Acta Linguistica Academica Vol. **64** (2017) 2, 313–324
DOI: 10.1556/2062.2017.64.2.7

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Abstract: This paper reports on an acoustic study of the tonal system of the Pahari language. To achieve this aim, an experiment was conducted. Eight native speakers were given a set of monosyllabic triplets bearing three target tones to read them aloud for recording in a carrier sentence. The acoustic measures included F0, final velocity, and duration. The acoustic and statistical results show that (1) the average F0 demonstrates significant difference in the height of the pitch track of the three target words/tones; (2) final velocity shows three trends, namely falling, level, and rising associated with high, mid, and low tones, respectively; and (3) duration results indicate that high pitch track was significantly shorter than each of the other two pitch tracks. The study concludes that Pahari has three tones, namely high-falling, mid-level, and low-rising.

Keywords: tone; Pahari; pitch; velocity; duration

1. Introduction

This study aims to present an acoustic study of the tonal system of the Pahari language, an Indo-Aryan language spoken by 4.5 million people in Azad Jammu, Kashmir and Murree Hills (Khan 2012; Lothers & Lothers 2010). According to Khan (2012), Pahari has 30 consonants, 12 oral vowels, and 5 nasal vowels. Duration and nasality are phonemic in this language. There are also some phonetic contrasts whose nature is not yet fully clear. For example, words like [pa] 'price', [pa] 'quarter' and [pa] 'filth of cow' sound different to the native ear, yet they are segmentally identical. Thus there is likely a suprasegmental contrast. One possibility is that the contrast is tonal. According to Baart (2003), many languages spoken in a large area in South Asia that covers the northwestern corner of India, the northern parts of Pakistan and possibly some bordering regions in Afghanistan, are tonal. He further states that tone languages spoken in this region are from different language families. Tonal languages include varieties, such as Hindko, Pahari-Pothwari, which are closely related to Punjabi, and somewhat more distant ones like Dardic languages spoken in northern Pakistan, and Burushaki, an isolate language. He conducted a

2559–8201/$ 20.00

survey of 18 tonal languages spoken in the northern part of Pakistan and divided the tonal languages in three classes. First, Shina-type languages (Shina, Burushaski, and Indus Kohistani) show two types of tones (Falling and Rising) on long vowels. Second, Punjabi-type tone languages (Punjabi, Gojri, Hindko, Pahari, etc.) have a three-way surface contrast in stressed words (high, mid and, low). The third type includes languages that have more than a three-way surface contrast like Kalam 'Kohistani.

Baart (2003) points out that the degree of contact between the languages in Northern Pakistan seems to be a more important factor in the development of tone system than the genetic relationship between the languages. For example, Indus Kohistani is genetically closely related to Kalam and Torwali; yet due to its geographical location, it is in contact with Shina, and thus its tone system looks more like that of Shina than that of Kalami or Torwali.

Bhatia (1975) tried to show how the tone system developed in Punjabi type languages and established that Punjabi type languages that include Pahari have developed a tonal system that is the result of the loss of either voiced aspirates or the voiced glottal fricative /h/. Pahari as well as Punjabi speakers in Pakistan all speak Urdu, a modern Indo-Aryan language, as the second language. Urdu still retains voiced aspirates. In Punjabi, Urdu voiced aspirated cognates are produced with the low tone (Bhatia 1975). For example, [gʰoɽa] 'horse' is pronounced as [kòːɽaː] 'horse'. Like Punjabi, Pahari also lacks voiced aspirated stops and affricates (Khan 2012), but also has cognates of Urdu voiced aspirates, as shown below.

(1)

Urdu		Pahari	
[bʰul]	'forget'	[pʊ̀l]	'forget'
[gʰoɽa]	'horse'	[kòːɽaː]	'horse'
[dʰol]	'dust'	[ʈ̪ùːl]	'dust'

Bhatia (1975) focused on the development of tone and its developmental stages with a focus on Punjabi but no study has yet been conducted exclusively on the Pahari tone pattern. The present study, without tracing the development of tone and its developmental stages, aims to investigate acoustically the real time data to show how tone is realized in the language.

2. Surface contrast

In non-tonal languages, the words are identified by consonants and vowels. But in tonal languages, some melodic features are an inherent aspect of the pronunciation of a word just like the consonants and vowels (Baart 2003). In other words, words in a tone language are made up of consonants, vowels, and of melodic characteristics. In tone languages, the identity of a word is changed when the melody of that word is changed. Many examples of this phenomenon are found in Pahari. The minimally contrastive sets of words in the form of triplets and minimal pairs in the following table show that on each row, tone is the only distinction between the words. Words in each line have the same consonants and vowel sounds but each word has a different meaning. It shows that the meaning of a word changes with a change in its melodic characteristics (tone). Eight Pahari speakers were asked to listen to these words and they confirmed that they perceive them differently and have different meanings.

Table 1: Minimally contrastive sets of Pahari words

Low tone	Mid tone	High tone
koːɽaː 'horse'	koːɽaː 'bitter'	koɽaː 'leper'
kæɽiː 'watch'	kæɽiː 'link of a series'	kæɽiː 'a type of curry'
tʃaː 'porcupine'	tʃaː 'desire/pick up'	tʃa 'tea'
paː 'rate/price'	paː 'put'	Pa 'filth of cow/buffalo'
tʃhæɽ 'clouds'	tʃæɽ 'bed bug'	tʃæhɽ 'get on'
paːr 'weight'	Paːr 'across'	
koːl 'dispute'	koːl 'near'	
paːr 'weight'	paːr ' away'	
t̪aːr 'edge'	t̪aːr ' wire'	
tʊknãː 'bend'	tʊknãː 'to cut'	
nãːnãː 'take bath'	nãːnãː 'grandfather'	
təkk 'cover'	təkk 'part'	

The above list of words shows that Pahari has three types of tones. Having established the surface contrast, we will now report on the results of an acoustic experiment aimed to identify a systematic tone pattern in Pahari.

3. The experiment

3.1. Participants

Eight Pahari native speakers (six male and two female) from the same dialectal area (Azad Jammu and Kashmir) participated in this study. The speakers were born and raised in the Pahari speaking area in the Pakistan-administered part of Kashmir. They all majored in different subjects and graduated from the University of Azad Jammu and Kashmir, Pakistan. They all were in their 30s. Six out of the eight speakers were also working after the completion of their degrees. These speakers use Pahari at home and at the market place. None of the speakers had reported any speech or hearing impairment.

3.2. Stimuli

A list of minimal pairs/triplets containing the targeted tones was prepared. A set of monosyllabic triplet words with their meaning given in Urdu (*pa:* 'rate/price', *pa:* 'quarter', *Pa* 'filth of cow/buffalo') were written on cards. The words were presented in carrier sentences. Each member of the triplet in the carrier sentence was written on a separate card. The participants were asked to read them aloud at a normal speed and voice. The words were presented in random order and each word was repeated five times. Three words containing target tones were recorded forming a total corpus of 120 tokens for analysis (3 words × 5 repetitions × 8 speakers = 120). The following words were recorded:

(2) Low tone: *pa:* 'rate/price'
Mid tone: *pa:* 'quarter'
High tone: *Pa* 'filth of cow/buffalo'

3.3. Recording

The recordings were done in a quiet room in one of the participants' home. Prior to the recordings, the speakers were given a practice task during which the procedure was explained to them. The words were presented to them on separate cards in carrier sentences and they were instructed to read each word as naturally as possible. During the actual recordings, which were monitored, the speakers read at their own pace. Recordings were done in two days. On the first day, the six male speakers were

recorded, while on the second day, the two female speakers were recorded. The material was recorded in Praat with a sampling rate of 44100 Hz. The recordings were made on a laptop using a high fidelity microphone (Countryman Isomax Hypercardiod). The participants were seated in front of the laptop screen and wore a head-mount microphone approximately two inches away from their mouth. All the five repetitions of each test word were used for measurement.

3.4. Measurements

The tokens were segmented and the vowel portion was labeled in Praat (Boersma & Weenik 2012) by running Prosodypro (Xu & Prom-on 2014) on audio files. The Prosodypro application provided the following measurements over time: fundamental frequency (F0), final velocity, and average duration. The pitch was calculated at ten points across the duration of tone bearing vowel for each speaker. The values were averaged across five repetitions of each speaker individually and later, the data from all the speakers were averaged. To reconstruct the pitch track, the averaged values were plotted on a graph.

3.5. Statistical analysis

The analyses of F0, final velocity, and duration involved one way repeated measures ANOVA with three levels (corresponding to three tones) supplemented with a Bonferroni post-hoc test to indicate the difference within groups/participants.

4. Results

To establish the canonical forms of the three tones produced by the eight Pahari speakers in this study, F0, final velocity, and duration of the tones produced in isolation were analyzed.

4.1. F0 results

Figure 1 shows the average F0 contours for the syllable /pa/ in the three tones with the standard deviation bar obtained by averaging overall tokens produced by all the eight speakers (40 tokens for each tone). The average

F0 values for the three tones are 160 Hz, 148 Hz and 139 Hz as shown in the following bar chart.

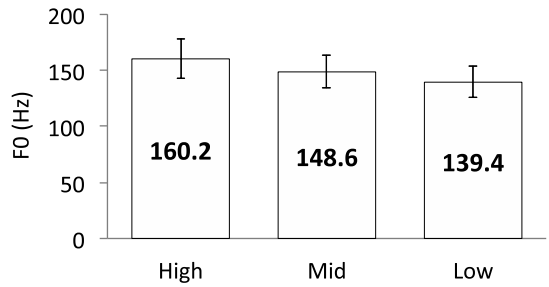

Figure 1: F0 difference (along x-axis) in high (H), mid (M) and low (L) tones. The error bars represent standard errors.

The statistical analysis indicated a significant difference among the three tones in Pahari. One-way repeated measures ANOVA was conducted on the data and was supplemented by a Bonferroni post-hoc test. One way repeated measures ANOVA showed that the average pitch of the three groups interacted significantly ($F(2,7) = 19.875$; $p < 0.05$). The Bonferroni post-hoc test confirmed a significant difference in pairs like L, M ($p < 0.005/0.0167$), H, M ($p < 0.005$) and H, L ($p < 0.005$). This significant difference suggests that Pahari has three different tones, namely high (for high F0), mid (for mid F0) and low (for low F0). The average F0 difference in the production of the three tones is not as big as in some languages, e.g., Mandarin (Xu 1997), but it is not uncommon to see relatively small differences of fundamental frequency in the contrastive tones of other tone languages (Fok Chan 1974; Peng 1997; Barry & Blamey 2004).

It is important to mention here that these F0 values are not absolute; rather they are relative, and the three pitch tracks plotted in Figure 2 are time normalized.

Figure 2 indicates that the high, mid, and low pitch tracks show falling, level, and rising trends, respectively. High tone starts with a high F0 value (161 Hz) and consistently lowers to the end of the syllable (141 Hz). Mid tone starts with a slightly lower F0 value (154 Hz), falls to the lowest point 143 Hz at point 4, and then stabilizes till the end (144 Hz). Tone 3 starts with the lowest F0 (148 Hz) of the three tones, like the other two tones falls to point 4, the lowest point (128 Hz), and then rises sharply to the end of the syllable (149 Hz).

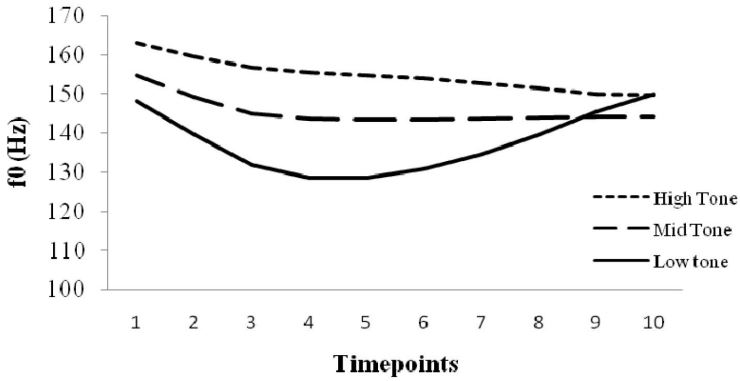

Figure 2: Mean time-normalized F0 value measured at ten points

4.2. Final velocity

To establish the direction of the three pitch tracks as shown in Figure 1, we applied a method developed in a recent study (Xu & Prom-on 2014) which uses final F0 and final velocity to determine the direction of pitch tracks (Chen & Xu 2006; Liu et al. 2013). The method was motivated by the finding that tones are articulated as unidirectional movements toward their respective underlying targets within the tone-bearing syllable (Xu & Wang 2001). As a result, the F0 and its velocity near the end of the syllable would most closely reflect the underlying pitch target of the tone. The overall trends of the three tones in terms of final velocity are shown in Figure 3.

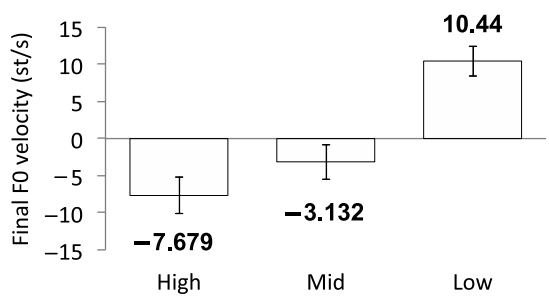

Figure 3: Mean final velocity of H, M and L tones with the standard errors

The graph shows that the mean final velocity is negative (−7.6 Hz) for high and mid (−3.1 Hz) tones, which means that the pitch tracks are falling. But the mean final velocity for mid tone is (−3.1 Hz) close to zero, which means that the pitch track is level. On the other hand, the mean final velocity is positive (10.4 Hz) for the low tone, which means that the pitch track is rising. One way repeated measures ANOVA with a Bonferroni post-hoc test was conducted to see if the mean final velocity values differed significantly according to the tonal categories. The ANOVA test confirmed that the three tone types are significantly different from one another in terms of their mean final velocity ($F(2, 7) = 35.313,\ p < .0001$). A subsequent Bonferroni post-hoc test showed that all the three tones are significantly different from each other in terms of their mean final velocity values. This suggests that the three Pahari tones, namely high, mid, and low interact with the final velocity values and are associated with a particular pitch track shape/direction, namely falling, level and, rising, respectively. It can be concluded from the above discussion that Pahari speakers distinguish tones based on the height and shape/direction of the pitch track (F0).

4.3. Duration

Beyond differences in fundamental frequency (F0), the tonal differences in some languages are accompanied by systematic difference in duration. It has been observed that the vowels bearing low tones are phonetically longer than those with high tones. This shows an inverse/negative relationship between F0 and duration in languages like Cantonese, Thai, and Xulu (Peng 1997). But there are other languages which show a positive relationship between vowel duration and F0. Shanghai Chinese is reported to have shorter low tone syllables than the high or mid tone ones (Xu 1997).

As discussed above, Pahari has a system of three tones, i.e., High-falling, mid-level, and low-rising. The durations of each of the three tones are illustrated in Figure 4.

In terms of duration, the above figure shows that the high tone is the shortest (230.4 ms on average), the low tone is the longest (296.6 ms), while the mid tone has an intermediate duration (297.5 ms). This suggests that Pahari follows a L > M > H relationship with L longer than M and M longer than H, but the statistical analysis below does not support this trend and shows that there is no significant difference in the duration of low and mid tones. The high tone is significantly shorter than both the low and mid tones. It means L, M > H, which indicates that the vowel

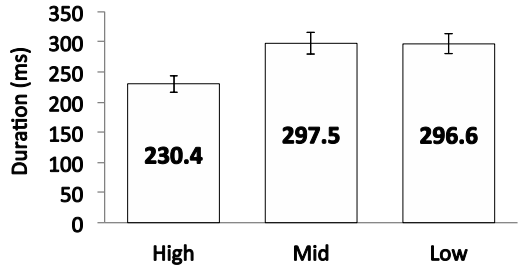

Figure 4: Mean duration (ms) of the three tones with the standard errors

bearing high tone is shorter than the vowels bearing mid and low tones. The analysis has shown that the duration of the High tone is significantly shorter than that of the Mid and Low tones. Although this duration pattern is in some way consistent with previous reports of tone-duration correlation (e.g., Liu & Samuel 2004; Faytak & Yu 2011), it is hard to identify a clear causal relation. The fact that there are no three-way durational differences, however, suggests that duration provides only a secondary cue to tone identification in Pahari.

One way repeated measures ANOVA with tone as a factor indicated a significant effect on the duration of the vowels carrying tone ($F(2, 7) = 18.5$, $p < 0.0015$). The Bonferroni post-hoc test indicated that the duration of the vowel bearing high tone was significantly shorter than that of each of the other tones ($p < 0.0167$) but the other two tones were not significantly different from each other.

5. Discussion

The acoustic results from the experiment showed differences in the F0 of the three target tones, and a statistical test ANOVA confirmed that these differences are significant. The Bonferroni Post hoc test further established a significant difference among the three pairs of tones, which suggests that Pahari has three different tones, namely high, mid, and low. This implies that F0 is the primary acoustic measure to identify/differentiate tones in Pahari. The terms high, mid, and low are relative, not absolute. The results support Baart (2003), who claimed that Punjabi-type languages have three tones (high, mid, and low) which can be significantly distinguished by the height of the tone, but this study further claims that along with the height

of the pitch track, the shape/direction of the pitch track is also a significant factor in identifying the tone in Pahari. Whereas Chinese languages have a big gap among the pitch tracks of distinct tones, in Pahari, the difference is not very big, although it is significant.

The acoustic results showed a difference in terms of the average final velocity of the tones, and ANOVA further confirmed that the three tones are significantly different from each other in terms of their final velocity, showing falling, level, and rising patterns. The results showed that the three directions of the three tones are associated with the height of the tones. This suggests that low, mid, and high have rising, level, and falling trends, respectively.

The results demonstrated that the three tonal categories are significantly different not only in terms of the average F0 but also in terms of the shape of the pitch track. Hence, it can be concluded from the above discussion that the three lexical tones in Pahari are High-falling, Mid-level, and Low-rising.

Acoustic measurements showed that tones with a low and mid F0 are longer than the vowels of the high tones. Besides, ANOVA also showed a significant difference in the duration of the tones. The Bonferroni post-hoc test indicated that the duration of high tones is significantly shorter than the duration of low and mid tones but no significant difference was found in the duration of low and mid tones.This shows that the height of the tone affects the duration of the vowel. In an experiment involving Northern Chinese speakers, Liu and Samuel (2004) also report a correlation between syllable duration and F0. In a cross-linguistic study, Faytak and Yu (2011) claimed that the duration of vowels is inversely proportional to the average F0. The results of this study support the previous findings that tone affects the duration of the tone bearing unit. The study shows a L, M $>$ H pattern in Pahari and suggests that duration provides a secondary cue to tone identification. In addition, though not addressed in this study, voice quality/phonation may also play a role in tonal distinctions.

The results show that tone and duration are correlated as shorter duration is always associated with high-falling tone, while longer duration is always associated with mid-level and low-rising tones (Table 2).

Table 2:

	H	M	L	ANOVA
F0	160	148	139	$p < 0.05$
Final velocity	−7.6	−3.1	10.4.77	$p < 0.05$
Duration	230.4	297.5	296.6	$p < 0.05$

6. Conclusion

Considering the acoustic and statistical analyses, it can be concluded that Pahari has three lexical tones that are primarily distinguished by the height and direction/shape of the pitch tracks. The study further shows that tone pattern affects the duration of the tone bearing segment and supports the claim that the low toned vowels tend to be longer than the high-toned vowels and it suggests a L, M > H pattern in Pahari. The methodology used in the study to identify tones can be applied to other potentially tonal languages in the area. The association of breathy phonation with tones and its potential link to voiced aspiration can be further explored in future research.

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