

## **Voiced geminates in Indo-Aryan languages: Acoustic evidence from Punjabi**

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### **1. Introduction**

Geminates are described as long consonants that differ from their singleton counterparts in terms of duration (Davis, 2011). Cross-linguistic studies have shown that voiceless geminates are more frequent than voiced geminates (Blevins, 2004). In some languages (e.g., Tokyo Japanese), voiced geminates are partially devoiced (Kawahara, 2015). This devoicing is generally attributed to the aerodynamic constraints. From an articulatory perspective, maintaining voicing and long closure duration in voiced geminates is challenging (Ohala, 1983). Punjabi, an Indo-Aryan language, has been reported to contrast voiceless/voiced singletons and geminates (Bhatia, 1993). However, it is not known if voiced geminates in Punjabi are completely voiced and how their duration differs from voiceless geminates.

Geminates in Punjabi are restricted to word-medial position and are always preceded by short vowels (Bhatia, 1993). Singletons, on the other hand, can occur freely with both long (/i e ε a o ɔ u/) and short (/ɪ ə ʊ/) vowels. The most important acoustic correlate of the word-medial geminate stops of Punjabi is closure duration (Hussain, 2015). This is evident from other languages as well where closure duration of geminates has been shown to differ significantly from singletons (Hindi: Ohala, 2007; Bengali and Turkish: Lahiri & Hankamer, 1988). There are also durational differences in singletons and geminates in terms of voicing. Voiced singletons and geminates are generally shorter than voiceless singletons and geminates (Siene Italian: Stevens & Hajek, 2004).

Although closure duration is a primary acoustic correlate to the distinction between singletons and geminates, speakers may use the duration of preceding vowel as an additional cue to gemination. In Makasar, preceding vowels are consistently shorter before geminates than before singletons (Tabain & Jukes, 2016). Other languages that shorten the preceding vowels include Italian (Esposito & Di Benedetto, 1999), Hindi (Ohala, 2007) and Bengali (Lahiri & Hankamer, 1988). There are very few languages that lengthen the preceding vowels when the following consonant is a geminate. Japanese is usually reported to show this kind of durational pattern. Idemaru and Guion (2008) demonstrated that the duration of preceding vowels in Japanese is longer before geminates (75 ms) than before singletons (59 ms). The duration of the

preceding vowels can also vary depending on the voicing of the following consonant. Vowels are longer before voiced than voiceless consonants (Chen, 1970).

The duration of the following vowels has also been reported to serve as a cue to quantity distinction between singletons and geminates. The mean duration of the following vowels in Japanese is 63 ms after geminates but 76 ms after singletons (Idemaru & Guion, 2008). Similarly, in Punjabi, the duration of following vowels is longer in voiceless singletons than in voiceless geminates (Hussain, 2015). Italian, unlike Japanese and Punjabi, does not show any effect of gemination on the following vowels (Esposito & Di Benedetto, 1999).

The aim of the current study is to investigate the voicing (voiceless vs. voiced) and length (singleton vs. geminate) contrasts in word-medial stops of Punjabi. In particular, we investigate how voicing affects the durational properties of the word-medial stops and the flanking vowels.

## **2. Methods**

### **2.1 Participants**

Four male Punjabi speakers participated in the experiment (24 to 26 years of age, mean 24.7 years). All the participants spoke the Lyallpuri dialect of Punjabi that is widely used in Faisalabad and surrounding areas. In addition to Punjabi, the participants were also fluent in Urdu and had some knowledge of English.

### **2.2 Stimuli and experimental procedure**

The stimuli consisted of six pairs of word-medial voiceless/voiced singleton and geminate stops, with C1V1C2V2 template (C1: /k<sup>h</sup>/; V1: /ə/; C2: singleton /p b t̪ d̪ k g/ or geminate /p: b: t̪: d̪: k: g:/; V2: /a/).<sup>1</sup> All the words were elicited in citation form. Each word was repeated five times, resulting in 240 tokens (12 words × 5 repetitions × 4 speakers = 240). The participants were invited into a quiet room at the Corpus Linguistics Lab, Government College University, Faisalabad. Before the experiment, a practice session was conducted to familiarize participants with the task. Target words were written in Punjabi orthography (Shahmukhi script) and presented on a computer screen. The recordings were made using a Zoom H6 digital voice recorder with a built-in microphone at a sampling rate of 44.1 KHz.

### **2.3 Acoustic and statistical analyses**

A total of 240 tokens were segmented in Praat (Boersma & Weenink, 2014). One token was excluded due to mispronunciation. The preceding (V1) and following (V2) vowels

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<sup>1</sup>Punjabi also contrasts retroflex and palatal stops that are not reported here.

of the remaining 239 tokens were segmented as clear F2 energy in the spectrogram. Closure durations and VOTs of C2 were collapsed to get the total C2 duration (Hussain, 2015). A repeated-measures ANOVA was conducted using the `aov()` function in R (R Core Team, 2012). V1, C2, and V2 durations were used as dependent variables, place (labial vs. dental vs. velar), voicing (voiceless vs. voiced), and length (singleton vs. geminate) were used as independent variables ( $p$  value was set at 0.05).

### 3. Results

Figure 1 shows the durations of preceding vowel (V1), word-medial consonant (C2) and following vowel (V2) across voicing (voiceless vs. voiced), length (singleton vs. geminate), and place (labial vs. dental vs. velar). Statistical results are presented in Table 1. The output of the repeated-measures ANOVA indicated that there was an effect of voicing, length, and place on the duration of preceding vowel (V1). There were no significant interactions in any of the factors for V1. The duration of C2 varied across voicing and length, and there was a significant interaction between voicing  $\times$  place, length  $\times$  place, and voicing  $\times$  length  $\times$  place. The effect of place on C2 duration was not significant. The duration of the following vowel (V2) was significantly different across consonantal length and places of articulation. However, no effect of voicing was observed on V2 duration.

Table 1: Results of repeated-measures ANOVA with V1, C2, and V2 durations as dependent variables, voicing (voiceless vs. voiced), length (singletons vs. geminates), and place (labial vs. dental vs. velar) as independent variables. Bold values indicate significant results with the  $p$  value of 0.05.

Factors	V1			C2			V2		
	df	$F$	$p$	df	$F$	$p$	df	$F$	$p$
Voicing (V)	1	9.19	<b>=0.002</b>	1	172.33	<b>&lt;0.001</b>	1	0.01	=0.918
Length (L)	1	18.22	<b>&lt;0.001</b>	1	1226.84	<b>&lt;0.001</b>	1	67.49	<b>&lt;0.001</b>
Place (P)	2	43.83	<b>&lt;0.001</b>	2	1.21	=0.297	2	9.49	<b>&lt;0.001</b>
V $\times$ L	1	0.01	=0.915	1	3.17	=0.076	1	0.24	=0.620
V $\times$ P	2	0.22	=0.798	2	5.19	<b>=0.006</b>	2	0.92	=0.399
L $\times$ P	2	0.85	=0.424	2	10.31	<b>&lt;0.001</b>	2	0.59	=0.552
V $\times$ L $\times$ P	2	1.76	=0.174	2	4.96	<b>=0.007</b>	2	0.19	=0.819

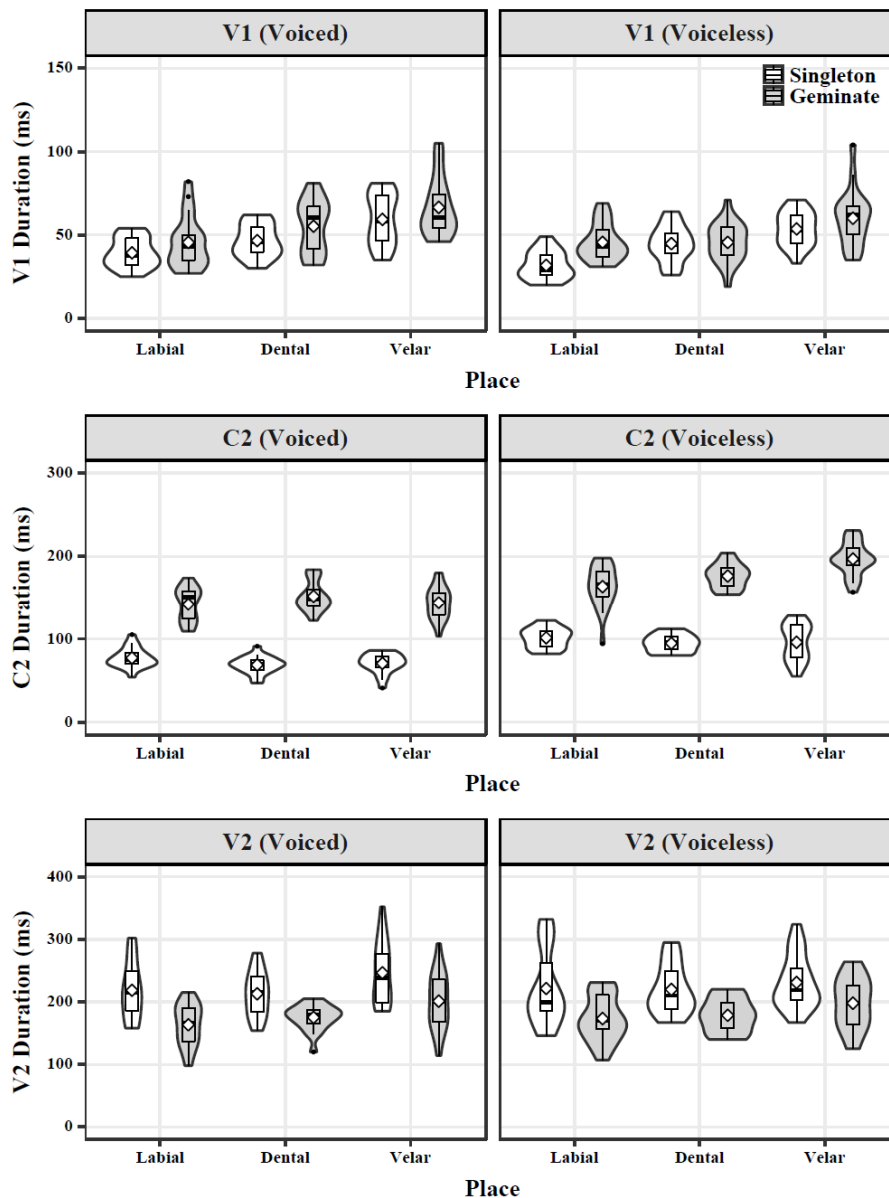


Figure 1: Violin (box) plots of preceding vowel (V1), word-medial consonant (C2), and following vowel (V2), across voicing (voiceless vs. voiced), length (singleton vs. geminate), and place (labial vs. dental vs. velar). White diamonds indicate the mean.

#### 4. Discussion

The current study examined the durational correlates of voicing and length in word-medial stops of Punjabi. The results indicate that geminates are longer than their singleton counterparts. In terms of voicing, voiced geminates are shorter in duration compared to voiceless geminates. This is in line with other studies where voiced

geminate were also reported to have short duration (Sienese Italian: Stevens & Hajek, 2004).

The duration of the preceding vowel (V1) varied depending on the voicing (voiced > voiceless) of the word-medial stops (C2). This is consistent with the previous studies that showed lengthening of preceding vowels when the following consonant is voiced (Chen, 1970). It was also noted that V1 duration before geminates was slightly longer than before singletons, as found in Japanese (Idemaru & Guion, 2008). The duration of the following vowel (V2) was longer when C2 was a singleton. These findings indicate that Punjabi speakers differentiate the consonantal length and voicing contrasts by adjusting the duration of the consonants as well as preceding and following vowels.

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