ACOUSTIC STUDY OF VC TRANSITIONS FOR HINDI STOPS

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ABSTRACT

Do languages like Hindi with large segment inventories show less contextual variation? VC transitions of stops in different vocalic environments were examined to see if (a) the different places of articulation were cued similarly, and (b) if the five places of articulation were well-differentiated. The results show that acoustic cues for place are highly variable and context dependent -- even in a language with a large segment inventory.

INTRODUCTION

Hindi has a large and, by some measures, a crowded segment inventory: 33 consonants and 11 vowels. If distinctive geminate consonants and nasalized vowels were included, the total number of phonemes would be 85. Of the 33 singleton consonants, 20 are stops or affricates, produced at 5 different places of articulation: labial, dental, retroflex, palatal, and velar (the palatal stops are affricates). See Table 1 (where geminate consonants are not indicated; see [4, 5] for further details). This raises the question of how well these sounds are differentiated; how is coarticulation managed? Following some ideas of Lindblom [2] and Lindblom and Maddieson [3], one might expect Hindi with its crowded phoneme space to permit less allophonic variation than might be the case with a language with a smaller phoneme inventory. To the extent that two different phonemes or even two different sequences of phonemes exhibit similar acoustic patterns, it would presumably make the task of the listener more difficult. In general, the amount of variability and thus the ambiguity inherent in the signal should be inversely related to the inventory of possible message units.

p	t		ʈ	t͡ʃ		k	
pʰ	tʰ		ʈʰ	t͡ʃʰ		kʰ	
b	d		ɖ	dʒ		g	
b̤	d̤		ɖ̤	d͡ʒ̤		g	
f	s			ʃ			
	z						
m	n						
w				j			h
	r		ɽ				
	l						
	i		ĩ			u	ũ
	ɪ		ɪ̃			ʊ	ʊ̃
	e		ẽ			o	õ
	ɛ		ɛ̃	ə	ə̃	ɔ	ɔ̃
		æ		ɑ	ɑ̃		

Table 1. Segment inventory of Hindi (excluding 25 geminate consonants).

To address this issue I examined VC transitions of stops in different vocalic environments and asked (a) are these places cued similarly in different vocalic environments? and, (b) are the five places of articulation well differentiated by formant transitions alone i.e., without the benefit of stop or affricate releases? Additionally, I noted whether formant patterns characteristic of place are similar to those found in other languages. Although it is now known that other cues such as rate of formant movements, stop bursts, etc., also play a role [6], they have not been examined in this study, and thus in this respect the study is limited and should be treated as a preliminary investigation.

METHOD

Speakers and speech corpus

I recorded three male native speakers of Standard Hindi uttering syllables of the form /pVC/ where V = one of the following eight front/central/back vowels

[i, ɪ, ɛ, ə, u, ʊ, ɔ, a] and C = a voiced or voiceless (unaspirated) stop that was bilabial, dental, retroflex, palatal, or velar. (The palatal stop is actually a palato-alveolar affricate.)

The recordings were made in the Language Laboratory of the Jawahar Lal Nehru University, Delhi, using high-quality analog portable equipment. All test words were read in two different random orders in the frame vo____aya 'he____came'.

Analysis Methods

The recorded speech was band-pass filtered at 68 Hz to 7.8 kHz, digitized at 16.7 kHz and analyzed with the aid of waveform and LPC spectral displays produced by the CSRE speech analysis software and related programs. The VC formant transitions (the last 100 msec of the vowel) was extracted from computed spectrograms and analyzed. The results given below are for the most part based on 9 tokens per utterance (3 tokens X 3 speakers) (In a few cases there are fewer tokens, but never less than 7.)

Results

Fig. 1 gives the averaged formant tracks for three vowels /i a u/ before 5 different places of voiced stop (or affricate). (The formant tracks for voiceless consonants are not given due to space limitations but they were similar to those for the voiced consonants.) The rightmost column gives a superimposition of the formant patterns from the leftmost three columns. This last column of formant tracks is difficult to read for the sake of isolating the patterns for specific VC combinations but it does show global patterns better, e.g., presence or absence of a restricted range of terminal frequencies for the VC transitions. Mid vowels are not represented but, in general, their patterns were interpolated between those shown here, e.g., the pattern for /ɛ/ is approximately in between those for /i/ and /a/.

DISCUSSION

The following patterns can be noted (I also give the patterns for the vowels [ɪ, ʊ, ɛ, ɔ, ə] even though they have not been included in Fig. 1).

Characteristic differences in VC transitions: bilabials showed the characteristic lowering of F2 (and/or F3) after front vowels but not after back vowels where F2 and F3 were essentially flat. Velars exhibited the familiar convergence of F2 and F3 only after [i]. After other vowels the transitions were more or less flat. For dentals, F2 showed the typical bending toward mid-frequency terminal values in the range 900 - 2000 Hz; F3 had an even narrower range of terminal values, 2500-2800 Hz. Retroflexes showed a marked convergence of F2 and F3 and also a lowering of F4, except after [i] and [I] (though even in these cases there was a noticeable lowering of F4). Palatals had a rising F2 and F3 except after [i] where the transitions were flat; terminal values for F2 ranged from 1000 to 2300 Hz.

Characteristic similarities in VC transitions: after [i] and [ɪ] the bilabials and dentals have very similar patterns--lowering of F2 and F3. After [ɛ] retroflexes and velars were similar in their F2 and F3 patterns, however, retroflexes had a lowered F4. After [u] and [ɔ] bilabials and velars had similar and essentially flat transitions for all formants. After [u, ɔ, a, ə], dentals and palatals had similar transitions except that for palatals F2 rises higher and starts this rise earlier.

The formant frequencies I obtained for the VC transitions are fairly similar to those obtained for Gujarati by Dave [1] for the subset of the data that lent itself to comparison.

CONCLUSIONS

These results reinforce the accumulating evidence that the acoustic cues for place are highly variable and context-dependent -- even in a language with a

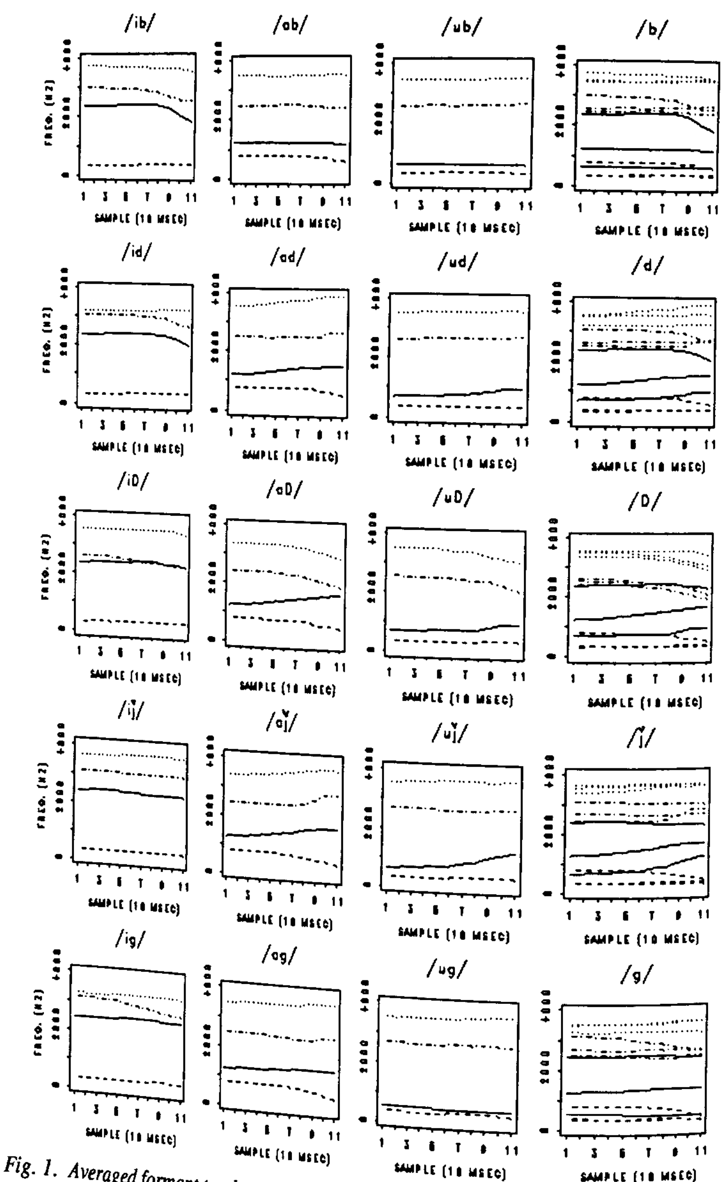

Fig. 1. Averaged formant tracks for various vowel + voiced stop sequences. Abscissa: measurement points: 10 msec intervals for a total of 11 measurements immediately preceding the vowel offset. Ordinate: frequency in Hertz. Parameters: F1 = dashed lines, F2 = solid line, F3 = dash-plus-dot lines, F4 = dotted lines. Columns from left to right: /i/, /a/, /u/, superimposition of those three vowels. Rows from top to bottom: bilabial, dental, retroflex (symbolized 'D'), palatal (symbolized 'j'), velar.

crowded segment inventory. It is also of interest to note that velars (except after [i] do not show the characteristic F2-F3 convergence found in other languages. On the other hand, convergence of these two formants is found for retroflexes in some vocalic environments. F4, which is not usually considered an important cue for place, seems to exhibit a highly consistent lowering for retroflexes (as also noted by Stevens and Blumstein [6]). Finally the following caveat must be given: the VC environment (in final position) is known for neutralizing various distinctive features including place of articulation. Thus the fact that the transitions in the data reported were quite similar for a number of consonants is perhaps not so surprising.

ACKNOWLEDGMENTS

I thank A. Abbi and V.V. Sahni for their help in the use of facilities at Jawahar Lal University and T. Nearey and T. Wells for help in using the speech analysis systems at the University of Alberta. I thank John Ohala for his help with the data analysis and figures. The research was supported by a sabbatical leave from SJSU and a research grant from the U of Alberta.

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