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THE ACOUSTICS OF TONOGENESIS

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In recent years much interest has focused on the phonetic origins of tone systems. Cope (1970), Ladefoged (1971), and Louw (1971) among others have presented phonological evidence that certain consonants modify the realizations of tones in several African languages. Phonetic studies of English such as Lehiste and Peterson (1961) and Lea (1973) indicate that certain consonants affect the pitch of neighboring vowels; e.g. voiceless aspirated stops raise the pitch of the initial part of a following vowel, voiced stops lower the pitch of the initial part of a following vowel, and both lower the pitch of final part of a preceding vowel. Haudricourt (1972) presented data from Camŭhi, which can be taken to indicate that the merger of fortis (aspirated?) stops with plain stops generated three tones: a high tone on following vowels, a low tone on preceding vowels, and a mid tone whenever the word contained no such consonant.

Data from Gill and Gleason (1963) on the correlation of Hindi breathy voiced stops with Panjabi tones have been cited by various phonologists as an instance of the consonantal origins of tone. Phoneticians have sighted the data in their listing of consonantal effects on fundamental frequency. Recently the Panjabi/Hindi data has been proposed as a model for the historical development of tone (Ohala, 1974). Purcell (1974) proposed a model for the development of tone in Balto-Slavic, very similar to the Panjabi/Hindi model.

Because no extensive phonetic study of this exemplary instance of tonogenesis had yet been reported, it was decided to investigate the acoustic manifestations of the 'before' and 'after' of tonogenesis on the Indian subcontinent. A list of Hindi and Panjabi cognates was prepared: five words exemplifying the correspondence $\underset{\sim}{C}V \sim CV$, five words exemplifying the correspondence $\underset{\sim}{V}C \sim \underset{\sim}{V}C$, five words exemplifying the correspondence $\underset{\sim}{V}h \sim \underset{\sim}{V}$, and five words exemplifying the correspondence $CV \sim \underset{\sim}{C}V$. Test words were presented in isolation and in the middle of a frame sentence.

Panjabi [kɪtab dəwɪtʃ _____ ʃabd hæ]

Hindi [jɛh ʃabd _____ kɪtab me hæ]

Three linguistically naive native speakers of Hindi and three linguistically naive native speakers of Panjabi read the appropriate texts. Data were recorded on a Uher 4000-L and analyzed on a Kay Elemetrics spectrograph. Measurements of fundamental

frequency were made on narrow band expanded scale spectrograms at the start, end, and fundamental frequency peak within vowels. Segmentation procedures used were those set forth in Peterson and Lehiste (1960) including the modifications proposed by Naeser (1970).

Figures one, two, and three present the data for similar syllable structure, comparing Hindi consonantal effects to Panjabi tone. A cursory examination of these plots should indicate that the general slope and configuration of the Panjabi tones bear a great resemblance to the Hindi consonantal effects. This resemblance is not surprising in view of the widely held opinion that Panjabi tone developed from the consonantal effects which are still manifested in Hindi.

Figures four and five present the data for Panjabi and Hindi separately, contrasting the Hindi consonantal environments and the Panjabi tones. As shown on figure four (a), a postvocalic breathy voiced consonant effects a higher fundamental frequency within the preceding vowel, while a prevocalic breathy voiced consonant effects a lower fundamental frequency on the following vowel. Panjabi (figure four (b)) shows similar fundamental frequency patterns without the conditioning consonants still present in Hindi.

A careful examination of figure four will reveal that the differences between the Panjabi high and low tones are greater than the differences between the curves representing Hindi consonantal effects. If we calculate the percentage increase from the lower to the higher curve at the three respective points (start, mid, and end) then the differences between the Panjabi tones are on the average 4% greater than the corresponding consonantal effects in Hindi.² This greater difference between the Panjabi tones than between the Hindi consonantal effects is surely due to exaggeration. Panjabi has made the intertonal differences greater than the original consonantal effects. Chen (1970) presented data for the exaggeration of vowel lengthening before voiced consonants in English; here we present data for the exaggeration of pitch.

Figure five presents averages for Hindi comparable consonantal effects and averages for comparable Panjabi tones, in disyllabic words. Since the Panjabi and Hindi cognates sometimes had different vowels and since the comparable high and low environments in either language show vowel quality differences which can be assumed to affect actually measured fundamental frequency, it was decided to factor out these intrinsic pitch effects. Therefore, figure five presents averages adjusted to reduce the pitch effects of vowel quality differences. By factoring out intrinsic pitch effects, we obtain a truer picture of the relative realizations of Hindi consonantal effects and Panjabi tones.³ The data show that Panjabi intertonal differences are on the average 2% greater than the differences between the comparable Hindi consonantal effects, when comparing equivalent points in the first syllable. Panjabi

differences in the second syllable are on the average 1% greater than the Hindi effects. Thus the exaggeration fades as we get further from the original consonantal location. This same trend holds in figure four. Our data show that Panjabi intertonal differences are 10% greater than the Hindi consonantal effects at the start of the vowel, 5% greater at the mid, and 4% less at the end. From this we infer that the exaggeration fades as one moves further from the location of the original consonants.

Another very interesting phenomena appears in our data. As can be seen in figure five, the lower/higher effects of Hindi breathy voiced consonants appear in the second syllable, even though the consonants occur in the first. The same holds true for the Panjabi data: the high/low distinction appears in the second syllable; indeed the difference is greater in the second syllable than in the first. Even though the original prevocalic breathy voiced consonant in the first syllable was far from the vowel in the second syllable, an effect obtains. And even where our model would lend one to believe that the pitch should drop after a postvocalic breathy voiced consonant, when that consonant appears in the first syllable, the pitch remains high. In short the higher/lower effects obtain in both languages, in both syllables. In fact, the percentage differences between high and low environments are much greater in the second syllable than in the first; in spite of the fact that both languages consider the first syllable to be prominent. There is little in current models of phonetics or phonology that would explain the appearance of these differences in the second syllable. It is very interesting to note than studies of Serbo-Croatian word-tone (Lehiste and Ivić 1963) and Purcell (1973) have noted exactly the same phenomena: even though the first syllable is considered prominent, the second syllable tends to show differences in acoustic cues for tone which are greater than those which appear on the first. In our view the similarity between Panjabi/Hindi and Serbo-Croatian phenomena is more than accidental. Purcell (1974) hypothesized that Balto-Slavic tone originated from the sorts of consonantal effects and losses exhibited by Hindi and Panjabi.

Figure 6 displays the data for breathy voice effects in Hindi and corresponding Panjabi tones, for monosyllabic words; with the addition of the data for postvocalic [h]. As can be seen, there is a great degree of resemblance of the curves for postvocalic [h] and the curves for Hindi postvocalic breathy voice and Panjabi high tone. These data showing that [h] raises pitch on a preceding vowel match Wayne Lea's (1973) data for American English.

Time does not permit us to present the data for Panjabi mid tone and Hindi 'other' environments, but briefly we can say that they do not pattern neatly, and they do not fit published impressionistic descriptions of Panjabi tone. Figure 7 shows data for a minimal triplet for the three Hindi consonantal environments and the three Panjabi tones. Note that the Hindi environments pattern as expected, as do the Panjabi high and low tones,

while the Panjabi mid tone is not as expected.

In summary, we have presented data on tonal patterns in Panjabi and corresponding consonantal environments in Hindi. We take this data, along with comparative etymological evidence as proof that Panjabi tone originated from the loss of previously existing consonants. We have shown that there is a good match between Panjabi tonal contours and Hindi consonantal effects. We have shown that Panjabi has exaggerated the consonantal effects visible in Hindi. We have shown that the exaggeration tends to fade as one moves along the time dimension further from the affecting environment. We have shown that the pitch effects of Hindi consonants obtain in the second syllable, even though the consonants occur in the first. Similarly, Panjabi tonal contours exhibit the greater effects in the second syllable, even though the first syllable is judged prominent and the Panjabi tone is ascribed to this first syllable. We have pointed out that similar phenomena occur in Serbo-Croatian, where phonological tone, ascribed to the first syllable, actually shows greater acoustic differentiation in the second. We feel that this similarity is hardly accidental, that it is attributable to the Indo-European system of word prominence and similarities of historical development. And finally, we have presented the data for original postvocalic [h] and cited the resemblance between the effects of this consonant and postvocalic breathy voiced consonants.

Notes

1. Our test words were:

Panjabi	Hindi	
CV̄(C)	CVC	
kā	gās	'grass'
kōra	gōra	'horse'
tōl	ḍol	'drum'
čāru	ḷaru	'broom'
tōbi	ḍobi	'washerman'
CVC	CVC	
kōra	koṛi	'leper'
dūd	duḍ	'milk'
lāb	lab	'profit'
kālla	akēla	'alone'
ēnna	anna	'blind'
CV̄(C)	CV(C)	
kī	ki	'that, if'
kōra	koṛa	'whip'
kā	kā	'vomit'

Panjabi	Hindi	
ḡā	ḡa	'go'
čā	ča	'desire'
CV	CVh	
čá	čaj	'tea'
tí	tis	'thirty'
rá	rah	'path'
ría	raha	'stayed'
cája	caha	'desired'

Grateful thanks to Saeed Ali for his help in arranging the test corpus.

2. Our method of computation was the following: if the value at the start of the lower curve was 100 Hz and the value of the upper curve was 110 Hz, then the upper curve represented a 10% increase over the lower at the start, and there was a 10% difference between the two curves at this point.

3. Our reanalysis of the data for vowel intrinsic pitch was based on Lehiste and Peterson's (1961) data. First, we summed the intrinsic pitch values for all vowels in disyllabic words, in each syllable, for each consonantal environment. Next we calculated the mean intrinsic pitch value for all vowels in all syllables, for all environments (168 Hz). Next we compared the calculated intrinsic pitch for each syllable and each consonantal environment with the grand mean. If they differed, we adjusted our actually measured values accordingly. For instance, the second syllables of our Hindi CVC disyllabic words contained the vowels /a/, /i/, and /u/. Using Lehiste and Peterson's data, the mean intrinsic pitch for the three vowels would be 176 Hz. Our grand mean for all vowels in all environments was 168 Hz. Therefore, the means of our actually measured values for the second syllable of Hindi CVC words were lowered by 8 Hz. We lower the means for the start, peak, and end of the vowel, since the words in our corpus contained vowels which could be expected to artificially raise the relevant f_0 values.

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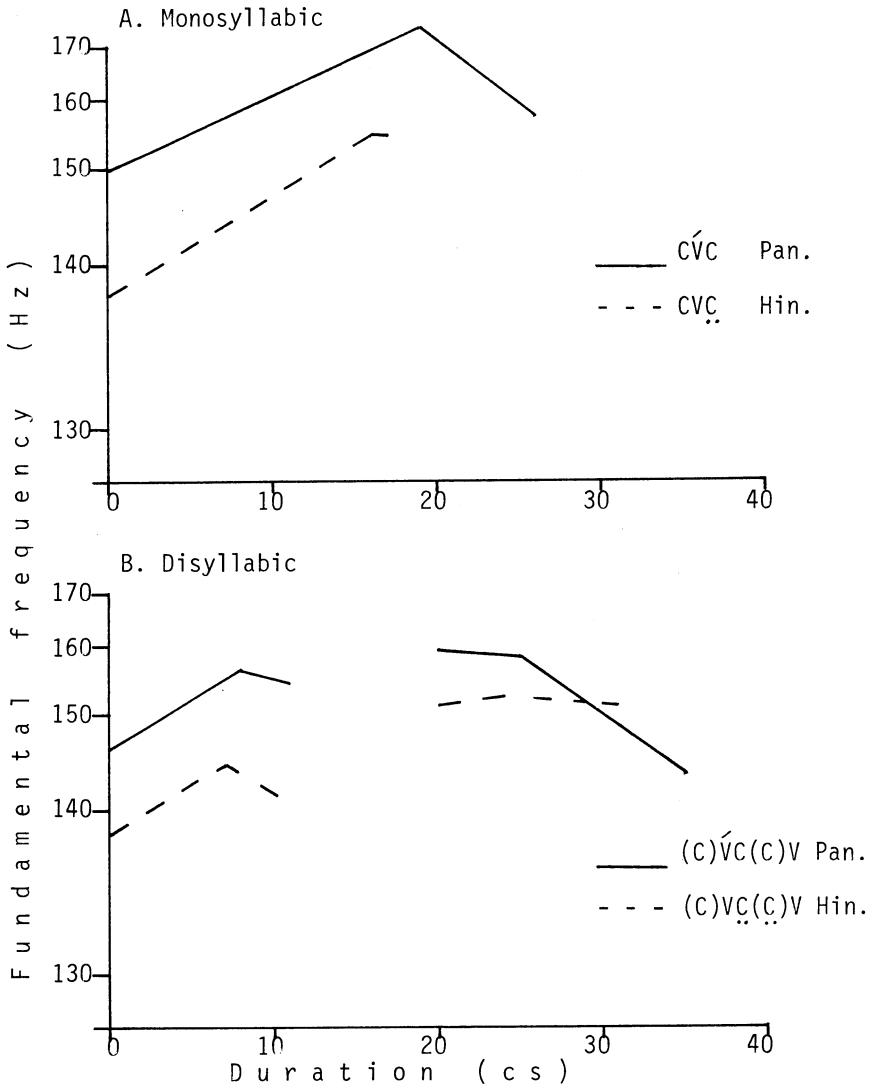


Figure one. Mean fundamental frequency vs. duration plots for monosyllabic and disyllabic cognates; Hindi postvocalic breathy voiced consonants vs. Panjabi high tone.

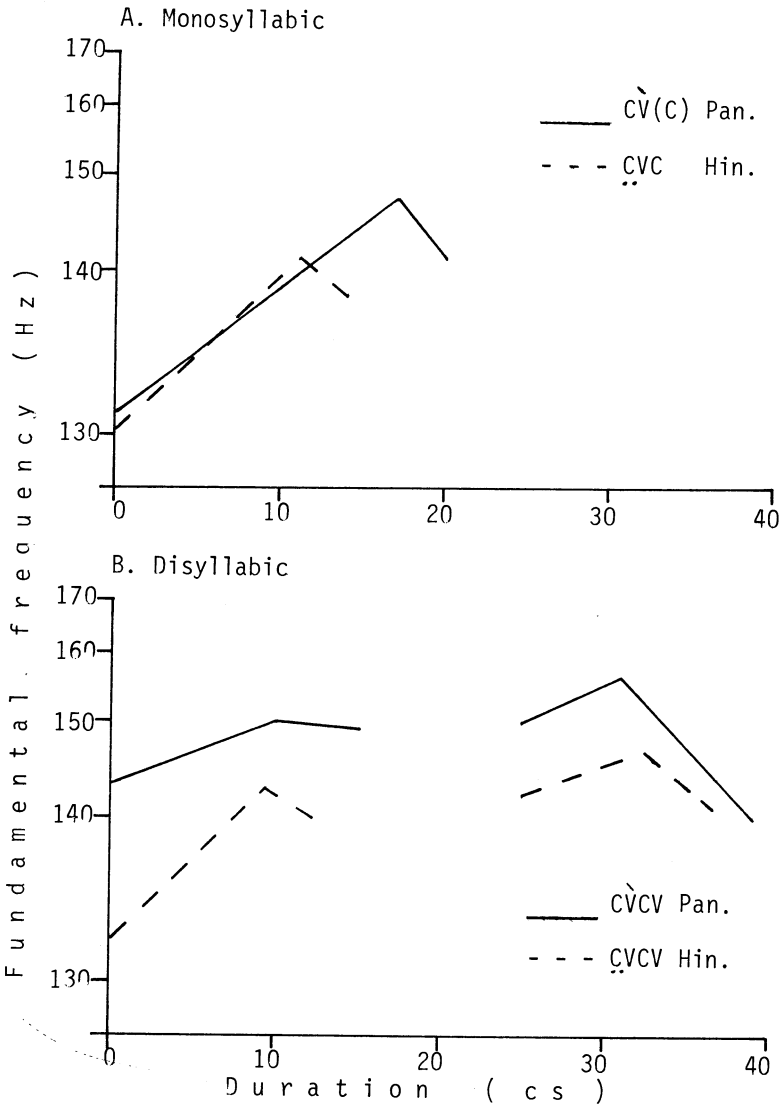


Figure two. Mean fundamental frequency vs. duration plots for monosyllabic and disyllabic cognates; Hindi prevocalic breathy voiced consonants vs. Panjabi low tone.

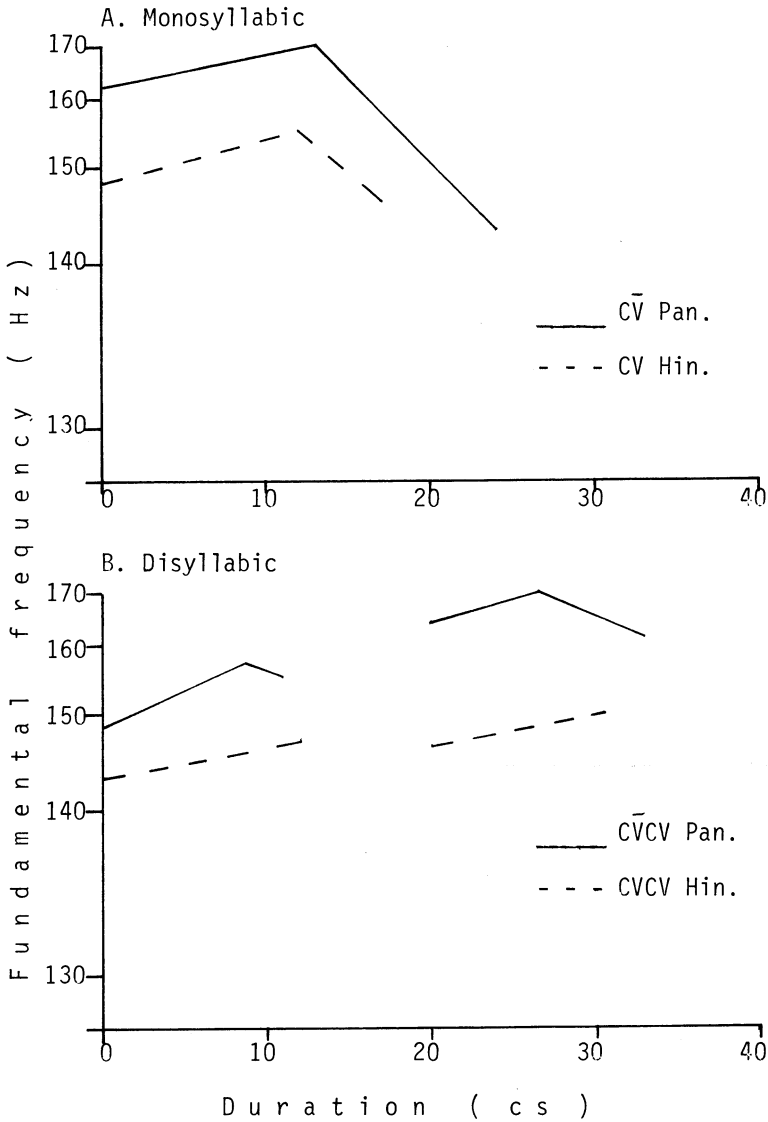


Figure three. Mean fundamental frequency vs. duration plots for monosyllabic and disyllabic cognates: Hindi 'other' consonants vs. Panjabi mid tone.

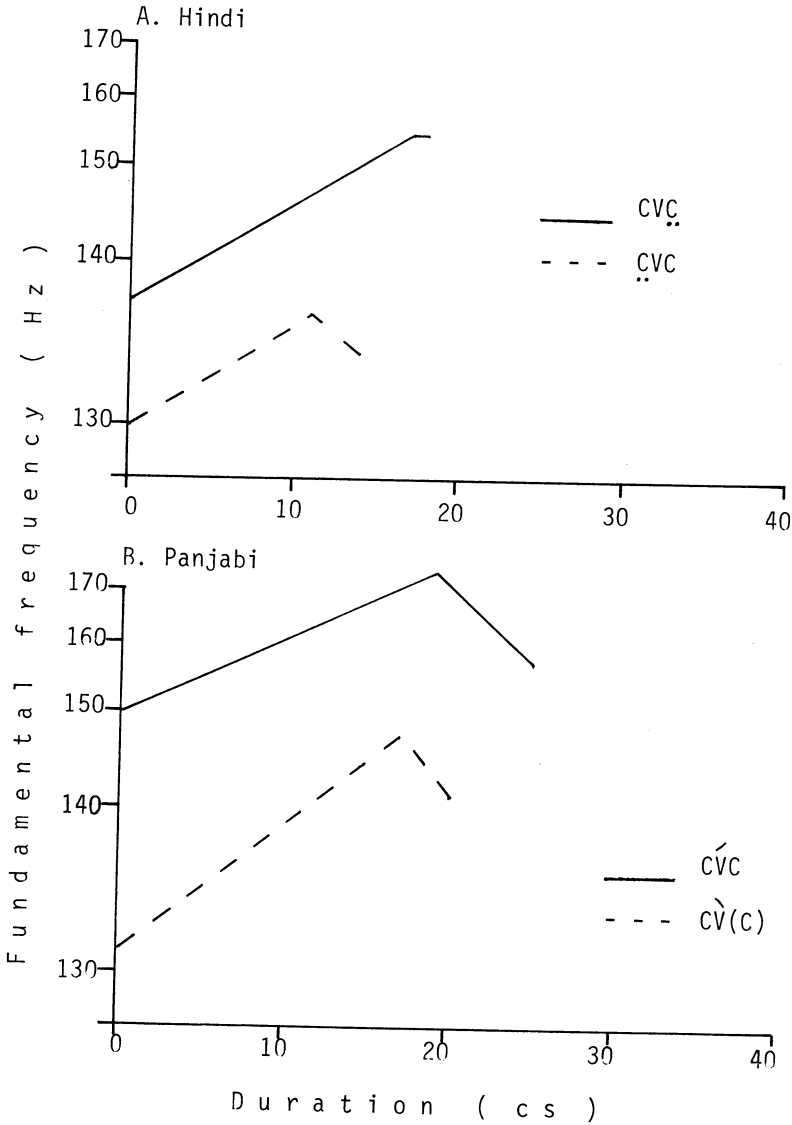


Figure four. Mean fundamental frequency vs. duration plots for monosyllabic cognates; (A) Hindi prevocalic vs. postvocalic breathy voiced stops and (B) Panjabi high vs. low tones.

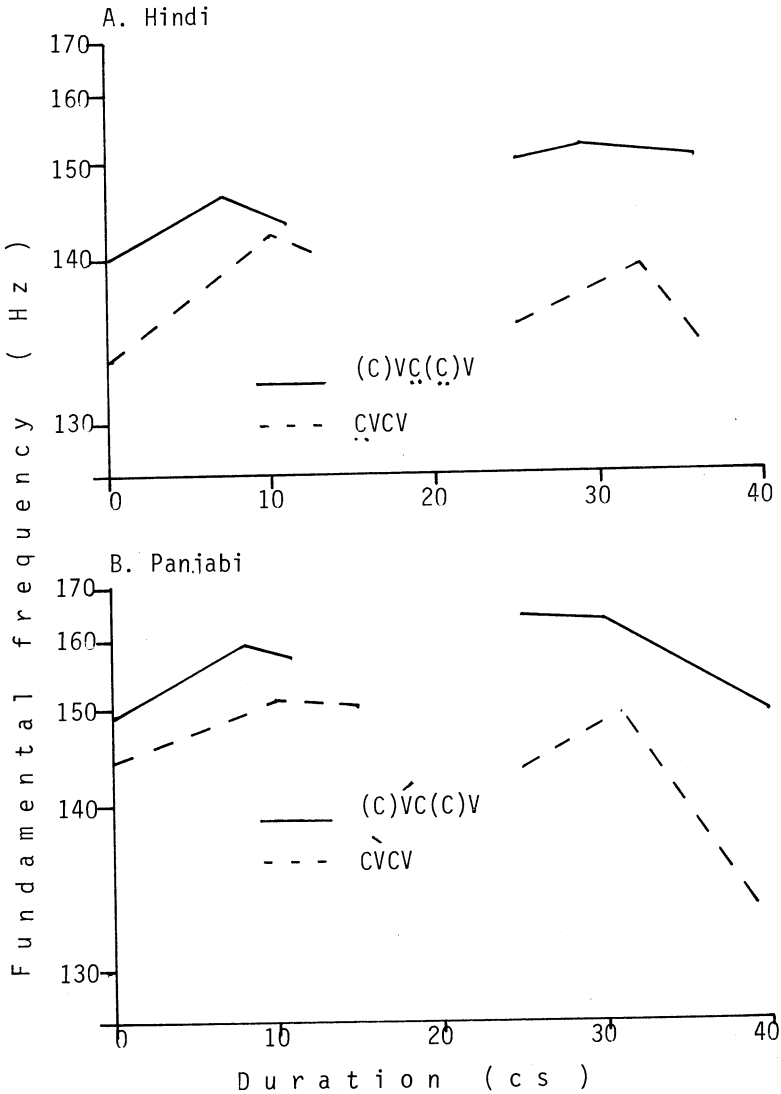


Figure five. Mean fundamental frequency vs. duration plots for disyllabic cognates; (A) Hindi prevocalic vs. postvocalic breathy voiced consonants and (B) Panjabi high vs. low tones.

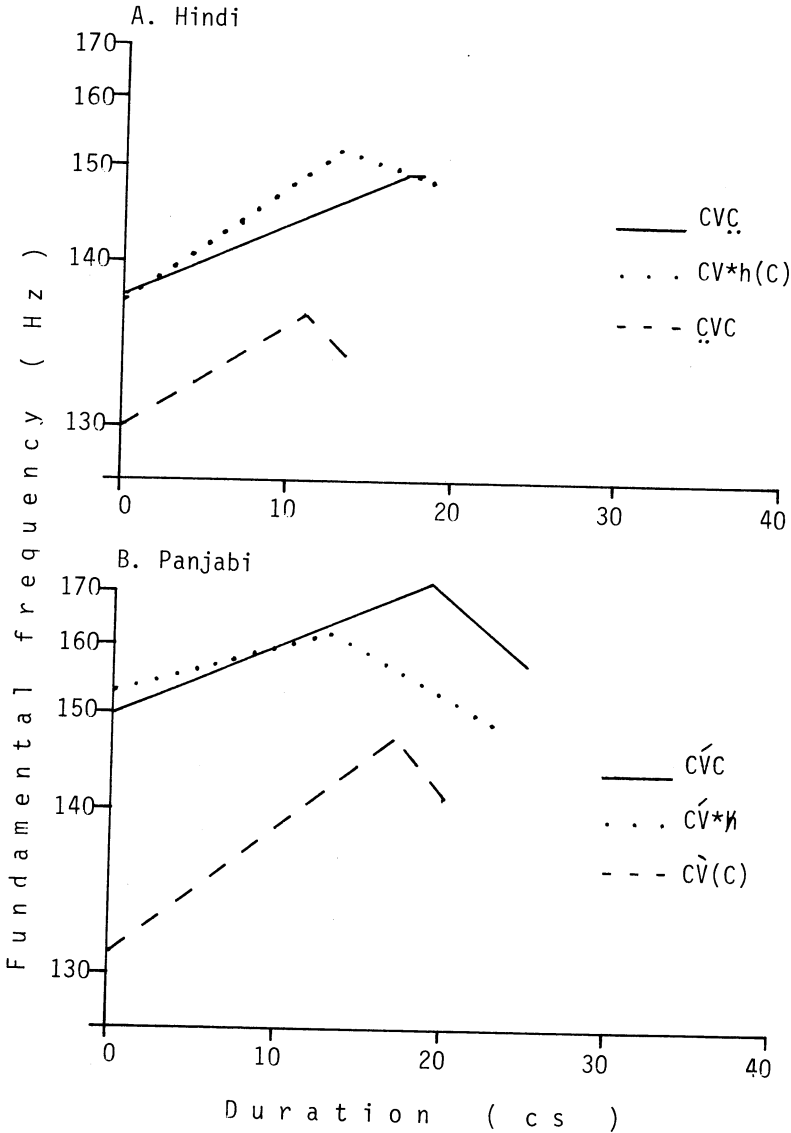


Figure six. Mean fundamental frequency vs. duration plots for monosyllabic cognates; (A) Hindi postvocalic h (or reflex of a postvocalic h) vs. prevocalic and postvocalic breathy voiced consonants, and (B) Panjabi high and low tones from equivalent cognate consonants.

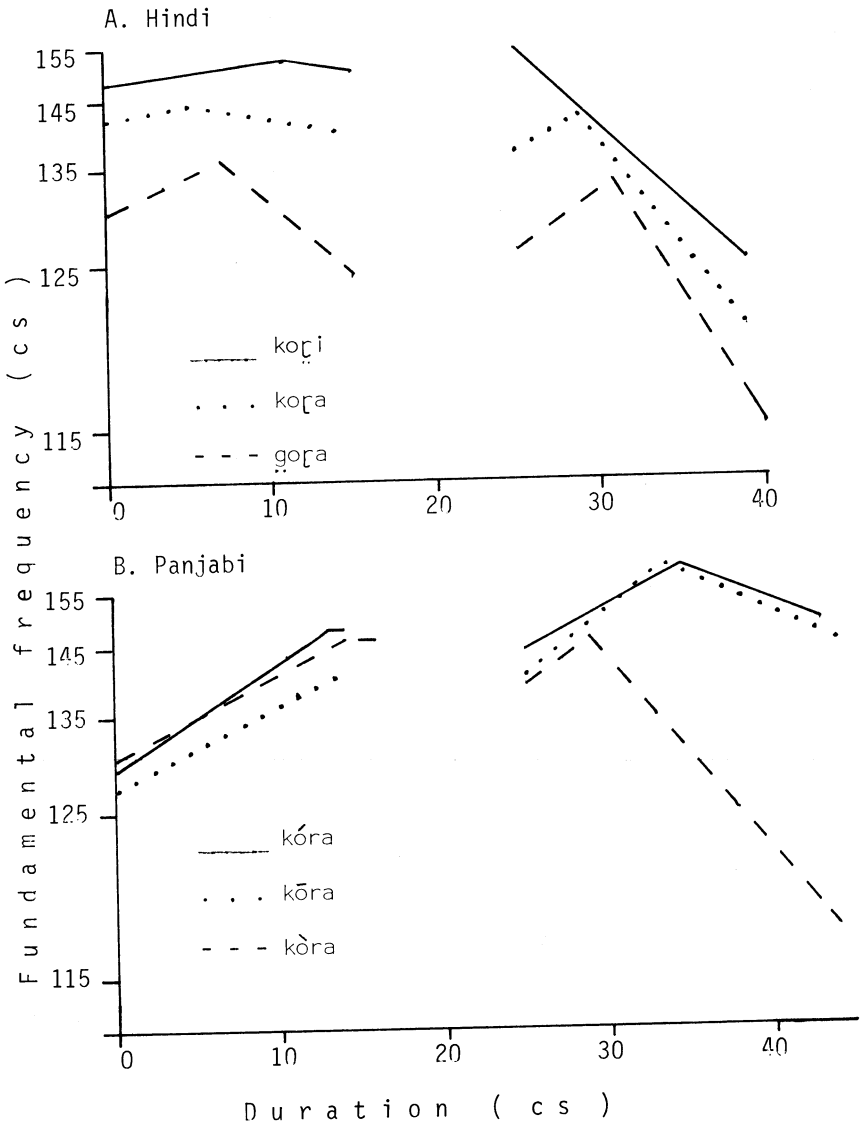


Figure seven. Mean fundamental frequency vs. duration plots for three cognates; Hindi consonantal effects vs. Panjabi tone.