A free refereed web journal and archive devoted to the study of the languages of the Himalayas

Himalayan Linguistics

An Acoustic Study of Bodo Vowels

Priyankoo Sarmah

Leena Dihingia

Dimple Choudhury

Indian Institute of Technology Guwahati

ABSTRACT

This paper provides an acoustic analysis of Bodo vowels. While it is agreed that Bodo has six vowels, the nature of the vowels is not quite clear. For instance, the non-peripheral vowel of Bodo is described as [ə], [ɨ] or [ɯ], in different descriptions of the vowel system of the language. Considering this, this paper provides a comprehensive analysis of the Bodo vowels and characterizes the sixth, non-peripheral vowel of the language. This study also provides a dispersion theory based comparison of the Bodo vowel system in relation to other vowel systems across languages. Results from acoustic and statistical tests conducted on Bodo vowels reveal that the sixth, non-peripheral vowel is a mid, central, unrounded vowel transcribed as /ə/. However, in case of diphthongs beginning with /ə/, the vowel is almost as high as /i/ or /u/. Hence, the six vowel system of Bodo consisting /i, u, e, ə, o, a/ is the most commonly observed six vowel system across world's languages.

KEYWORDS

Bodo, vowels, Bodo-Garo, vowel dispersion, Tibeto-Burman

This is a contribution from *Himalayan Linguistics, Vol. 14(1): 20–33.*
ISSN 1544-7502

Himalayan Linguistics, Vol. 15(1). © Himalayan Linguistics 2015
ISSN 1544-7502

An Acoustic Study of Bodo Vowels[1]

Priyankoo Sarmah
Leena Dihingia
Dimple Choudhury
Indian Institute of Technology Guwahati

1 Introduction

Bodo is a Tibeto-Burman language of the Bodo-Garo subfamily of languages spoken by 1,350,478 people primarily in the states of Assam and Meghalaya in North East India (NEI)[2]. While not much linguistic work is available on Bodo, there has been some work on family resemblance among the Bodo-Garo languages (Joseph and Burling, 2001; Basumatary, 2005), tones of Bodo (Joseph and Burling, 2001; Sarmah, 2004) and on the phonological inventory of the Bodo language (Basumatary, 2005; Burling, 2013). Considering the various conflicting views about the vowel system of Bodo, this paper aims at providing an acoustically based argument for the choice of IPA symbols for the vowels of Bodo. This work reports the results of acoustic studies on vowels in the eastern variety of Bodo recorded from 12 speakers in the field. This paper aims at (a) providing a comprehensive acoustic analysis of the vowels as spoken by the eastern Bodo speakers (b) characterizing the sixth vowel in Bodo and (c) analyzing how the vowel system of the language stands in comparison to the vowel systems seen across the world's languages specifically in relation to the arguments provided in Liljencrants and Lindblom (1972).

1.1 Bodo language and its classification

The name Bodo is an old English approximation of the name of the language (Jacquesson, 2002) and in the recent years authors have resorted to at least two alternative versions of the language name namely, Boro and Baro. However, in this work, we have decided to use the most common spelling of the language, Bodo, without any prejudice to the alternative spellings.

---

[1] The authors would like to thank the two anonymous reviewers who provided comments and suggestions to an earlier version of this paper.

[2] Data from 2001 census of India, retrieved from the website of the Office of the Registrar General and Census Commissioner of India at http://www.censusindia.gov.in, on August 20, 2014.

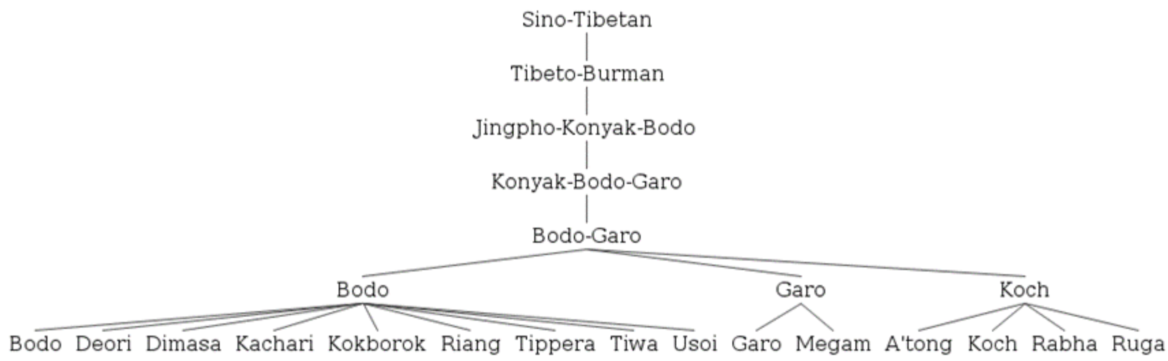

Figure 1: Family tree of the Bodo-Garo languages (showing only the relevant branches)

Bodo is considered to be one of the languages belonging to the Bodo-Garo subfamily of languages. Burling (2003) classified Bodo as a member of the Bodo-Konyak-Jingphaw subfamily of the Tibeto-Burman languages. Similarly, van Driem (2001) proposes the term Brahmaputran to refer to the languages of the Bodo-Garo, Konyak and Luish languages. Nevertheless, both Burling (2003) and van Driem (2001) consider Bodo as belonging to the Bodo-Garo subfamily of the Jingpho-Konyak-Bodo family of languages. The family tree of Bodo-Garo languages is shown in Figure 1 with only the relevant branches expanded.

1.2 Varieties of the Bodo language

Bodo is known to have at least two varieties depending on the geographic distribution of its speakers. Bhattacharya (1977) has considered at least four dialect areas of the Bodo language in Assam: a) the northwest dialect area: covers the northern regions of Goalpara and Kamrup districts. The North-Goalpara and the North-Kamrup are the two forms of speech of sub-dialects that belongs to this dialect area, b) the south-west dialect area: covering South Goalpara, Garo Hills and a few places of South Kamrup; c) the North Central Assam dialect area: comprising the district of Darrang, Lakhimpur and a few places of NEFA (now Arunachal Pradesh) and d) the Southern Assam dialect area: covering Nowgong, North Cachar and Karbi Hills, Cachar and its adjacent areas. In Basumatary (2005) three major regional dialects of Bodo in Assam are mentioned, namely, e) the Western Bodo dialect (Swnabari): covering the districts of Kokrajhar, Dhubri and Chirang; f) the Eastern Bodo dialect (Sanzari): comprising the district of Baksa, Kamrup (the northern part of the Brahmaputra Valley) and mainly the Udalguri dialect and g) the Southern Bodo dialect (Hazari): comprising the district of Goalpara and Kamrup district. The distinctions in the varieties of Bodo are phonological and lexical. Some of the phonological variations observed between the North Kamrup and North Goalpara varieties are shown as in Table 1.

Alteration	North Goalpara	North Kamrup	Gloss
ō – a	phōy	phay	come
s – kh	saw	khaw	burn
rs – kh	harsa	hakha	caste Hindu
d/rd – r	geded/ gederd	geder	big

Table 1: Phonological alterations in two varieties of Bodo (Bhattacharya, 1977)

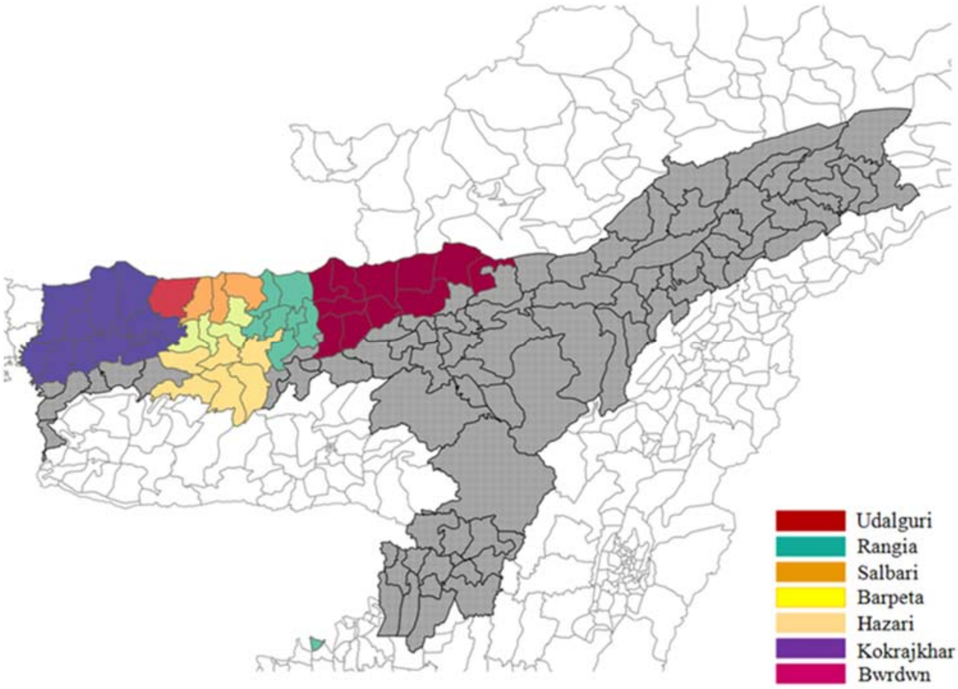

Figure 2: Map showing the distribution of Bodo varieties on a map of Assam (shaded area)

Hakasam (2013) identifies another distinct variety of Bodo called Magra, that is spoken on the south bank of the Brahmaputra between Gumi-Chhaygaon and Krishnai. This particular variety also has voiced aspirated stops, unlike other varieties of Bodo. He also notes that the [ɯ] vowel of standard Bodo is replaced with [i], [u], [o] or [a] in this variety. In Magra variety, diphthongs [ou], [ao] and [ɯi] are also reduced to monophthongs as [u], [o] and [i], respectively.

Variety	Sub varieties
Sanzari	*Rangia*
	Salbari
	Barpeta
Swnabari	*Bwrdwn*
	Kokrajhar
	Udalguri
Hazari	-

Table 2: Varieties and their sub varieties of Bodo

While collecting data for this research, several facts about the dialectal variations were revealed. Firstly, while talking to our subjects we realized that Bodo speakers do recognize three broad varieties of the language mentioned in Basumatary (2005). At the same time, it was revealed to us that these variations do not follow strict geographical boundaries. Three different varieties may be spoken in three contiguous villages (due to migration, most of the times). On the other hand, as the speakers of one variety may practice a different religion from speakers of the other variety, many a times, a Bodo variety gets perceived as a representative of a group of people practicing a particular religious faith. Our consultation with the speakers revealed that the three varieties can be divided into sub-varieties that can be distinctly identified by the native speakers. In consultation with our Bodo consultant we managed to distinguish these varieties and sub varieties as shown in Table 2. Further, we plotted the distinct areas of Bodo varieties as shown in Figure 2.

1.3 Vowels in Bodo

As far as the number of monophthong vowels is concerned, all previous works agree that Bodo has a six-vowel system. However, there is disagreement regarding the quality of vowels in Bodo. Bhattacharya (1977) considers Bodo as having an inventory of /i u e a o ō/ vowels. In this work, /ō/ is described as an unrounded vowel that may spread from half-close to close, central to back and overlaps with /u/ and /o/. He also mentions that the nearest phoneme to /ō/ in IPA is /ɐ/. Basumatary (2005) considers Bodo as having an inventory of /i u w e o a/. In this case he considers the vowel /w/ as a high, back, unrounded vowel[3]. He also mentions Bodo having eight diphthongs, namely, /ui wi wu oi iu au eu ai/. Burling (2013) describes the language as having six vowels. They are /i u e o a ɯ/. According to him, the sixth Bodo vowel is more central than the corresponding vowel in Rabha-neither as far back nor as high, but it is clearly cognate to Rabha /ɯ/. It seems to be used more freely in open syllables in Bodo, than the corresponding vowel in Rabha. Considering the disagreement regarding the status of the sixth vowel in Bodo, in this work we hope to arrive at an account of the Bodo vowels derived from acoustic data and analysis.

In one of the acoustic studies, Sarma *et al* (2012) agree with a vowel inventory size reported in Bhattacharya (1977), Basumatary (2005) and Burling (2013). However, in terms of the sixth vowel in Bodo (claimed to be /ɯ/ in Burling, 2013), Sarma *et al* (2012) is of the opinion that it is more akin to a high, central vowel /ɨ/. Moreover, they demonstrate that in Bodo, /ɨ/ and /u/ have higher variations and a tendency to overlap. Hence, the status of the sixth vowel is somewhat unclear in Bodo and the current work tries to resolve the uncertainty regarding it.

1.4 Vowel inventories in world's languages

According to Adaptive Dispersion theory proposed by Liljencrants and Lindblom (1972), vowel system size and relative spacing between peripheral vowels are directly related. As the number of vowels in a language increases, the separation of vowels in that space should be optimized. However, Livijn (2000) argues that unless the number of vowels in the system is greater than eight, the distance between peripheral vowels need not increase. Liljencrants and Lindblom (1972) use the principle of maximal separation to predict that a six-vowel system should contain three high vowels, /i ɨ u/. However, in Schwartz et al. (1997), it is shown that typological evidence does not support this prediction. In a phase space simulation of vowel systems it is simulated that the most favorable six vowel system will be the one with /i ɛ e o u ɔ/. In the same study, based on the data from UPSID (*UCLA Phonological Segment Inventory Database,* Maddieson, 1984), it was shown that the most frequently occurring six vowel system in the world is /i e o ə u a/, seen in 48%

[3] The /w/ vowel mentioned in Basumatary (2005) is actually the high, back, unrounded vowel /ɯ/ in IPA. It seems like Basumatary used the 'w' for typographical simplicity.

of the six vowel systems; followed by /i ɨ u e o a/ and /i u e ɛ o ɑ/, each observed in 22% of the six vowel systems. Considering such cross-linguistic patterning of vowels, the earlier proposed vowel inventory for Bodo as /i u e o a ɯ/ or /i u e ɐ o a/ certainly needs more careful investigation. Hence, in the current work, our focuses are a) to provide an acoustically supported description of Bodo vowels and b) to examine the extent to which Bodo vowel system conforms to the six vowel systems observed in Maddieson (1984).

2 Methodology

2.1 Speakers

As mentioned in Section 1.2, Bodo has at least three known broad varieties and among them the eastern variety spoken in the Udalguri town area was chosen for this study. Data was collected from 12 speakers from this area (7 male and 5 female speakers). The speakers were in the 26 to 50 age group at the time of data collection. Almost all speakers can speak four languages, namely, Assamese, Bodo, English and Hindi. All speakers use the Udalguri subvariety of Bodo in their daily life. While all 12 speakers were recorded producing the list of monosyllables, disyllables were included in the wordlist for collection only after the first three speakers were done recording. Hence, 5 male and 4 female speakers were recorded producing disyllables. The distribution of the resulting number of 1643 tokens is shown in Table 3.

Monophthongs						Diphthongs			
i	e	u	o	a	ə	ai	ao	eo	əi
102	237	188	204	509	38	198	50	67	50

Table 3: Number of tokens recorded for vowels in Bodo

2.2 Materials and recording

In our initial consultation with informants, the minimal sets presented in (1) and (2) emerged for Bodo monophthongs. These two sets along with other words with Bodo monophthongs and diphthongs constituted our wordlist for recording.

(1) /zi/ *tear, which*
/ze/ *net*
/za/ *eat, become*
/zo/ *sit, together, disjoin*
/zu/ *packet*
/zə/ *sting, kick*

(2) /p^hi/ *wet*
/p^he/ *be mild, be introduced, be intoxicated*
/p^ha/ *along with*
/p^ho/ *pluck, stem*
/p^hu/ *uproot*
/p^hə/ *sow*

The speakers were recorded reading a list containing 78 lexical items in total. Each word was recorded at least two times[4] in the sentence frame - "*I* ___ *said*"([aĪ ___ buĪdɨĪmɨn])[5]. All

[4] In case of some speakers there were more than two iterations of the words.

[5] In this case, we are following the transcription convention of Sarma *et al* (2012) for Bodo vowels.

iterations were subjected to acoustic analysis. While preparing the datalist it was ensured that the list contained words frequently used in daily conversation. The list contained words with Bodo monophthongs and diphthongs in monosyllables and disyllables. The data for disyllables did not contain all monophthongs of Bodo. Hence, in this study, vowels produced in monosyllables are analyzed. While Basumatary (2005) mentions that there are eight diphthongs in Bodo, in the present work our data consisted of only four of the most commonly occurring diphthongs. The analysis of those four diphthongs is also presented in Section 3.2. Data from the speakers was recorded in the field, in a noiseless environment. Data was captured with an Audio-Technica AT 2020 USB microphone connected to a laptop computer.

2.3 Acoustic and statistical analysis

Acoustic analysis was done in Praat 5.3 (Boersma, 2001). For monophthongs, the first three formants (F1, F2, F3) were calculated at vowel midpoint using the Burg algorithm. For diphthongs, the first three formants were calculated at 30% and 70% of the onset of the vowels, in order to capture their dynamic nature. The Hertz values were transformed to Mel using Praat's inbuilt function, HertzToMel that uses the formula in (3).

(3) $x = 550 \ln (1 + x / 550)$

After Mel values for formants were extracted, they were normalized for speaker variations using the Lobanov normalization method in NORM (Thomas & Kendell, 2007). Normalized values were used to plot formants of vowels for group means with one standard deviation ellipses. In order to test Dispersion Theory prediction of optimal peripheral vowel separation (Liljencrantz & Lindblom, 1972) in Bodo, two-dimensional Euclidean Distances between the vowel categories were measured. Apart from that, to confirm gender and vowel type effects we conducted one-way Analysis of Variance (ANOVA) tests on the analyzed data.

3 Results

In Section 3.1 and 3.2 to follow, we report the results of acoustic tests conducted on the Bodo data. The data collected for this study included both monosyllables and disyllables. While in monosyllables we had the full vowel inventory of Bodo available, in case of disyllables, we could only collect data for a restricted type of vowels. In Sarmah et al. (2013) it was observed that the vowels in initial syllables of monosyllables tend to be reduced due to the short duration of the initial syllable. Hence, to determine vowel quality, we only included data from monosyllables in our analysis.

3.1 Formant frequencies

As mentioned in Section 2.3, vowel formants were calculated separately for male and female speakers from monosyllables. Formant frequencies for the first three formants were normalized and data for the first and the second formants (F1 and F2) were plotted on an F1-F2 plane using NORM (Thomas & Kendell, 2007). Figure 3 and Figure 4 are the F1-F2 representation of average vowel formants with one standard deviation ellipses for female and male speakers respectively. Table 4 and

Table 5 shows the non-normalized F1, F2 and F3 formant values for Bodo vowels for female speakers and male speakers respectively. While Figure 3 and Figure 4 and the formant values in Table 4 and Table 5 indicate distinctiveness of Bodo vowels, we decided to conduct one-way ANOVA tests separately on F1, F2 and F3 values for each Bodo vowel separated into subgroups of gender of the speakers. The matrices provided in Table 6 and Table 7 show the significance of interaction between vowel types and formant values.

In order to see how formant frequencies and vowels interact in Bodo, we conducted one-way ANOVA tests on F1, F2 and F3 for male and female speakers separately. For both male and female speakers, the results of the ANOVA test indicated strong vowel type and formant frequencies interaction. For all the first three formants analyzed in this study, statistically significant interaction with vowel type was noticed.

A subsequent Bonferroni post-hoc test was unable to establish any systematic relationship between F3 and vowel types at least in the data examined for Bodo in this paper. In case of F3, we noticed that the F3 for vowel /a/ was significantly different from the F3 of vowels /e/ and /i/ in case of both male and female speakers. The F3 for the vowel /i/ differed significantly from /o/ and /u/ for both male and female speakers. In case of the vowel /ə/, there was no significant difference from the F3 of any of the vowels in Bodo inventory. In case of F2 we noticed systematic patterns of interaction among vowels in both male and female speakers. We noticed that except /ə/ and /a/, all vowels interacted with each other in a significant way. This implies that in terms of vowel backness, all Bodo vowels are significantly different from each other. However, the backness of /a/ and /ə/ vowels is not different significantly. In case of F1 again we noticed consistent patterns of interaction in male and female speakers. In case of both male and female speakers, F1 was significantly different in all vowel pairs except in the /u/–/ə/ pair.

As mentioned in Section 2.3, we calculated the Euclidean distances between vowel pairs in the Bodo vowel inventory separately for male and female speakers. The Euclidean distances between vowel pairs are presented in Table 8 and Table 9 for female and male speakers respectively. In case of the three peripheral /i/, /u/ and /a/, as expected we see the biggest differences. The smallest differences are observed in case of the /u/–/o/ pair in both male and female speakers of Bodo. Average Euclidean distance and overall vowel space pairs differed by gender. While for male speakers the average Euclidean distance is 232 mels, for female speakers it is 251 mels.

In this study we are particularly interested in the status of the sixth vowel of Bodo. Hence we looked at the distribution of the vowel /ə/ in Bodo vowel space. According to Liljencrants & Lindblom (1972), in any language peripheral vowels /i/ and /u/ would have similar values as they will be maximally in the vowel space to increase salience in perception. However, in subsequent modifications to his theory of adaptive dispersion, Lindblom emphasized on 'sufficient perceptual contrast' and not on 'maximal contrast'. Hence, he observes a tradeoff between articulatory economy and perceptual distinctiveness. This tradeoff between articulatory economy and perceptual distinctiveness can be noticed in the data for high vowels presented in Yang (1996). As American English has only two high peripheral vowels, /i/ and /u/ the perceptual difference between these two vowels is 474 mel. Korean has three high vowels in its vowel inventory, /i/, /ɨ/ and /u/ which results in an increased F2 range and subsequently an increased perceptual distance between /i/ and /u/ vowels of 685 mel.

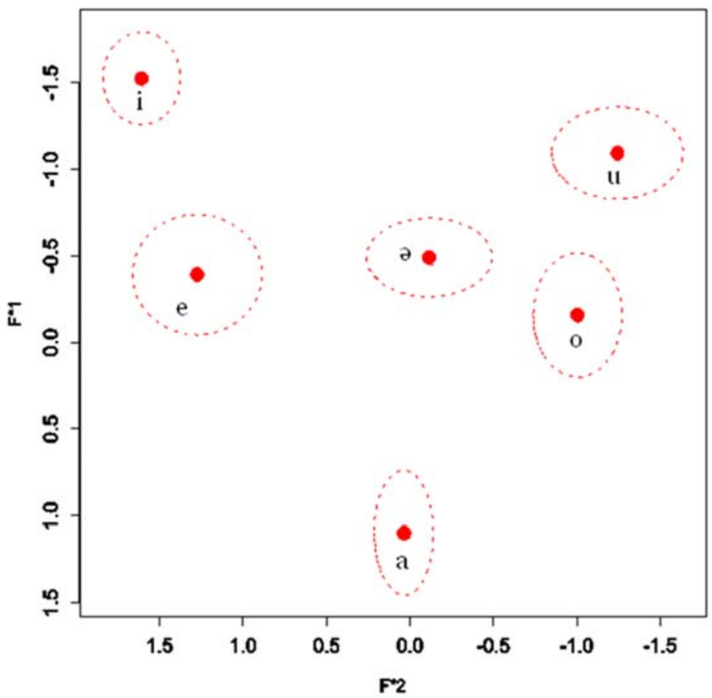

Figure 3: Average Lobanov normalized F1-F2 values for female Bodo speakers

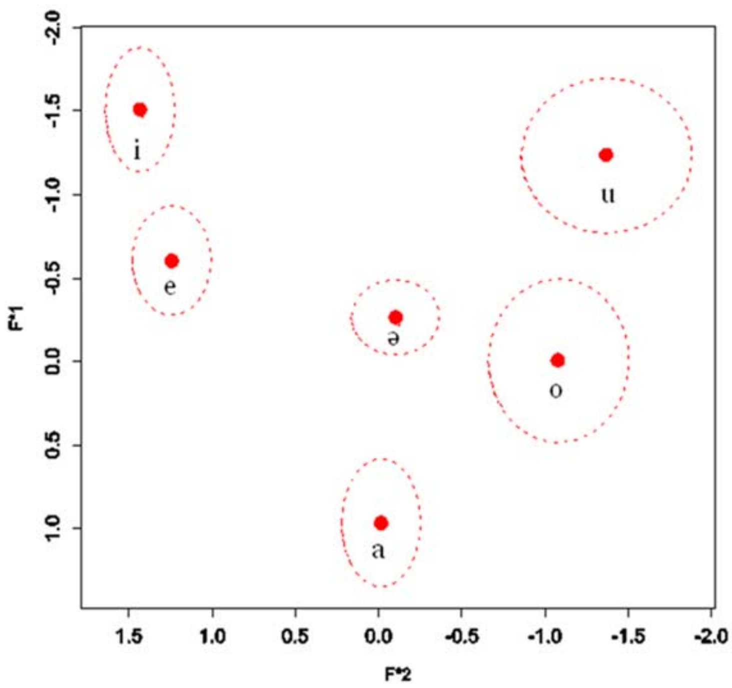

Figure 4: Average Lobanov normalized F1-F2 values for male Bodo speakers

Vowel	F1 (SD)	F2 (SD)	F3 (SD)
i	242 (22)	955 (40)	1046 (44)
ə	336 (22)	714 (55)	1019 (20)
u	288 (34)	542 (60)	990 (30)
e	362 (39)	907 (66)	1022 (36)
o	386 (37)	576 (45)	993 (46)
a	529(46)	726 (30)	985 (70)

Table 4: Non-normalized formant values in Mel for female speakers with standard deviation

Vowel	F1 (SD)	F2 (SD)	F3 (SD)
i	228 (19)	895 (23)	1032 (45)
ə	290 (15)	704 (38)	954 (9)
u	271 (39)	497 (70)	962 (29)
e	324 (26)	853 (27)	973 (46)
o	377 (48)	534 (60)	958 (50)
a	466 (36)	678 (25)	946 (64)

Table 5: Non-normalized formant values in Mel for male speakers with standard deviation

Female	F1					F2					F3				
	e	i	ə	o	u	e	i	ə	o	u	e	i	ə	o	u
a	*	*	*	*	*	*	*	!	*	*	*	*	!	!	!
e		*	*	*	*		*	*	*	*		*	!	!	!
i			*	*	*			*	*	*			*	*	*
ə				*	!				*	*				!	!
o					*					*					!

Table 6: Significance matrix for formant frequencies of female speakers of Bodo[6]

[6] In Table 6 and Table 7, a "*" represents statistical significance, while ! indicates non-significance.

Male	F1					F2					F3				
	e	i	ə	o	u	e	i	ə	o	u	e	i	ə	o	u
a	*	*	*	*	*	*	*	!	*	*	*	*	*	!	!
e		*	*	*	*		*	*	*	*		!	!	*	*
i			*	*	*			*	*	*			!	*	*
ə				*	*				*	*				!	!
o					*					*					!

Table 7: Significance matrix for formant frequencies of male speakers of Bodo

	i	ə	u	e	o
ə	260				
u	402	162			
e	121	211	372		
o	396	136	107	334	
a	371	207	308	261	208

Table 8: Euclidean distance between vowel pairs in Bodo for female speakers

	i	ə	u	e	o
ə	201				
u	391	198			
e	108	152	349		
o	398	198	111	328	
a	325	183	263	224	176

Table 9: Euclidean distance between vowel pairs in Bodo for male speakers

In case of the data presented for Bodo, we claim that the sixth vowel in Bodo is a mid, central, unrounded vowel /ə/. From Table 6 and Table 7 it is clear that the F1 of the /ə/ vowel and the /u/ vowel of Bodo are not statistically significantly different in the data we analyzed. However, in terms of the vowel plots in Figure 3 and Figure 4 it is clear that in terms of tongue advancement, the vowel /ə/ is as central, and in terms of tongue height it is a close-mod vowel.

Analysis of the first three formant frequencies and subsequent statistical tests conducted on them shows that in Bodo; at least the first two formants of vowels are distinct for each vowel. In a recent study, it was reported that Rabha, one of the Bodo-Garo languages, rely on F3 to distinguish between some of its vowels (Sarmah and Redmon, 2013). Cross linguistically it has been noticed that while F1 and F2 are invariably related to the height and backness of vowels, F3 can be useful in the estimation of perceptual dispersion. Becker-Kristal (2010) reports that F3 contributes to the perception of frontness in fronter vowels (front unrounded, front rounded and high to mid central unrounded vowels). The same study also reports that in front vowels, F3 behaves differently from other vowel types, and increases, rather than decreases, with decrements in F1. From the Lobanov normalized plots of F1-F2 values in Section 3.1, it is clear that Bodo vowels maintain sufficient perceptual distance from each other so that listeners can easily discriminate between them. As F1 and F2 serve as sufficient acoustic cues for vowel perception, Bodo probably does not need another cue (such as F3) for maintaining perceptual distinctiveness.

3.2 Bodo diphthongs

In the current study, we have analyzed four diphthongs of Bodo that appeared in monosyllables of our data[7]. Even though the diphthongs we analyzed are only half of the total number of diphthongs that appear in Bodo, we decided to include our analysis as we considered the results to be of importance in arguing for a higher than normal mid, central vowel almost akin to high, central vowel /ɨ/ in Bodo. Out of the eight Bodo diphthongs described in Basumatary (2005) namely, /ui wi wu oi iu au eu ai/[8],only /əi eo ai ao/ were analyzed in this study. The diphthong /əu/ that occurs in Basumatary's data immediately confirms our claim that the /w/, frequently occurring in literature on Bodo vowels, cannot be a high, back, unrounded vowel /ɯ/ as it is not possible for a vowel to change its roundness feature to become a dynamic vowel. Nevertheless, we wanted to examine the four diphthongs that occurred in our data namely, /əi eo ai ao/. The dynamic formant patterns for these diphthongs are presented in Figure 5 and Figure 6 for female and male speakers respectively. Figure 5 and Figure 6 represent averaged data from all speakers in the left panel. The right panel represents dynamic formant data from individual speakers. As one would assume for /eo/, the formants begin at the position for the vowel /e/ and move to the position of the vowel /o/. The onset and offset values in this case are almost the same as the values for the individual monophthongs, represented in Figure 3 and Figure 4. Similarly, the onset of the diphthong /ai/ is at the place where the monophthong /a/ is located in Figure 3 and Figure 4. However, the offset of the diphthong /ai/ is not as low in F1 as the F1 for the monophthong /i/ is. In case of the diphthong /ao/, however, the onset of the diphthong is a little more back than the monophthong /a/ itself. However, the offset of the diphthong /ao/ is as high as the prototypical /o/ as seen in Figure 3 and Figure 4.

In case of the diphthong /əi/ we notice that the onset is always at the center on the F2 domain. In no way does the onset F2 correspond to the F2 of the high, back vowel. In case of F1 values, we notice that the onset of the diphthong /əi/ is higher than mid vowels. However, the offset value of the diphthong is almost as the value for the monophthong /i/. It can be concluded from the formant movements for the diphthong /əi/ that the onset value is not similar to the prototypical values for high, back vowels such as /u/ or /ɯ/

[7] In case of diphthongs, data was collected from only nine speakers.

[8] The diphthongs /wi/ and /wu/ described in Basumatary (2005) are written as /əi/ and /əu/ in our transcription convention.

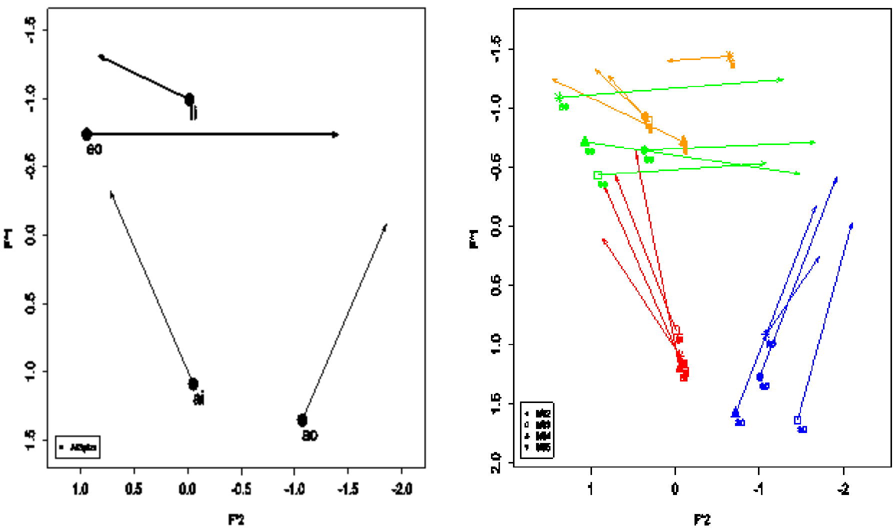

Figure 5: Four Bodo diphthongs produced by four female speakers

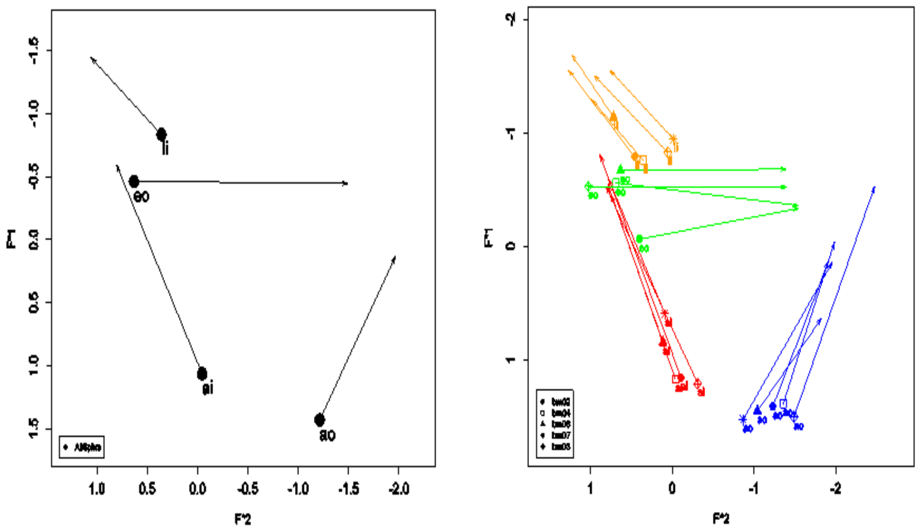

Figure 6: Four Bodo diphthongs produced by five male speakers

4 Conclusion

This paper reports the results of an acoustic analysis of the vowels of Bodo as spoken by the speakers of the Udalguri (eastern) variety. Acoustic analysis was conducted on six Bodo monophthongs and four diphthongs in this study. As far as the sixth vowel of Bodo is concerned, from the normalized F1-F2 plots it is clear that it is neither as low as a /ɐ/ nor as back as a /ɯ/ as claimed in Bhattacharya (1977), Basumatary (2005) and Burling (2013). Hence, we consider it as a mid, central, unrounded vowel, transcribed in IPA as /ə/. However, it has also been noticed that the sixth vowel closely resemble the vowel /i/ of Bodo in terms of vowel height. Again, while analyzing diphthongs it was seen that the vowel /ə/ is almost as high as /i/ and /u/. As reported in Basumatary (2005), Bodo has a diphthong /wu/. As diphthongs are dynamic vowels changing their backness and height properties, existence of diphthong /wu/ that changes only in the roundness feature is a theoretical impossibility. Hence, we conclude that Bodo vowel inventory consists of six vowels namely, /i, u, e, ə, o, a/ where the vowel /ə/ is a higher than a normal mid, central vowel.

From the data for perceptual distances presented in Table 6 and Table 7 we notice the distance between the peripheral high vowels /i/ and /u/, D_{iu} in Bodo is roughly 400 mel. Compared to that Korean has a D_{iu} of 685 mels and American English has a D_{iu} of 474 mels (Yang, 1996). In terms of F1 space, we noticed that for Bodo male D_{ia} is 325 mels and female D_{ia} is 371 mels. Bodo male D_{ua} is 263 mels and for female it is 308 mel. Compared to that Korean male D_{ia} is 560 mels but that of the Korean female vowels is 654 mel. Korean male D_{ua} is 416 mels while that of the female group is 603 mels (Yang, 1996). Hence, it can be concluded that as Bodo is a six-vowel system, it does not need to increase the perceptual space between peripheral vowels. Compared to Bodo, Korean and American English vowel systems reported in Yang (1996) has 10 and 12 vowels in their systems respectively. Hence, an increase of perceptual space between peripheral vowels is noticed as predicted by Liljencrantz & Lindblom (1972) and Livijn (2000).

References

Basumatary, Phukan Chandra. 2005. *An introduction of the Boro language*. New Delhi: Mittal Publication.

Becker-Kristal, Roy. 2010. *Acoustic typology of vowel inventories and Dispersion Theory: Insights from a large cross-linguistic corpus*. Ph.D. Diss, University of California at Los Angeles.

Benedict, Paul King. 1972. *Sino-Tibetan: A conspectus*. Columbia University: Cambridge University Press.

Bhattacharya, Pramod Chandra. 1977. *A descriptive analysis of the Boro language.* Guwahati: Gauhati University Press.

Boersma, Paul. 2001. "Praat, a system for doing phonetics by computer". *Glot International* 5:9/10, 341-345.

Burling, Robbins. 2003. "The Tibeto-Burman Languages of Northeastern India". In: Graham Thurgood and Randy J. LaPolla (eds.), *The Sino-Tibetan languages*, 169-192. London & New York: Routledge.

Burling, Robbins. 2013. "The 'sixth' vowel in the Boro-Garo languages". In: Gwendolyn Hyslop, Stephen Morey and Mark Post (ed.s), *North East Indian Linguistics* 5: 271-280. Foundation Books.

Hakasam, Upen Rabha. 2013. "*Boro bhaxar magra upobhaxa:eti porisoymulok adhyoyon*" (tr. The Magra dialect of Bodo: An Introductory Study). In *Asamiya aru Asamar Jati-Janagosthio: Prasanga-Anusanga*, 140-150. Dhemaji: Kiran Prakashan.

Jacquesson, François. 2002. "An approach to Comparative Bodo-Garo phonology". Paper presented at *ICSTLL* 35. Arizona State University, Tempe, Arizona.

Joseph, U.V.; and Burling, Robbins. 2001. "Tone correspondences in Bodo-Garo languages". *Linguistics of Tibeto-Burman Area* 24.2: 41-55.

Liljencrants, J.; and Lindblom, B. 1972. "Numerical simulation of vowel quality contrasts: the role of perceptual contrast". *Language* 48.4: 839-862.

Livijn, P. (2000). "Acoustic distribution of vowels in differently sized inventories: Hot Spots or Adaptive Dispersion?" XIIIth Swedish Phonetics Conference Proceedings, 93-96.Skövde, Sweden.

Maddieson, I. 1984. *Patterns of sounds.* Cambridge: Cambridge University Press

Sarma, Mousmita; Sarmah, Priyankoo; and Prasanna, S.R.M. 2012. "Acoustic analysis of Assamese and Bodo monophthongs". Paper presented at AICL, North Eastern Hill University, Shillong.

Sarmah, Priyankoo; Redmon, Charles. 2013. "Acoustic separation of high-central vowels in Bodo, Rabha and Korean", Proceedings of Acoustics 2013, CSIR - National Physical Laboratory, New Delhi.

Sarmah, Priyankoo; Wiltshire, Caroline; and Hong, Seung-ah. 2013. "Tiwa tones in monosyllables". In: Gwendolyn Hyslop, Stephen Morey and Mark Post (eds.), *North East Indian Linguistics* 5: 249-270. New Delhi: Foundation Books.

Sarmah, Priyankoo. 2004. *Some aspects of the tonal phonology of Bodo*. M.Phil. thesis, Hyderabad, CIEFL.

Schwartz, Jean-Luc; Boë, Louis-Jean; Vallée, Nathalie ; and Abry, Christian. 1997. "The Dispersion-focalization theory of vowel systems". *Journal of Phonetics* 25.3: 255-286.

Thomas, Eric R; and Kendall, Tyler. 2007. NORM: The vowel normalization and plotting suite. [Online Resource: http://ncslaap.lib.ncsu.edu/tools/norm/]

van Driem, George. 2001. *Languages of the Himalayas: An ethnolinguistic handbook of the Greater Himalayan Region*, Leiden: Brill.

Yang, Byunggon. 1996. "A comparative study of American English and Korean vowels produced by male and female speakers". *Journal of Phonetics* 24: 245-261.

Priyankoo Sarmah
priyankoo@iitg.ernet.in