ACOUSTIC ANALYSIS OF THE BARAM PHONEMES

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Baram is a critically endangered Tibeto-Burman language spoken in the Gorkha District of central Nepal. This work carries out a preliminary acoustic study of the language. Baram plosives are acoustically characterized by VOT, the fricatives by the peak value and the affricates by the rise time and friction duration. Similarly, the nasals, lateral, trill and glides are characterized by formant structure. Similarly, the distribution of the F1 and F2 reveals the height of the tongue and frontness/backness of the vowels. The height of the vowels is also depicted by their intrinsic F0 as it increases as the height of the vowel increases. Baram has five diphthongs which are close diphthongs and the second target is always [i].

Keywords: VOT, plosive, formant, frication, F0

1 Introduction

This paper presents an example of how we can carry out linguistic study with a handful of data. In endangered languages, the archived data is always limited and it is a type of general collection; generally, not collected for a specific purpose. So a specific study based on such data is really challenging but it is possible to carry out specific studies up to a level using such data. This study investigates some phonetic and phonological aspects of the Baram consonants and vowels. The phonemic inventory and minimal pairs for contrast have been adopted as given in Kansakar et el. (2011c). The phonetics and phonology of Baram shows great proximity with Nepali phonetics and phonology. Simply, we can guess that it is a result of heavy language contact and language shift but the outline of ancient Baram phonetics and phonology is still unknown, so without comparison we are not at the position of making any claim.

1.1 The Baram language

Baram is a Tibeto-Burman language spoken by a minority ethnic group of Nepal called Baram. The Baram people reside mainly (more than 90%) in the central southern part of the Gorkha district (CBS 2011) along Daraundi and Budhigandaki rivers and their tributaries in the central part of Nepal. It is a seriously endangered language because it is spoken only in two villages of the Gorkha district: Mailung and Dandagaun. There are 9 speakers in Mailung but they do not use the language in day-to-day conversation. In Dandagaun, it is spoken in day-to-day conversation in a very limited number of domains of language use. In 2007, there were 51 speakers and 44 terminal-speakers, and 34 rememberers. Most of the speakers were very senior in age and their number is decreasing. Six of the speakers passed away within the period of 3 years (Kansakar et al. 2011a).

The cognate comparison shows that the closest genetic affiliation of the Baram language is with Thami, second closest language is Chepang and Newar and Magar are close to it, too (Chalise 2015).

1.2 The consonants

Baram language consists 21 consonant phonemes in the native words as collected in Kansakar et al. (2011c). They are plosives /p/, /t/, /k/, /p^h/, /t^h/, /k^h/, /b/, /d/, /g/; fricatives /s/, /h/; affricates /ts/, /ts^h/, /dz/; nasals /m/, /n/, /ŋ/; lateral /l/; trill /r/ and glides /j/, /w/. The Baram consonant phonemes are presented in Table 1.

The sounds given in the parentheses, in the table 1, are found in a very limited number of native words and there are not minimal pairs available to justify their phonemic status. Mostly they are found in the Nepali loans; and the number of Nepali loans is extremely high in the language in comparison with the native words. The Nepali loans have been an indispensable part of the Baram lexicon without which communication is almost impossible. So the sounds are not phonemes in the native words but they are phonemes in the Baram language. This study has attempted to analyze only the phonemes in the native Baram words so the phonemes in parentheses are out of the scope of this study.

Table 1: The Baram consonants

	bilabial	dental	alveolar	palatal	velar	glottal
plosives	p b p^h (b^h)	t d t^h (d^h)	(ʈ) (ɖ) (ʈ^h) (ɖ^h)		k g k^h (g^h)	
affricates			ts dz ts^h (dz^h)			
fricatives			s			ɦ
nasals	m		n		ŋ	
lateral			l			
trill			r			
glides	w			j		

1.3 The vowels

There are six contrastive vowels in Baram, viz. /i/, /e/, ə/, /a/, /o/ and /u/. There is no length, breathiness and nasalization contrast in Baram but, in perception, we realize allophonic length for emphatic purposes. Similarly, nasalization of the vowel (both prenasalization and postnasalization) is perceived in the environment of nasal consonants. In Kansakar et al. (2011b), there are a handful of nasal vowels in the native Baram words, but they have their counterparts with non-nasal vowels, for example, /aĩkok/ or /aŋkok/ for 'a kind of tree' which justifies that there is no phonemic status of nasal vowels.

Kansakar et al. (2011c) has classified the basic vowels in Baram in terms of height of the tongue: high /i/ and /u/, mid /e/ and /o/ and low /ə/ and /a/; part of the tongue active to produce the vowel: front /i/ and /e/, central /ə/ and /a/ and back /u/ and /o/. But there is not mentioned the parameter of shape of the lips, i.e. it is silent about whether there are rounded and unrounded vowels. In fact, the back vowels /u/ and /o/ are round vowels.

2 The materials and method

Consonant analysis is based on the 885 Baram native words recorded by the author from three (one female and two male) nearly 70 years old native speakers with normal speech ability in the field, in July 2010, for the purpose of a multimodal dictionary of Baram. The measurement of VOT and closure duration is solely from the words produced by the female speakers because the tokens from the male speakers are insufficient in number for this purpose. VOTs and closure durations were measured from 10 different words with similar phonetic structure for each of the segments. Accordingly, for each of the segments, there were 10 VOT values and 10 closure duration values. Both VOT and closure durations are measured in millisecond (ms). The durational values were measured manually from the spectrogram and the frequency values were extracted from a selection from the relatively steady part of the respective sounds.

General observations of the phonetic phenomena like devoicing, deaspiration and spirantization have included the tokens from the male speakers, too.

The analysis of the vowels is based on the words recorded from the same three speakers at the same time for the purpose of the analysis of the formant structure of the vowels. The wordlist includes six words containing the six vowels in the similar environments. Ten tokens of each of the words were recorded from each of the speakers. For the purpose of formant plot for this study, five tokens of each word from the middle part (excluding first two and last three) from one male and one female speakers have been taken. Later, the averages of the five tokens of each of the vowels were calculated and the average values were used for the purpose of formant plotting.

The words were recorded using Sony ECM-MS908C Electret Condenser microphone and EDIROL, R09HR audio recorder maintaining a distance of 10-12 inches between the microphone and the mouth of the speaker in CD quality.

The statistical calculations were made using 'http://www.vassarstats.net/' a commonly used statistical computation website.

3 Acoustic characterization of the consonants

3.1 The plosives

The plosives vary from each other in terms of closure duration, voice onset time (VOT), release burst and formant transition out of the preceding vowel (vowel to plosive) and into the following vowel (plosive to vowel). This study has incorporated the VOT and closure duration to characterize them (Figure 1).

There are some challenges with measuring the closure duration of the Baram plosives. Distributional feature of some plosives and plosive weakening are the main challenges. The aspirated plosives are mainly found in the word initial position in which it is not possible to measure the closure duration and when they are found in intervocalic position, in limited cases, because of spirantization, they are no longer plosives. The phenomenon of spirintization is equally found in the both voiced and voiceless bilabial and velar segments in the intervocalic position. As a result, [b] and [g] are changed into [β] and [ɣ] respectively; and [p] and [k] are changed into [φ] and [x] respectively. Similarly, as a result of deaspiration [pʰ], [tʰ], [kʰ] are changed into [p], [t], [k]. Sometimes, [b] is pronounced as the bilabial approximant [w]. In some instances, with voiceless and most of the instances with voiced plosives have very feeble release burst very difficult to figure out. The situation is further difficult with the voiced segments. So, in this study, the plosives have been characterized in terms of Voice Onset Time (VOT)

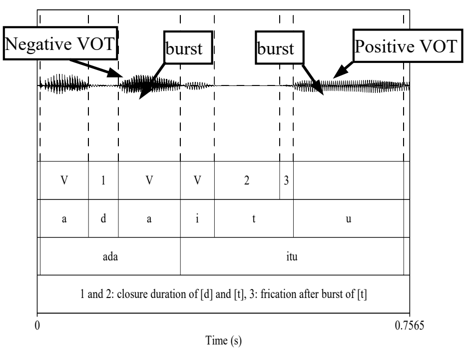


Figure 1: The different phases of plosive production

Because of the plosive weakening VOT measurement in the intervocalic position is problematic in Baram so all the VOT values were measured in the word initial position. It is a key phonetic cue to distinguish the voicing and aspiration in both plosive and affricate classes. The voiced ones have negative VOT (see 3.1.2[1]) and the voiceless ones have positive VOT. Similarly, the aspirated ones have fairly longer VOT than the unaspirated ones.

The VOT values for [p], [t] and [k] are 17.2 (sd. 4.73), 16.6 (sd. 3.47) and 27.2 (sd. 7.13). The VOT values between [p] and [t] are not significantly different ($t = 0.44$, $p = 0.67$), but they are highly significant between [p] and [k], and [t] and [k] [($t = -3.28$, $p = 0.009$) and ($t = -3.74$, $p = 0.004$).

The mean VOT values for [pʰ], [tʰ] and [kʰ] are 54.16 (sd. = 12.20), 74.16 (sd. = 9.43) and 85.5 (sd. = 19.17) respectively with significant differences (for [pʰ] and [tʰ], $t = -2.99$, $p = 0.03$; [pʰ] and [kʰ], $t = -4.08$, $p = 0.009$; and [tʰ] and [kʰ], $t = -2.51$, $p = 0.05$). It justifies that the VOT interacts with the places of articulation and it increases from front to back.

3.2 The fricatives

The fricatives are characterized in terms of voicing and place of articulation. There are two fricative sounds in Baram [s] and [h]. Regarding voicing the first one is clearly voiceless as there is noise component (aperiodic wave) throughout the closure time whereas the second one is anomalous in nature. In the word initial position, it begins with a short voicelessness and it overlays its noise into the following vowel and the vowel carries breathy nature in the initial part and finally it is changed into modal voicing. So in this position it is partly voiceless and partly voiced. Similarly, in the intervocalic position the preceding vowel is breathy (sometimes initial part and sometimes whole) and the second vowel is modal. In this way the existence of [h] is seen as breathiness in the vowel (Figure 2).

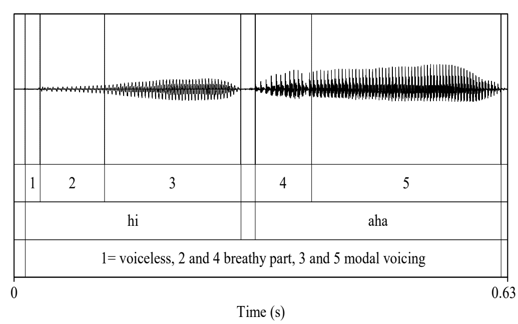


Figure 2: [h] in word initial and intervocalic positions

Regarding the place of articulation, [s] is alveolar and [h] is glottal. The peak frequency of [s] is about 7500 Hz and its relative amplitude of peak

[1] The closure duration of the voiced plosive is its negative VOT.

frequency is high (nearly 44 dB) which justifies its place of articulation (Figure 3). It could not be possible to extract the spectral structure of [h] because its independent existence could not be found in the data.

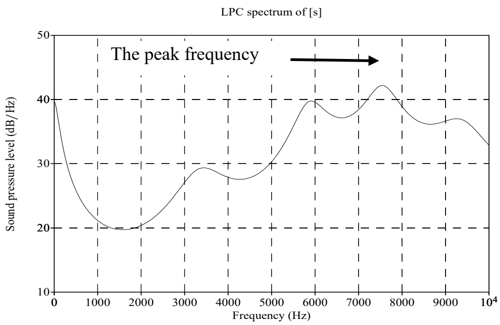


Figure 3: Peak frequency of [s] in LPC spectrum

3.3 The affricates

Two alveolar affricates, viz. [ts] and [dz], are found in Baram. Affricates are regarded to be a combination of stop and fricative and their acoustic characteristics are similar to those of plosives and fricatives at the same place of articulation (Reetz and Jongman 2009:199) (Figure 4).

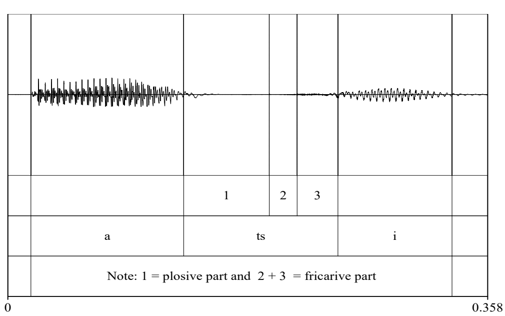


Figure 4: The different phases of affricate production

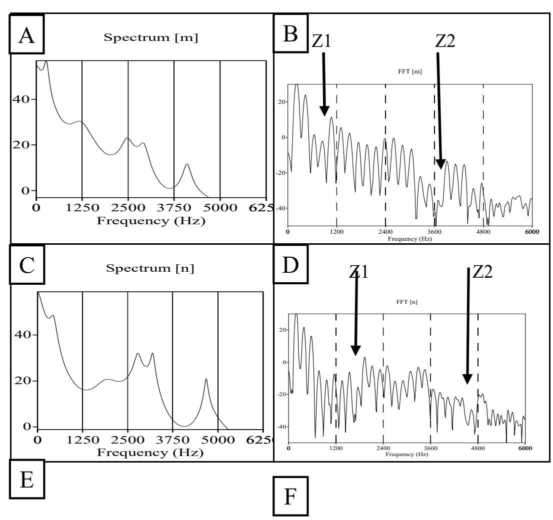
In Baram, the closure duration (plosive part) ranges from around 40-60 ms and the first part of the fricative part, the rise time[2] ranges from around 15-30 ms and the second part of the fricative part, the frication ranges from around 30-60 ms. The frication part is relatively longer in the aspirated counterpart.

3.4 The nasals

Baram has three nasal sounds viz. bilabial [m], alveolar [n] and velar [ŋ]. The nasals are characterized by the nasal formants (N1, N2, N3, …) and the anti-formants or zeros (Z1, Z2, …). The first nasal formant is also called nasal murmur which is the strongest formant. Its value gradually increases from bilabial to velar places of articulation. So the value of N1 is an important cue for the place of articulation of a nasal consonant (Harrington, 2010:113).

Table 2: The five formants of the nasals (averaged from 10 tokens for each nasal sound)

	[m]	[n]	[ŋ]
N1	300	452	593
N2	1233	1937	1660
N3	2131	2758	2504
N4	2699	3178	3455
N5	4200	4700	4548



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2 Rise time is the duration between the release point and the maximun size of the aperature is obtained in the production of a fricative or an affricate.

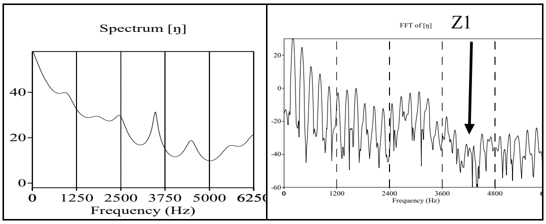


Figure 5: LPC and FFT of [m], [n] and [ŋ] respectively

The first five nasal formants of [m], [n] and [ŋ] are presented in Table 2 which show that the formant structures of the nasals differ for different places of articulation (Figure 5A, 5C, 5E). The formant structure of a nasal is the result of the interaction between the resonance caused by the tube from glottis to nostrils and anti-resonance (anti-formant or zero) caused by the side branch of the tube (the mouth) during their production.

The anti-formants (zeros) also vary according to the places of articulation. For [m], the first anti-formant (Z1) is found around 800-1200 Hz (Figure 5B); for [n], it is found around 1600-1800 Hz (Figure 5D) and for [ŋ] it is found around 3000-3400 (Harrington, 2010:113-118) as presented in Figure 5F. The anti-formants in different nasal consonants are presented in their respective FFT spectrum and are pointed with arrows in Figure 5.

3.5 The lateral and trill

Baram has one alveolar lateral [l] and one alveolar trill [r]. For [l], the tip of the tongue rests lightly against the alveolar ridge, dividing the airflow into two streams that emerges over the sides of the tongue for every [r], the tip of the tongue hits the alveolar ridge one to three times against the alveolar ridge. In every hit the tongue is grooved and the tip does not completely block the medial line so some of the airflow and acoustic energy emerges centrally, although much of it is emitted from the lateral side as it does in the production of [l] (Raphael, Borden and Harris, 2011: 119).

The lateral is characterized by well-defined formant pattern. There occurs abrupt change in the formant structure during the formation and release of the occlusion. Because of the occlusion, the first formant is low but it is higher than in the nasals. Reetz and Jongman (2009:197) states that average adult male formant frequencies for [l] are approximately 340 Hz, 1200 Hz and 2800 Hz respectively. In Baram, for adult female speaker the first, second and third formant means are 418 Hz (sd. 46.34), 1592 Hz (sd. 65.98) and 2330 Hz (sd. 199.45). Naturally the formant frequencies are relatively higher in the production of a female speaker.

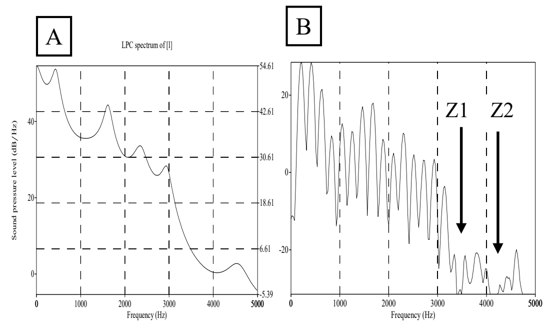


Figure 6: LPC and FFT of [l]

The LPC spectrum and FFT spectrum in Figure 6A and 6B present the formant structure of the [l] sound in Baram. The energy level abruptly decreases in the frequency components higher than 3100 Hz and there are found anti-formants in the region.

The trill is characterized by well-defined formant patterns as in the lateral. There occur changes in spectrum during the close and open successions (Figure 7B). The formant structure changes during the close and open phases. It needs detailed study to find out the changes during the close and open phases. The average formant structure is presented in Figure 7A. The first formant is found in 400-500 Hz range, second formant is found in 1300-1500 Hz range and the third formant is found in 2200-3000 Hz.

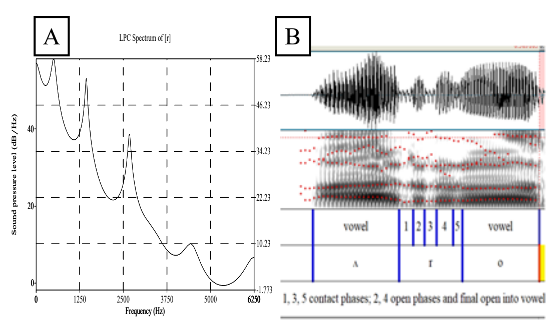


Figure 7: LPC, oscillogram and spectrogram of [r]

3.6 The glides

The glides are vowel-like consonants of which [j] is close to [i] and [w] is close to [u]. So [j] has low F1 and high F2 and [w] has low F1 and low F2. On one hand they are close to monophthongs in terms of formant structure and on the other hand they are close to diphthongs in terms of gliding (formant transition). The transition from [a] to [j] is like the transition from [a] to [i] and the transition from [a] to [w] is like the transition from [a] to [u]. Figure 8 presents the formant structure and transition pattern in words [aja] 'rice' and [awa] 'water' in Baram.

The first formant values and fourth formant values are very close to each other but the main difference is between the F2 and F3 values which are significantly higher in [j] than in [w].

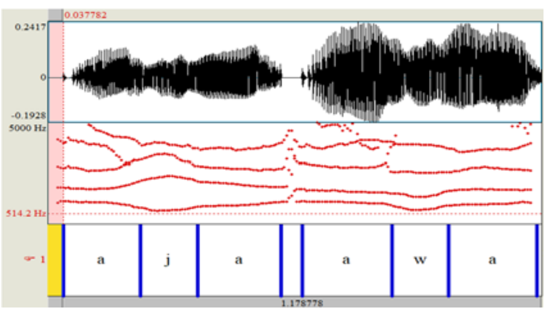


Figure 8: Oscillogram and formants of [j] and [w]

In the two words, [j] has F1 = 637, F2 = 2307, F3 = 3412 and F4 = 3971; and [w] has F1 = 676, F2 = 1316, F3 = 2516 and F4 = 3879.

Mostly the glides occur in the word initial position or in the consonant-glide cluster in the word initial position, their distribution in intervocalic position is very limited. So I could not calculate the average among the glides in intervocalic position. In the word initial position, the mean values among ten instances of the glides were calculated and are presented in Table 3.

Table 3: Four formant frequencies of [j] and [w]

[j]	F1	F2	F3	F4
mean	391.2	2629.4	3526.2	4469.6
sd.	37.84	67.89	133.22	219.03

[w]	F1	F2	F3	F4
mean	507.75	899	2668.5	4066.25
sd.	28.47	72.97	161.85	206.1

The comparison of the formant values in a-glide-a position and in the word initial positions reveals that the formant structure of the glides varies as per the phonetic environment they occur in. Because of the fact that [a] has high F1 so F1 of the glides in that context is high.

4. The vowels

4.1 The basic vowels

Formant plot of the vowels is an important aspect of vowel description in phonetics and phonology because it specifies where the vowels are produced from in the vowel space.

The measurements of the formant frequencies of the vowels and their plotting on the F1XF2 plane as presented in Figure 1 and Figure 2, support the findings of the Kanaskar et al. (2011 a and b) to a great extent and reveal some new facts about them.

Regarding the height of the tongue (location on the vertical dimension), the formant plot in F1XF2 plane supports the findings of Kansakar et al. (2011c) as /i/ and /u/ are high, /e/ and /o/ are mid and /a/ is low. But the height of the tongue of /ə/ is mid in this study (in Fig. 9&10) but previously it was classified as a low vowel. This vowel is very inconsistent in nature and location, and it is very difficult to determine whether it is to be represented with [ə] or [ʌ] because in the formant plot of male speaker it is very near to [ʌ] but in the formant plot of the female speaker it is very much near to [ə]. So in this study I have followed the trend used in the literature.

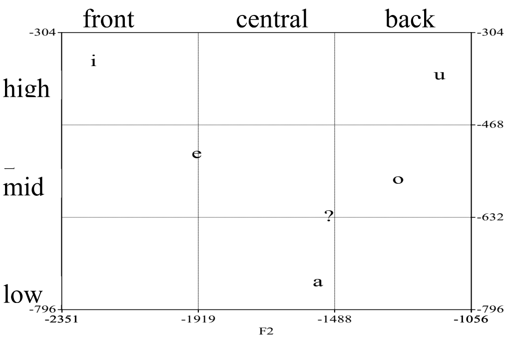


Figure 9: Average formant values in F1XF2 plane (produced by a male speaker) [Note: symbol ?=vowel ə in figures]

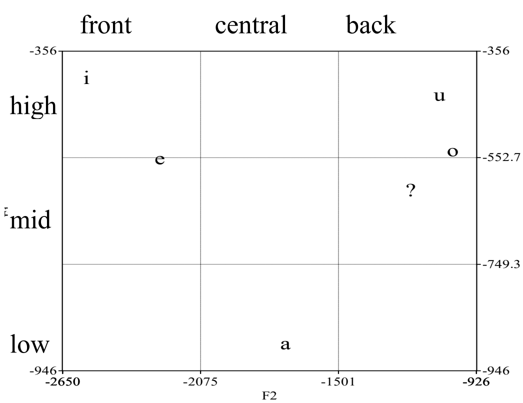


Figure 10: Average formant values in F1XF2 plane (produced by a female speaker)

Similarly, in the case of frontness/backness (location on the horizontal dimension), this study has supported the findings of Kansakar et al. (2011c) regarding /i/ and /e/ as front vowels, /u/ and /o/ as back vowels but the finding is quite different concerning /ə/ and /a/. /a/ and /ə/ were supposed to be roughly central vowels but this study revealed /a/ as a purely central vowel. The case with /ə/ is again confusing as it is central in the tokens produced by the female speaker and back in that of the male speaker. So it can be said that /ə/ is an unstable vowel in Baram and it fluctuates in the mid-low and central-back region in the vowel space.

The formant values of the vowels presented in Figure 9 and 10 are the values calculated from the words produced in isolation in a controlled environment. A vowel while produced for the second time is not articulated exactly the way it was produced before, so we get different formant values measuring different tokens of the same vowel. Similarly, there is higher degree of quality variation of the vowels in the running text than in the production of individual vowels.

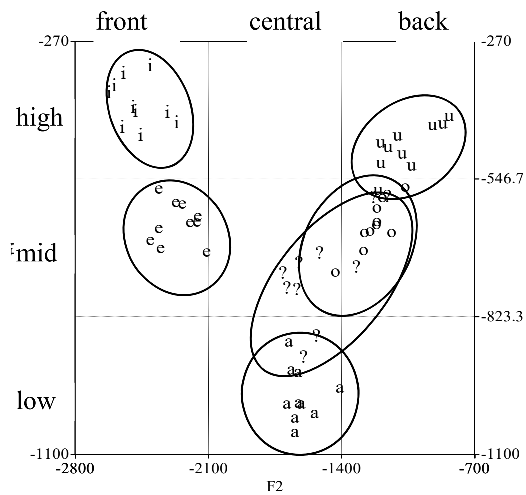


Figure 11: Scattered plot of F1 and F2 of the individual vowels

Scattered plot of the formant values of the different vowels is an important means to observe the possible range of quality variations of the vowels. Fig. 11 presents the scattered plot of the first and second formant values of 60 tokens of Baram vowels (6 vowels ×10 tokens per vowel = 60 tokens) taken from a running text produced by a female speaker of age 72.

It shows that all vowels are not equally stable in quality in different tokens. [i], [u] and [a] are the most stable vowels in Baram. Similarly, [e] and [o] are relatively less stable whereas [ə] is the least stable in the scatter plot.

Quantal Theory[3] of speech perception explains that there are quantal regions in the vowel space and the vowels produced from any point within its quantal region is perceived to be the same but if the production even slightly crosses the quantal region, it is perceived to be a different sound. The scatter plot presents the quantal regions of the vowels in the vowel space.

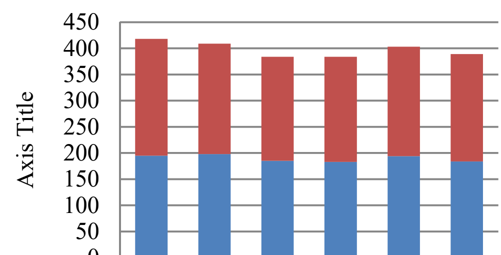
The front and high region in the vowel space is the quantal region for the production of [i]. The back and high region in the vowel space is the quantal region for the production of [u] but it is not as high as that of [i]. Similarly, the front and mid part of the vowel space is the quantal region for [e], back and mid region for [o], and central and low region for [a]. The distribution of [ə] is diffusive. It distribution is in the mid-central, mid-back and low-back regions.

The scatter plot also reveals the levels of stability of the Baram vowels. [i], [u] and [a] are the most stable vowels and show the nature of the quantal vowels. Relatively [e] and [o] are stable but not as stable as the previous three. In comparison, [e] is more stable than [o]. Of all, [ə] is the most unstable vowel and it fluctuates in the wide area of central-back and mid-low regions. Chalise (2015) reveals the status of the [ə] in Baram phonology as "It is a confusing rhyme in Baram because some of the native speakers replace it with *-a-* in most of the situations but it occures in some instances. It is difficult to say whether it is a stable rhyme in the language or not but its distribution is relatively higher in the language. It is very difficult to get a true minimal pairs to show the contrastive distribution between /a/ and /ə/.

4.2 The intrinsic F0

It has been identified that the intrinsic fundamental frequency of a vowel is correlated to its height. In the identical environment phonetically higher vowels have a propensity to have higher F0 (Harrington, 2010: 87). It is obvious that when the vowel height increases the value of F1 decreases. F1 decreases when the size of the tube behind the point of constriction increases. To increase the size of the back tube we have to stretch the walls of the tube to expand it. While we stretch the walls of the tube, there increases tension in the vocal folds and the rate of vibration of the vocal folds gets slightly increased. So the F0 of the vowels correlates with the high of the vowels.

For measuring F0 of the vowels the words containing the vowels in the identical environment were recorded from one male and one female speaker of similar age. The measurements were taken for single tokens using spectrograms produced using PRAAT. The Baram vowels support the idea that the F0 of the high vowels is higher than that of the low vowels as in Figure 12. But the F0 of [e] and [o] is slightly higher than that of their corresponding higher vowels and it needs further investigation.



	i	e	ə	a	o	u
female	223	211	199	201	209	205
male	195	198	185	183	194	184

Figure 12: F0 of the different Baram vowels

4.3 The diphthongs

However, Kansakar et al. (2011c) has given a sketch of 10 possible vowel sequences in Baram with examples and classified them in to initial, medial and final sequences. There is no claim about whether they are diphthong or not. The proposed possible vowel sequences are: [ei], [əi], [ai], [oi], [ui], [eo], [eu], [əu], [au] and [ou].

While analyzing 3676 dictionary entries, in Kansakar et al. (2011b), I could find only 5 diphthongs viz. [ei], [əi], [ai], [oi] and [ui] in the native Baram morphemes. In the Nepali loans the diphthongs of Nepali have been borrowed. It

[3] Quantal theory states that some sounds are naturally easier to produce and such sounds are commonly found in the languages and are more stable in articulation.

means that the second target of the Baram diphthongs is [i] so they all are closing diphthongs directed towards high-front of the vowel space.

Among five tokens produced by a female speaker, one token containing one diphthong was taken for the analysis of its formant structure. For formant structure of each diphthong, formant values were measured at four points on their trajectories (beginning and end, and two equidistant points between them). Figure 13 presents the trajectories of the five different Baram diphthongs.

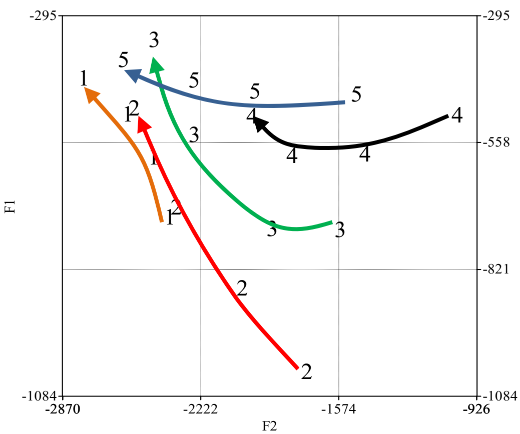


Figure 13: The Baram diphthongs

[Note: 1=ei, 2=ai, 3=əi, 4=oi and 5=ui]

The four points in the figure represent the four points of trajectory of each of the diphthongs. The trajectories of the diphthongs are curves rather than straight line. It means that the movement of the tongue from the first target of the diphthong to the second target is not straight.

The next remarkable point is that the speakers try to normalize the duration of the transition from the first target to the second target of the diphthongs as a result there is displacement of the target point(s) in diphthongs in comparison to the target points of the corresponding monophthongs. The distance between [e] and [i] is very short whereas the distance between [a] and [i] is relatively very long. While producing diphthong [ei] the distance is increased by lowering and centering the first target and raising and fronting the second target. Similarly, while producing [ai], the first target is fronted and raised and the second target is lowered and centered as in Figure 13.

5 Summary of the findings

Baram has 21 consonant phonemes in its native words. There are 9 plosives, 3 affricates, 2 fricatives, 3 nasals, 1 lateral, 1 trill and 2 semivowels. The plosives contrast in terms of three places of articulation (bilabial, dental/alveolar and velar), voicing (voiced and voiceless) and aspiration (aspirated and unaspirated). The affricates are alveolar and contrast in voicing and aspiration. The nasals are all voiced and contrast in place of articulation (bilabial, alveolar and velar). The lateral and trill are voiced and are alveolar. The semivowels are voiced and one is bilabial and another is velar.

The plosives have gone under the process of weakening and spirintization and deaspiration are commonly found. Because of this phenomenon and lack of data, plosives have been characterized in respect of VOT. All the voiced plosives are characterized by full voicing which is also called negative VOT and voiceless plosives are characterized by positive VOT. The VOT in aspirates is nearly three times higher than in their unaspirated counterparts. VOT gradually increase from bilabial to velar which highly significant in aspirates.

In fricatives, [s] is a strong sibilant with high peak frequency nearly 7500Hz. There is confusion whether the glottal fricative is [h] or [ɦ]. In word initial position, there is voicelessness for a very short period of time and the sound overlays the following vowel causing it breathy [4] and in intervocalic position, we can see the trace of it as breathiness over the vowels. The affricates have short closure duration of around 50 ms and followed by 15-30 ms rise time. The friction duration is longer in aspirate and shorter in inaspirate.

[4] A breathy sound is produced with wider glottis along with the vibration of the vocal folds as a result there is noise componant overlaid.

The nasals are characterized with respect to nasal formants and anti-formants. The first nasal formant value increases from bilabial to velar and the first anti-formant value follows the same pattern, too. The lateral is similar to nasal regarding the formant structure but the formants are stronger in the lateral but because of the oral occlusion there is abrupt decrease of energy level above 3100 Hz. The trill has one to three succession of taps during the production. The energy level is lower during the contact phase and higher during the open phase.

The glides have very low first formant and the main difference is between the F2 and F3 values which are significantly higher in [j] than in [w]

There are six basic vowels [i], [e], [ə], [a], [o] and [u]. The first two formants of the vowels are sufficient to acoustically characterize them. Plotting of the formant values of the vowels in F1XF2 plane shows that out of the Baram six basic vowels [i] and [u] are high, [e] and [o] are mid and [ə] and [a] are low; and [i] and [e] are front, [ə] and [a] are mid and [u] and [o] are low. Of them, [o] and [u] are rounded. But the position of [ə] is always fluctuating from [a] to [o] and it is an unstable vowel and does not have quantal nature in Baram. Similarly, the intrinsic F0 of the vowels also a cue to identify the height of the tongue of the vowels in Baram as high vowels have higher F0 than the low vowels

There are found only five diphthongs in the native Baram morphemes. In all of them the second target is [i]. So the diphthongs in Baram are closing diphthongs heading towards the high-front of the vowel space. The acoustic analysis has found that the speakers try to normalize the duration of the transition from the first target to the second target of the diphthongs although the targets are very close in some diphthongs and far in some others. This is managed by dislocation of the targets from their locations in the corresponding monophthongs.

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