# Amplitude Envelope and the Perception of Breathy Stops in Hindi

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## 1. Introduction

In common with other Indo-Aryan languages of Northern Indian Hindi is characterized by a four-way contrast within the stop consonant series, the following phonological categories being present: voiceless, voiceless-aspirated, voiced, and breathy or murmured. While the first three categories are differentiated by Voice-Onset-Time (VOT), this does not hold for the description of the breathy stops. Breathy stops in Hindi are produced with prevoicing as the voiced stops are, but there is a significantly different release of the closure, i.e. the first part of the following vowel is breathy.

Fischer-Jørgensen (1967) and Dave (1977) who examined breathy and clear vowels in Gujarati did not find any difference in the formant structure of these vowels. The analysis of !Xõó and Gujarati carried out by Bickley (1982) showed that the relationship of the first and second harmonic is significantly different in breathy and clear vowels. The amplitude of the first harmonic is always higher than the amplitude of the second harmonic in breathy vowels.

The aim of the present study is 1) to check Bickley's results with Hindi material, and 2) to investigate the influence of the amplitude of the breathy part of the stop on the perception of breathy stops.

## 2. Material and Procedure

A list of single words containing all Hindi stop phonemes in initial position was produced by 4 native speakers of Hindi. The recordings were made in the sound-proofed room of the Institute. A digital copy of the material was prepared and the first syllable of all words containing a breathy stop in initial position was segmented in the following way. Four parts of the syllable were defined:

1. prevoicing,
2. burst+voiceless aspiration,
3. breathy part of the vowel,
4. steady part of the vowel.

In addition to these 4 parts all voiced portions were segmented into single periods to allow manipulation of these portions. Beside other values the following ones were calculated: the amplitude of the single pitch periods, average values for the amplitude of all harmonics for the single pitch periods, and the relation of the 1st and 2nd harmonic for the breathy and steady part of the vowel.

The relation between the 1st and the 2nd harmonic agreed with Bickley's results. The amplitude of the first harmonic was significantly greater in the breathy part than in the steady part of the words produced (from 3.46 dB to 20.02 dB). The comparison of the amplitude envelope of the breathy part with that of the steady part of the vowel also showed a significant difference. The amplitude of the breathy part was between 9.8 dB and 30.05 dB lower than that of the steady part. Taking these results as the point of departure test stimuli for two perception tests were produced by manipulation of naturally produced speech material.

## 3. Test Material

Previous investigations of the breathy stops in Hindi (cf. Schiefer 1983) showed that a breathy-to-voiced continuum can be generated by reducing the breathy part of the vowel in equal steps. The first stimulus of the continuum thus contains the whole breathy part of the vowel while the breathy part is completely eliminated for the last stimulus. Clear categorical perception between breathy and voiced is found.

The original stimulus chosen for the manipulation was taken from the word /dhobi/ containing the following values for the individual parts:
1. prevoicing 134 ms,
2. burst+aspiration 30 ms,
3. breathy part 105 ms,
4. steady part 154 ms.

The stimuli for TEST I were produced by reducing the breathy part in steps of 3 periods, i.e. in steps of about 15 ms, thus generating a continuum of 8 stimuli. The pitch periods used were taken from different parts of the breathy section to avoid distortion of the articulatory movements as much as possible. The newly defined stimuli were then constructed from the original stimulus with the help of a resynthesis program.

The stimulus used as point of departure for the manipulation had a burst of 30 ms with an amplitude of -45.7 dB and thus differed both in length and amplitude of the burst from normal realisations in breathy dental plosives. In order to study the influence of the amplitude as well as the duration of the burst the basic continuum was subjected to a further manipulation with respect to these two parameters. For the second continuum the amplitude of the burst was reduced by 30% in the third continuum the aspiration was eliminated and in the fourth continuum both these changes were made.

In order to investigate the influence of the amplitude envelope of the breathy part on the perception of breathy stops the whole breathy part of the vowel was eliminated in TEST II, generating a stimulus that consisted of prevoicing, burst+aspiration, and the steady part of the vowel; thus the breathy phonation characteristic of the category was removed. We then superimposed the amplitude contour of the breathy section on the first 21 pitch periods of the steady section by adjusting the amplitude of each period to the amplitude of the corresponding period. Pre-tests with phonetically trained staff and students of the Institute ensured that the manipulated stimulus was unambiguously assigned to the breathy category. The continua 2-4 of TEST II were generated in the same way as described for TEST I.

Two identification tests were prepared, each containing a set of 32 stimuli, which were repeated 5 times and were presented in randomized order with interstimulus intervals of 4 s and a pause of 10 s following a block of 10 stimuli. The tests were run at the Centre of German Studies at the Jawaharlal Nehru University in New Dehli. One group of listeners participated in the tests; all subjects were students of the Centre and native speakers of Hindi. The subjects were instructed that the presented stimuli were manipulated by computer. They were asked to decide to which phonemic stop category /t, th, d, dh/ the presented stimuli belong.

## 4. Results and Discussion

The results for TEST I show clear categorical perception in the identification test in the continuum from breathy to voiced (cf. Fig. 1). (For this preliminary investigation no discrimination tests were run. The tests were repeated in March 1983 using other stimuli as point of departure. This time clear categorical perception was found in both identification and discrimination tests.) The category boundary for all continua is located near the end of the continuum. The point of intersection for both breathy and voiced scores lies between the 6th and the 7th stimulus, to be precise at 6.54. A boundary shift was found in the other three continua, where the category boundary lies at 6.49, 6.3 and 5.97 (cf. Figs. 2-4). This shift was found to be not significant in a correlated t-test.

The results for TEST II again show clear categorical perception from breathy to voiced; the category boundary lies at 6.99 (cf. Fig. 4). But it may be noticed that the identification rate is not as high as in TEST I. There is also a shift in the category boundary found for the continua 2-4 where the category boundary lies at 6.58, 6.26 and 5.93, which again is not significant (cf. Figs. 5-8). The values for the points of intersection for both tests are nearly the same.

The perception test run by Bickley (1982) for Gujarati showed that vowels were judged as breathy when the amplitude of the first harmonic was increased. Thus she assumed that 'the increased prominence of the fundamental with respect to the first harmonic is the acoustic correlate of breathiness'. The aim of our study was to examine the importance of the amplitude

Results of Test I

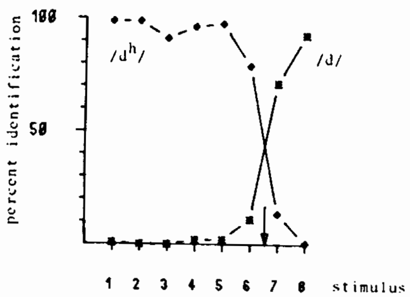


*Figure 1.* Continuum 1.

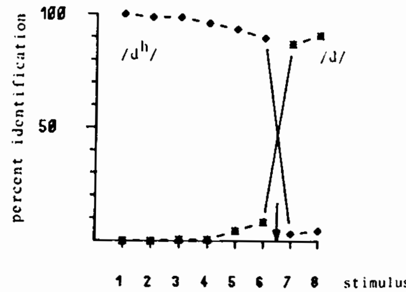


*Figure 2.* Continuum 2.

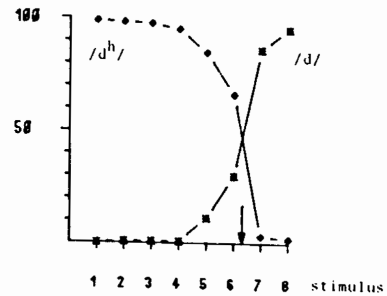


*Figure 3.* Continuum 3.

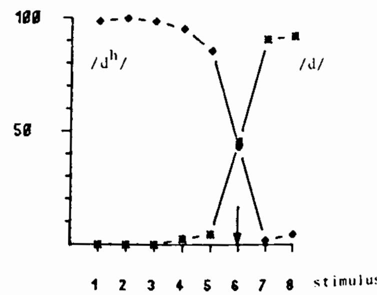


*Figure 4.* Continuum 4.

Results of Test II

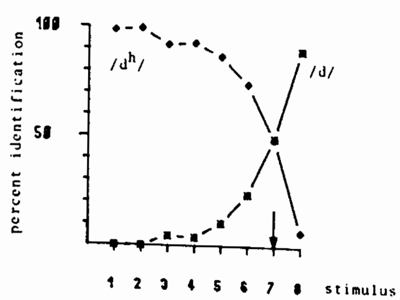


*Figure 5.* Continuum 1.

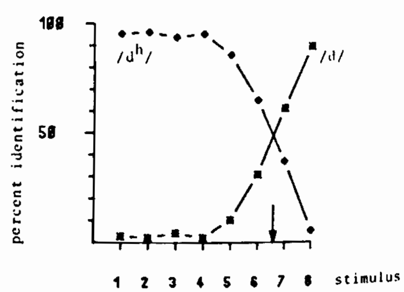


*Figure 6.* Continuum 2.

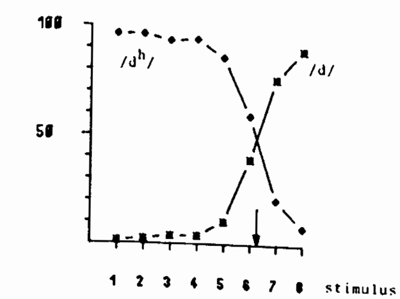


*Figure 7.* Continuum 3.

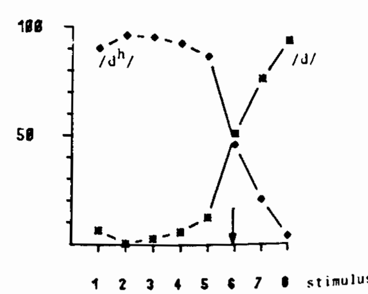


*Figure 8.* Continuum 4.



envelope of the breathy part of Hindi stops. Our results show that the amplitude envelope is also an important acoustic correlate for breathy stops. In addition we found that the manipulation of only 6 pitch periods is enough for the identification of breathy stops. Comparing the points of intersection of both breathy and voiced scores in both tests some interesting observations can be made. It is noticable -as found by Bickley too- that the breathiness of the productions does not contribute in a significant degree to the perception of breathy stops. The manipulation of the burst leads to nearly the same results in both tests. A shift in the category boundary was found in both tests, but it was obviously not significant.

This leads to the concluding observation, that rather than the 'acoustic content' of the signal the 'articulatory gesture' is judged by the listener (cf. Tillmann 1980). Further investigations should be undertaken to verify this hypothesis on the basis of a variety of natural stimuli differing in the duration as well as in the amplitude contour of the breathy part of the stop.

## References

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