ASPIRATION IN ALVEOLAR FRICATIVES IN BODO

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ABSTRACT

Aspirated fricatives are typologically rare in world's languages, occurring mostly in the Sino–Tibetan languages. However, they are hitherto unreported in the Tibeto–Burman languages spoken in North–East India. In this study we present data from Bodo, a Tibeto–Burman language spoken in Assam, India and argue that the Bodo voiceless alveolar fricative is an aspirated voiceless alveolar fricative.

To substantiate our argument, we consider a set of acoustic analysis and compare the results with acoustic properties reported for Korean, as it attests aspirated alveolar fricative. Results confirm that while aspiration duration and F1 onset follows the pattern reported for aspirated fricatives in Korean, intensity, H1–H2, centre of gravity and onset f_0, do not have any patterns consistent with aspiration.

Keywords: Aspirated alveolar fricative, Bodo, Tibeto–Burman, Bodo–Garo, acoustics.

1. INTRODUCTION

Bodo is a Tibeto–Burman language of Bodo–Garo subfamily, spoken in North–East of India by about 1.3 million speakers [1]. Bodo is known to have at least three major varieties and about six sub varieties [2] with an inventory of 16 consonants, 6 vowels and two lexical tones [3]. While looking into Bodo phonemes it was noticed that the fricative /s/ in Bodo has some aspiration associated with it. However, neither Bodo nor any of the Bodo–Garo languages reports the existence of aspirated fricatives. While aspirated fricatives are typologically rare, they do occur in Sino–Tibetan languages such as Burmese, Tibetan languages, Sgaw Karen, Bai, Zhaba, Rtau, Horpa and Pumi [4]. Apart from the Sino–Tibetan languages, there is strong evidence that Korean also uses [s] and [s^h] contrast phonologically [5, 6, 7].

Hence, in this work we present acoustic evidence to argue that the phoneme /s/ in Bodo is actually an aspirated fricative [s^h]. However, vowel context plays a significant role in the production as [s^h] is non–existent before [i], whereas they systematically occur before [a] vowels. Apart from that we also noticed that depending on the variety of Bodo, the occurrence of aspirated [s^h] changes. While all speakers from Udalguri and Tamulpur area produced [s^h], only 30% of the iterations recorded from speakers from Barpeta contained aspiration followed by /a/ vowel, rest of the alveolar fricatives were non–aspirated.

2. METHODS

2.1. Participants

Six male speakers from Barpeta area, eleven speakers (seven male and four female) from Udalguri area and twelve speakers (six male and six female) Tamulpur area participated in the production test. All of them were native speakers of Bodo and could speak Assamese and Hindi in varying degrees. The average age of the participants in each area was 29 years with a standard deviation of 8.3. All the Bodo speakers were at least high school graduates.

2.2. Materials

The Bodo speakers read a list of 82 Bodo words in a sentence frame. A subset of the produced words that had [s^h] as onset was considered for acoustic analysis. The words included for acoustic analysis were [s^{h}a], [s^{h}an]. The word [s^{h}a] is associated with three different meanings, namely, *north*, *place a fishing instrument* and *ache*. The word [s^{h}an] is associated with the meaning *day*. The word [si] meaning *wet* found only in the Tamulpur variety does not have aspiration in the fricative.

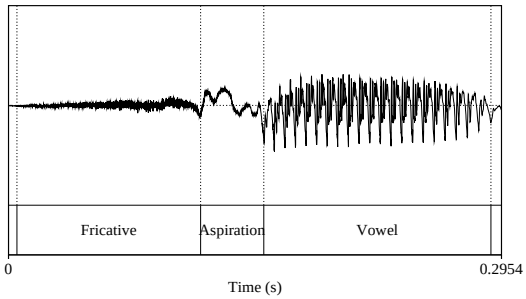
2.3. Recording and data preparation

An interviewer prompted the Bodo word by providing the meaning in Assamese to the Bodo speaker. In response to the prompt a Bodo speaker provided the word in isolation and then in the sentence frame /aŋ X buŋdəŋmən/ meaning *I said X*. Each word appeared in the list for three times resulting in a total of 284 iterations. The response was recorded with a Shure SM10 microphone attached to a Tascam DR 100 MKII solid–state audio recorder in .wav format. Sampling frequency was set at 44.1 kHz with bitrate of 16 bit/sample. All recordings were conducted in quiet environment.

Later the recorded audio files were transferred to a personal computer for segmentation and analysis. Praat 5.3.59 [8] was used to view the sounds and to

annotate the sounds. Each of the target word was segmented indicating the time indexes for frication, aspiration and vowel parts as shown in Fig. 1.

Figure 1: Segmentation of /s^{h}a/



2.5. Measures

Among the languages that exhibit aspirated and non–aspirated contrast in fricatives, only Korean has considerable number of acoustic phonetic studies. It has been seen in Korean that mean durations for aspiration and frication are statistically significantly different for aspirated and non–aspirated fricatives [5]. Frication duration for Korean aspirated /s^h/ is significantly shorter than the frication duration for /s/. On the contrary, aspiration duration for /s^h/ is significantly longer than for /s/.

On the other hand, spectral measurements for the Korean /s^h/–/s/ contrast have also yielded significant results. F1 onset into a low vowel after a Korean non–aspirated fricative is much lower than after an aspirated fricative [6]. Also it was noticed that after a non–aspirated fricative intensity build up into a low vowel is more rapid than after an aspirated fricative [6]. An aspirated fricative induces more breathy quality into the following vowel. At the same time it was noticed that f_0 onset, average vowel intensity and vowel length are not affected by the aspiration contrast of Korean fricatives [6].

Considering the measurements provided for Korean /s^h/–/s/ contrast in [5] and [6], we decided to take the measurements in Table 1 for the current study.

Table 1: Acoustic measurements in the current study.

Measurements
1. Vowel duration
2. Aspiration duration
3. Frication duration
4. Average vowel intensity
5. f_0 at three locations
6. F1 onset
7. Centre of gravity
8. Spectral tilt (H1–H2)

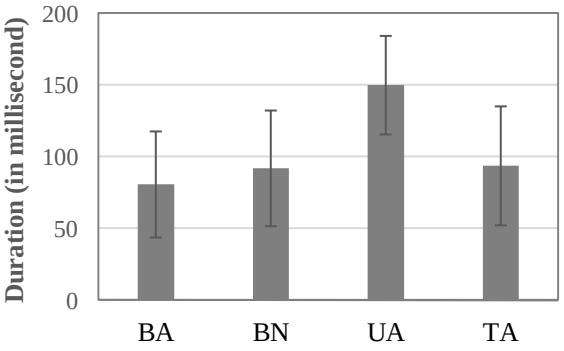
3. RESULTS

During the segmentation of the data, we noticed that while Udalguri and Tamulpur speakers of Bodo produced only the aspirated fricative for the words beginning with [s^{h}a], the Barpeta speakers produced both aspirated and non–aspirated fricatives for the same words. Hence, in categorizing the data for analysis we decided to compare among Barpeta unaspirated [s] (BN), Barpeta aspirated [s^h] (BA) and Udalguri aspirated (UA) and Tamulpur aspirated [s^h] (TA) sounds.

3.1. Vowel duration

A one–way ANOVA with a post–hoc Bonferroni confirmed that vowel durations were significantly different among the four groups compared. The pairs- BA – BN, BA – UA, BN – UA, and UA – TA were significantly different from each other (see Fig. 2). Other pairs were not significantly different from each other.

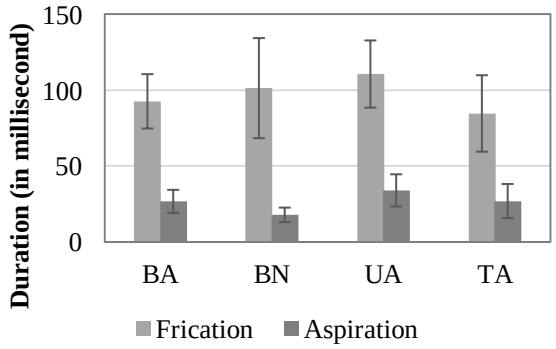
Figure 2: Duration of vowels after fricatives



3.2. Aspiration and frication duration

An ANOVA test confirmed that the average frication durations and the aspiration duration of the four groups were statistically significant (see Fig.3.). The Bonferroni post–hoc test revealed that frication duration is not significantly different for the pairs-

Figure 3: Duration of aspiration and frication



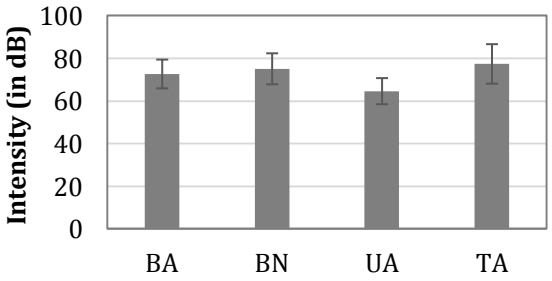
UA – BN, BA – BN and BA – TA. The pairs UA and TA, UA and BA and TA and BN are significantly different in terms of their frication duration.

In terms of the average aspiration duration, except for the TA – BA pair, the other pairs of the four groups were significantly different from each other as the Bonferroni test indicated. We can construct the aspiration hierarchy as the following- UA > TA > BA > BN.

3.3. Vowel intensity

An ANOVA test showed significant interaction of the four groups and the average vowel intensity. However, a Bonferroni test confirmed that there is no statistically significant intensity difference due to the change of aspiratedness. In the Barpeta variety there was no difference between the aspirated and non-aspirated tokens in terms of intensity. Other groups are significantly different from each other in terms of the intensity values as seen in Fig. 4.

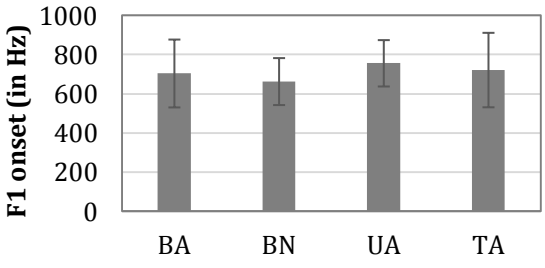
Figure 4: Intensity of vowels after fricatives



3.4. F1 onset

F1 onset was measured at the first visible cycle of the vowels following [s^h]. F1 onset values are found to be significantly different for the four groups and a Bonferroni post-hoc test confirmed that while the F1 onset following Udalguri and Barpeta non-aspirated fricatives are significantly distinct, F1 onsets following Barpeta aspirated and Barpeta non-aspirated fricatives are not significantly different as seen in Fig. 5.

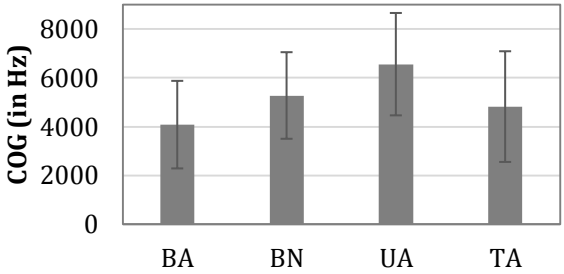
Figure 5: F1 onset of vowels after fricatives



3.5. Centre of gravity

In [7], it is claimed that the Korean aspirated and non–aspirated fricatives differ significantly in terms of centre of gravity (COG) of the mid 25 ms of the frication. In Bodo, it was found that while COG is different for the pairs – UA – TA, UA – BA and UA – BN; there is no significant difference between the BA – BN, BA – TA and BN – TA pairs (see Fig. 6).

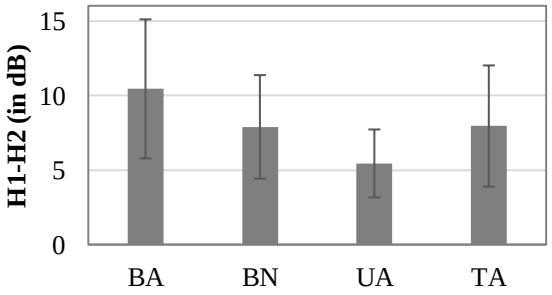
Figure 6: COG of fricatives



3.6. Spectral tilt

The aspiration of the fricative is seen to affect the phonation of the vowel, making it breathy at least in the starting portion [7]. Spectral tilt (H1–H2) indicates the breathiness or creakiness of the vowel, the breathier vowels having higher H1–H2 values, i.e. a steeper spectral tilt. The H1–H2 values are found to be significantly different in the ANOVA test for the Udalguri variety than those of the Barpeta variety (see Fig. 7). Except for the TA – BN pair, the other pairs are significantly different from each other. The positive values of the spectral tilt indicate breathiness of the vowels following the aspirated fricative in all varieties.

Figure 7: Spectral tilt of vowels after fricatives

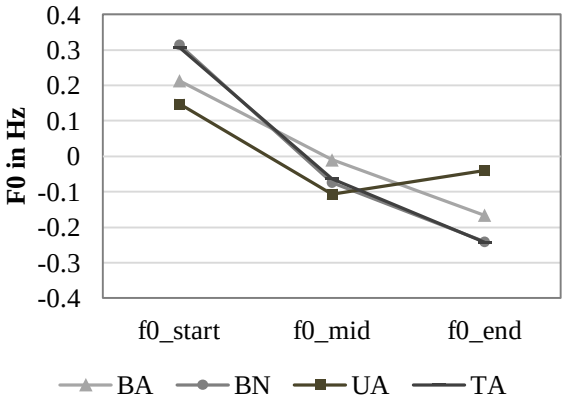


3.7. F_0 values at three locations

F_0 is measured at the vowel start, vowel mid and vowel end positions to see how far the effect of the aspiration goes into the vowel.

The Barpeta aspirated and unaspirated groups and Udalguri and Tamulpur groups differ significantly in terms of the f_0 values at all the three points (see Fig. 8).

Figure 8: F_0 value at three locations in the vowel



3.8 Comparison of values with Korean

In Table 2, and Table 3 we compare the values of measurements obtained in this study with that of Korean as reported in [5], [6] and [7]. As seen in Table 2, while vowel duration of Korean compared to Bodo is distinct, in terms of amount of aspiration the values are still comparable.

Table 2: Comparison of temporal measurements

	Frication (ms)	Aspiration (ms)	Vowel (ms)
Ko–Asp	138	53	334
Ko–NA	203	11	343
Barpeta–Asp	92	26	78
Barpeta–NA	101	17	119
Udalguri–Asp	110	33	159
Tamulpur_Asp	84	26	93

Table 3: Comparison of intensity and other spectral measurements

	F1 onset (Hz)	Intensity (dB)	H1–H2	COG
Ko–Asp	753	71	11	5200
Ko–NA	507	72	–3	5500
Barpeta–Asp	704	73	10	4810
Barpeta–NA	662	76	8	5275
Udalguri–Asp	756	65	5	6516
Tamulpur_Asp	721	77	7	4819

When compared for the proportion of aspiration in the fricative, Table 2 shows that in case of all four aspirated alveolar fricatives (Korean, Barpeta Bodo, Udalguri Bodo and Tamulpur Bodo) the values are very similar; 27%, 22%, 23% and 23% for Korean, Barpeta, Udalguri and Tamulpur, respectively.

In Table 3 we report the values for F1 onset, intensity, H1–H2 and COG. H1–H2 and intensity did not show any consistent pattern to indicate any effect of aspiration. F1 onset did show similar results to the ones reported for the same vowels in Korean, confirming that F1 onset following aspirated fricatives is higher than following non–aspirated fricatives.

4. DISCUSSION

It is evident from the temporal measures reported in this study that there is a significant portion of aspiration present in the production of voiceless alveolar fricatives in the three varieties of Bodo. However, only 30% of the tokens produced by Bodo speakers from Barpeta area produced the alveolar fricatives with aspiration. Hence, it can be argued that the occurrence of aspirated fricatives in Bodo is dialectally defined.

In the current study, the data collected is limited to the /a/ vowel context. Hence, we can claim that when followed by the /a/ vowel, an aspirated [s^h] is present. We also noticed from our wordlist that in Barpeta and Udalguri varieties, [s^h] becomes [z] before /i/. However, in Tamulpur variety it was noticed that the aspiration in the fricative is lost before the /i/ vowel and a plain /s/ is produced instead. The absence of [s^h] before /i/ vowel is comparable to the phenomenon in Korean where the alveolar aspirated fricatives become alveo-palatal fricatives, [ɕ] when followed by the vowels /i/ and /j/ [9].

Even though Bodo does not contrast between [s] and [s^h], aspiration is present consistently with the voiceless alveolar fricatives. That is despite of the fact that aspiration in fricatives is an unstable feature and it has neutralized in many languages such as Burmese [4]. At the same time it is also argued that it is a feature present in the Sino-Tibetan languages [4]. Hence, it is not surprising if a Tibeto-Burman language like Bodo also happens to have an aspirated fricative in its consonant inventory.

This study confirms Bodo voiceless alveolar fricatives are aspirated as evident from the significantly long portions of glottal frication. As in Korean, in Bodo, the high F1 onset of the low vowel /a/, following alveolar fricatives also confirm that the preceding fricatives are aspirated.

5. REFERENCES

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