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An acoustic analysis of Pahari oral vowels

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The aim of the current study is to present an acoustic account of the twelve oral vowels of Pahari by analyzing their formant pattern (F1 and F2) and duration. To achieve this aim, an experiment was conducted. Tem native speakers of Pahari participated in the study and were given a list of 12 oral vowels in CVC context for recording, where V is the target vowel. The recorded material was analyzed by using Praat software. The spectral analysis (F1 and F2) show that Pahari has four close, six mid and two open vowels. The results also show that in term of duration these vowels occur in the form of long-short pairs that differ significantly quantatively (vowel duration).The study further exhibits that the short vowels are centralized as compared to their long counterpart.

Keywords: Formant Pattern (F1, F2), long-short pairs, duration, acoustic space

1. Introduction

According to the 16th edition of Ethnologue of World languages, there are seventy-seven languages spoken in Pakistan. Out of these, seventy-two are indigenous languages (Lewis 2009). Pahari is an Indo-Aryan Language, spoken over a large area starting from Nepal and running through the foothills of the Himalayas, in the Himachal Pardesh, Indian administered part of Kashmir, Azad Jammu & Kashmir and in the Northern Pakistan. The focus of present study is Pahari spoken in Azad Jammu and Kashmir, Pakistan. According to the 1998 census, Pahari is spoken by 3.5 million people living in the Pakistani administered part of Kashmir and a projected rate showed in 2004 that the speakers of Pahari are around 3.8 million. Lothers & Lothers (2010) report that there are over one million Pahari speakers living in District Rawalpindi and District Abbottabad. Lothers & Lothers (2003) state that there are over half a million immigrants in United Kingdom (UK) from this language group, mostly from district Mirpur. These reports show that estimated population of Pahari speakers today, is around five million.

In the small amount of literature previously written about Pahari, only a short description on vowels is found. Karnai (2003) has given nineteen oral and nasal vowels but did

not use IPA symbols for the vowels; rather he uses Urdu characters. Khan (2012) presents the descriptive study of Pahari vowels based on minimal pairs and distribution of sounds in words. He established that Pahari has twelve oral vowels. So the present study is based on the descriptive study of Pahari Vowels (Khan 2012) and aims to present the vowel inventory of Pahari language after an acoustic analysis of Pahari vowels.

2. Background

2.1. Vowel formant characteristics

In articulatory phonetics, vowels are mainly described in terms of three features: (1) height of the tongue (2) backness of the tongue and (3) lip rounding. Acoustic studies approach the description of vowel differently. "An acoustic analysis of vowel stresses the different formant configurations that are characteristic of each vowel. The relationship among the vowels can be examined by comparing their formant values" (Olive et al. 1993). Vowels are frequently described with reference to their formant structure, which provides an indication of vocal tract resonance and therefore articulatory shape (Fant 1960). The high-low and front-back distinctions are represented by the first and second formants on the spectrogram (Olive et al. 1993). First formant (henceforth F1) shows the high-low distinction. That is, the lower the formant value, the higher the vowel. Second formant (henceforth F2) shows the front-back distinction. If the value of F2 is high, the vowel is closer to the front position. The relationships between (F1) and the height of tongue, and F2 and the front/back dimension ensures that when the first two formants of a set of vowel targets are plotted on axes with appropriate scaling characteristics, the result closely resembles the traditional auditory vowel map. Such vowel spaces, with axes F1 and F2, rely on the concept of the vowel target. The target is the vowel component least influenced by its surrounding phonetic context, and it is considered to be either a point in the time course of the vowel or else a section of time during which the vowel position remains stable. A single point is often used to provide a representation of the target position and for most vowels, this can be assumed to be approximately mid way though the nucleus.

2.2. Vowel duration

Cochrane (1970) states that vowels may be distinguished in terms of duration for those languages and dialects that employ phonemic vowel length. This durational contrast may or may not be the only distinctive feature between two vowels. For example, English short vowels /ɪ/, /ə/ and /ʊ/ are qualitatively distinct from their corresponding long vowels. According to Tsukada (2002), vowel duration is used contrastively in some languages, but not in others. He states that English and Hindi differ from Japanese and Thai since both these languages use vowel duration as an acoustic cue for the length distinction in addition to qualitative differences to maintain the contrast between /ɪ/ and /i:/, /u/ and /u:/, /a/ and /a:/. It shows that in Japanese and Thai, length contrast is a prominent cue, whereas English uses other acoustic cues, such as spectral differences. Watson & Harrington (1999) claim that vowel classification experiments show increased accuracy when frequency and durational

information are combined. According to Cochrane (1970), the major difference between long and short vowels is simply one of total vowel duration. However, the difference is relative rather than absolute as contextual and prosodic factors affect the ultimate length of the vowel. Peterson & Lehiste (1960) describe short vowels as showing a short target and slow relaxation, whereas for long vowels, the target is maintained for longer followed by a more rapid offglide. Lindblom (1967) documents that openness is positively correlated with length, and therefore open vowels tend to be longer than close vowels. He suggests that this is universally the result of the increased biomechanical effort required to produce low vowels.

The study selected above mentioned two acoustic parameters namely Spectral and temporal characteristics to for the experiment with the aim to come up with the vowel inventory of Pahari oral vowels in the form of a quadrilateral by drawing F1XF2 plot.

3. Methods

3.1. Participants

Ten native speakers of Pahari, five male and five female participated in this study. They were students at the University of Azad Jammu and Kashmir, Muzaffarabad, born and raised in Pahari speaking area in Azad Jammu and Kashmir. They all speak Pahari with their friends, family and at market places. They speak Urdu with people who do not speak Pahari. Their ages range from 20 to 30 years at the time these recordings were made. All the participants were interacted with to ensure that they had no hearing or articulation problems. None of the speakers had reported any speech or hearing impairment.

3.2. Stimuli

A list of monosyllabic words exemplifying 12 monophthongs of Pahari was constructed such that the target vowels occur between /m/ and /l/.

Table 1: List of words in CVC context used in this study

Vowel	Words /mVl/	Vowel	Words /mVl/
iː	miːl	ɪ	mɪl
eː	meːl	e	mel
æː	mæːl	æ	mæl
aː	maːl	ə	məl
oː	moːl	o	moːl
uː	muːl	ʊ	mʊl

3.3. Recording

Recording was done in five sessions in a quiet room at the University of Azad Jammu & Kashmir, Muzaffarabad. The participant was seated comfortably in front of the laptop

screen, wearing a headset microphone. The microphone was about two inches away from the left side of the participant's lips. The words with target vowels were displayed on laptop screen in random order. The participants were asked to read each word three times in random order. The participants were instructed to read words with normal speed. Ten speakers gave a total of 360 tokens (10 speakers × 3 repetitions × 12 vowels). They were recorded directly on Praat (www.praat.org) software by using high fidelity microphone.

3.4. Measurement

The waveforms and spectrograms, for each target vowel, were used to determine first two formant frequencies. Measures of the lowest two formants of vowels were made using Praat software. The words were segmented on the basis of visual information in a wide band spectrogram. F1 and F2 were determined and measured in Hz in the middle of the target vowel since it can be assumed that the influence of an adjacent segment is minimal and the articulatory target is maximally achieved in this position. The target is the vowel component least influenced by its surrounding phonetic context and is considered to be either a point in the time course of the vowel or else a section of time during which the vowel position remains stable. A single point is used to provide a representation of the target position and for most vowels; this is assumed to be approximately mid way through the nucleus. Figure 1 shows the spectrogram of a speaker's utterance 'mal' with the target vowel [a] selected in three cursors. The mid cursor indicates the middle of the formants at which measurement of the formant frequencies are taken in Hertz (Hz), while the two extreme cursors measure the duration of the vowel from the beginning of the sound (left) to the end (right) in seconds.

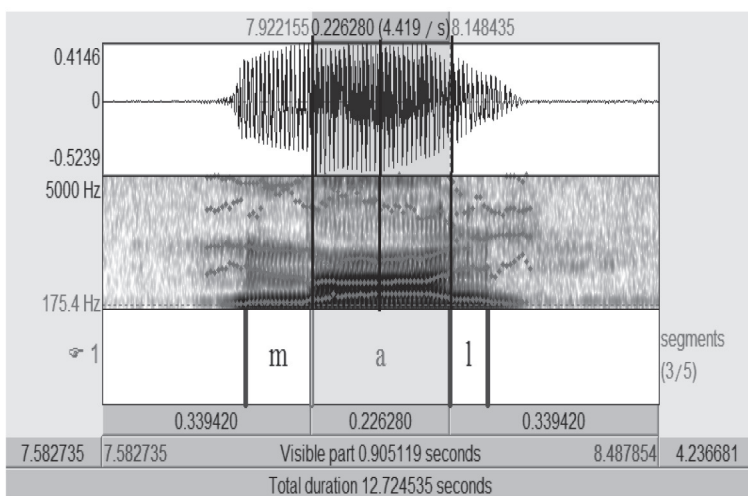

Figure 1: Spectrogram showing measurement of Formants and duration

4. Results and discussion

As mentioned earlier, the parameters selected for acoustic analysis are the formant frequencies (F1, F2) and vowel duration. Table 2 illustrates mean F1 and F2 and Table 3 shows mean vowel duration values with standard deviations for the data from ten Pahari speakers in CVC context. The standard deviation represents the variance of means of the three tokens for each of the ten speakers. The measurements of three tokens within each participant are treated as repeated measures and therefore averaged.

4.1. Formant frequencies

Table 2 gives the mean F1 and F2 values with standard deviations. Figures 2 and 3 display the mean F1 and F2 frequencies in Hz of the vowels, respectively.

Table 2: Pahari CVC mean vowel formants in Hertz with standard deviations

Vowels	F1 (s.d)	F2 (s.d)
i:	310 (28.5)	2234 (170.5)
ɪ	332 (34.6)	2140 (170.1)
e:	412 (29.6)	1909 (131.5)
e	401 (29.8)	1850 (99.1)
æ:	578 (51.1)	1730 (106.9)
æ	567 (44.6)	1660 (83.1)
a:	625 (78.9)	1143 (95.8)
ə	582 (76.7)	1158 (92.2)
o:	460 (52.5)	955 (123.6)
o	441 (48.2)	984 (142.7)
u:	364 (61.7)	854 (159.8)
ʊ	370 (37.5)	950 (135.6)

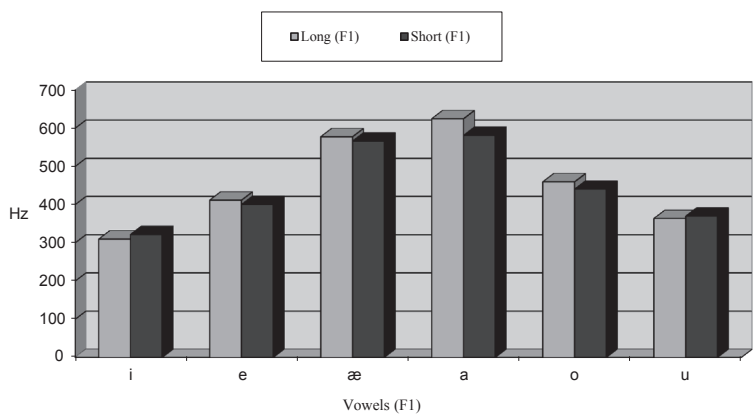

Figure 2: F1 of long and short vowels

The bar diagram above shows that there is very little difference between the F1 values of short and long vowels.

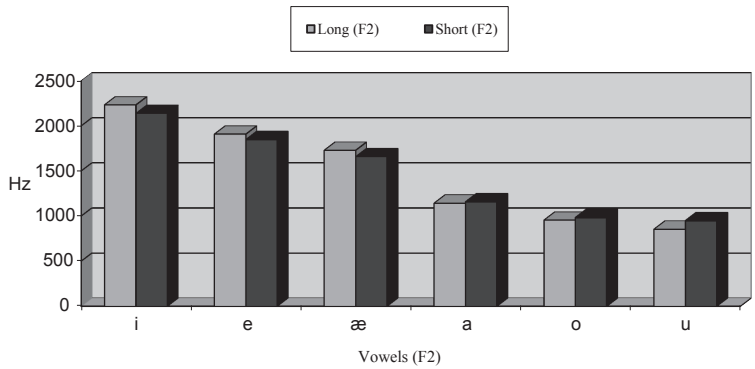

Figure 3: F2 of long and short vowels

Figure 3 shows that there is very little difference in F2 values of long vowels and their corresponding short vowels. Figure 4 illustrates F1-F2 difference more elaborately.

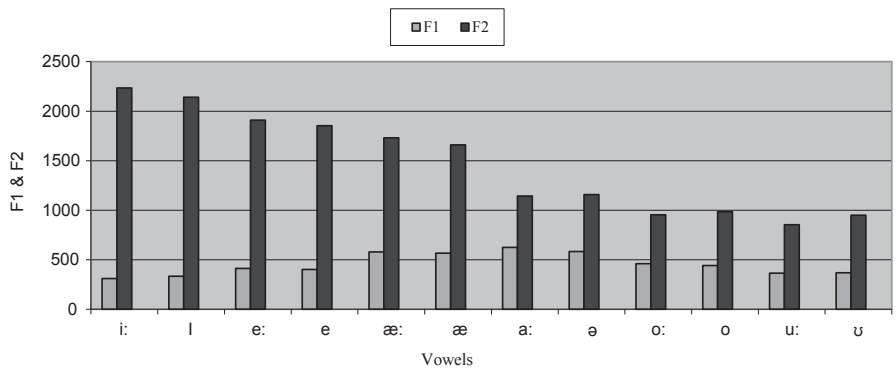

Figure 4: F1-F2 contrast between long and short vowels

Figure 4 show that, for front vowels, F1 becomes lower when the constriction in the oral cavity increases. As /i:/ is the most constricted front vowel, it has the lowest F1. It means that F1 increases as the tongue position gets lower for front vowels i.e., F1 of high front vowel /i:/ is 310 Hz, while F1 of mid front vowel /æ:/ is 567 Hz. In case of back vowels, F1 decreases with the height of the tongue i.e., mid back long vowel /o:/ has 460 Hz, while high back long vowel /u:/ has 370 Hz. In contrast to F1, /i:/ has the highest F2 and /u:/ has the lowest F2. This suggests that high vowels have low F1 and low vowels have high F1. Pahari has only one low vowel /a:/ and it has the highest F1 value (625 Hz). Figure 4 further displays that the maximum separation between F1 and F2 occurs with the close front vowels, and it is the smallest with the low vowels. For back vowels, F2 is much lower and closer to F1.

4.2. Vowel duration

The means for the duration values are provided in Table 3, while Figure 5 illustrates the relative nucleus durations for each vowel. It is observed that when speakers of the same geographical region produce same vowel, the result is different vowel durations. This is because some speakers speak faster and some speak slower.

Table 3: The means of duration values and standard deviations for the vowels in ms

	Mean duration	Standard deviation
i:	218	19.3
ɪ	93	15.5
e:	225	18.2
e	92	07.2
æ:	228	25.8
æ	99	10.5
a:	235	18.8
ə	94	12.8
o:	221	41.6
o	88	11.2
u:	218	17.5
ʊ	96	15.1

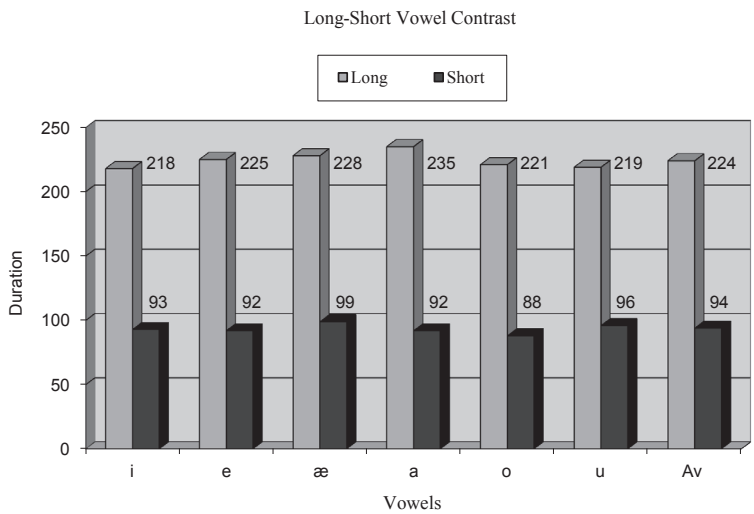

Figure 5: The length of vowels in milliseconds

The bar chart above shows the average duration of each long and short vowel in the speech of selected participants. The data indicate that durational contrast between long and short vowels is very much prominent and distinctive. The average duration of long and short vowels is 224 ms and 94 ms, respectively. The data further show the increase in length with vowel openness. /a:/ has 235 ms duration that is longer than that of two other front mid and front close vowels /e:/ and /i:/ respectively. The length of back vowels decreases with vowel

closeness as the close back vowel /u:/, is shorter than mid back vowel /o:/. It is also evident that all the long vowels are over two times longer than their corresponding short vowels.

The above results show that durational contrast is significant. It is phonemic in Pahari. Though it is the most distinctive and prominent and does help the listener to place vowels in large categories, such as long and short, still it is not sufficient in itself to enable identification of any individual vowel. For example, [e] and [ɪ] can't be differentiated on the basis of duration as both are short and have mean duration 93 and 92 ms, respectively. It means only quantity is not enough to identify the individual vowels. To identify individual vowels both the quality, quantity and quality cues are important in Pahari.

4.3. Vowel space

This section shows the vowel plots that were generated with Plot Formants. The graph shows F2 on the horizontal axis and F1 on the vertical axis.

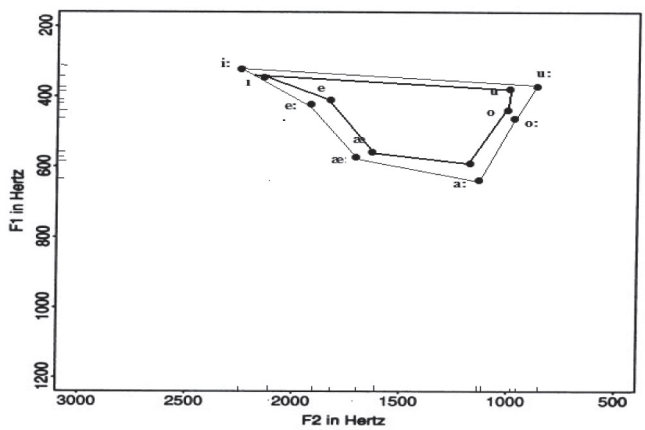

Figure 6: F1-F2 acoustic space for Pahari vowels

Figure 6 shows the acoustic space enclosed by long and short vowels. As it is seen, all the short vowels are centralized and do form the inner circle of vowel space as compared to their corresponding long vowels, which are distributed peripherally in vowel space. This shows that the acoustic space enclosed by long vowels is more than that for the short vowels.

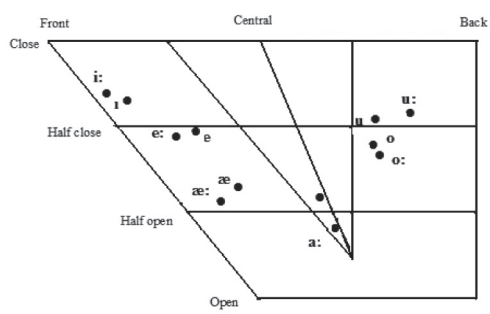

Figure 7: Quadrilateral of Pahari vowels

Figure 7 shows that only 2 vowels, one long and one short are central, while other 10 are peripheral in Pahari. The long and short vowels are located close to each other in the quadrilateral. This shows that there is very little spectral/qualitative difference between long and short vowels. This suggests that duration is an important and distinctive cue in Pahari. It further exhibits that all the short vowels are centralized as compared to their long counterparts. Another trend appears that F1 of mid short vowels is lower than that of their corresponding long vowels. In contrast, all the close centralized vowels have higher F1 than that of their long counterparts. The following table summarizes the description of Pahari Oral vowels.

Table 4: Summary of Pahari oral vowels description

i:	front	close	long	unrounded
ɪ	front	close	short	unrounded
e:	front	mid	long	unrounded
e	front	mid	short	unrounded
æ:	front	mid	long	unrounded
æ	front	mid	short	unrounded
a:	central	mid	long	unrounded
ə	central	mid	short	unrounded
o:	back	mid	long	rounded
o	back	mid	short	rounded
u:	back	close	long	rounded
ʊ	back	close	short	rounded

Based on the acoustic analysis, it is concluded that Pahari operates on 12 vowel system. These vowels are presented in Table 5.

Table 5: Oral vowel phonemes

	Front	Central	Back
Close	i: , ɪ		ʊ , u:
Mid	e: , e		o , o:
	æ: , æ	ə	
Open		a:	

5. Conclusion

With respect to Pahari oral vowels, the analysis shows that Pahari has four close, six mid, two open vowels. The data suggest that oral vowels are described as occurring in the form of long-short pairs that differ significantly quantitatively (vowel duration) and qualitatively (spectral characteristics). This study shows that long vowels are over two times longer (e.g., /i:/ and /ɪ/ are 218 ms and 93 ms, respectively) in terms of duration than their short- counterparts. Spectral differences also occur among long-short pairs i.e., all the short front vowels show low F2, while all the short back vowels show higher F2 than that of their corresponding long vowels. This shows that long vowels are peripheral in quadrilateral,

while short vowels are centralized as compared to their corresponding long vowels. Long vowels enclose more vowel space than short vowels. Duration cue is the most important as the language clearly exhibits long-short distinction and duration is phonemic in Pahari vowel system.

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