A PRELIMINARY ACOUSTIC INVESTIGATION OF KALASHA RETROFLEX (RHOTIC) VOWELS

Alexei Kochetov[1], Paul Arsenault[2], Jan Heegård Petersen[3]

[1]University of Toronto, [2]Tyndale University College, [3]University of Copenhagen
al.kochetov@utoronto.ca, parsenault@tyndale.ca, janhp@hum.ku.dk

ABSTRACT

This paper presents results of an acoustic analysis of a typologically rare contrast between retroflex (rhotic) and plain vowels in Kalasha (Northwestern Indo-Aryan, Pakistan). Formant values were extracted from 10 oral vowels (/iˬ, eˬ, aˬ, oˬ, uˬ/ and /i, e, a, o, u/) in 72 words produced by two male speakers of the Bumburet dialect. The results showed that retroflex vowels are most clearly characterized by a lower F3, which was overall lower in back vowels and higher in front vowels. In addition, retroflex vowels were centralized – showing a lower F2 for /iˬ/ and a higher F2 for /aˬ, oˬ, uˬ/, compared to their plain counterparts. The two speakers were similar in the extent of F3 lowering but differed in vowel centralization. While preliminary in scope, the study provides a baseline for further investigation of Kalasha vowels and contributes to the phonetic typology of rhotic vowels in general.

Keywords: Kalasha, retroflex, rhotic, vowels, acoustics.

1. INTRODUCTION

Kalasha, an Indo-Aryan language of Pakistan, has a typologically rare set of retroflex (rhotic) vowels that contrast with their plain (oral and nasalized) counterparts. As shown in Table 1, all Kalasha vowels are paired with respect to retroflexion, as well as nasalization [21, 8, 5, 7].

Table 1: Kalasha vowel phonemes in (a) and word examples in (b).

a.

	front	*central*	*back*
close	i ĩ iˬ ĩˬ		u ũ uˬ ũˬ
mid	e ẽ eˬ ẽˬ		o õ oˬ õˬ
open		a ã aˬ ãˬ	

b.

V	e.g. bag ‘garden’, pe ‘if’
Ṽ	e.g. bãg (djek) ‘to poke’, wẽ- ‘upriver’
Vˬ	e.g. waˬ ‘scrotum’, weˬ (hik) ‘snowed-in’
Ṽˬ	e.g. bãˬg ‘suddenly’, pẽˬ ‘palm’

The term ‘retroflex’ is used here to refer to /iˬ, ĩˬ, uˬ, ũˬ, etc./ in a general phonological sense, as these segments are part of a larger phonemic retroflex/non-retroflex system, and have arisen historically through the elision of retroflex consonants and /r/ (e.g. [aˈzạˬi] ‘apricot’ < Old Indo-Aryan [aṣaḍʱiːja] [8]). In a stricter phonetic sense, the vowels can be referred to as ‘rhotic’ or ‘rhotacized’ [13]. In terms of their articulation, they may or may not be produced with tongue retroflexion (with both strategies being typical of rhotic vowels; [13]). This was indirectly observed by Heegård and Mørch [8], but the question of the articulatory realization of the contrast requires further investigation (see [11] for ongoing articulatory work).

Previous phonetic descriptions of the language have noted that retroflex vowels are auditorily centralized compared to their plain counterparts and are acoustically characterized by a lower F3 [16, 17, 8, 5]. These observations, however, were based on auditory impressions of the authors, supplemented by a few illustrative spectrograms. The goal of this paper is to provide a more systematic, albeit exploratory, acoustic analysis of the Kalasha retroflex/non-retroflex contrast. This is done by examining formants of ten oral vowels elicited from two native speakers of the language. The results are further discussed in relation to previous acoustic findings for retroflex/rhotic vowels in other languages.

2. METHOD

2.1. Speakers

The speakers were two males in their 30s, Sikandar Kalas (Speaker 1) and Taj Khan Kalash (Speaker 2). They grew up in the village of Krakal [krakaˬ] in the Bumburet valley (Chitral District, Khyber Pakhtunkwa Province, Pakistan), but at the time of the recordings were residing in Greece. Both speakers are multi-lingual, speaking also English, Khowar, Urdu, and Greek. (It should be noted that multilingualism is rather widespread in Chitral [7]).

2.2. Materials and recordings

The word list contained 72 words with stressed oral retroflex and plain vowels (/a, i, u, e, o/ vs. /aˬ, iˬ, uˬ, eˬ, oˬ/) based on Trail and Cooper’s dictionary [21]. Most vowels were represented by 3 to 7 words, except for the low /a, aˬ/, which occurred in a larger number

of items (see Table 2). Words with target plain vowels were selected so that they did not contain retroflex consonants, /r/, or retroflex vowels, as retroflexion can be induced though local coarticulation or long-distance spread [8, 1, 2, 3].

Table 2: Numbers of words per vowel investigated in the study.

Plain (oral)		*Retroflex (oral)*	
i	5	iˠ	5
e	3	eˠ	3
a	26	aˠ	12
o	7	oˠ	3
u	4	uˠ	4

Each word was pronounced in isolation. On average, two repetitions of each word were recorded, with a total of 157 tokens for Speaker 1 and 140 tokens for Speaker 2. The recordings were made in a quiet room in Thessaloniki, Greece (where the speakers resided), using a *Zoom H4n* digital recorder and an *AudioTechnica AT831b* lavalier microphone, with a 44,100 Hz sampling rate.

2.3. Acoustic analysis

Annotation and acoustic analysis of the vowels were performed using *Praat* [4]. Formants F1-F3 were extracted at 10 equidistant points using a script and averaged over the mid 60% of the vowel. Vowel plots were produced using the *PhonR* package [14] for *R* [19]. Linear mixed regressions were used to evaluate F1-F3 differences between retroflex and plain vowels, separately for each vowel quality. Retroflexion was a fixed effect; Speaker and Word were random effects. The significance value was adjusted to 0.01 given multiple comparisons.

3. RESULTS

Figure 1 presents results for Speaker 1, with plots showing vowel means and standard deviations in the F1/F2 and F2/F3 space. It can be seen that retroflex vowels are more centralized than their plain counterparts: F2 values of central/back vowels /aˠ, oˠ, uˠ/ are on average higher than for /a, o, u/, while F2 values of front vowels /iˠ, eˠ/ are on average lower than for /i, e/. In addition, the low /aˠ/ shows a lower F1 than /a/. Most clearly, however, retroflex vowels are distinguished by F3: their values are typically below 2200 Hz, while values for plain vowels are above this threshold. F3 values decrease uniformly from front to back vowels. The high vowels /iˠ uˠ/ are produced by this speaker with overall more variation (larger standard deviation ellipses) than non-high retroflex vowels.

Figure 1: F1/F2 (Hz, top) and F2/F3 (Hz, bottom) plots showing means (symbols) and 2 standard deviations (ellipses) for oral vowels by Speaker 1.

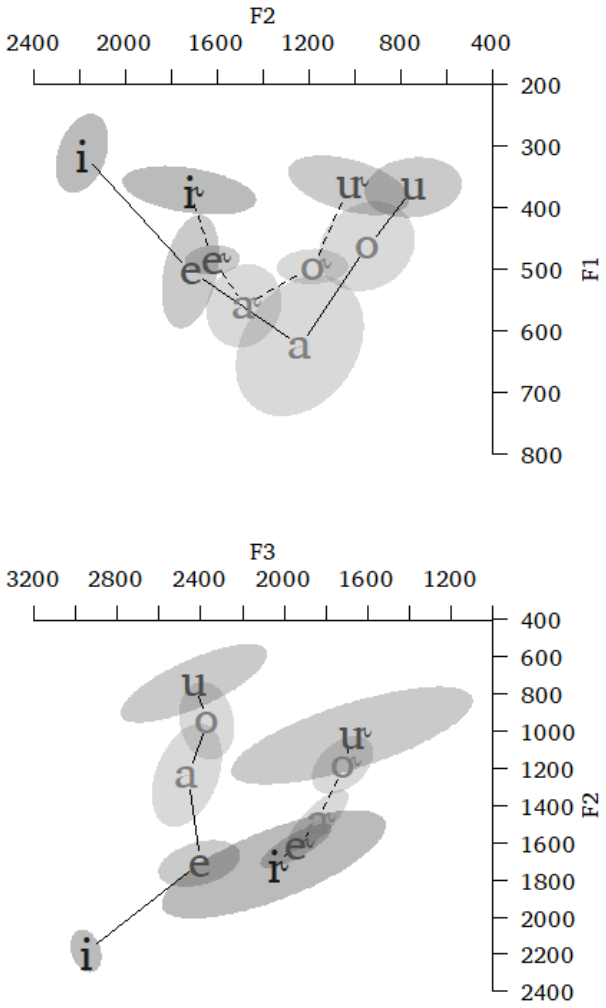

Figure 2 presents vowel plots for Speaker 2. The results are strikingly similar to Speaker 1 in terms of F3 patterns: showing the same threshold of around 2200 Hz. In terms of F2 (and F1 for /a/), this speaker shows considerably less centralization, especially for mid vowels /eˠ, oˠ/.

The results of mixed effects models largely confirmed the observations of differences between retroflex and plain vowels in F2 and F3. (None of the comparisons in F1 were significant.) As shown in Table 3, retroflexion significantly lowered F2 for high front vowels; it significantly raised F2 for low and high back vowels; the difference for the mid front vowels did not reach significance. The magnitude of F2 difference was the highest for /i/, exceeding 400 Hz.

Figure 2: F1/F2 (Hz, top) and F2/F3 (Hz, bottom) plots showing means (symbols) and 2 standard deviations (ellipses) for oral vowels by Speaker 2.

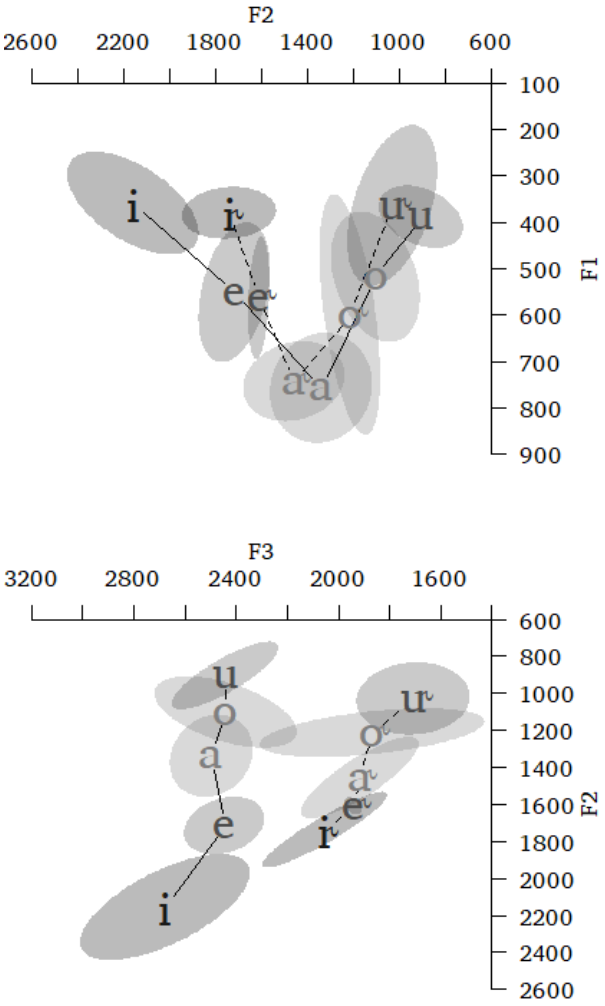

Table 3: Results of linear mixed effect models for F2 (Hz); significant results are indicated with '*'.

Vowel	*Mean*	*SE*	*DF*	*t*	*p*	
/i/	2172	35				
vs. /iˬ/	-427	58	13	-7.36	<0.0001	*
/e/	1716	28				
vs. /eˬ/	-73	37	11	-1.95	0.0776	
/a/	1281	39				
vs. /aˬ/	194	37	73	5.26	<0.0001	*
/o/	1020	61				
vs. /oˬ/	188	52	19	3.61	0.0019	*
/u/	819	52				
vs. /uˬ/	206	57	15	3.59	0.0027	*

As shown in Table 4, retroflexion significantly lowered F3 for all vowel qualities. The differences ranged from about 400 Hz to 750 Hz, being the highest for high vowels.

Table 4: Results of linear mixed effect models for F3 (Hz); significant results are indicated with '*'.

Vowel	*Mean*	*SE*	*DF*	*t*	*p*	
/i/	2810	84				
vs. /iˬ/	-742	98	13	-7.59	<0.0001	*
/e/	2424	84				
vs. /eˬ/	-397	106	11	-3.76	0.0031	*
/a/	2478	26				
vs. /aˬ/	-603	25	73	-24.05	<0.0001	*
/o/	2395	51				
vs. /oˬ/	-613	63	19	-9.71	<0.0001	*
/u/	2435	66				
vs. /uˬ/	-757	93	15	-9.10	<0.0001	*

4. DISCUSSION AND CONCLUSION

4.1. The retroflex/non-retroflex contrast in Kalasha

The acoustic analysis of Kalasha (oral) plain and retroflex vowels from two speakers has confirmed the general observations reported in previous descriptive studies [16, 17, 8, 5]: retroflex vowels are somewhat centralized and are characterized by a lower F3, compared to their plain counterparts. The difference in F3 was found to be particularly robust, with retroflex and plain vowels falling below or above the threshold of 2200 Hz, respectively. This indicates that F3 is the main correlate of the retroflex-plain contrast in Kalasha.

The differences between the speakers in the extent of the vowel centralization were unexpected. In addition, both speakers showed no significant difference in F2 for the front mid vowels /eˬ/ and /e/. This suggests that F2 differences for most vowel qualities are optional, in contrast to the obligatory differences in F3. Alternatively, the observed variation in F2 may be attributed to language attrition, as our speakers have lived outside the language environment for an extended time. Given this, it is important to confirm the findings with data from other speakers of the language, and most importantly from those residing in the Kalasha villages. It is also necessary to extend the acoustic analysis to nasalized retroflex and plain vowels (see Table 1), which were not considered in this study.

In this paper, we examined Kalasha vowels in relatively neutral consonant contexts – next to non-retroflex (labial, dental, palatal, and velar) consonants. An important question remains as to what happens to the contrast next to retroflex consonants. Vowels in such contexts are typically transcribed as plain (e.g. [noʂ] 'spout', [ʤaʦʂ] 'spirit beings' [21]); however, it has been noted by researchers that these vowels can be auditorily ambiguous and alternatively transcribed as retroflex [16]. Our preliminary acoustic

examination of such cases suggested that vowels between two retroflex consonants (e.g. [ʂiʂ] 'head', [ʈoʈ] 'apron') tend to be phonetically retroflex (having a steady low F3), in contrast to vowels next to a single retroflex (e.g. [biʂ] 'poison', [pʰoʈ] 'chaff'; which show F3 transitions). Note that the former context corresponds to the domain of (retroflex) consonant harmony in Kalasha, by which across-vowel coronal obstruents in roots are required to have the same place (i.e. ʈVʈ, ʈʂVʈʂ, ʂVʂ, etc. [1, 2, 3]). The relation between these phonetic and phonological patterns requires further study.

A related, and equally interesting, question is the spread of retroflex quality among neighbouring vowels (so called 'retroflex vowel harmony'). This process was described in the literature as optional and predominantly perseveratory (progressive), most commonly affecting immediately adjacent vowels and occasionally applying through consonants [8]. Our preliminary acoustic investigation of the phenomenon [12] does confirm the optional 'spread' of F3 across multiple vowels, at least for one of the speakers. Which specific factors condition this process and whether it is categorical (phonological assimilation) or gradient (phonetic coarticulation) is still an open question.

4.2. Typology of retroflex/rhotic vowels

While adding to the phonetic documentation of Kalasha, the current study also contributes to the phonetic typology of the cross-linguistically rare contrast in vowel retroflexion/rhoticity. As Ladefoged and Maddieson [13] note, phonemic rhotic vowels are exceedingly rare, occurring in less than one per cent of world's languages. Apart from Kalasha, only one other language, Badaga (Dravidian), has been reported to have a full set of retroflex vowels (which were also reported to differ in the degree of retroflexion – fully- and partly-retroflex [6]). The dialect described in the original work, however, is no longer spoken [10, 13], and therefore Kalasha appears to present a unique case of a retroflex-plain contrast comprising all vowel qualities. Notably, other cases of phonemic rhotic vowels are limited to a much smaller subset of vowel qualities, as, for example, in North American English (the central /ɚ/ vowel as in *bird* [9]), some varieties of Canadian French (/ø, œ, œ̃/ [15]), and Beijing Mandarin (/ɚ, ɻ̩/ [22]).

Despite the difference in the number of retroflex/rhotic segments, these vowels in Kalasha are characterized by the same acoustic properties as rhotic vowels in other languages. Like in Kalasha, /ɚ/ in English, /øˠ, œˠ, œ̃ˠ/ in French, and /ɚ, ɻ̩/ in Mandarin have much lower F3 than the closest non-rhotic vowels. Specifically, an average F3 for the rhotic English vowel is around 1700 Hz (for males from Eastern Michigan [9]). The three French rhotic vowels have F3 around 1900-2100 Hz (normalized, for males and females [15]). The Mandarin /ɚ/ and /ɻ̩/ have average F3 values of 1800 Hz and 1950 Hz, respectively (for male speakers [22]). While the F3 range across these rhotics is large, the values are overall comparable to the Kalasha retroflex vowels (where back vowels have lower F3 than front vowels).

The Kalasha retroflex vowels, however, differ from rhotic vowels in these languages in the extent of vowel centralization. The English /ɚ/ is truly central, and so are the French /øˠ, œˠ, œ̃ˠ/ (being similar in F2 to /a/ and rather different from /ɛ/ [15]). The Mandarin /ɚ, ɻ̩/ are not only central, but also high (so that /ɚ/ differs from /ə/ considerably both in F1 and F3 [22]). This stands in contrast to the Kalasha retroflex vowels which are only moderately or inconsistently centralized (with a possible exception of /iˠ/), and do not differ from their plain counterparts in height (with a possible exception of /aˠ/). The moderate degree of centralization in Kalasha retroflex vowels can be attributed to the need to preserve the front/back contrasts within the retroflex subset.

It should be noted that allophonic retroflex vowels, have been reported in the nearby Indo-Aryan language Dameli [18] and the Nuristani languages Kati and Waigali [20]. In these languages, vowels take on the rhotic/retroflex quality from the adjacent /ʈ/ or /ɻ/. An acoustic investigation of such vowels is very important and may shed light on the historical development of Kalasha retroflex vowels, and rhotic vowels in general.

To conclude, our preliminary phonetic documentation of the Kalasha plain-retroflex contrast in vowels can serve as a starting point for further investigations of the phonetics and phonology of this unique contrast and for a more systematic study of the cross-linguistic typology of rhotic vowels.

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5. REFERENCES

[1] Arsenault, P. 2012. Retroflex consonant harmony in South Asia. Ph.D. dissertation, University of Toronto.

[2] Arsenault, P. 2017. Retroflexion in South Asia: Typological, genetic and areal patterns. *Journal of South Asian Languages and Linguistics*, 4, 1-53.

[3] Arsenault, P. & Kochetov, A. (in press). Two types of retroflex harmony in Kalasha: Implications for phonological typology. In: Baart, J. L. G., Liljegren, H., Payne, T. E. (eds.), *Languages of Northern Pakistan and Its Surrounding Regions (Linguistic Studies Dedicated to the Memory of Carla Radloff)*. Oxford University Press, Pakistan. 24 pp.

[4] Boersma, P., Weenink, D. 2018. Praat: doing phonetics by computer [Computer program]. Version 6.0.39, retrieved 3 April 2018 from http://www.praat.org/

[5] Di Carlo, P. 2010. *I Kalasha del Hindu Kush: Ricerche Linguistiche e Antropologiche* (Vol. 12). Firenze University Press.

[6] Emeneau, M. B. 1939. The vowels of the Badaga language. *Language*, 15, 43-47.

[7] Heegård Petersen, J. 2015. *Kalasha texts – With introductory grammar, Acta Linguistica Hafniensia* 47:sup1, 1–275.

[8] Heegård, J., Mørch, I. E. 2004. Retroflex vowels and other peculiarities in the Kalasha sound system. In A. Saxena (ed.), *Himalayan Languages, Past and Present*. Berlin & New York: Mouton de Gruyter, 57–76.

[9] Hillenbrand, J., Getty, L. A., Clark, M. J., Wheeler, K. 1995. Acoustic characteristics of American English vowels. *J. Acoust. Soc. Am.*, 97, 3099–3111.

[10] Hockings, P., Pilot-Raichoor, C. 1992. *A Badaga-English Dictionary*. Berlin & New York: Mouton de Gruyter.

[11] Hussain, Q., Mielke, J. 2018. An acoustic and articulatory description of retroflex vowels of Kalasha. Paper presented at the Annual Meeting on Phonology, University of California, San Diego, October 2018.

[12] Kochetov, A., Arsenault, P. 2018. Parameters in Kalasha retroflex vowel harmony: Preliminary acoustic evidence. Poster presented at the annual meeting of the Linguistic Society of America, Salt Lake City, UT, January, 2018.

[13] Ladefoged, P., Maddieson, I. 1996. *Sounds of the World's Languages*. Oxford: Blackwell Publishers.

[14] McCloy, D. R. 2016. phonR: Tools for phoneticians and phonologists. R package version 1.0-7. http://drammock.github.io/phonR/

[15] Mielke, J. 2015. An ultrasound study of Canadian French rhotic vowels with polar smoothing spline comparisons. *J. Acoust. Soc. Am.*, 137, 2858–2869.

[16] Mørch, I. E. 1995. Vokaler i kalashamon. [Vowels in Kalashamon.] Exam paper, University of Copenhagen.

[17] Mørch, I. E., Heegård, J. 1997. Retroflekse vokalers oprindelse i kalashamon fra et historisk og areallingvistisk perspektiv. Variation i sprogbeskrivelsen: Vokaler i kalashamon. [The origin of retroflex vowels in Kalashamon in historical and areal-linguistic perspective. Variation in language description: Vowel length in Kalashamon.] MA thesis, University of Copenhagen.

[18] Perder, E. 2013. *A Grammatical Description of Dameli.* Stockholm: Stockholm University dissertation.

[19] R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. URL http://www.R-project.org/.

[20] Strand, R. 2011. The sound system of nišei-alâ. http://nuristan.info/Nuristani/Kalasha/Nishei/NisheiLanguage/Lexicon/phon.html (accessed December 2, 2018).

[21] Trail, R., Cooper, G. R. 1999. *Kalasha Dictionary – with English and Urdu.* Islamabad: National Institute of Pakistan Studies, Quaid-i-Azam University and Summer Institute of Linguistics.

[22] Zee, E., Lee, W.-S. 2001. An acoustical analysis of the vowels in Beijing Mandarin, In *Proc. EUROSPEECH-2001*, 643–646.