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Correlation between Sylheti Tone and Phonation

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Abstract

The canonical theories of tonogenesis distinguish voiced obstruents as the pitch suppressor of the following vowels whereas their voiceless counterparts are predicted to raise it (Yip 2004, Hombert 1978). These predictabilities however, do not seem to work in Sylheti which observes a high tone following the loss of breathiness contrast ([d̪án] 'paddy' [d̪ʰ>d̪], [d̪àn] 'donate'), and/or a low tone associated with a voiceless consonant ([ɸɔ́r] 'read' [p>**ɸ**], and [ɸɔ̀r] 'guard' [p>**ɸ**]) (Gope & Mahanta, 2015, 2014).

To understand the tonogenetic property of Sylheti this study attempts to examine the phonation qualities of the vowels carrying contrastive tones. Twenty monosyllabic words were recorded from 9 native speakers. The results of various spectral measurements showed (relatively) greater and mostly (positive) values associated with the vowels carrying low tone than the vowels carrying high tone. The low values (though mostly positive) associated with the vowels carrying high tone indicate that the vowels associated with high tone are in the continuum of modal to creakiness, thus justifying the association of high tone and the property of creakines. On the contrary, the vowels associated with low tone seem to be modal in nature.

Index Terms Sylheti, phonation, harmonics, breathy, creaky

1. Introduction

The foundation of canonical theories of tonogenesis is driven by the interaction between consonantal features and predicable pitch patterns of the following vowel. Generally voiced obstruents are expected to lower the f_0 of the following vowels whereas their voiceless counterparts may even raise it (Yip 2004, Hombert 1978). However, such predictions do not seem to work in case of Sylheti- a variety of (Eastern) Bangla (Chatterjee 1971). The phoneme inventory of this language is considerably reduced due to the loss of (underlying) breathiness contrast ([d̪ʰan > **d̪**an] 'paddy', [t̪ʰala > **t̪**ala] 'plate'), spirantization ([por] > [**ɸ**ɔr] 'read', [pʰul] > [**ɸ**ul] 'flower', ([kali] > [**x**ali] 'ink', [kʰal] > [**x**al] 'drain/channel'), and deaffrication ([tʃa] > [**s**a] 'tea', [tʃʰuti] > [**s**uti] 'holiday', [dʒal] > [**z**al] 'net', [dʒʰal] > [**z**al] 'spicy') (Gope & Mahanta, 2015, 2014). These changes, especially the loss of breathy voice contrast [+spread glottis] among the obstruents (both voiced and voiceless) in Sylheti gave birth to the high tone ([d̪án] 'paddy' [d̪ʰ>d̪] and [d̪àn] 'donate', [bát̪] 'rice' ([bʰ>b]), and [bàt̪] 'arthritis'). Further, it was also observed that each homophonous pair is marked with contrastive tones regardless of the voicing property of adjacent (onset) consonant. As such a low tone was also observed after a voiceless consonant ([ɸɔ́r] 'read' [p>**ɸ**], and [ɸɔ̀r] 'guard' [p>**ɸ**]) (Gope & Mahanta, 2015, 2014). The phonological patterns which seem to be divergent as observed in the case of Sylheti, i.e., the unpredictability of consonant-tone interaction, therefore require explicable environment that can account for the patterns of such derivations. Further, these patterns must be well supported and motivated by acoustic evidence.

This paper attempts to address the phonologized correlation between tone and phonation qualities of the vowels (bearing contrastive tones) by providing a detailed acoustic analysis. The following section gives a brief account of acoustic correlates of phonation types and their realization in terms of pitch.

2. Acoustic correlates of phonation

Phonation or voice quality refers to the production of speech sounds by the vibration of vocal folds (Ladefoged 1971, 1996, Gordon 2001, Wayland and Jongman 2002, Esposito 2010a, 2011, Huffman 1987). Ladefoged (1971) is of the opinion that depending on the variations of the glottal constriction continuum, degrees of phonation types could be determined. In his model he argued that the size of the glottis might range from voiceless (when the vocal folds are held furthest apart), through breathy voice (where the glottis is held more open), to regular (modal voicing), to creaky (produced with a constricted glottis) and lastly to glottal closure (when the vocal folds are held closest together, hence no vibration and without phonation).

Even though the basic acoustic display of waveforms and spectrograms can easily differentiate between a modal and nonmodal (viz. creaky- irregularly spaced glottal pulses and reduced intensity compared to modal) and breathy- lower f_0 relative to modal and by substantial aperiodic or noisy energy) (Gordon 2001), researchers have proposed a variety of acoustic properties suitable for measuring various phonation types. Among those, spectral measurements have been the most popular and consistent method of phonation used in various languages such as Hmong [distinguishes breathy and modal vowels] (Huffman 1987, Gordon 2001), Mazatec- differentiates between breathy, modal and creaky vowels (Blankenship 1997), Khmer- distinguishes breathy and clear vowels (Wayland and Jongman 2002), and so on. Tilt is determined by the shape of the glottal pulse and measures the difference between the amplitude of the first harmonic and the second or prominent harmonic of the first and/or higher formants (such as (H_1-H_2), (H_2-H_4), (H_1-A_1), (H_1-A_2), and (H_1-A_3)). Among various tilt measurements, the difference between the amplitudes of the first and second harmonics (H_1-H_2) and the difference between the amplitudes of the first harmonic and third formant (H_1-A_3) have been used to draw the distinction in phonation types among various phonations in languages such as English (Stevens and Hanson 1995),

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Krathing Chong (Blankenship 2002), Takhian Thong Chong (DiCanio 2009), and so on.

Gordon and Ladefoged (2001), further noted that non-modal phonation types are generally associated with lowering of fundamental frequency. For example, in a language such as Mam (England 1983) and many Northern Iroquoian languages such as Mohawk, Cayuga and Oneida (Chafe 1977, Michelson 1983, Doherty 1993), the creaky phonation is associated with a lower f_0 (relative to modal phonation). This lowering effect of creaky voice, however, is not universal across languages. Hombert et al. (1979) showed that the process of glottalization can be associated with high tone in the historical development of some of the Athabaskan languages, while the same glottalization process is associated with a low tone in closely related languages (Leer 1979, Gordon and Ladefoged 2001, Kingston 2011). Breathy phonation, on the other hand is more consistently connected with a lower f_0 in the majority of languages (Gordon and Ladefoged 2001).

To understand phonation related qualities of the vowels associated with contrastive tones, an experiment has been conducted to examine various spectral components. In general, breathy vowels are marked with greater and positive values (in dB), an intermediate values for the modal vowels (in dB) and less and often negative values (in dB) for the vowels associated with creaky voice (Stevens and Hanson 1995).

3. Experimental procedure

3.1. Speech material, subjects and recording procedure

For the acoustic experiment twenty monosyllabic words (comprising the vowel [a]) were considered (Table 1). The contrastive pairs were chosen in such a manner that historically one of the words had distinctive breathiness property[1]. Further, since the high first formant of the vowel [a] minimizes the effects on first and second harmonics (Bickley 1982, Ladefoged 1983, Huffman 1987, Ladefoged et al. 1988, Krik et al. 1993, Blankenship 1997, Gordon 2001), the experiment contained homophonous pairs containing the vowel [a] only.

Sylheti words	Gloss	Sylheti words with a history of underlying breathiness property [+spread glottis]	Gloss
[zào]	'gruel'	[záo]	'tamarisk'
[gà]	'body'	[gá]	'wound'
[gài]	'cow'	[gái]	'stroke'
[bàt̪]	'arthritis'	[bát̪]	'rice'
[ɖàx]	'roaring of cloud	[ɖáx]	'drum'
[bàn]	'tie'	[bán]	'pretend'
[d̪àn]	'donate'	[d̪án]	'paddy'
[xàl]	'skin'	[xál]	'channel/drain'
[xuà]	'well'	[xuá]	'jackfruit cell'
[zàl]	'net'	[zál]	'chilly hot'

Table 1: *The dataset displaying the list of monosyllabic words considered for the current experiment.*

9 native speakers of Sylheti (7 male, 2 female) from Dharmanagar district of north Tripura participated in the production experiment. The target words were embedded in a fixed sentence frame of "I am saying **X**" [ami **X** xɔiar], **X** being the target word. For the subjects to be able to maintain the tonal contrast between the words with distinct meanings, a method of priming was used. It involved the recording of an example sentence where the meaning of the contrastive word would be best illustrated. For example, in order to elicit the word [bát̪] 'rice', an example sentence 'I am eating **rice**' [ami **bát̪** xɔiar] was recorded first, followed by the target word [bát̪] in the carrier frame. Speech data was recorded with a *Shure* unidirectional head-worn microphone connected to a *Tascam* linear PCM recorder (confirming a constant mike-to-mouth distance) via an xlr jack.

3.2. Measurement

Post recording, all the target words were segmented into phonemes using wide band spectrograms and waveform, and PRAAT Textgrid files were created for each of the target words. Acoustic measurements of the target words over time were taken automatically using the software VoiceSauce[2]. The software is run as an extension through Matlab. Corrections of the harmonic amplitudes were done automatically in VoiceSauce by using measured formants frequencies and bandwidths estimated by those frequencies. The correction procedure in VoiceSauce is similar to the method used by Hansen (1995, as mentioned in Shue *et al.* 2011) which was later extended by Iseli *et al.* (2007). All the spectral measurements of each vowel were estimated at a 30 ms window at 2 ms intervals. The following spectral measurements were considered for the current experiment:

1) the difference between the amplitude of first and second harmonic (H_1*- H_2*);
2) amplitude of the second harmonic minus the amplitude of the fourth harmonic (H_2*- H_4*);
3) difference between the amplitude of the first harmonic and the amplitude of the first formant peak (H_1*- A_1*);
4) difference between the amplitude of the first harmonic and the amplitude of the second formant peak (H_1*- A_2*), and;
5) difference between the amplitude of the first harmonic and the amplitude of the third formant peak (H_1*- A_3*);

Mean value of each of these acoustic components of each subject was used to plot the bar diagrams for visual inspection of the words with contrastive tones. Separate statistical measurements were conducted using SPSS to test the significance of each of the acoustic parameters for each subject. Altogether, 540 tokens were examined for the current experiment (20words * 3repetitions * 9subjects).

3.3. Statistical tests

It is reasonable to assume the null hypothesis that the sample distribution is not different from the normal distribution of the population. In order to verify this assumption, we conducted a Shapiro-Wilk test on the data of each of the acoustic parameters and for every subject separately. The Shapiro-Wilk test confirmed that our data is not normally distributed (alternative hypothesis), and as such it rejects the null hypothesis (see Figure 1 for example). In order to account for the absence of a normal distribution, we conducted a non-parametric Mann-Whitney U test separately for each subject

[1] Note that, the loss of this (underlying) breathiness property is realized with a high tone (Gope & Mahanta 2014)

[2] (Shue *et al*. 2011)

and for each acoustic component to compare and test the significance of various spectral measurements of the vowels with contrastive tones.

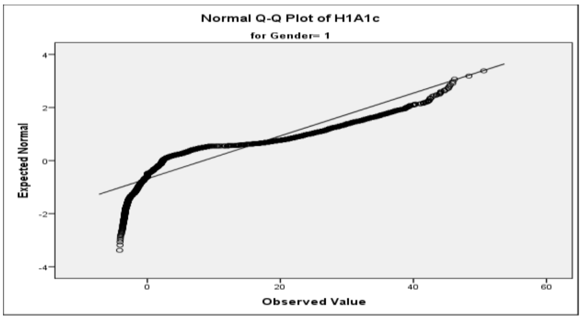

Figure 2: *An example of normal Q-Q plot showing the distribution of the values of the H_1*- A_1*. Gender=1 (p<.05) represents the data of a male subject, H1A1c is the corrected value generated by VoiceSauce which is normally represented with an asterisk (*) such as H_1*- A_1*.*

4. Results

As the Shapiro-Wilk test confirmed non-normalized distribution of a large amount of data, a non-parametric Mann-Whitney U test has been adopted for each subject separately (since all the spectral measurements of each vowel were estimated at a 30 ms window and at 2 ms intervals for each speaker separately). The Mann-Whitney U test has been conducted using tone-type as factor and various tilt components such as, H_1*- H_2*, H_2*- H_4*, H_1*- A_1*, H_1*- A_2*, and H_1*- A_3* as dependent variables to examine the significance difference (if any) among the vowels carrying contrastive tones. Since we have a relatively large population, we considered mean values of the token instead of median values (this was also done due to the fact that we observed identical values of mean and median for the sample of individual speakers) to draw bar diagrams for visual inspection.

(1) The difference between the amplitude of first and second harmonic (H_1 - H_2*):

H_1*- H_2* indicates relatively higher values for the vowels associated with low tone (than the vowel associated with high tone) [Figure 2]. This is observed for all the subjects.

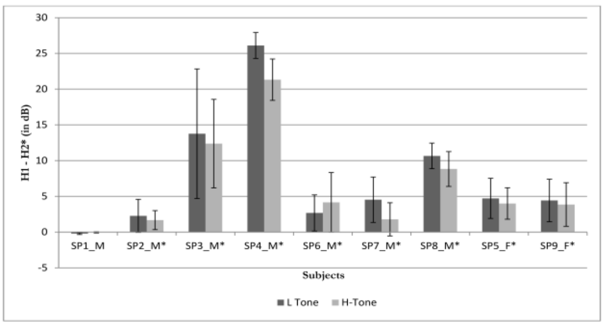

Figure 2: *comparison of mean values (with standard deviation as error bars) of (H_1* - H_2*) (measured in dB) of the vowels carrying contrastive tones, measured for each speaker separately (M=male, F= female), (L Tone= low tone [dark gray scale], H Tone= high tone [light gray scale]), Significance among the contrastive tones for each speaker is marked with an asterisk [*].*

According to the Mann-Whitney U test this difference is significant for speaker 2 (U = 12515.5, Z = -2.35, p = 0.02 [two-tailed]), speaker 3 (U = 12737, Z = -.74, p = 0.02 [two-tailed]), speaker 4 (U = 11821, Z = -5.34, p = 0.00 [two-tailed]), speaker 5 (U = 3489, Z = -.96, p = 0.03 [two-tailed]), speaker 7 (U = 4228, Z = -6.7, p = 0.00 [two-tailed]), speaker 8 (U = 76842, Z = -2.61, p = 0.00 [two-tailed]), and speaker 9 (U = 2006, Z = -6.15, p = 0.00 [two-tailed]) respectively. No significant difference of H_1*- H_2* values was observed among the vowels with contrastive tones for speaker 1. Interestingly, data from speaker 6 presents a reverse pattern where the vowels carrying high tone bear higher values than the vowels associated with low tone and the difference was found to be significant (U = 3618, Z = -2.24, p = 0.03 [two-tailed]).

2) The difference between the amplitude of second and fourth harmonic (H_2*- H_4*):

H_2*- H_4* also shows higher values for the vowels carrying low tone (for all the speakers) than the vowels associated with high tone. Mann-Whitney U test confirms this difference to be significant for speaker 1 (U = 301, Z = -3.55, p = 0.00 [two-tailed]), speaker 3 (U = 9947, Z = -3.15, p = 0.02 [two-tailed]), speaker 4 (U = 8122, Z = -8.89, p = 0.00 [two-tailed]), speaker 6 (U = 2180, Z = -5.95, p = 0.00 [two-tailed]), speaker 7 (U = 6447, Z = -3.14, p = 0.02 [two-tailed]), and speaker 8 (U = 87386, Z = -2.62, p = 0.01 [two-tailed]) respectively. No significant difference of H_2*- H_4* was observed among the vowels with contrastive tones for speaker 2, speaker 5, and speaker 9 (even though the vowel with L tone exhibited higher H_1*- H_2* values (in dB)).

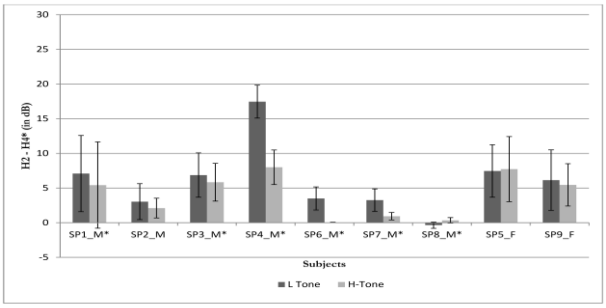

Figure 3: *comparison of the mean values (with standard deviation as error bars) of (H_2* - H_4*) (measured in dB) of the vowels carrying contrastive tones, measured for each speaker separately (M=male, F= female), (L Tone= low tone [dark gray scale], H Tone= high tone [light gray scale]), Significance among the contrastive tones for each speaker is marked with an asterisk [*].*

3. Difference between the amplitude of the first harmonic and the amplitude of the first formant peak (H_1*- A_1*):

H_1*- A_1*, however, does not show a uniform pattern. Data from majority of the subjects (speaker 2, speaker 5, speaker 6, speaker 7, speaker 8, and speaker 9) indicate higher values associated with the vowels carrying low tone. According to the Mann-Whitney U test, this difference is significant for speaker 5 (U = 2995, Z = -2.42, p = 0.01 [two-tailed]), speaker 7 (U = 5478, Z = -4. 7, p = 0.00 [two-tailed]), speaker 8 (U = 28810, Z = -18.09, p = 0.00 [two-tailed]), and speaker 9 (U =

4147, Z = -.264, p = 0.04 [two-tailed]) respectively. On the other hand, the value of H_1*- A_1* seems to be higher for the vowel associated high tone for speaker 1 (U = 386, Z = -2.54, p = 0.01 [two-tailed]), speaker 2 (non-significant), speaker 3 (non-significant), and speaker 4 (non-significant).

4. The difference between the amplitude of the first harmonic and the amplitude of the second formant peak (H_1*- A_2*):

The values of H_1*- A_2* are also found to be higher for the low tone vowels (for most of the subjects) than their counterparts (Figure 4). Mann-Whitney U test confirms this difference to be significant for speaker 1 (U = 79411, Z = -4.72, p = 0.00 [two-tailed]), speaker 2 (U = 9142, Z = -5.89, p = 0.00 [two-tailed]), speaker 5 (U = 2692, Z = -3.32, p = 0.00 [two-tailed]), speaker 6 (U = 3234, Z = -3.24, p = 0.01 [two-tailed]), and speaker 7 (U = 2413, Z = -1.27, p = 0.00 [two-tailed]) respectively. Data from speaker 4 (Significant: U = 12333, Z = -4.84, p = 0.00 [two-tailed]), and speaker 8 (non-significant) show a reverse pattern, that is, relatively higher values for the vowels carrying high tone.

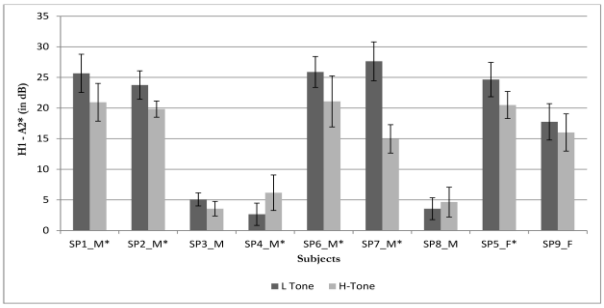

Figure 4: *comparison of the mean values (with standard deviation as error bars) of (H_1* - A_2*) (measured in dB) of the vowels carrying contrastive tones, measured for each speaker separately (M=male, F= female), (L Tone= low tone [dark gray scale], H Tone= high tone [light gray scale]), Significance among the contrastive tones for each speaker is marked with an asterisk [*].*

f. The overall spectral tilt (H_1*- A_3*):

The final acoustic component- the overall spectral tilt also shows higher values for the vowels carrying low tone for all the speakers (Figure 5).

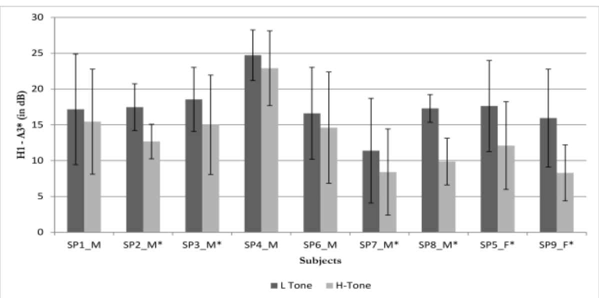

Figure 5: *comparison of the mean values (with standard deviation as error bars) of (H_1* - A_2*) (measured in dB) of the vowels carrying contrastive tones, measured for each speaker separately (M=male, F= female), (L Tone= vowel carrying low tone [dark gray scale], H Tone= vowel carrying high tone [light gray scale]), Significance among the contrastive tones for each speaker is marked with an asterisk [*].*

According to Mann-Whitney U test this difference is significant for speaker 2 (U = 14372, Z = -.397, p = 0.69 [two-tailed]), speaker 3 (U = 8467, Z = -4.42, p = 0.00 [two-tailed]), speaker 5 (U = 2074, Z = -5.15, p = 0.00 [two-tailed]), speaker 7 (U = 7620, Z = -1.23, p = 0.04 [two-tailed]), speaker 8 (U = 57195, Z = -10.59, p = 0.00 [two-tailed]), and speaker 9 (U = 2797, Z = -3.97, p = 0.00 [two-tailed]) respectively. Data from speaker 1, speaker 4, and speaker 6 do not show any significant difference.

5. Discussions

As mentioned above, the literature on phonation types generally associate greater and positive values (in dB) with breathy vowels, an intermediate value for modal vowels, and less and often negative values for creaky vowels generated from various spectral measurements (Stevens and Hanson 1995, Blankenship 2002, DiCanio 2009, Waylad and Jongman 2002, Esposito 2010b, Esposito and Khan 2012). In case of the current experiment, we have observed (relatively) greater and mostly (positive) values associated with the vowels carrying low tone than the vowel carrying high tone. However, the data recorded from the 9 native speakers of Sylheti do not suggest a clear evidence of breathy or creaky voice qualities of the vowels carrying contrastive tones (we did not hear any breathiness, and only very few tokens from two speakers seem to be slightly creaky). The low values associated with the vowels carrying high tone gathered from all the acoustic components and from all the speakers suggest that the vowels associated with high tone are in the continuum of modal to creakiness, thus justifying the association of high tone and creakiness property. On the contrary, the vowels associated with low tone seem to be modal in nature.

On the basis of the detailed discussion of phonation properties of the vowels with contrastive tones presented here, we propose a two-fold evolution of Sylheti tonogenesis- first, the historical development of the loss of intended feature [+spread glottis] associated with breathy voiced obstruents is indeed reinterpreted and readjusted with a perturbed f_0 in the following vowels (in order to maintain the lexical distinctions among the likely homophonous words); secondly, due to hypo-correction- a linguistic phenomenon which may occur in historical processes as proposed by Ohala (1993), where the listeners probably fail to normalize the coarticulatory effects such as, in this case, the effects of [+spread glottis] on f_0, the vowels following the breathy voiced obstruents might have been compensated with a perturbed f_0. Since the [+spread glottis] quality of the consonants was reinterpreted and readjusted on the adjacent vowels, the vowels seem to acquire a property similar to creakiness (as could be heard in few speakers' tokens at least) in order to maintain the lexical distinction of homophonous words with an increased f_0 (since the conditioning environment wasn't completely lost - leading to hypo-correction). Once the conditioning environment (for example, the feature [+spread glottis]) was lost, the f_0 patterns were phonologized for the homophonous words with contrastive lexical tones.

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