

## ACOUSTIC AND PERCEPTUAL CHARACTERISTICS OF GEMINATED HINDI STOP CONSONANTS

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**ABSTRACT :** In the present paper the effect of gemination on the acoustic properties of the stop consonants have been studied. Analysis of duration of silence and preceding vowel shows a strong correlation with the presence of gemination. It is also seen that burst is stronger for geminates and pitch rises abruptly towards the end of the preceding vowel indicating the presence of a geminate. Speech perception tests indicate that about 1.5 times silence duration is required to perceive a geminate.

**1. INTRODUCTION:** Many researchers have studied acoustic properties of clusters in English and other languages [1, 2, 3]. In the studies of the acoustic properties of certain VCC utterances by means of spectrographic analysis [1] it was shown that the period of the silent interval of a stop consonant varies with the place of articulation and the frequency spectrum of the plosive bursts occur in distinct regions. Repp [2], showed that when the closure period of a naturally produced utterance with two different stop (cluster) consonants in a vocalic context is spliced out only the second stop consonant was heard by the listeners and not the first. To perceive both the consonants (i.e., cluster), 50 to 100 msec. of silence is needed between the two vocalic portions depending on the particular stimuli used. However much longer silent interval (approx. 200 msec)

is needed to perceive same stop consonants (i.e. a geminate) [3]. Thus the interval required to perceive a sequence of two intervocalic stop consonants is much longer when the two phonemes are the same as compared to when they differ in place of articulation. To differentiate between the geminates and non-geminates it was decided to undertake the study of acoustic characteristics of Hindi words (natural speech) containing single and double stop consonants.

### 2. METHOD:

**2.1 Speech Material:** Sixteen stop consonants which include 8 voiced i.e. /b, d, ɖ, g, b<sup>h</sup>, d<sup>h</sup>, ɖ<sup>h</sup>, g<sup>h</sup>/ and 8 unvoiced i.e. /p, t, ʈ, k, p<sup>h</sup>, t<sup>h</sup>, ʈ<sup>h</sup>, k<sup>h</sup>/ were used for the present experiment. These were used in between the two vowels of cvCvc and cvCCvc syllables, eg. /sAtAr/ and /sAttAr/. The preceding and following vowel to the stop consonants was always a short vowel /A/ in our stimuli.

**2.2 Data Recording And Analysis:** All the words were recorded by five adult male speakers who were native of Hindi and had no articulatory defects, on a TEAC cassette deck (model C-2X) using Sennheiser microphone (Model MD-421). The recorded samples were filtered at 70 Hz - 7 KHz and then digitized at 16 bit, 16 K samples per second using Ariel's DSP 16 card on a PC-AT 386. The speech samples were

analysed using a SENSIMETRICS speech analysis package to obtain the audio waveform and digital spectrograms etc. A representative spectrogram of words /sAtAr/ and /sAttAr/ is shown in fig. 1.

unvoiced stops. In case of the geminates also the same is true. Overall results of the preceding vowel duration shows that it has larger values in the context of non-geminates than that of geminates.

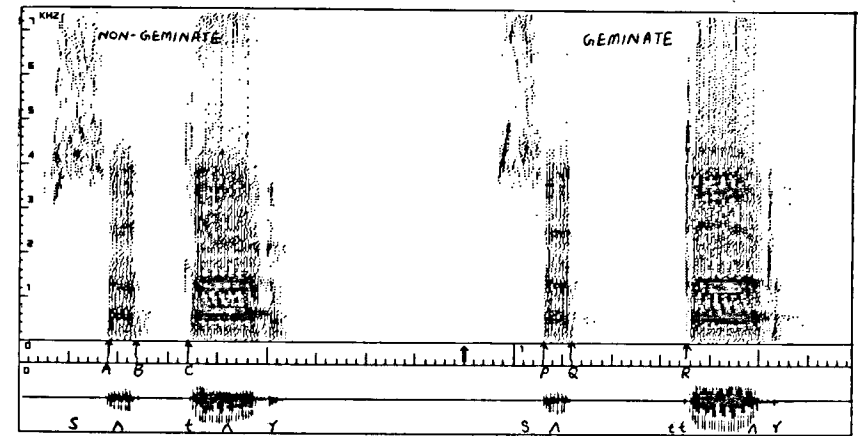


Fig. 1. A representative spectrogram of words /sAtAr/ and /sAttAr/.

A--->B and P--->Q = Preceding Vowel Duration of the non-geminate and geminate.

B--->C and Q--->R = Closure Duration of the non-geminate and geminate.

C and R are the bursts of the non-geminate and geminate respectively.

### 3. RESULTS AND DISCUSSION:

Table-1 shows the durations of the preceding vowel and closure for the non-cluster (single stop) and their corresponding cluster words (geminates). The table is divided into four categories i.e. UnVoiced-UnAspirated, Voiced-UnAspirated, UnVoiced-Aspirated and Voiced-Aspirated stop consonant.

#### 3.1 Preceding Vowel Duration (PVD):

Table-1 indicates that the duration of the preceding vowel was greater for the non-geminate words as compared to its duration for the geminate words. Vowels before voiced consonants have longer durations as compared to those with the

#### 3.2 Closure Duration (CD):

Closure duration for the geminates has larger values (about 2.5 times) than that for the non-geminates. There is a significant difference between the closure durations of voiced and corresponding unvoiced stops, whether they are unaspirated or aspirated. The closure duration for both the cases of unvoiced stops i.e. Unvoiced Unaspirated and Unvoiced Aspirated is greater than that of the voiced stops i.e. Voiced Unaspirated and Voiced Aspirated. However in case of the non-geminates the closure duration for Unvoiced Unaspirated and Voiced Unaspirated is found equal to that of the Unvoiced Aspirated and Voiced Aspirated sounds

Table 1: Average durations of the preceding vowel and closure for the non-cluster and cluster words.

	Non-clus. word	PVD (ms)	Avg. (ms)	CD (ms)	Avg. (ms)	Clus. word	PVD (ms)	Avg. (ms)	CD (ms)	Avg. (ms)
U	चपर	70	70	110	90	चपर	65	60	230	225
V	सतर	65		90		सतर	55		225	
U	कटर	70		70		कटर	60		230	
A	चकर	65		90		चकर	55		215	
V	कवर	80	85	85	70	कवर	80	75	180	185
U	गदर	85		70		गदर	75		190	
A	कडर	90		55		कडर	85		180	
	लगर	80		70		लगर	70		180	
U	सफर	70	65	105	90	सफर	60	55	225	225
V	कघर	65		85		कघर	50		220	
A	गठर	65		90		गठर	60		235	
	पखर	60		85		पखर	50		215	
V	बभर	85	80	75	70	बभर	70	65	175	185
A	लधर	80		70		लधर	60		180	
	पठर	85		60		पठर	60		200	
	बधर	80		75		बधर	70		185	

PVD = Preceding Vowel Duration  
CD = Closure Duration

Avg. = Average  
Clus. = Cluster

respectively. It may thus be summarized that in the case of the Unvoiced stops the closure duration is more for both non-clusters as well as geminates.

**3.3 Pitch:** The changes in the fundamental frequency of the vowel preceding the stop consonant were studied using the CD\_LABEL computer software [4]. Fig.2 shows an abrupt rise in pitch towards the

end of the preceding vowel indicating the presence of a geminate, whereas it remains nearly constant for non-geminates. This is an important acoustic landmark for the presence of a geminate.

**3.4 Burst:** Various properties of the burst e.g. duration, spectral shape etc were studied. The results revealed that the burst of geminates is stronger (by about 10 db)

as compared to the burst of non-geminates (Fig. 3). However there are no significant changes in the duration and spectral shape of the non-geminate and geminate sounds.

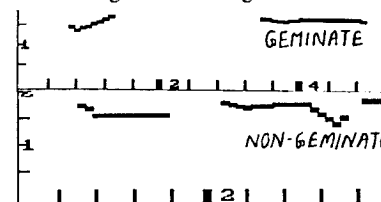


Fig. 2: Comparison of the pitch of the non-geminate and the geminate. [Words /kʌtʌr/ and /kʌtʌrʌr/].

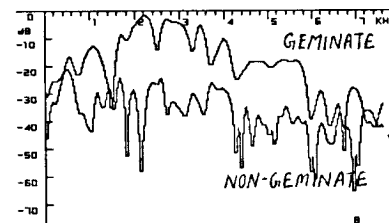


Fig. 3: Comparison of the burst spectra of the geminate and the non-geminate. [Words /pʌtʌr/ and /pʌtʌrʌr/]

**3.5 Perception Tests:** While preparing the stimuli for the perception tests all the non-geminated words were segmented from the centre of the closure and silence was introduced in between these two files in addition to the original silence in steps of 25 msec. These samples were presented to 5 listeners, who were asked to differentiate them as geminate or non-geminate sounds. The results show that a silence duration of 100 msec or less leads to the perception of non-geminate but as soon as the silence duration is made 125 msec. these are perceived as geminate. Thus there is a state of confusion between 100 and 125 msec during which 60% listeners perceive them as geminate while the rest perceive them as non-geminate.

**4. CONCLUSIONS:** The following conclusions may be drawn from the above studies. (i) For geminates the closure duration is more than double as compared to that for non-geminates. (ii) Closure duration has larger values for UV stops. (iii) preceding vowel duration has greater values for non-geminates while less for the geminates. (iv) Pitch shows an abrupt rise towards the end of the vowel indicating the presence of a geminate. (v) Perception tests show that when the closure durations of non-geminate sounds are increased they are perceived as geminate sounds.

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