Breathy Nasals in Indic Languages

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In addition to having a four-way oral stop contrast, breathiness in some Indic languages (like Marathi) extends to nasal stops. Bengali and Hindi do have sequences of phonemic [N]+[h]. However, it is not clear if these are single breathy nasals or [Nh] clusters.

### Note on terminology

- Traditionally, segments like [b̥] are referred to as “voiced aspirated”.
- We will use the term “breathy” for the nasal counterparts.

**Terminology**

- b̥ = breathy
- Tʰ = voiceless aspirated
- Dʰ = voiced aspirated
- Dh = a voiced oral stop followed by an [h]
- Nh = a nasal stop followed by an [h]

### Previous work

- Previous work on breathiness in Indic languages has focused on oral stops (Ohala 1983, Dixit 1987, to name a few.)
- Breathy nasals in a closely related language:
  - Urdu (Aziz 2002)
  - Speakers were asked to produce word-initial, word-medial, and word-final [N]+[h] sequences.
  - Word-Initial - Spectrographic evidence revealed that there was no breathiness on the nasal, and that speakers consistently inserted a schwa between the nasal and the [h].
  - Word-Medial - Speakers were inconsistent in their pronunciation of [h].
  - Word-Final - Speakers nasalized the preceding vowels creating a [ṽh] sequence. (The nasal was always deleted.)

### Current Study

- There is disagreement in the literature as to whether the Hindi [Nh] is single breathy nasals or clusters.
  - clusters (Ohala 1983; Botma 2004)
  - single breathy nasals (Maddieson 1984; Hinskens and van de Weijer 2003)
- No previous research has been done on Bengali [Nh].

#### Do [N]+[h] behave like single breathy nasals or [Nh] clusters in Bengali/Hindi?

- To answer this question, simultaneous audio, aerodynamic, and electroglottographic (EGG) recordings were made of Bengali, Hindi, and Marathi speakers.

### Background: Breathiness in Indic Languages

- In addition to having a four-way oral stop contrast, breathiness in some Indic languages (like Marathi) extends to nasal stops.

<table>
<thead>
<tr>
<th></th>
<th>Bengali</th>
<th>Hindi</th>
<th>Marathi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral nasal</td>
<td>b̥ati 'bowl'</td>
<td>b̥al 'hair'</td>
<td>d̥a 'caste'</td>
</tr>
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Bengali and Hindi do have sequences of phonemic [N]+[h]. However, it is not clear if these are single breathy nasals or [Nh] clusters.

Specifically, the following comparisons were made:

1. **Within-language comparison** - Compare the duration, airflow, and EGG data of Bengali and Hindi voiced aspirated consonants to potentially breathy nasal ones
2. **Cross-language comparison** - Compare the duration, airflow, and EGG data of Marathi phonemically breathy nasals to Bengali/Hindi
3. **Vowel lengthening** -
   1. Bengali: Vowels are longer in open syllables than in closed syllables. Are vowels preceding a [Dh] or [Nh] more like vowels in an open or closed syllable?
   2. Hindi: Vowels are longer before breathy consonants than before modal ones (Maddieson & Gandour 1975). Are vowels longer before [Nh] than before [N]?
About the Languages

- **Bengali**
  - spoken by approximately 171 million speakers in Bangladesh and India

- **Hindi**
  - spoken by approximately 180 million speakers in northern India

- **Marathi**
  - spoken by approximately 68 million speakers in central India

Within- and Cross-Language Comparison Methods

- **Speakers**
  - **Bengali**: 1 adult male and 1 adult female speaker
  - **Hindi**: 1 adult female speaker
  - **Marathi**: 1 adult female speaker

- **Speech Materials**
  - **Marathi**: The speaker produced 6 words per type, each repeated 3 times.

<table>
<thead>
<tr>
<th>Descriptions</th>
<th>Symbol Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nasals</td>
<td>N</td>
</tr>
<tr>
<td>2. Breathy nasals</td>
<td>Nh</td>
</tr>
<tr>
<td>3. Voiced Unaspirated Stops</td>
<td>D</td>
</tr>
<tr>
<td>4. Voiced Aspirated Stops Followed by [h]</td>
<td>Dh</td>
</tr>
<tr>
<td>5. Voiced Aspirated Stops</td>
<td>D̈</td>
</tr>
<tr>
<td>6. Glottal Fricative</td>
<td>h</td>
</tr>
</tbody>
</table>

  - **Carrier sentences**: Bengali: [ʃe ____ bollo] “S/he said _____” ; Hindi: [ʃb ____ kath] “Please say _____ now”
  - **About schwa insertion**: speakers were not explicitly told to avoid inserting schwas between an [N] or [D] and the following [h].

Procedure

- **Simultaneous aerodynamic, electrogastrographic, 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).**

  - **Duration**
    - duration of the modal/unaspirated portion (for [D] and [N], this would be the duration of the entire segment)
    - duration of the breathy/aspirated portion (for [h], this would be the duration of the entire segment)
    - duration of peak oral and nasal airflow (as shown in the figure below)

  - **Airflow**
    - The peak airflow (oral or nasal, depending on the consonant being measured) was taken at two points:
      1) modal/unaspirated
      2) breathy/aspirated

  - **Closed Quotient (CQ)**
    - was measured automatically using AcQuirer at two points:
      1) modal/unaspirated
      2) breathy/aspirated

  - **Closed quotient**
    - H = 25% threshold
    - Closed quotient = $\frac{Tc}{(Tc + To)}$ (From http://www.lpl.univ-aix.fr/~ghio/pedago-EggUK.htm)
Results – Within-language comparison

Duration

Bengali

- The duration of [Nh] is more like that of [Dh] than that of [Dh].

Airflow

Bengali

- The airflow in [Nh] is mostly nasal, but does have a small amount of oral flow.

Closed Quotient (CQ)

Bengali

- The modal half of [Nh] is just as modal as [N], or the first half of [Dh] or [Dh].
- The breathy half of [Nh] is just as breathy as [h], or the second half of [Dh] or [Dh].

Hindi

- In Hindi, schwas were occasionally inserted between 1) N and h and always between 2) D and h. Tokens with schwa were excluded from the analysis.
- The duration of [Nh] is similar to [Dh].
- [Nh] has both oral and nasal flow during its breathy ([h]) portion. It is likely that the nasal portion of the [h] is simply due to co-articulation.
Summary

Within-Language Comparison

- **Bengali**
  - Duration: [Nh] is more like the cluster [Dh] than like [Dh] and other single segments.
  - CQ: [Nh] behaves like both the cluster [Dh], and the single [Dh].
  - Airflow: The airflow in [Nh] is mostly nasal suggesting a singleton, but does have a small amount of oral flow.

- **Hindi**
  - Duration: [Nh] is similar to the singleton [Dh].
  - CQ: [Nh] has similar CQ values to the individual segments [N]+[h], suggesting a cluster.
  - Airflow: [Nh] has both oral and nasal flow during its breathy ([h]) portion suggesting it is more like a cluster.

Results – Cross-language comparison

Duration of Peak Airflow of [N]/[Nh]

- **Marathi** – The [Nh] is composed mostly of nasal flow, with a small amount of oral flow near the end of the segment.
- **Hindi** and **Bengali** – The [Nh] is composed of similar parts nasal and oral flow, both taking place near the end of the segment.

Results – Cross-language comparison

Closed Quotient (CQ)

- In Marathi, the [Nh] is overall breathier (i.e. has a lower CQ) than the [N].
- This is not true of Bengali or Hindi, where the [Nh] has a lower CQ only during the [h] portion.

Cross-language comparison

Duration of Peak Airflow of [N]/[Nh]

- **Marathi** – The [Nh] is composed mostly of nasal flow, with a small amount of oral flow near the end of the segment.
- **Hindi** and **Bengali** – The [Nh] is composed of similar parts nasal and oral flow, both taking place near the end of the segment.

Summary

Cross-Language Comparison

- **Bengali**
  - Duration of peak airflow: The [Nh] is composed of similar parts nasal and oral flow at the end of the segment, as opposed to Marathi, where the [Nh] has mostly nasal flow. This suggests the Bengali [Nh] is more like a cluster.
  - CQ: The [Nh] is breathy only during the [h] portion, unlike Marathi, where the [Nh] is breathier for most of the segment. This suggests the Bengali [Nh] is more like a cluster.
  - Airflow: In Marathi and Bengali the [Nh] has mostly nasal flow. This suggests that the Bengali [Nh] is realized as a singleton ([h]).

- **Hindi**
  - Duration of peak airflow: The [Nh] is composed of similar parts nasal and oral flow, as opposed to Marathi, where the [Nh] has mostly nasal flow. This suggests the Hindi [Nh] is more like a cluster.
  - CQ: The [Nh] is breathy only during the [h] portion, unlike Marathi, where the [Nh] is breathier for most of the segment. This suggests the Hindi [Nh] is more like a cluster.
  - Airflow: In the Hindi [Nh] there is considerable oral flow (in addition to nasal), suggesting co-articulation of nasal [N] and oral [h]. This suggests the Hindi [Nh] is more like a cluster.

Vowel Lengthening

- **Bengali**
  - In Bengali, vowels are longer in open syllables than in closed syllables.
  - Are vowels preceding a [Nh] more like vowels in an open or closed syllable?

- **Hindi**
  - In Hindi, vowels are longer before breathy consonants than before modal ones (Maddieson & Gandour 1977).
  - Are vowels longer before [Nh] than before [N]? (or is the vowel as it would be before other clusters)
Procedure

Methods
- **Speakers** – 2 adult Bengali speakers; 1 adult Hindi speaker
- **Speech Materials** - The speakers were asked to produce words with VC0V sequences, where the C0 was one of the following:
  - voiced aspirated oral stop [VDȺȺ]
  - voiced unaspirated oral stop [VDV]
  - potentially breathy nasal stop [VNHV]
  - modal nasal stop [VNV]
  - a cluster involving any of the above [VD.CV], [VNV], [VD.hV], etc.

**Procedure**
- Measured the duration (ms) of vowels before each consonant (or consonant sequence).
- Controlled for vowel quality and stress

**Vowel Lengthening - Bengali**

- In Bengali, vowels followed by a single segment ([D], [Dh], [N]) are longer than those followed by clusters ([D.C], [Dh], and [N.C]).
- Vowels preceding [Nh] are just as long as those preceding [D], [Dh], or [N]; in this sense, [Nh] behaves more like a single segment than a cluster of [N.C], [D.C], or [Dh]

**Conclusion - Do [N]+[h] behave like single breathy nasals or [Nh] clusters in Bengali?**

<table>
<thead>
<tr>
<th>Without Language Comparison</th>
<th>Cross-Language Comparison</th>
</tr>
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<tbody>
<tr>
<td>Duration</td>
<td>Cluster</td>
</tr>
<tr>
<td>CQ</td>
<td>Cluster</td>
</tr>
<tr>
<td>Duration of Airflow</td>
<td>Cluster</td>
</tr>
<tr>
<td>Airflow</td>
<td>Cluster</td>
</tr>
<tr>
<td>Vowel Lengthening</td>
<td>Cluster</td>
</tr>
</tbody>
</table>

- The evidence is split.
- At this point, it is not clear if Bengali [Nh] is a single segment or a cluster.

**Selected References**


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  - the UCLA Phonetics Lab for their comments and suggestions

**Vowel Lengthening – Hindi**

- Vowels before [Nh] are actually shorter than ones before [N].
- This is the exact opposite of what is found with vowels before [Dh], which are longer than those before [D].

**Conclusion - Do [N]+[h] behave like single breathy nasals or [Nh] clusters in Hindi?**

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</tr>
<tr>
<td>CQ</td>
<td>Cluster</td>
</tr>
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<td>Duration of Peak Airflow</td>
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- With the exception of duration, the evidence for Hindi points toward cluster.
- It is debatable where duration is a good indication of cluster status.