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Voice Onset Time and Burst Duration of Bangla Labial Stop Consonant in Consonant-Vowel (CV) Context

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Abstract

Consonant-Vowel (CV) construction is the most frequent syllable in Bangla. The present study examine the acoustic properties of Bangla four labial stop consonants [p, ph, b and bh] in the initial position in a consonant-vowel context with seven following vowels /ɔ, a, e, æ, i, u, o/. Bangla is a type of language that uses aspiration as an addition feature to distinguish phoneme. Bangla labial stops are investigated to provide acoustic information. Acoustic parameters, voice onset time (VOT) and burst duration (BD), are measured from wave form and spectrogram of CV syllable. The study shows that the VOT duration for all consonant has its lowest absolute value when followed by /a/. In case of voiced consonants a high negative VOT (ms) is shown when the stop consonant is followed by vowel /e/. There is no significant difference between median burst duration of aspirated and unaspirated stop.

Keywords: Bangla labial stops, voice onset time and burst duration, acoustic study.

Introduction

In speech recognition, one of the most difficult task is the acoustic study of consonant due to the speaker dependent nature and different context of the stops. Stop consonants are generally produced by the complex movement in the vocal track with the nasal cavity closed and the rapid closure and opening is affected by the oral cavity.

In 1979 and 1986 Sarkar [1, 2], established 16 canonical syllable patterns in Bangla, which are as follows: CV, CVC, V, VC, VV, CVV, CCV, CCVC, CVVC, CCVV, CCVVC, CVCC,

CCCV, CCCVC, VVC, and CCCVV. Among these 16 patterns, CV has the maximum number of frequency, approximately 54% in the language [3]. Thus, the study of Bengali stop consonant is important in order to understand their time and frequency domain characteristics.

Method

Participants

One normal male native speaker of Bangla served as participant. While participant had learned Bangla as his first language and was bilingual with English as his second language.

Equipment

All the speech samples were recorded with a microphone (Sony IC Recorder) placed approximately 25 cm away from lips with 45 degree angle in a quiet room. The microphone output was line-fed into a personal computer. The speech signals were digitally sampled at 44.1 kHz and 16 bit.

Parameter Measurement

To measure the acoustic features of labial consonant in CV syllable, Wavesurfer and Praat were used.

Voice Onset Time (VOT)

The term Voice Onset Time (VOT) refers to the temporal interval between the release of the consonantal constriction and the onset of voicing i.e. the timing of the beginning of vocal cord vibration in CV sequences, and is expressed in milliseconds (ms) [4, 6].

Burst Duration (BD)

Duration measurements for CV syllables were made for the burst of initial consonant, CV vowel transition. The duration of formant transition was selected from the onset of the formant to the steady state of vowel formant.

Results

Measurements of 28 CV syllables were done manually. In the following description only the initial labial consonants of CV syllable were discussed. The important acoustic measurements include initial consonant burst duration (BD) and the voice onset time (VOT) of the consonant. The median values of these parameters with their standard deviations (SD's) are shown in the Table 1 and Table 2 for unvoiced and voiced stops respectively.

	Following Vowel						
Stop	/a/	/æ/	/e/	/i/	/o/	/ɔ/	/u/
/b/	-178.0 55.46	-131.0 25.72	-192.0 31.63	-187.0 31.97	-160.0 21.78	-167.0 12.50	-139.0 30.14
/bh/	-68.0 17.39	-61.0 12.77	-78.0 26.23	-81.0 12.66	-94.0 0.58	-87.0 5.13	-116.0 2.52
/p/	19.0 4.93	12.0 3.79	20.0 1.53	26.0 3.06	26.0 3.21	38.0 4.04	21.0 3.46
/ph/	94.5 36.06	52.0 17.09	96.0 15.56	79.0 1.53	95.0 4.04	112.5 4.95	118.0 20.74

Table 1: Median values with their standard deviation (SD) of VOT measured for initial unvoiced and voiced labial stop consonant from CV syllable.

The VOT duration for the unvoiced /p, ph/ and voiced /b, bh/ have been grouped as the VOT value for /b, bh/ is negative and large while for /p, ph/ it is always positive and small. For /p, ph/, the average VOT are 23.1 ms and 92.3 ms respectively.

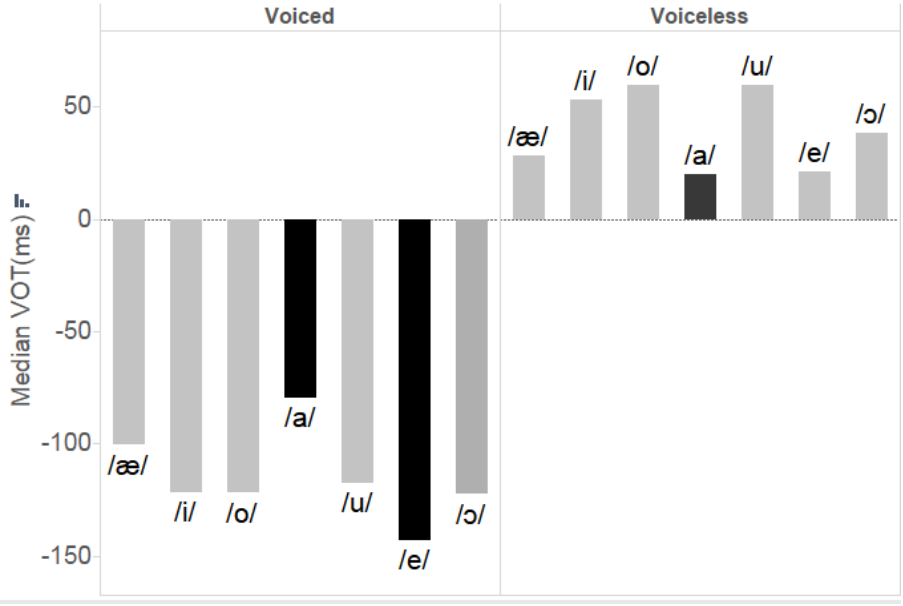

Figure 1: VOT values of voiceless /p, ph/ and voiced /b, bh/ when followed by vowel /ɔ, a, e, æ, o, i, u/.

The average VOT for voiced /b, bh/ are -164.8 ms and -83.6 ms respectively. The VOT for /b, bh/ is affected by the vowel /a/ and /e/. The VOT values are minimum when it is followed by the vowel /a/ for both voiced and voiceless subgroup of consonants. For voiced consonants, a high negative VOT is observed when the consonant is followed by /e/. These differences show that the VOT information is a very important cue for identifying the dissimilarities between voiced and unvoiced consonants.

	Following Vowel						
Stop	/a/	/æ/	/e/	/i/	/o/	/ɔ/	/u/
/b/	7.00 0.577	9.00 1.000	11.00 2.646	11.00 3.606	7.00 2.309	13.00 2.517	9.00 3.464
/bh/	9.00 1.732	11.00 0.000	10.00 0.000	9.00 1.528	10.00 0.577	9.00 1.000	10.00 0.577
/p/	8.00 2.646	6.00 1.732	6.00 3.606	8.00 1.732	10.00 0.000	10.00 2.646	6.00 2.309
/ph/	16.00 1.414	15.00 4.359	11.50 2.121	14.00 1.000	11.00 1.732	16.50 3.536	8.00 2.887

Table 2: Median values with their standard deviation (SD) of BD measured for initial unvoiced and voiced labial stop consonant from CV syllable.

The average burst duration (BD) for voiceless /p, ph/ are 2.4 ms and 13.1 ms respectively. For voiced /b, bh/ the average burst duration are 9.5 ms and 9.7 ms respectively.

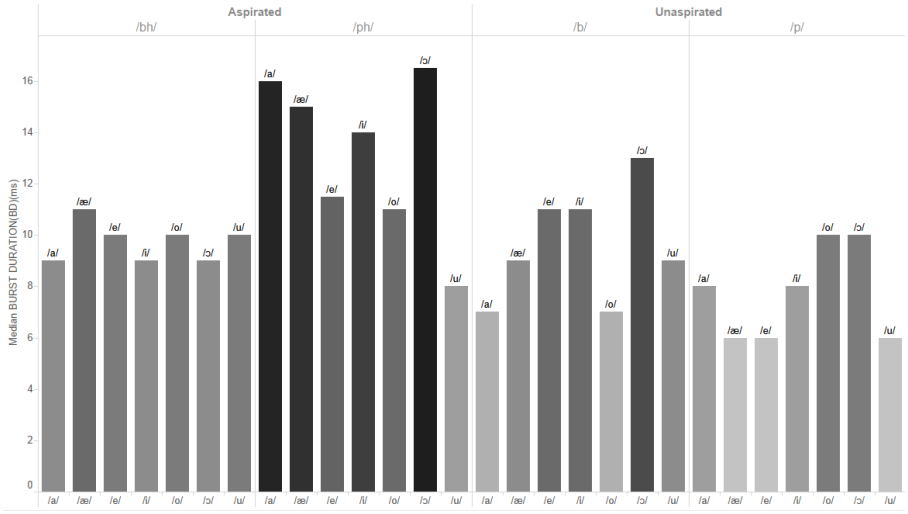

Figure 2: BD values of stop consonant /p, ph, b, bh/ when followed by vowel /ɔ, a, e, æ, o, i, u/.

While analyzing the burst duration (ms) in CV sequence of labial consonants (aspirated and unaspirated both), no significant pattern is identified. However, we have observed relatively high values of BD for the consonants when followed by /ɔ/ except voiced aspirated consonant/bh/ [Fig. 2].

Discussion

The findings of this study suggest the voicing feature of labial stop production in Bangla parallel to the study made by Lisker and Abramson, 1964 [5][6]. That is, the voiced unaspirated

/b/ and aspirated /bh/ reside on the negative side of the VOT range while the voiceless unaspirated /p/ and aspirated /ph/ are located in the positive half of the VOT range. (Fig.3)

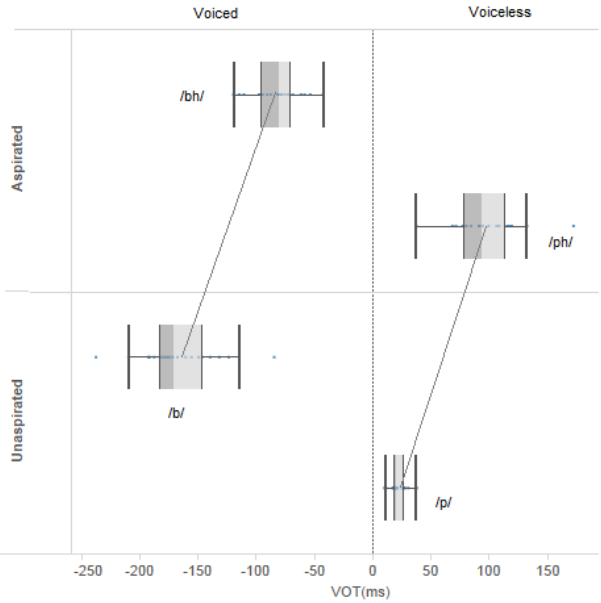

Figure 3. Median voice onset time as a function of voicing and aspiration for four labial stop consonants in Bangla. Error bars represent standard deviation range where the greyed box represents the area containing 3 quarters of the measurements.

It can be observed, VOT duration of labial unaspirated voiceless stop /p/, is concentrated with a short range of 27ms with a median value of 21ms. Whereas, a relatively wide VOT range is observed for/ph/, /b/, /bh/ are 95ms, 95ms, 77ms respectively.

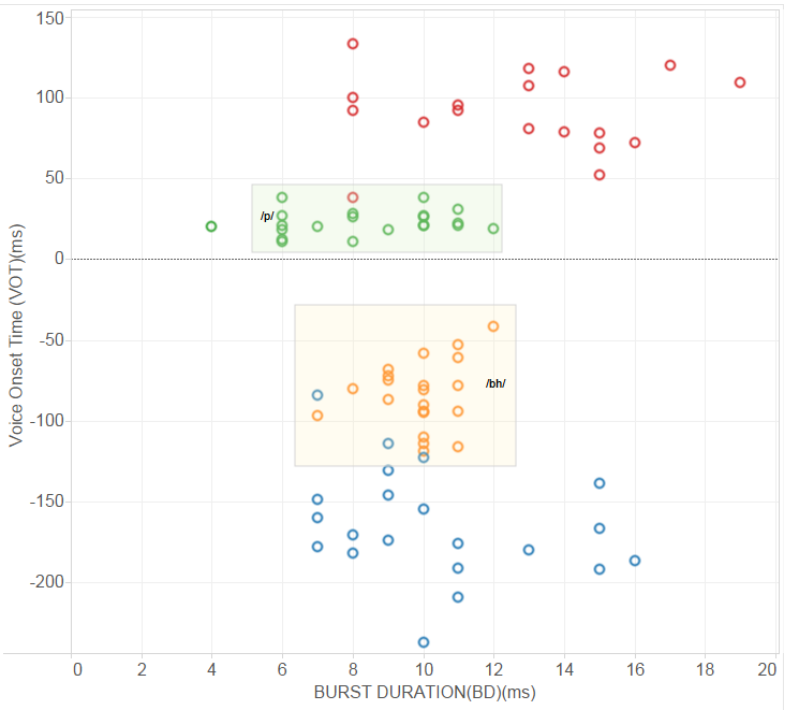

Figure 4. Relationship between VOT (ms) and BD (ms) for all measurements of stop consonants in CV seq. X axis and Y axis represents VOT and BD respectively. Measurements from /p/, /bh/, /b/ and /p/ consonants are represented as green, orange, blue and red dots respectively.

The above diagram tries to understand the relationship between the VOT and BD for all CV sequence of labial consonants. It can be observed that the data points representing /p/ and /bh/ are confined in a very small region. On the contrary, /ph/ and /b/ data points have been scattered all over the place. Therefore, it can be concluded that the ratio between VOT and BD for labial consonant in a CV sequence has a limited variation.

In order to identify how closely the values are related, we tried to identify the Euclidian distance between the centroid of the area for each stop consonant to each of the measurement points, as represented in above chart (X axis represents VOT and Y axis represents BD in milliseconds). In order to identify the centroid for area of a particular stop consonant we have

performed a k-means clustering, with partition size as 1. Following this, we have calculated the Euclidian distance of each of the points. The subsequent table documents the median, maximum and minimum equation distance for each of the labial stop consonants as measured from there centroids.

Labial Stop Consonant	Euclidian Distance (ms)		
	Median	Min	Max
/p/	4.91	2.35	15.05
/ph/	18.71	4.07	56.96
/b/	18.10	5.24	80.11
/bh/	12.03	3.00	42.05

Conclusion

Thus, the acoustic study shows that the Bangla labial stop consonants in initial position of syllables preceding a vowel are impacted by various acoustic attributes such as onset of the periodic glottal pulsing and the articulation is associated with the release of the consonant burst etc. Therefore, the following vowel plays a very important role in the classification of stop consonant.

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