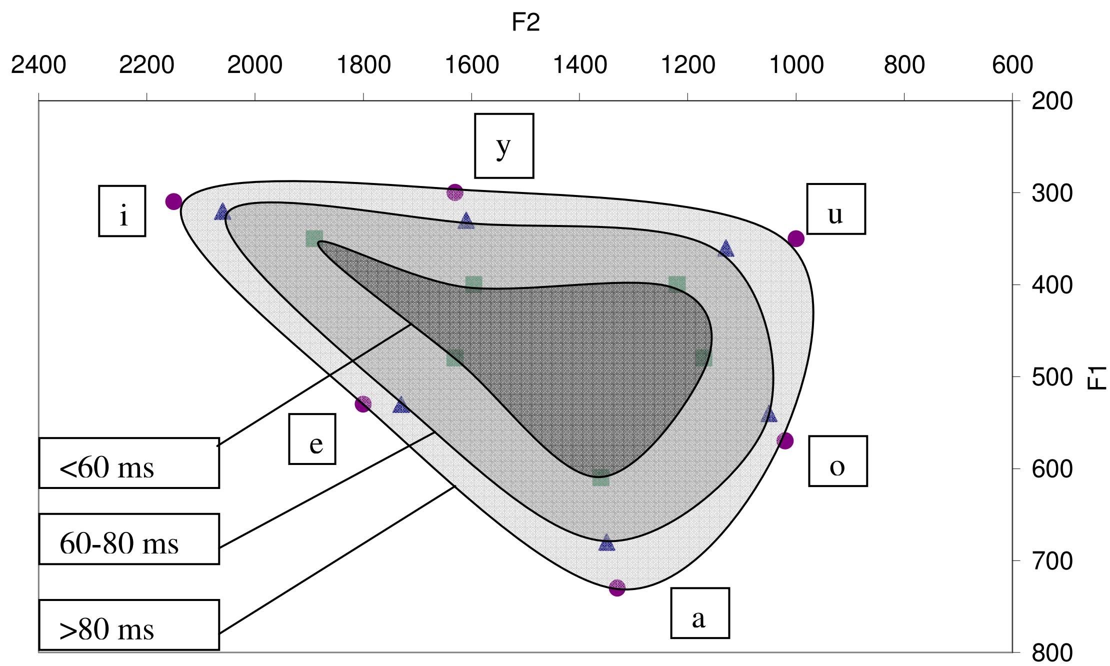
(6) *Measured mean average values of F1 and F2 for French vowels according to duration, data from Gendrot and Adda-Decker (2006), selected vowels only*



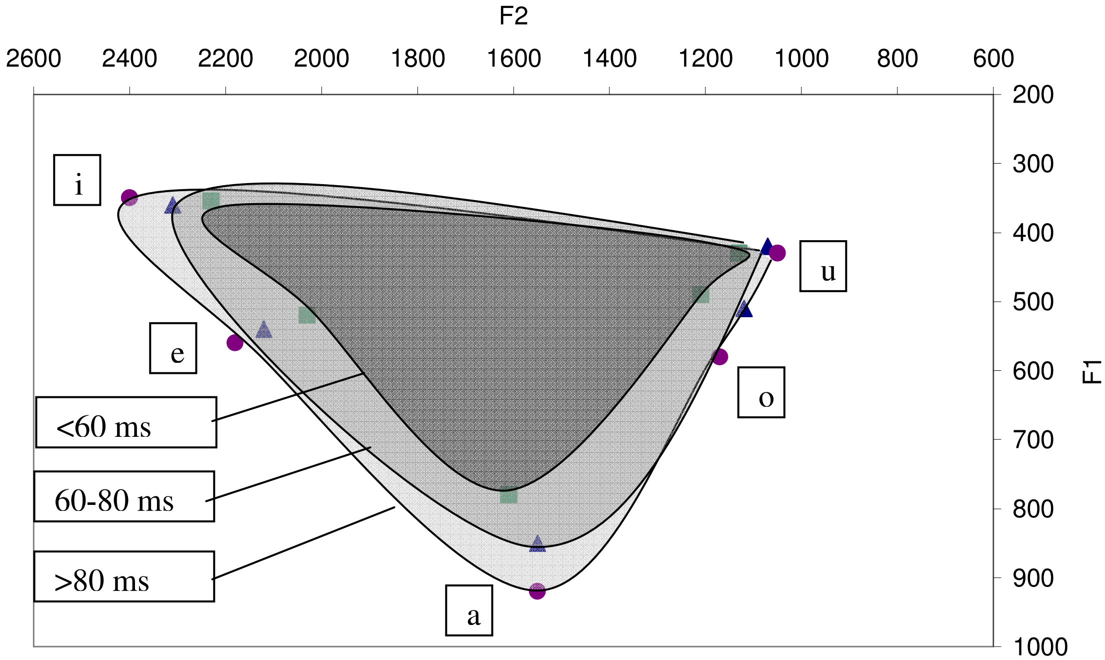
(7) *Measured mean average values of F1 and F2 for English vowels according to duration, data from Gendrot and Adda-Decker (2006), selected vowels only*



(8) *Measured mean average values of F1 and F2 for German vowels according to duration, data from Gendrot and Adda-Decker (2006), selected vowels only*



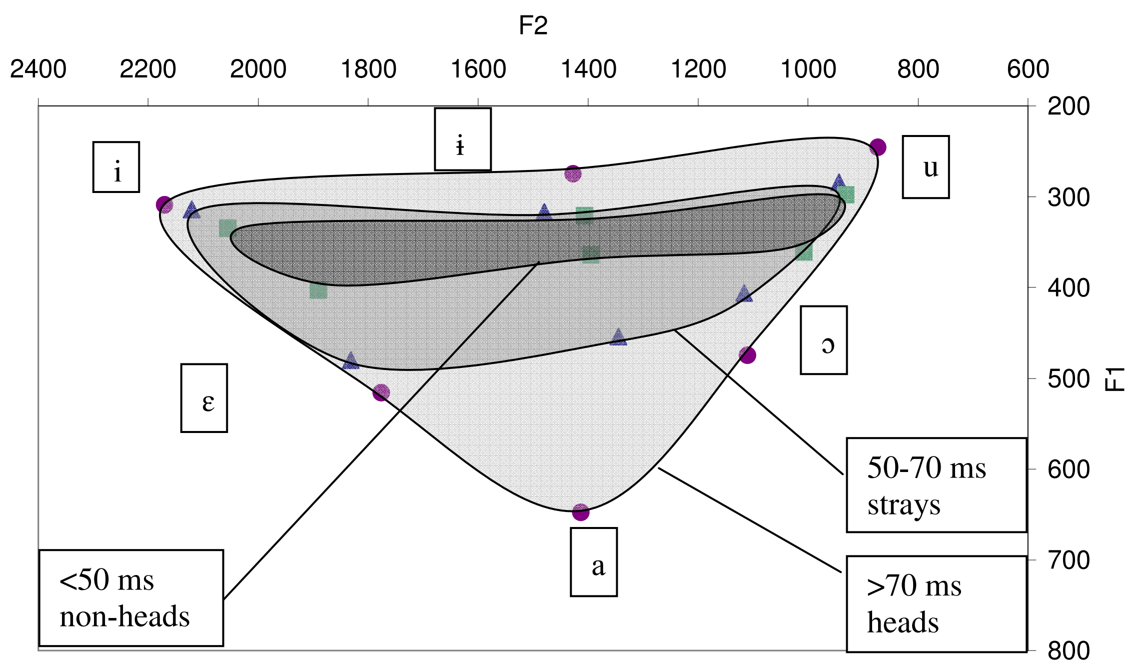
(9) *Measured mean average values of F1 and F2 for Mandarin vowels according to duration, data from Gendrot and Adda-Decker (2006)*



The other languages measured by Gendrot and Adda-Decker giving similar results were: Arabic, Spanish, Italian, and Portuguese. The question arises whether it is possible to claim the same kind of vowel reduction for all languages. At first glance there appear to be counter-examples in the work of Archambault and Maneva (1996) and Gussenhoven (2004). The first of these studies considers devoicing in post-vocalic Canadian-French obstruents. Other cues for devoicing were measured, including the vowel duration and quality. They make the observation that lax vowels, which appear before voiceless obstruents are shorter, while tense vowels, which appear before voiced obstruents are longer. This would seem to be the inverse of the diagrams above. However, as the sample included both high and non-high vowels, and as separate results are not given, we cannot compare this study with that of Gendrot and Adda-Decker. This study also refers only to vowels before obstruents where the voicing is known to affect a number of cues. So the results could be different if a more comprehensive study of vowels in all positions were made. A similar comment can be made for the Gussenhoven study on Limburgian dialects of Dutch and English coda obstruents. The results seem to be the inverse of what we are expecting, but this study is again looking at specific cases where a phonological contrast is being cued by the duration and quality of the vowel. Gussenhoven notes that high vowels are perceived as longer than non-high vowels, possibly compensating for the inverse relationship in production. Maddieson (1997) and Catford (1977) claim that high vowels tend to be shorter than non-high vowels in production because the articulators are already in position making it easier to move on to the next consonant. These results show that the relationship between duration and quality can be affected by a number of factors. Clearly, we certainly cannot assume that every language behaves like the eight tested by Gendrot and Adda-Decker, and it seems that the trends can be reversed where phonological contrast plays a role, but their work merits further research, and a useful development would be to look at more non-Indo-European languages.

We now turn to consider what the plot would be for Kera. It is not possible to use the same size of corpus, but nevertheless, the following plot gives significant differences between the three polygons.

(10) *Measured mean average values of F1 and F2 for Kera vowels according to duration*

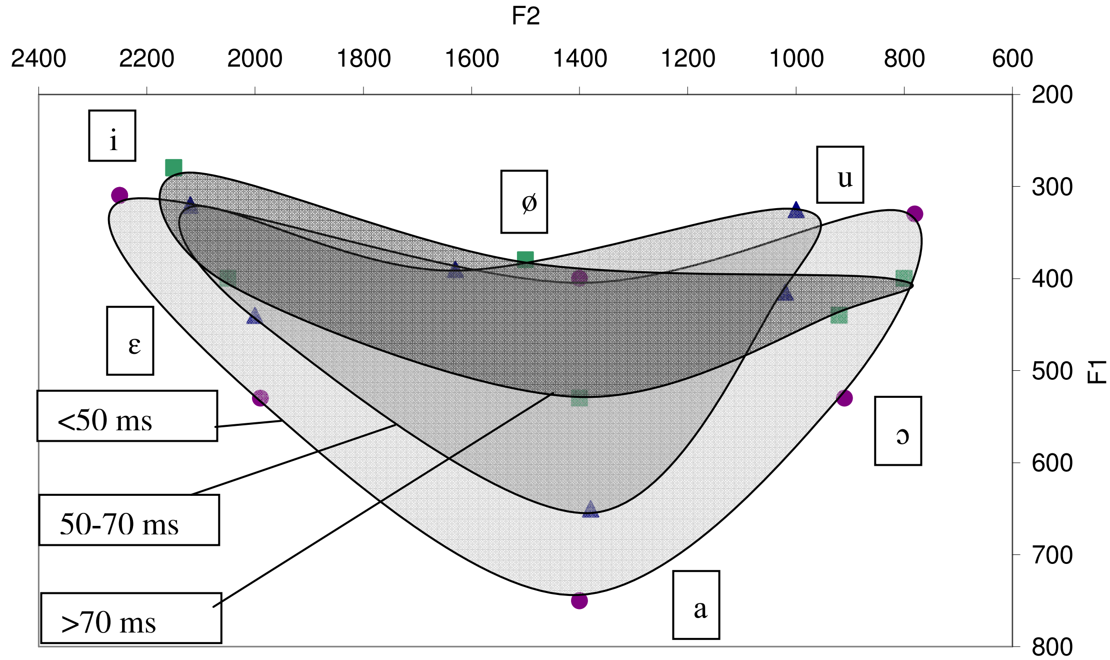


Kera shows a similar convergence to that found in the other languages, but only in one dimension. The convergence is towards a horizontal line rather than a point. The variation is most striking for the /a/ vowel. As with French, high vowels are relatively unaffected by duration. But unlike French, the F2 value is also unaffected by duration. The Kera result makes the articulatory explanation less appealing, but it is hard to find another explanation. A categorical phonological explanation does not appear to fit the facts as there does seem to be a gradient. But the question remains open as to why only one dimension changes. Unlike the eight languages measured in the study of Gendrot and Adda-Decker, Kera has vowel harmony. It is possible that this fact has a role to play in the different pattern, but as Kera has fronting, rounding, height and total harmony over different domains, it is hard to see why some types of harmony affect this result while others don't. As the domain for height harmony is larger than the domain for other types of harmony, it is possible that some loss of height is tolerated without loss of overall information because other vowels in the word indicate whether the vowels are phonologically high or not. The only way to test this would be to measure several other languages with vowel harmony to examine if similar patterns emerge. Without this information, we have to stay tentative about why Kera differs from other languages. One such language would be Pasiego Spanish, with reduction and height harmony (McCarthy 1984, Harris and Lindsey 1995, Penny 2000, Walker 2005) At this point, there is little information available from other African languages, but one which appears to behave in a similar manner to Kera is Rangi (Stegen 2000). The number of vowels in Rangi is in dispute, ranging from 5 to 9, but focusing on the non-high front and rounded vowels, the move from a typical [+ATR] to a typical [–ATR] position appears to be gradient (both in terms of quality and how far the quality 'spreads'), suggesting that the differences may be caused by undershoot or some other phonetic cause rather than from an allophonic binary split.

5 Categorical or gradience, or both?

Before returning to our main question as to the phonological nature of the non-high vowels, we will consider one more plot of F1/F2 vowels. This time, the speaker is Kera, but speaking French. As this is the plot of only one speaker, we cannot base our conclusions mainly on this graph, but the result is interesting nonetheless, as there appears to be a combination of the two plots for French (6) and Kera (10). When a Kera man speaks French, it appears that the short vowels are like Kera, whereas the middle range and longer vowels show similar patterns in phonetic reduction to French. So this plot could lead us to conclude that for this speaker at least, the non-head vowels may be phonologically distinct from other vowels, but that there is also a phonetic reduction occurring at the same time. This applies to his French, but is less clear when he is speaking Kera.

(11) *Measured mean average values of F1 and F2 for the French vowels of one Kera speaker according to duration, selected vowels only*



A number of languages are known to have both gradient and categorical effects within the same vowel system, for example Brazilian Portuguese, Bulgarian and Russian (Barnes 2007). A profitable next step in this research would be to measure the vowels in these languages under similar conditions to the measurements referred to above.

5 Conclusion

We have considered arguments for both allophony based on weight and undershoot based on duration. Barnes (2006) and Crosswhite (2001) suggest that there are two common situations in languages. Either there is prominence-reducing vowel reduction, in which case the lack of stress means a reduction in quality in a desire to avoid effortful articulations, or there is vowel undershoot in which case there is insufficient time to produce the quality in non-high vowels. The first of these options tends towards being categorical and the second gradient. In the Kera case discussed here, undershoot seems more likely because of the gradient nature of the results and because only non-high vowels are affected.

We are still left with the question as to whether these 'allophones' should be dealt with by phonology or phonetics. It is possible that the answer is that both processes are involved. It may be that the variation had a phonetic and gradient origin, based on the ability of the articulators to reach their target in time, but then synchronically, there could be a process of phonologization as subsequent generations observe that non-head vowels always have the [+ATR] allophone. The vowel harmony facts could also be playing a role in the exact positioning of the target for each vowel.

To test these ideas, there is a need for an investigation into other vowel harmony languages, and also languages where an allophonic variation of this kind has been attested. What is clear is that the Kera vowel system is not as clear cut as it seems at first, and it may be that what we are seeing here is a language in process of change where a process with a phonetic explanation is being phonologized. If so, it certainly merits further study. There is also potential in enlarging the number of languages that have been measured in the detail required to produce the F1/F2/duration plots, particularly for non-Indo-European languages.

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