Breathy Nasals and /Nh/ Clusters in Bengali, Hindi, and Marathi

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Abstract

Previous work on breathiness in Indic languages has focused primarily on the acoustic properties of breathy (also known as voiced aspirated) oral stops in languages like Hindi (/baːl/ ‘hair’ vs. /bʱaːl/ ‘forehead’) and Bengali (/bati/ ‘bowl’ vs. /bʱati/ ‘kiln’). However, contrastive breathiness in some Indic languages also extends to nasal stops, as in Marathi (/maːɾ/ ‘beat’ vs. /m̤aːɾ/ ‘Mahar caste’). It is not clear if languages such as Hindi and Bengali have breathy nasals in addition to breathy oral stops. This study addresses the following question: in Bengali and Hindi, are underlying sequences of a modal nasal (/N/) followed by breathy-voiced /ɦ/ phonetically realized as singleton breathy nasals ([N̤]), or as clusters ([Nɦ])? To answer this question, simultaneous audio, aerodynamic, and electroglottographic recordings were made of Hindi, Bengali, and Marathi speakers. Within- and cross-language comparisons were made, and phonological evidence was examined. While some within-language comparisons gave inconclusive results for Hindi and Bengali, other comparisons with Marathi and within-language phonological evidence pointed to the lack of breathy nasals in Hindi and an uncertain status for breathy nasals in Bengali.

1 Introduction

The Indic languages are typologically unusual, possessing a four-way oral stop contrast that includes both voiceless and voiced aspirates.[1] This is exemplified in Table 1, with data from two Indic languages, Bengali and Hindi.

	Bengali	Hindi
Voiceless unaspirated	pati ‘mat’	pa:l ‘take care of’
Voiceless aspirated	pʰati ‘I burst’	pʰa:l ‘knife blade’
Voiced unaspirated	bati ‘bowl’	ba:l ‘hair’
Breathy-voiced aspirated	bʱati ‘kiln’	bʱa:l ‘forehead’

Table 1: Examples of the four-way oral stop contrast in Bengali and Hindi.

In some Indic languages, including Marathi, Konkani, and Rajasthani (Masica 1991),

as Braj and Bhojpuri), the form examined here is Mo

underlying /ɦ

(p. 53). recent research, however, finds that potentially breathy nasals (/N/+/ɦ/) (e.g. /brɔmɦo/ ‘Brahma’, /ʧinɦo/ ‘sign’, /ʃiŋɦo/ ‘lion’) behave as consonant clusters, given distributional and durational evidence (Sen Gupta 1980; Bhattacharya 1984). Unlike breathy oral consonants, but like clusters beginning with a nasal, /N/+/ɦ/ clusters are described as being restricted to word-medial position, and are found to undergo lengthening of the nasal (e.g. /ʧ

during breathy phonation. The amount of oral and/or nasal airflow produced during speech can be measured with masks that fit securely around the speaker's mouth and nose. Aerodynamic properties have been a reliable measure of phonation in Jingpho, Wa, Yi, and Haoni (Maddieson & Ladefoged 1985).

5.2 Electroglottograph

The electroglottograph (EGG) is a non-invasive device that indexes the contact area between the vocal folds by measuring electrical impedance. While human tissue is a fairly good conductor of electricity, air is not. During phonation, the vocal folds (i.e. human tissue) are, at times, separated by the glottis (i.e. air). As the vocal folds move apart, the glottis opens, thereby increasing the electrical impedance across the larynx. When the vocal folds come closer together, the size of the glottis decreases, thereby decreasing the electrical impedance across the larynx.

The most common EGG measure is CQ (for Closing Quotient or Contact Quotient), which is a measure of the closed portion of the glottal cycle. During breathy phonation, the vocal folds are far apart, producing a low closed quotient value. During modal phonation, the vocal folds are closer together than for breathy phonation; therefore, the closed quotient value is higher for modal phonation than for breathy phonation.

EGG measures have been applied to the study of linguistic phonations in various languages (e.g. Watkins 1999 on Wa, Guion et al. 2004 on Maa, Michaud 2004a and Michaud & Tuân 2004 on Vietnamese, and Esposito 200

question, simultaneous audio, aerodynamic, and electroglottographic (EGG) recordings were made for Bengali, Hindi, and (to provide a point for comparison) Marathi. Within-language comparisons of the breathy-voiced oral stops and the potentially breathy nasals were made in both Bengali and Hindi. In addition, cross-language comparisons of the potentially breathy nasals in Bengali and Hindi to the breathy nasals in Marathi were made. We also examined phonological evidence to see if /Nɦ/ in Bengali and Hindi behaves like a cluster or like a single segment. In the next section, we will begin by discussing the within-language comparisons, followed by the cross-language comparisons in section 8, and the phonological evidence in section 9. Section 10 provides a discussion and conclusion of the study.

7 Within-language comparisons

For the within-language comparisons, breathy-voiced aspirated oral stops (/Dʱ/) were compared to potentially breathy nasal ones (/Nɦ/) in Bengali and Hindi. If breathy nasals do exist in Bengali and Hindi, then it is expect that they will share some features with breathy-voiced aspirated oral stops (except, of course, for nasality). More specifically, the following hypotheses were made:

(1) If /Nɦ/ is realized as a cluster, then its duration should be more similar to a cluster such as /Dɦ/ than to a single consonant such as [Dʱ].

(2) If /Nɦ/ is realized as a cluster, then its CQ value should be more similar to a cluster such as /Dɦ/ than to a single consonant such as /Dʱ/.

7.1 Methods

7.1.1 Speakers

For Bengali, three adult male and two adult female speakers were recorded for this study. All the speakers were born in the Dhaka Division of Bangladesh and speak the Choltibhasha dialect of Bengali. For Hindi, one adult female speaker was recorded. All speakers spoke E pɨt

7.1.2 Speech Materials

The Bengali and Hindi speakers produced words that included the sounds given in Table 3:

Consonant/cluster type	Label	Bengali Example	Hindi Example
1. Modal Nasals	/N/	/banalam/ ‘I made’	/kʊmaːɾ/ ‘boy’
2. Potentially Breathy Nasals (nasals followed by /ɦ/)	/Nɦ/	/namɦaɹa/ ‘nameless’	/kʊmɦaːɾ/ ‘potter’
3. Voiced Unaspirated Stops	/D/	/beḓana/ ‘pomegranate’	/kʊbeːɾ

Each word was repeated three times in the carrier sentence [ʃe ____ bollo] 'He/she said ____' for Bengali, and [ab ____ kahie:] 'Please say ____ now' for Hindi. Simultaneous electroglottographic, aerodynamic, and audio recordings were made for each speaker. Tokens were digitized and analyzed at a sampling rate of 22 kHz using AcQuirer software (Scicon RD). Figure 1 shows the audio, oral flow, nasal flow, and EGG signals, respectively, for Hindi [paka:na:] 'to cook (transitive)' as displayed in AcQuirer (Scicon RD). The aerodynamic data (i.e. the oral and nasal flow data), are relevant to the cross-language comparison, Section 6.

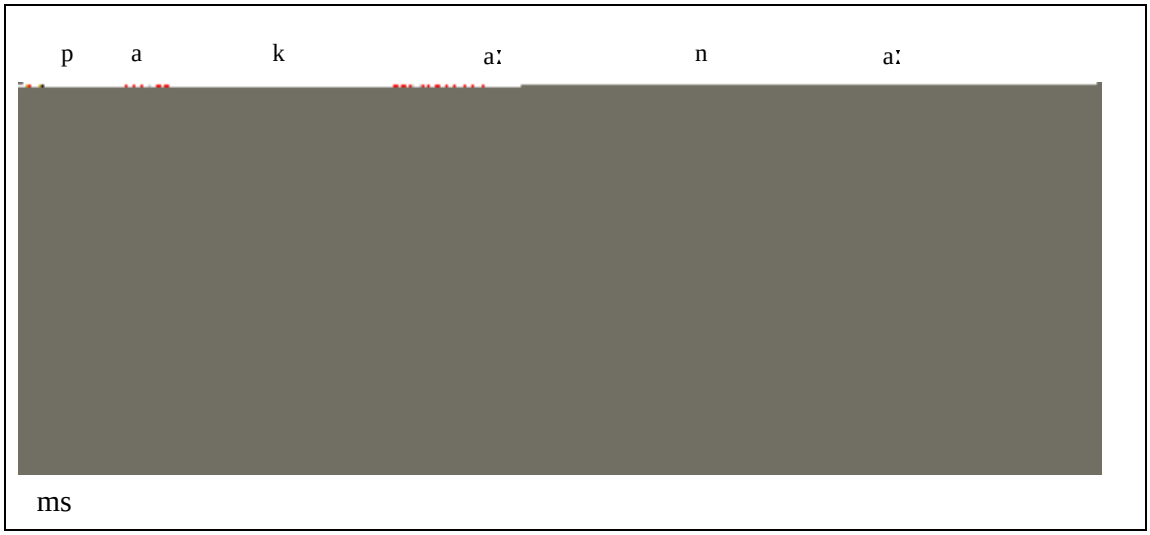


Figure 2: Audio, oral flow, nasal flow, and EGG signal of Hindi [paka:na:] 'to cook (transitive)'

Duration and closed quotient were measured for each token. In the next section, we detail how and where each measurement was taken.

7.2.1 Description of measures

7.2.1.1 Duration

For each segment, the duration of the modal/unaspirated portion and the duration of the breathy (-aspirated) portion were measured in milliseconds (ms) using spectrograms created from the audio signal. Here and throughout, breathiness was characterized on the

waveform as diminished energy and on the spectrogram as visible noise distributed across a wide range of frequencies during a period of visibly clear voicing. For the unaspirated voiced stops (/D/), the modal nasals (/N/), and /ɦ/, which are all produced with only one phonation type each, the duration of the entire segment was measured.

7.2.1.2 Closed Quotient

Closed quotient (CQ) was measured automatically with AcQuirer by dividing the amount of vocal fold closure (Tc) by the sum of the amount of vocal fold closure plus the amount of vocal fold opening (To) for each glottal pulse. Figure 3 shows this equation and how it was derived from a glottal pulse from the EGG signal.

We begin by presenting the results and discussion of the within-language comparison for Bengali, and then continue with Hindi.

7.3.1 Bengali

7.3.1.1 Duration

Figure 4 is a graph of the average duration of the breathy/aspirated and modal/ unaspirated portion of the segments /N/, /Nɦ/, /D/, /Dɦ/, /Dʱ/, and /ɦ/. Duration is graphed on the y-axis in ms. Due to typographical limitations, breathiness/aspiration is represented by an apostrophe < ' > and /ɦ/ is presented with an <h> in all graphs.

Duration (Bengali)

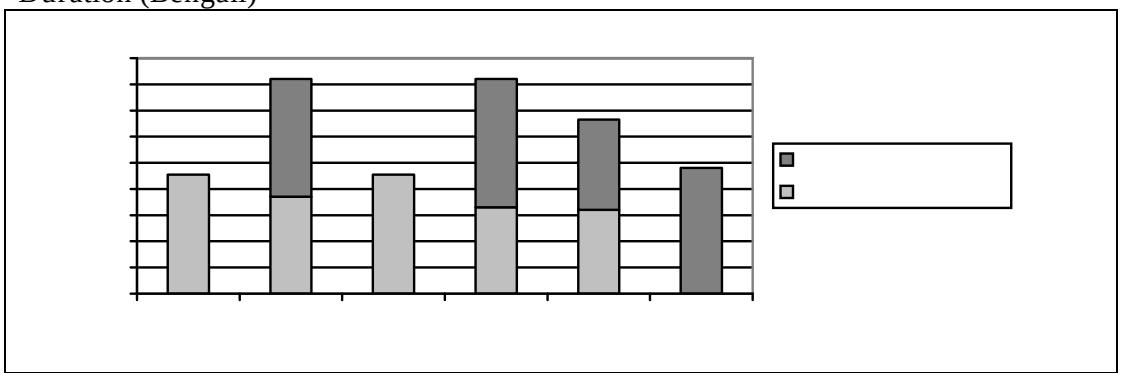


Figure 4: Graph of the average duration of the breathy/aspirated and modal/unaspirated portion of /N/, /Nɦ/, /D/, /Dɦ/, /Dʱ/, and /ɦ/ for Bengali.

The data presented here suggest that the duration of /Nɦ/ is similar to that of /Dɦ/. Like /Dɦ/, the duration of /Nɦ/ is longer than the single segment /Dʱ/. The data indicate that the duration of /Nɦ/ is more like that of a sequence than that of a single segment.

7.3.1.2 Closed Quotient

Figure 5 is a graph of the average CQ value for /N/, /Nɦ/, /D/, /Dɦ/, /Dʱ/, and /ɦ/. Lower values indicate increased breathiness.

Closed Quotient (Bengali)

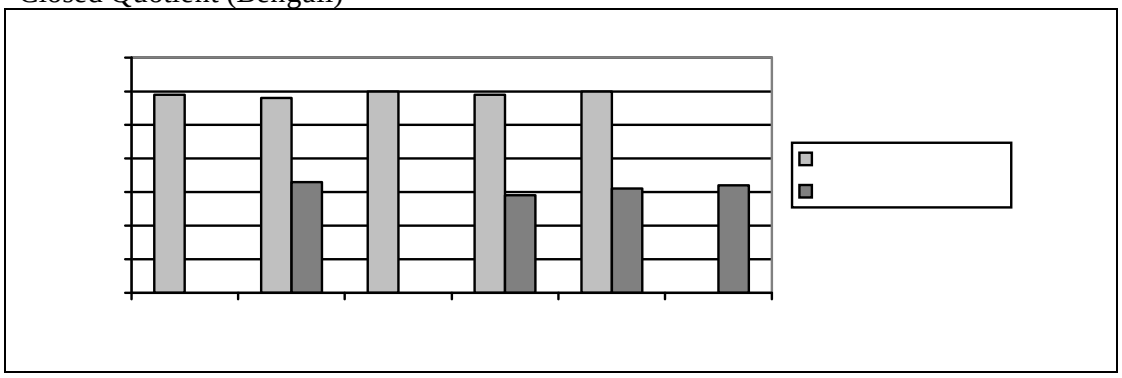


Figure 5: Graph of the average closed quotient of /N/, /Nɦ/, /D/, /Dɦ/, /Dʱ/, and /Dʱ/ for Bengali. The arrow indicates the direction of increased breathiness.

Figure 5 tells us little about the status of breathiness in general. The CQ data fails to distinguish even the phonemic distinction between /Dʱ/ and /Dɦ/; the CQ values of the unaspirated portions of both consonant types are si

yielding some productions of [Nəɦ]. This phonetic variation even occurred across tokens of the same word. As the epenthesized schwa could potentially confound many of the acoustic measurements taken, all tokens with schwa epenthesis were excluded from the measurements of duration, CQ, peak airflow, and duration of peak airflow, including all the graphs below.

Figure 6 is a graph of the average durations of the breathy/aspirated and modal/unaspirated portions of the segments /N/, /Nɦ/, /D/, /Dʱ/, and /ɦ/. Duration is graphed on the y-axis in ms.

Duration (Hindi)

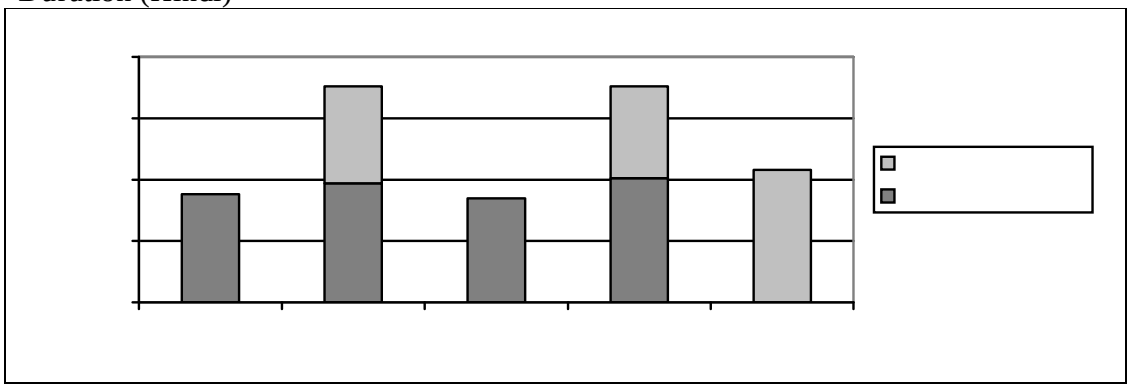


Figure 6: Graph of the average duration of the breathy/aspirated and modal/unaspirated portion of /N/, /Nɦ/, /D/, /Dʱ/, and /ɦ/ for Hindi.

The duration of /Nɦ/ is twice that of /N/, suggesting that it is a cluster of two consonants. However, the duration of the phonemically breathy-aspirated singleton consonant /Dʱ/ is also twice that of its modal counterpart /D/, suggesting that /Nɦ/ and /Dʱ/ are actually behaving in a similar pattern. In this respect, /Nɦ/ seems to be patterning like other breathy singleton consonants in Hindi.[7] However, it is hard to draw a firm conclusion from the duration data,, as the /Dɦ/ cluster data needed to serve as a point of comparison were not produced without schwa epenthesis ([Dəɦ]).

Despite the ambiguity of the duration results, the fact that schwa epenthesis occasionally breaks up /Nɦ/ into [Nəɦ] is in itself a strong indication that /Nɦ/ is a cluster,

because a single segment like /Dʱ/ is never split up by the sort of epenthesis consistently produced in tokens of /Dɦ/ clusters.

7.3.2.2 Closed quotient

Figure 7 is a graph of the average CQ value for Hindi /N/, /Nɦ/, /D/, /Dʱ/, and /ʔɦ/. Lower values indicate increased breathiness.

Closed Quotient (Hindi)

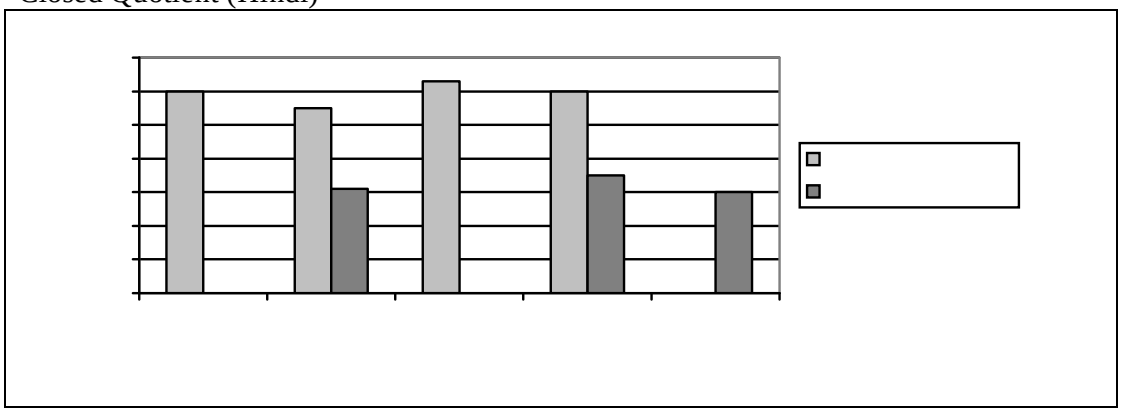


Figure 7: Graph of the average closed quotient of the breathy/aspirated and modal/unaspirated portion of

These consonants were produced intervocalically, with six words per consonant type. Each word contained one and only one of the consonant types in question.

8.1.2.2

segments under study. (The airflow during modal/unaspirated segments was always less than

Airflow is represented in ml/s on the y-axis. The /Nɦ/ in Bengali and Hindi and the /N̤/ in

Airflow (Marathi)

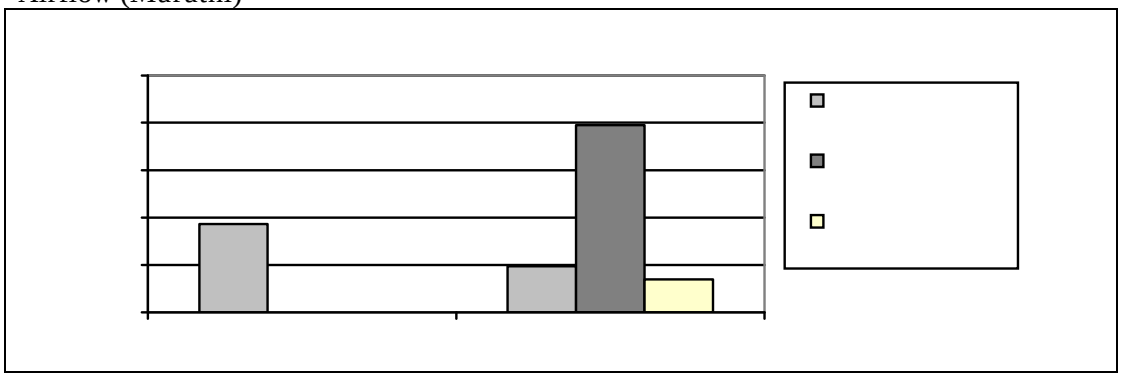


Figure 9: Graph of the average peak oral and nasal flow of /N/ and /N̤/ for Marathi.

Airflow (Bengali)

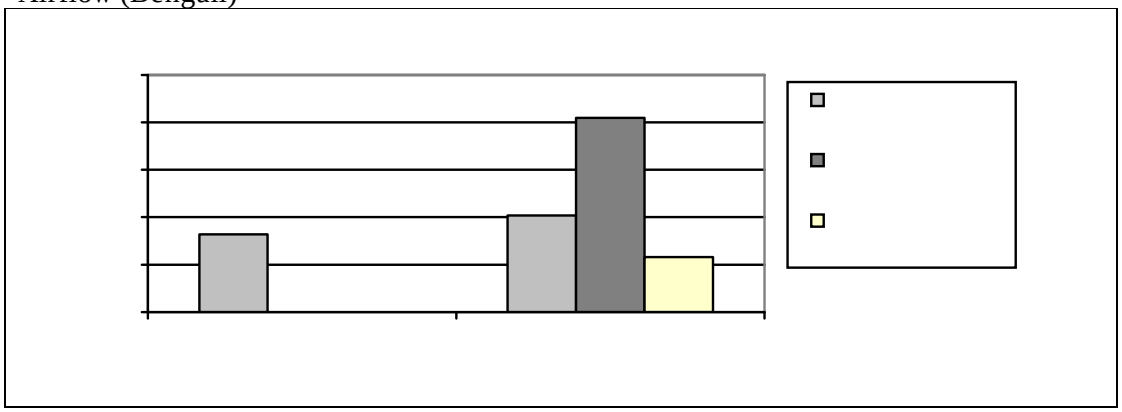


Figure 10: Graph of the average peak oral and nasal flow of /N/ and /Nɦ/ for Bengali.

Airflow (Hindi)

other hand, Hindi /Nɦ/ has a great deal of oral flow in addition to the nasal flow. This substantial oral flow suggests that the Hindi /Nɦ/ behaves like two distinct segments ([Nɦ]), one nasal ([N]) and another oral ([ɦ]), with some coarticulation, rather than like a single breathy nasal [N̤].

8.3.2 Closed Quotient

Figure 12, Figure 13, and Figure 14 are graphs of the average CQ value of the /N/ and /N̤/ for Marathi, and /N/ and /Nɦ/ for Bengali and Hindi. In each figure, an arrow is pointing in the direction of increased breathiness.

Closed Quotient (Marathi)

true of Bengali or Hindi, where the /Nɦ/ has a substantially lower CQ only during the [ɦ] portion; the modal portion of the /Nɦ/ has a similar CQ value to the modal /N/. (In Bengali, the CQ of the /N/ in /Nh/ is only narrowly lower than that of modal /N/, while the Hindi /Nɦ/ begins with an even higher CQ – indicating less breathiness – than the phonemically modal /N/.) Thus the /Nɦ/'s of Bengali and Hindi are not like the /N̤/ of Marathi with respect to CQ.

8.3.3 Duration of peak airflow

Figure 15, Figure 16, and Figure 17 represent the average duration of peak airflow for /N̤/ in Marathi, and /Nɦ/ in Bengali and Hindi. Duration is graphed on the x-axis in ms.

Duration of peak airflow (Marathi)

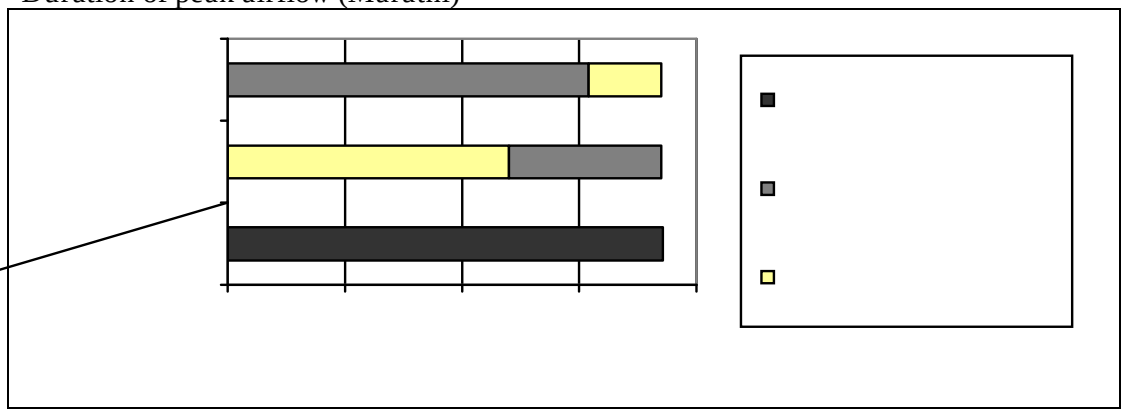
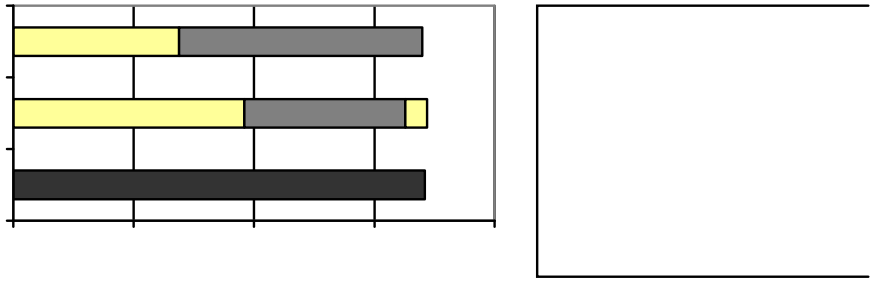


Figure 15: Graph of the average duration of peak airflow in Marathi /N̪/.

Duration of peak airflow (Bengali)



languages, the /Nɦ/ is composed of similar parts nasal and oral flow, both taking place near the end of the segment, suggesting that these languages lack the type of breathy nasal found in Marathi.

8.3.4 Summary of cross-language comparison

For the most part, the Bengali and Hindi data do not pattern like that of Marathi, suggesting that the /Nɦ/ sequences in these languages are not breathy nasals. For example, when looking at duration of peak airflow, the Bengali and Hindi /Nɦ/ is composed of similar parts nasal and oral flow at the end of the segment, as opposed to Marathi, where the [N̤] has peak nasal flow throughout most of the consonant. In addition, according to the CQ value, the Bengali and Hindi /Nɦ/ is breathy only during the [ɦ] portion, unlike Marathi, where the /N̤/ is breathier than its modal counterpart /N/ for most of the segment. The only evidence that the Bengali /Nɦ/ might be a single segment comes from peak airflow, where /Nɦ/ has mostly nasal flow, just like Marathi. However, in Hindi, the /Nɦ/ has considerable oral (in additional to nasal) flow, suggesting the Hindi /Nɦ/ is behaving more like a cluster.

9 Vowel length

In addition to the comparisons made above, we also examined phonological evidence to determine the status of the /Nɦ/ sequences in Bengali and Hindi. In these two languages, vowels are phonetically longer in certain environments:

- Bengali: vowels are longer in open syllables (Esposito, et al. 2005a)
- Hindi: vowels are longer before a breathy/aspirated consonant (Maddieson & Gandour 1977)

These facts can be used as a simple diagnostic to provide further insight into the question of /Nɦ/ sequences. In Bengali, if vowels are longer before an /Nɦ/ sequence, they are behaving as though they are in an open syllable, suggesting that /Nɦ/ is behaving as a single

In Hindi, the vowels being measured were unstressed /ʊ/'s.

9.2 Procedure

consistently shorter than 100ms. This suggests that /Nɦ/ is behaving more like a single segment ([N̤]) than like a cluster of [N.ɦ] in terms of syllabification, the same way that vowels before the single consonants /D/ and /Dʱ/ are consistently longer than those before clusters of an oral stop and another consonant (/DC/), including when the second consonant is /ɦ/ (/Dɦ/). Thus, /Nɦ/ patterns with singleton consonants such as /N/, /D/, and /Dʱ/ and not

In Bengali, vowels preceding an /Nɦ/ sequence were found to be longer than those preceding /N.C/ and other clusters, and more similar in length to vowels preceding the single segments /D/, /Dʱ/, and /N/. In Hindi, vowels preceding /Nɦ/ were found to be the same length as vowels preceding /N/. The phonological evidence here indicates that /Nɦ/ sequences in Bengali are behaving like single (breathy) segments, but that these sequences in Hindi behave as if they were clusters beginning with a modal segment.

10 Conclusion

To summarize, the Bengali data is ambiguous. For example, some data in the within-language comparison, (such as duration) point to cluster status for the /Nɦ/, while other data (such as vowel length), suggest that /Nɦ

Measurements	Within-language comparison	Cross-language

Colophon

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References

Aziz, O. 2002. 'Nasal Aspirates in Urdu'. Center for Research in Urdu Language Processing, National University of Computer and Emerging Sciences, Lahore.

Bhattacharya, K. 1984. 'Problems relating to some phonetic segments in Bengali'. Papers in Phonetics & Phonology, B.B. Rajapurohit (ed.). Mysore: Central Institute of Indian Languages.

Blankenship, B. 1997. The Time Course of Breathiness and Laryngealization in Vowels. Ph.D. dissertation. UCLA.

Bokhari, S. 1985. 'Phonology of Urdu Language'. Center for Research in Urdu Language Processing, National University of Computer and Emerging Sciences, Lahore.

– 1991. 'Urdu Zubaan ka Soti Nizaam'. Center for Research in Urdu Language Processing, National University of Computer and Emerging Sciences, Lahore.

Botma, B. 2004. Phonological Aspects of Nasality: an Element-Based Dependency Approach. Ph.D. dissertation, Utrecht University.

Chatterjee, S. 1962.