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VOICING AND ASPIRATION IN MARATHI STOPS

Ari Natarina
Department of Linguistics, University of Iowa
Iowa City, IA 52242, USA
ari.natarina@gmail.com

ABSTRACT

This paper addressed the debate on binary features [±voice] versus privative features [voice] and [spread glottis] as the phonological representation of laryngeal features in stop sounds across languages by studying the production of four-way stops (e.g. /b/, /b$^{h/}$, /p/, and /p^{h}/) in Marathi. This study was aimed at providing accurate data on voicing and aspiration in Marathi stops in utterance-initial and intervocalic positions, as well as investigating how voicing and aspiration are influenced by place of articulation and male-female differences. Three male and three female native speakers of Marathi were recorded in an anechoic chamber at the University of Iowa, and their recordings were analyzed using Praat. The data showed robust presence of voicing and aspiration in the production of voiced aspirated stops, supporting the privative features theory since the binary features [±voice] alone cannot distinguish the four-way stop contrasts in Marathi. Furthermore, place of articulation was found to be significantly correlated with the length of voicing and aspiration, whereas male-female differences did not have a significant influence on voicing and aspiration of the Marathi stops.

Key words: Marathi, voicing, aspiration, place of articulation, male-female differences

I. INTRODUCTION

Marathi, an Indo-Aryan language, has a four-way stop contrast: plain voiced /d/, voiced aspirated /d^{h}/, plain voiceless /t/, and voiceless aspirated /t^{h}/. The distinction between Marathi and other languages is that sonorants as well as affricates in this language can also have aspiration. This paper, however, mainly focuses on the four-way contrasts of bilabial, dental, and velar stop series. The goal of this paper is to present accurate data on voicing and aspiration in Marathi stops, as well as to investigate the influence of place of articulation and male-female differences associated to voicing and aspiration.

The representation of laryngeal features across languages has been debated over the years by phoneticians and phonologists. There are two main views on the representation of laryngeal features. The traditional view argues that [voice] feature is binary. With the binary feature, the two most common stops found in world languages: voiced and voiceless, can be represented by [+voice] and [-voice] feature. However, the study of Voice Onset Time (VOT) by Lisker & Abramson (1964) demonstrates that these stops have different phonetic realizations in different languages. On a spectrogram, Russian /b, d, g/ sounds, for example, have glottal buzz present prior to the release burst; however, glottal buzz is absent in the spectrogram of German lenis stops /b, d, g/ in utterance-initial position. Furthermore, German fortis stops /p, t, k/ were found to have an aspiration, unlike Russian /p, t, k/.[1]

In order to account for these differences using binary features, Keating (1984) differentiates phonological representation and phonetic representation of the laryngeal feature [voice] in languages

[1] Fortis (tense, strong) and lenis (lax, weak) distinction is used instead of voiced and voiceless to refer to the stops that do not have voicing distinction in languages such as German and English.

that have a different number of voice contrasts. According to Keating, phonologically, the [voice] feature can be represented as [+voice] and [-voice], whereas phonetically, it is signified as {voiced}, {voiceless unaspirated}, and {voiceless aspirated}. The realization of [±voi] is different depending on the language. In initial position, [-voi] is realized as {voiceless unaspirated} in Russian, but as {voiceless aspirated} in English. Moreover, [+voi] is realized as {voiced} in Russian but as {voiceless unaspirated} in English. This theory poses a problem for languages that have the fourth stop contrast: a voiced aspirated stop. There is no phonetic representation available for this type of stop.

According to the non-traditional view of laryngeal features (Beckman, J, M. Jessen, & C. Ringen; 2013), [voice] is a privative feature. Only voiced obstruent in true voice languages, like Polish, has this [voice] feature. In contrast, aspirating languages, like English, only have null feature [Ø] for the lenis obstruent because it is pronounced as plain voiceless obstruent and [spread glottis] feature for its voiceless obstruent since it is pronounced as voiceless aspirated. The laryngeal features across languages, according to non-traditional privative feature hypothesis, are illustrated in the following table.

Language	Voiced	Voiced aspirates	voiceless	Voiceless aspirates
Two-way contrast (i.e. Polish)	[voice]	-	[Ø]	-
Two-way contrast (i.e. English)	[Ø]	-	[sg]	-
Three-way contrast (i.e. Thai)	[voice]	-	[Ø]	[sg]
Four-way contrast (Hindi)	[voice]	[voice] [sg]	[Ø]	[sg]

Table 1. The representation of privative laryngeal features in different languages.

In recent years, VOT plays an important role in identifying the laryngeal feature contrast of stops in different languages. Helgason & Ringen (2008) conducted an acoustic study on Swedish stops to investigate voicing and aspiration, as well as voice assimilation phenomena in Swedish. In this study, they found that the two types of Swedish stop have both [voice] and [spread glottis] contrast in the utterance-initial position, while the stop contrast in medial and final position is only [voice].

Dutch, which has been known to have prevoicing in the production of its utterance initial lenis stops, was studied by van Alphen & Smits (2004) with the purpose of investigating the variation in the production and perception of prevoicing. In their first experiment, they discovered that 25% of the voiced stop productions were not prevoiced. They claimed that prevoicing production in Dutch was affected by place of articulation, male-female differences, and the environment of the lenis stop.

Lisker & Abramson (1964) were the first to conduct acoustic analysis on Marathi stops. Their findings show that Marathi has four separate stop categories. Table 2 below shows the VOT of Marathi stops in utterance-initial position by one speaker as measured by Lisker & Abramson. However, there is a limitation to these findings, as Lisker & Abramson only measured the prevoicing which represent [voice], but they did not measure the breathy voice for the voiced aspirated stops even though this is an important aspect of the voiced aspirated stops.

Place of Articulation	Plain voiced	Voiced aspirated	Plain voiceless	Voiceless aspirated

Bilabial	-117	-95	11	76
Dental	-111	-87	0	63
Velar	-116	-89	24	87

Table 2. Marathi stops VOT (Msec) in Lisker & Abramson (1964)

The most recent study on Marathi sounds were carried out by Berkson (2013). She performed acoustic analysis on Marathi consonants, focusing on the distinction of breathy voice in Marathi obstruents and sonorants. Although her study explored male-female differences, it is more focused on the different cues for breathy voice in obstruents and sonorants utilized by male and female speakers. Her measurements include duration of consonants and subsequent vowels, F0, Cepstral Peak Prominence (CPP), and other values. Berkson proposed that the reason why breathy sonorants are not found in many languages is because they do not make strong phonemic contrast.

Although acoustic analysis of Marathi sounds has been conducted previously, these studies did not look specifically at the influence of place of articulation and male-female differences on voicing and aspiration in Marathi stops. In addition, there is no accurate data on VOT for Marathi stops, except for Lisker & Abramson's data which were only collected from one Marathi speaker. Hence, this study is conducted to provide accurate data on VOT for utterance-initial position, as well as voicing and aspiration feature of Marathi stops in intervocalic position.

II. METHODS

2.1. Participants

The participants in this study were six native speakers of Marathi, three males and three females. Their mean age was 27.3 years (range: 24–34 years). They were all fluent speakers of English and Hindi, and they were also familiar with some other languages such as Gujrati, Tamil, Sanskrit, Spanish, Chinese, French, and German. All of these subjects were living in Iowa City at the time of the study with 5 years average length of residence in the Midwest. The data were recorded in an anechoic chamber at the University of Iowa.

2.2. Stimuli

Subjects read a word list (see Appendix A) that contain Marathi's four stops series, i.e. voiced, voiced aspirate, voiceless, and voiceless aspirate for each of the dental, labial and velar stops in initial, intervocalic, and final position. The words in the list were written in Marathi script with the English translation given next to it, and the subjects were asked to read the word list twice with a pause in between the words.

2.3. Acoustic analysis

Praat was used to create oscillograms and spectrograms for each analyzed token from the recorded speech. In this study, I measured the VOT of the utterance-initial stops. The closure duration, the voicing duration, and the postaspiration duration of the stops were measured for intervocalic stops.

2.3.1. Voicing duration

Figure 1a and 1b below illustrate how prevoicing of the dental stop in the utterance-initial position and how voicing duration of the velar stop in intervocalic position were measured in the word *dəgəɖ* "stone". Jessen (1998: 76) defined negative VOT or prevoicing as "the temporal amount of periodic low energy structure during stop closure immediately preceding stop release." The prevoicing of the utterance-initial plain voiced and voiced aspirated stops was measured from the first periodic sinusoidal wave to the beginning of the release burst. "Voicing during closure" (Jessen

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1998: 76) was measured for the stops in intervocalic position. Voicing during closure begins at the end of the second formant of the preceding vowel, which is often indicated by a drop of amplitude in the waveform, and it ends at the last low periodic wave in the closure interval (shown in Figure 1b). When there is no cessation of vocal fold vibration, it means that the stop closure is fully voiced and the end of the voicing is marked at the beginning of the release burst, which also signify the end of stop closure.

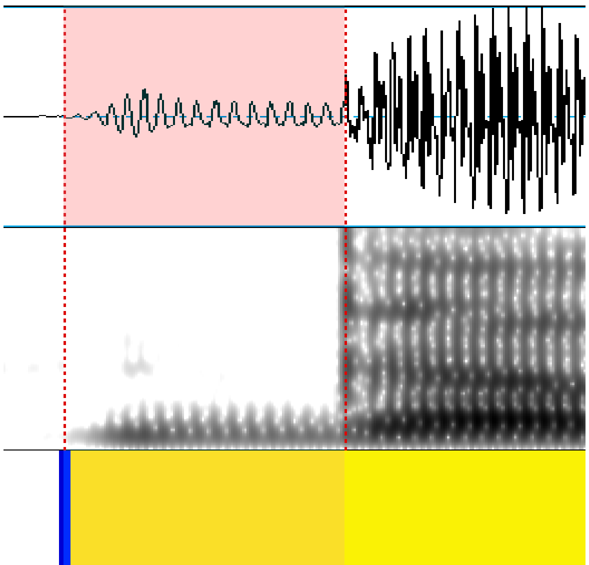

Figure 1a. Voicing in utterance-initial position

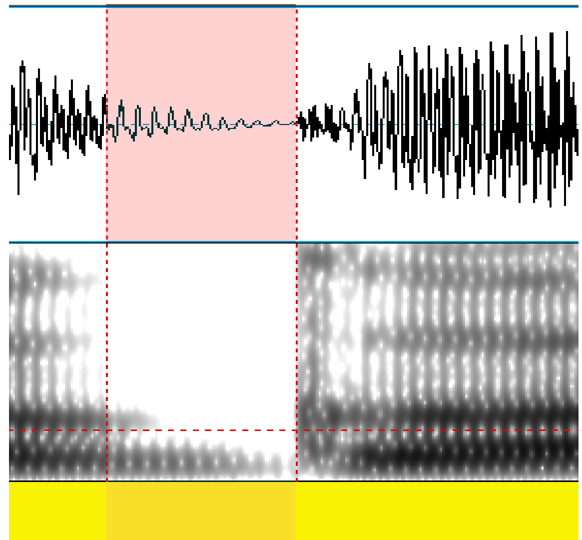

Figure 1b. Voicing in intervocalic position

2.3.2. Aspiration and breathy voice duration

Lisker and Abramson (1964) measured positive VOT from the release of the stop to the onset of glottal vibration or voicing, whereas Ladefoged and Maddieson (1996; Helgason & Ringen 2008: 610) suggest measuring the interval between stop release and the modal voice onset. Helgason & Ringen (2008) adopted the second interpretation of VOT and measured the postaspiration of plain voiceless and voiceless aspirated stops from the stop release to the onset of modal voicing rather than voice onset (as shown in Figure 2); thus, the breathy voice is included in the measurement of postaspiration.

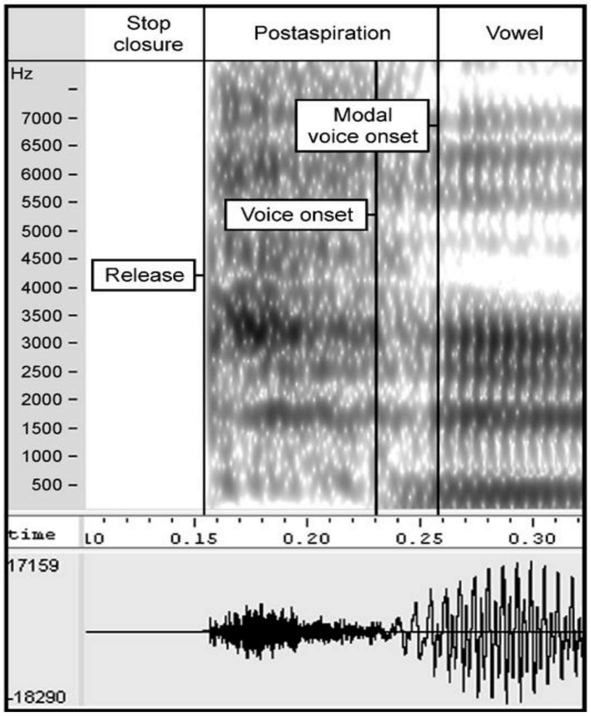

Figure 2. Examples of how postaspiration was measured by Helgason & Ringen (2008: 610)

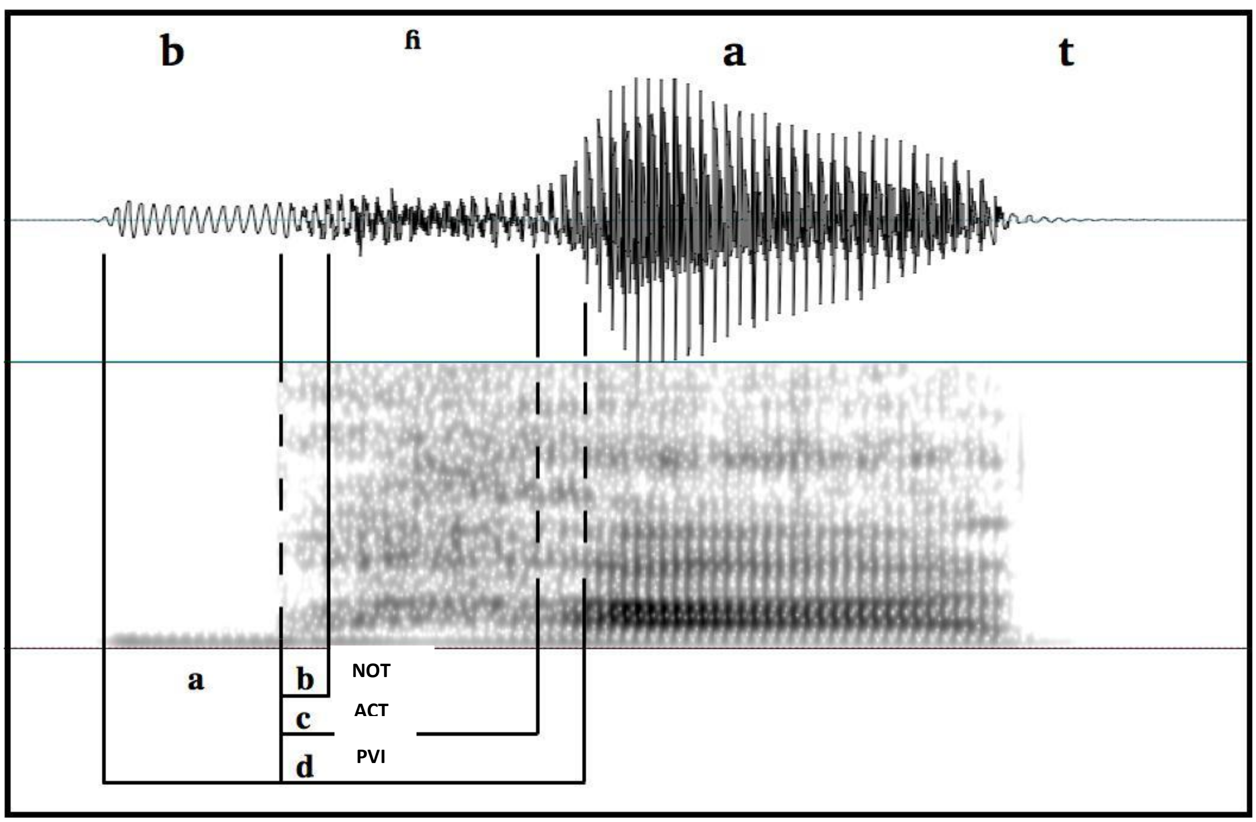

Figure 3. The measurements of NOT, ACT, and PVI according to Berkson (2012)

Earlier researchers proposed different ways to measure for breathy voice stops because it is not as easy to measure as postaspiration. Davis (1994) proposed the Noise Offset Time (NOT), which considers the interval between the release burst and the beginning of the second formant of the following vowel. Mikuteit & Reetz (2007) suggested the After Closure Time (ACT), in which the measurement begins from the release burst and ends at the beginning of periodicity in the waveform. In addition, Berkson (2012: 27) proposed the Pre-vocalic Interval (PVI) which refers to the duration beginning "from the release burst to the jump in intensity which coincides with the appearance of clear formants in the spectrogram of the following vowel." Figure 3 depicts how the NOT, ACT and PVI are measured in oscillogram and spectrogram (Berkson 2012: 42).

From Figure 2 and 3, it can be observed that both Berkson and Helgason & Ringen marked the end of aspiration at the modal voice onset, the first clear formant in the spectrogram and it is often indicated by the jump in intensity in the waveform, which signifies the beginning of the vowel. Thus, I used this method in measuring the aspiration of utterance-initial and intervocalic voiceless and voiceless aspirated, as well to the breathy voice of the voiced aspirated in Marathi, which will be referred to as aspiration henceforth.

III. FINDINGS & DISCUSSION

3.1. Utterance-initial stops

3.1.1. Plain voiced stops

In total, 72 tokens of utterance-initial plain voiced stops were analyzed; 12 tokens from each speaker. From these 72 tokens, 24 were bilabial, 24 were dental, and 24 were velar. 98.6% of these tokens were voiced with negative VOT ranging from -35ms to -133ms. Three tokens had prevoicing that ceased before the stop release, although approximately 89% of the stop closure for these three tokens was voiced. For that reason, these tokens were included in the analysis. Table 3 below shows the mean negative VOT of /b/, /d/, /g/ that were produced by male and female speakers.

Place of Articulation	Mean VOT	Mean VOT for Female	Mean VOT for Male
Bilabial /b/	-77.2	-62.5 ms	-91.9 ms
Dental /d/	-89.3	-81 ms	-97.6 ms
Velar /g/	-72.8	-60.3 ms	-85.3 ms

Table 3. The mean negative VOT in total and for male and female speakers (in ms)

There are several questions that can be raised about the fact that prevoicing in this study is shorter than the one in Lisker & Abramson (see Table 2). The fact that Lisker & Abramson only had one Marathi speaker in their study may be a factor in this difference. Thus, the question of whether there is between-subject variation in the prevoicing of plain voiced stops in Marathi must be addressed. A one-way ANOVA (analysis of variance) indicated that subject was not a significant factor in the prevoicing duration of Marathi plain voiced stops ($F(1, 70) = 0.002$, p-value = 0.965). This suggests that there was no significant variance in the production of prevoicing for plain voiced stops between subjects. Shorter prevoicing of the subjects in this study might be the result of influence from English.

From Table 2, it can be seen that male speakers have longer prevoicing compared to the female speakers. Previous VOT studies (Helgason & Ringen 2008; van Alphen and Smits 2004) found that males commonly have longer prevoicing than female which might be distributed to the differences in the size of the vocal tracts of men and women. Thus, male-female differences may be another reason why the mean negative VOT in this study is shorter than those of Lisker & Abramson.

Moreover, Table 2 also shows that different places of articulation show different means in length of prevoicing. Helgason & Ringen (2008) observed the increase of prevoicing duration in Swedish plain voiced stops to correlate with the frontness of stop place of articulation. The result of a two-way ANOVA test indicated that sex (F (1, 68) = 26.864, p-value <.001) and place of articulation (F (2, 68) = 4.707, p-value = 0.0122) were significant factors in the prevoicing duration.

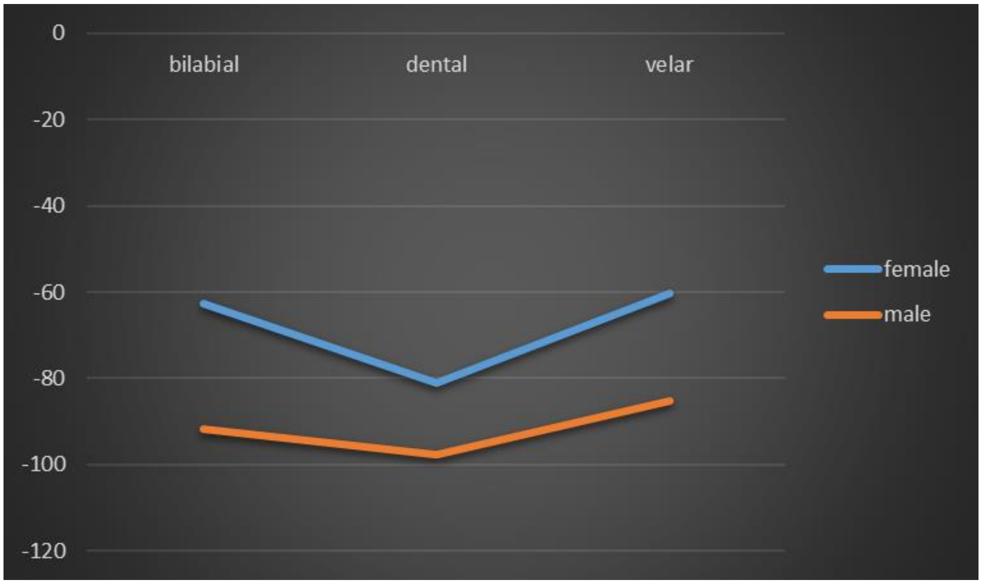

Figure 4. Mean negative VOT for each speaker (in ms)

Figure 4 illustrates the difference between the prevoicing of male and female speakers and between different places of articulation. As expected, the male speakers have longer prevoicing than the female speakers. Surprisingly, dental stop had the longest negative VOT, not the bilabial stop. Therefore, the increase in prevoicing duration for Marathi stops does not correlate with the frontness of the stop place of articulation.

3.1.2. Voiced aspirated stops

A total of 72 tokens with utterance-initial voiced aspirated stops were analyzed. There were 24 examples for each dental, labial and velar stop in utterance-initial position. Both the prevoicing and the postaspiration of each stop were measured.

100% of the voiced aspirated stops in utterance-initial position had prevoicing. 23.6% of these tokens had prevoicing that ceased before the stop release. Seven of these tokens were produced by speaker 1, four by speaker 3, three by speaker 4 and 2 by speaker 6. Of the stops that had voicing that stopped before the burst release, the ratio of the voicing duration to the interval between the onset of voicing and the release is 77.9%. An example of the utterance-initial voiced aspirated stop which voicing ceased before the release can be seen in Figure 5.

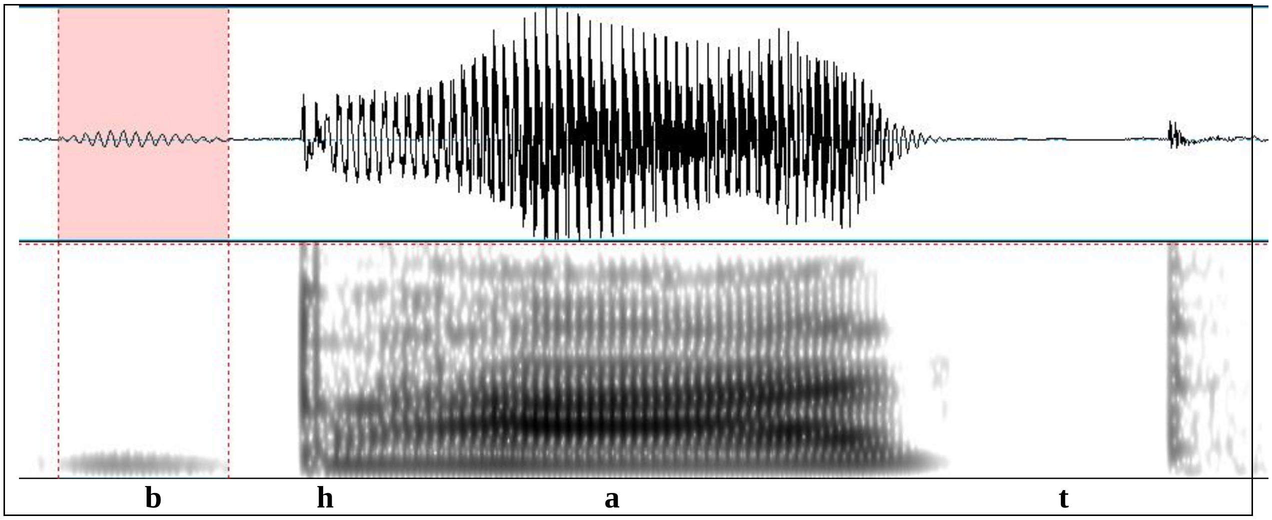

Figure 5. A spectrogram of utterance-initial voiced aspirated stop which prevoicing ceased before the release burst (in ms)

Table 4 below illustrates the mean of prevoicing and postaspiration for utterance-initial voiced aspirated stops in different places of articulation. When the mean ratio of the voicing duration to the duration of prevoicing is calculated for all the tokens, the voicing ratio of 94.8% is acquired. Thus, the calculation for the mean prevoicing duration given here includes the prevoicing duration for the stops which voicing ceased before the release.

Place of Articulation	Total Mean		Female		Male	
	Prevoicing	Postaspiration	Prevoicing	Postaspiration	Prevoicing	Postaspiration
Bilabial /bh/	-68.9	51.9	-64.4	54.3	-73.4	49.5
Dental /dh/	-72.9	62.6	-70	57.7	-75.7	67.4
Velar /gh/	-64.1	77.1	-57.7	81	-70.4	73.2

Table 4. Mean lead and lag time for voiced aspirated stops (in ms)

As with the plain voiced stops, the female speakers tend to have shorter prevoicing compared to the male speakers. Moreover, the ranking of prevoicing duration is the same with the voiced stops, in which the dental stop has the longest voicing duration and the velar stop has the shortest voicing duration. A two-way ANOVA test confirmed that sex ($F (1, 68) = 2.962$, $p\text{-value} = 0.0898$) was not a significant factor in the duration of prevoicing for voiced aspirated stops, unlike the plain voiced stops. On the other hand, the same test revealed that places of articulation have a significant effect ($F (2, 68) = 0.928$, $p\text{-value} = 0.4004$) on the prevoicing duration, and the ranking is consistent with the voiced stops: dental > labial > velar.

The postaspiration (breathy voice) for the voiced aspirated stops in this study is somewhat shorter than the findings in Berkson (2013). Berkson measured the mean PVI – which is equivalent to what I am calling postaspiration for breathy voice – for the bilabial breathy voice to be 72ms and dental breathy voice to be 77ms.

3.1.3. Plain voiceless and voiceless aspirated stops

The tokens analyzed include utterance-initial voiceless stops in three places of articulation (72 tokens) and utterance-initial voiceless aspirated stops in two places of articulation (48 tokens). The bilabial voiceless aspirated stops were not analyzed because all subjects in this study pronounced

/ph/ as a fricative. Table 5 shows the mean VOT for plain voiceless and voiceless aspirated stops in different places of articulation.

Place of Articulation	Voiceless (in ms)			Voiceless aspirated (in ms)		
	Total	Female	Male	Total	Female	Male
Bilabial	15.8	15.1	16.4	-	-	-
Dental	13.7	15	12.4	59.5	63.9	55.2
Velar	27.8	31.8	23.8	86.7	90.2	83.2

Table 5. Mean VOT for voiceless and voiceless aspirated stops

The findings can be summarized as follows: there is no significant difference between male and female speaker in their aspiration post stop release; however, place of articulation seems to have significant effect in the length of aspiration. Velar stops, both aspirated and unaspirated, had the longest voicing compared to the dental and labial stops.

A two-way ANOVA was conducted to check whether sex and place of articulation have a significant effect on the postaspiration duration for the voiceless aspirated stops. Sex was found to have no significant effect on the length of postaspiration (F (1, 46) = 2.458, p-value = 0.124). As expected, place of articulation significantly affected the production of postaspiration (F (2, 46) = 29.461, p-value < .001).

3.2. Intervocalic stops

There were 144 tokens analyzed in total, plain voiced (72 tokens) and voiced aspirated stops (72 tokens) in intervocalic position; however, 15.97% of the tokens were thrown out of the analysis because the targeted segment did not look like stops, in which there is a clear period of closure. Of these 23 tokens, most were velar stops (11 plain voiced and 9 voiced aspirated), 2 bilabials and 1 dental. Figure 7a illustrates an example of the intervocalic voiced aspirated stop that has a clear voicing throughout the closure, whereas Figure 7b depicts the same word produced by another speaker which does not have a stop-like segment intervocalically.

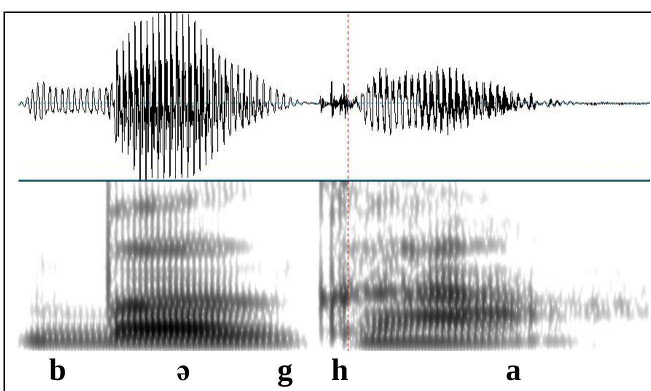

Figure 7a. Spectogram of speaker 1's production of the word ***begha*** *"look" showing clear closure interval and stop release intervocalically.*

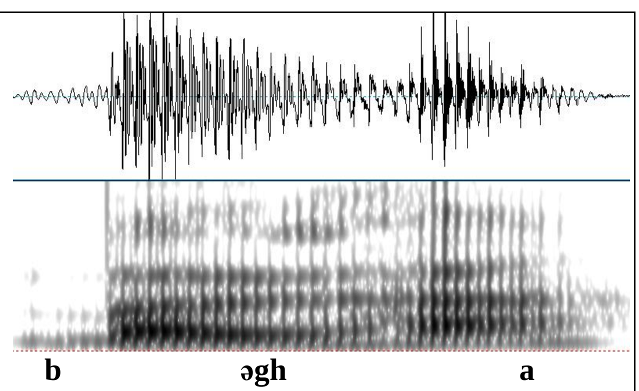

Figure 7b. Spectogram of speaker 2's production of the word ***begha*** *"look" showing no closure interval and stop release intervocalically.*

As with the utterance-initial tokens, the voiceless aspirated medial stops were not analyzed because they were pronounced as fricatives. Thus, 72 tokens of the plain voiceless stops and 34 tokens of voiceless aspirated stops were analyzed. 2 tokens of the word *shithil* "relax" for voiceless aspirated dental stops were discarded because they were pronounced as fricative (Figure 8a). Two instances of intervocalic voiceless and voiceless aspirated stop were also found to be fully voiced (Figure 8b); however, they were included in the analysis.

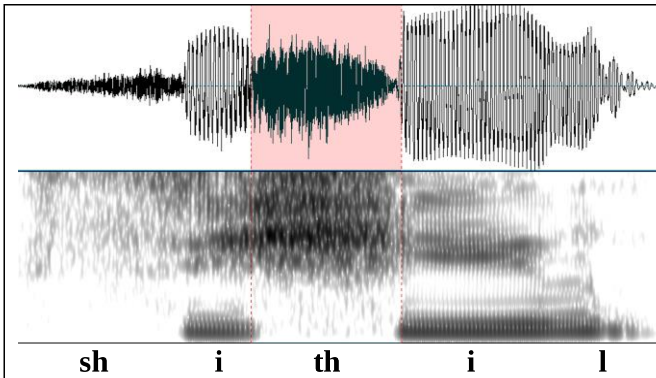

Figure 8a. Spectogram of speaker 5's production of the word shithil "relax" showing the intervocalic voiceless aspirated dental stop pronounced as fricative.

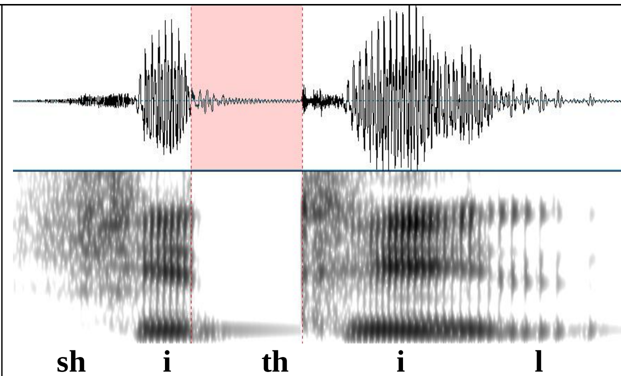

Figure 8b. Spectogram of speaker 4's production of the word shithil "relax" showing the intervocalic voiceless aspirated dental stop pronounced as voiced.

Interestingly, 7 tokens of intervocalic voiceless and voiceless aspirated stops had preaspiration, and 6 of them were velar stops. Because preaspiration is only found in 6% of the total tokens, it was not measured and analyzed further in this study. An example of spectrogram showing preaspiration in one of the tokens is depicted in figure 8 below.

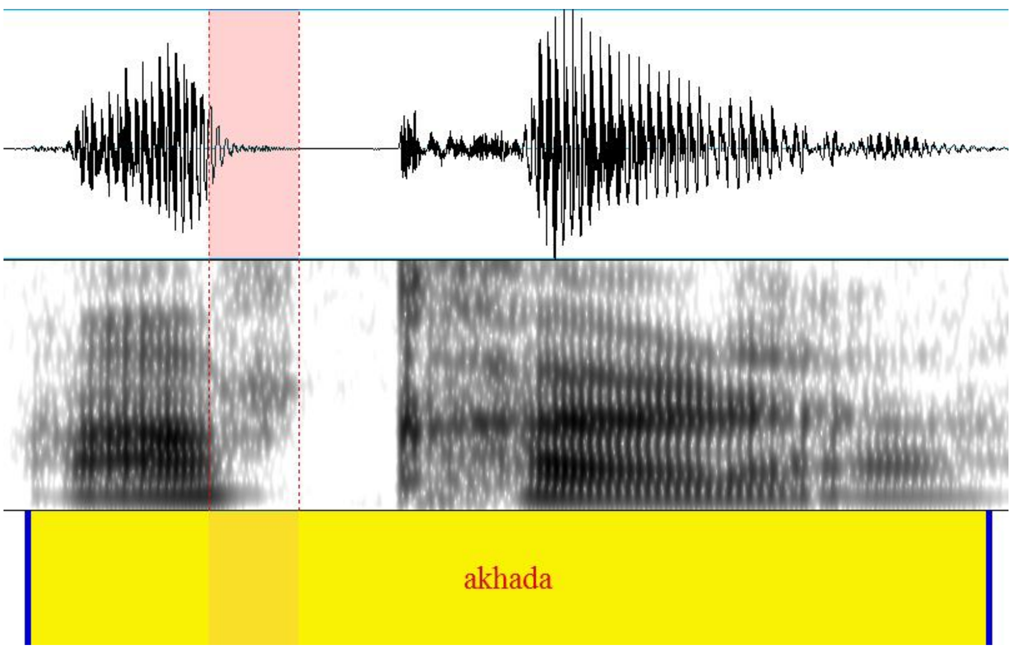

Figure 8. Spectogram of speaker 1's production of the word akhada "arena" showing preaspiration in the intervocalic position.

3.2.1. Voicing

In general, all speakers had robust voicing during the closure interval for plain voiced and voiced aspirated stops. In intervocalic position, the closure for most of the tokens was fully voiced (1:1 voicing ratio). Nevertheless, 19 out of 121 intervocalic plain voiced and voiced aspirated tokens were not fully voiced: 17 of these tokens were voiced aspirated and 2 tokens were plain voiced. On average, 95% of the closure interval is voiced for these two types of stops.

Place of Articulation	Total mean		Female (in ms)		Male (in ms)	
	Plain voiced	Voiced aspirated	Plain voiced	Voiced aspirated	Plain voiced	Voiced aspirated
Bilabial	73	58.7	74.8	60	71.4	57.3
Dental	66.2	55.5	65.8	54.2	66.7	56.8
Velar	54	46.5	49.5	44.9	61.1	48.3

Table 6. Mean voicing duration for intervocalic voiced and voiced aspirated stops.

Table 6 displays the mean voicing duration during the closure interval for voiced and voiced aspirated stops in intervocalic position. The duration of intervocalic voicing also seems to be influenced by male-female difference. Additionally, the voicing duration for voiced aspirated stops appears to be shorter than the plain voiced stop. Furthermore, if the duration of voicing during closure is compared, it shows that the duration of intervocalic voicing also depends on the place of articulation, yet the ranking is different than the utterance-initial tokens. For intervocalic voiced and voiced aspirated stops, the mean of voicing duration during closure interval for labial stops is greater than the dentals; thus, the ranking is labial > dental > velar.

To look at the significance of sex and place of articulation for the intervocalic plain voiced and voiced aspirated stops, two-way Anova test was run. The results indicated that sex is not a significant factor in voicing duration for both intervocalic plain voiced stops (F (1, 57) = 1.442, p-value = 0.235) and intervocalic voiced aspirated stops (F (1, 56) = 0.186, p-value = 0.66753). Nonetheless, the place of articulation was confirmed to have a significant effect on voicing duration for intervocalic plain voiced stops (F (1, 57) = 11.294, p-value <.001) and intervocalic voiced aspirated stops (F (1, 56) = 5.569, p-value = 0.00623). Moreover, another statistical test was conducted to see if the voice duration difference in plain voiced and voiced aspirated was significant, and the result confirmed that it is significant (F(1,119) = 23.1, p-value<.001)

3.2.2. Postaspiration

The comparison of mean postaspiration duration for all types of stops in different places of articulation can be found in Table 7. Corresponding to the previous findings, postaspiration for all types of velar stops was the longest. From Table 7, it can also be seen that the lag time for voiced aspirated stops is shorter than the voiceless aspirated stops, although the labials cannot be compared since there is no voiceless aspirated labial stop available.

Place of Articulation	Total mean (in ms)		Female (in ms)		Male (in ms)	
	Voiced aspirated	Voiceless aspirated	Voiced aspirated	Voiceless aspirated	Voiced aspirated	Voiceless aspirated
Bilabial	64.5	-	82.9	-	46.1	-
Dental	45	56.9	53.7	60.6	35.5	53.8
Velar	60.2	74.4	67.1	75.7	52.4	72.9

Table 7. Mean postaspiration duration for intervocalic stops

The results of two-way Anova test was conducted on sex and place of articulation. Sex was found to be a significant factor only in the postaspiration of intervocalic voiced aspirated stop (F (1, 56) =13.641, p-value = 0.000504), yet it does not have a significant effect on the postaspiration of intervocalic voiceless aspirated stops. The place of articulation, however, was found to be a significant factor in both postaspiration of intervocalic voiced aspirated ($F(1, 57) = 3.837$, p-value = 0.027448) and voiceless aspirated stops ($F(1, 31) = 9.141$, p-value = 0.00498). In addition, when the difference between the postaspiration of voiced aspirated and voiceless aspirated was considered, the results indicated that the difference was not significant ($F(1, 92) = 0.949$, p-value = 0.333).

IV. CONCLUSION

The findings indicated that place of articulation is has a significant correlation with voicing and aspiration duration of Marathi stops in initial and medial position. Maddieson (1996) explained that stop closure are expected to decrease depending on the backness of the place of articulation due to the size of the cavity and air pressure. Smaller cavity means smaller surface area, therefore the air pressure reach equality with pulmonic pressure faster (p.168). Thus, universal expectation is that the labials are longer than the dentals, and that velars have the shortest closure duration of all.

Previous studies agreed with this observation. The same result was observed in Dutch (van Alphen & Smits 2004) and Swedish (Helgason & Ringen 2008). The voicing of labial and dental stops in Swedish were found to be longer than the velar stops in utterance-initial and intervocalic position. Their findings showed that the negative VOT of utterance-initial bilabial stop was the longest (-96ms), followed by dental (-90ms), and velar was the shortest (-61ms).

In Marathi, the velar stops also had the shortest voicing duration. However, the dental stops had longer voicing compared to the bilabial stops. The same findings were observed in Bengali stops (Mikuteit & Reetz 2007). Nonetheless, when they ran a post hoc test, they found that the bilabial and the dental stops can be grouped together against velar stops. Therefore, the difference of voicing duration between the labial and dental stops in these Indo-Aryan languages may not be significant enough, although it disagrees with the universal pattern.

The place of articulation was also found to have significant influence on the postaspiration duration. Cho & Ladefoged (1999) studied the VOT of voiceless stops in 18 languages. They assumed the universal pattern with the principal findings that the further back the closure, the longer the VOT. Therefore, velar stops should have the longest closure compared to the dental and labial stops. The results of their study show that most languages conform to the universal pattern: the velar and uvular stops had the longest VOT, except for Dahalo that has the longest VOT for its alveolar stops. Marathi, like most languages, follow the universal pattern in which the duration aspiration of voiceless and voiced aspirated increased in correlation with the backness of the place of articulation. However, one irregular pattern was found for the postaspiration of the intervocalic voiced aspirated stops. The intervocalic bilabial voiced aspirated stop had the longest duration, followed by the velar and then the dental voiced aspirated stop.

In this study, the female subjects had shorter prevoicing compared to the male subjects, although the differences were not significant, except for the voicing of the utterance initial voiced stops. Earlier research reported male-female differences were present in the study of Swedish VOT (Helgason & Ringen 2008) and Dutch VOT (van Alphen & Smits 2004). According to Swartz (1992), anatomical differences between male and female, such as laryngeal size and supralaryngeal area, may be the reason for the potential difference in the VOT production.

From the study on English VOT by Whiteside & Irving (1998), it was observed that female subjects had longer VOT value than the male subjects. Nonetheless, a more recent study on English VOT (Morris et al. 2008) found that there is no significant difference between the production of male and female speakers of English. Moreover, another study on Korean VOT (Oh 2011) showed the opposite result. The male Korean speakers were observed to have a statistically significant longer aspiration for the aspirated stops than the female Korean speakers. In this study, even though female Marathi speakers generally had longer aspiration than the male speakers, the differences were not found to be statistically significant, except for the postaspiration of intervocalic voiced aspirated stop.

Lisker and Abramson (1964) measured the VOT of Marathi stops and mentioned that Marathi has four categories of stops. However, their result shows an overlap between plain voiced and voiced aspirated stops, as they only measure the prevoicing of these stops. As a conclusion, the fact that voicing and aspiration were robustly present in the production of voiced aspirated stops indicates that VOT alone is not a sufficient measure to distinguish stops in four-way contrast languages.

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APPENDIX. STIMULI

		INITIAL	INTERVOCALIC
Bilabial	/p/	pustək paach	kapus sopa
	/p^h/	phuphphus phataa	-
	/b/	bolne	kəbər

		baaraa	dhobi
	/bʰ/	bheʈne bhaat	ubhe əbhaw
Dental	/t/	Teraa Tas	rutuu pote
	/tʰ/	thuŋkii thaaʈi	ithe shithil
	/d/	dəgəɖ dar	kudəl padəp
	/dʰ/	dhəg dhaar	adhar adhi
Velar	/k/	kudel kakh	eka kaka
	/kʰ/	khup khas	akhaɖa
	/g/	gəwət gaal	saudagər dəgəɖ
	/gʰ/	ghər ghaar	nighuun bəgha