

CONTRAST REDUCTION AMONG CORONALS IS CONDITIONED BY THE FOLLOWING VOWEL

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ABSTRACT

There is evidence that coronal contrasts involving retroflexes are less clearly distinguished after a high front vowel /i/ [2, 9]. However, no detailed acoustic studies have been conducted to investigate whether following front vowels affect the contrastiveness of dentals, retroflexes and palatals. We examined the acoustic characteristics of three Punjabi coronal onsets /t̪ t̪ tʃ/ produced before five vowels /i e a u o/ by 12 Punjabi speakers. The results showed that only VOT and spectral variance of the release burst reliably distinguished Punjabi coronal stops in all vocalic contexts. Centre of gravity, skewness and kurtosis of release bursts did not differentiate the coronals in the /i/ context, but did distinguish them before /e a u o/. These findings shed more light on the phonetic basis of coronal contrasts in Indo-Aryan languages, and the ways that they interact with different following vowels.

Keywords: Punjabi, coronal, stop consonant, retroflex, VOT

1. INTRODUCTION

Previous investigations into coronal contrasts have established that retroflexes and a preceding [+front] vowel have antagonistic co-articulatory requirements [6, 7]. This leads to the cross-linguistic avoidance of retroflexes after front vowels [2, 6, 9]. However, it is not known if retroflexes interact with following vowels in the same way. The aim of the current study is to provide phonetic data to address the question of whether the contrastiveness of word-initial Punjabi coronals is reduced when they are followed by the front vowels /i e/.

Punjabi has a three-way coronal contrast (dental, retroflex, palatal) in all word-positions and vocalic environments. In Punjabi, retroflexes contrast with dentals and palatals before front vowels [3]. We provide evidence that there is nonetheless a contrast reduction between retroflexes and the other coronals before front vowels. In order to better understand the contrast reduction among coronals, we conducted temporal (VOT) and spectral moment analysis (CoG, variance, skewness, kurtosis) of Punjabi word-initial

coronals. These acoustic cues have been widely used to classify coronals in other languages [1, 11, 13].

We predicted that temporal and spectral moment analysis would reliably differentiate the three-way coronal contrast of Punjabi, but there would be reduction in the acoustic cues of Punjabi coronals in the context of front /i e/, compared to the low /a/ and back /u o/ vowels.

2. METHOD

2.1. Participants

Twelve male Punjabi speakers (20 to 29 years of age, M=22.6 years) participated in the current study. The dialect spoken by the speakers was Lyallpuri, a dialect of Punjabi spoken in Faisalabad (Pakistan) and surrounding areas [5].

2.2. Stimuli

Fifteen disyllabic (C₁V₁C₂V₂) nonce words were created, where C₁ was one of the following voiceless unaspirated coronal stops /t̪ t̪ tʃ/. C₂ was the voiceless aspirated labial /p^h/, and V₁ and V₂ were selected from the five vowels /i e a u o/. All vowels were long. A list of target items is presented in Table 1.

Table 1: Punjabi nonce word stimuli with the three coronal stops /t̪ t̪ tʃ/ in word-initial position, followed by each of the five vowels /i e a u o/.

	/t̪/	/t̪/	/tʃ/
/i/	/t̪ip ^h i/	/tip ^h i/	/tʃip ^h i/
/e/	/t̪ep ^h e/	/tep ^h e/	/tʃep ^h e/
/a/	/t̪ap ^h a/	/tap ^h a/	/tʃap ^h a/
/u/	/t̪up ^h u/	/tup ^h u/	/tʃup ^h u/
/o/	/t̪op ^h o/	/top ^h o/	/tʃop ^h o/

2.3. Procedure

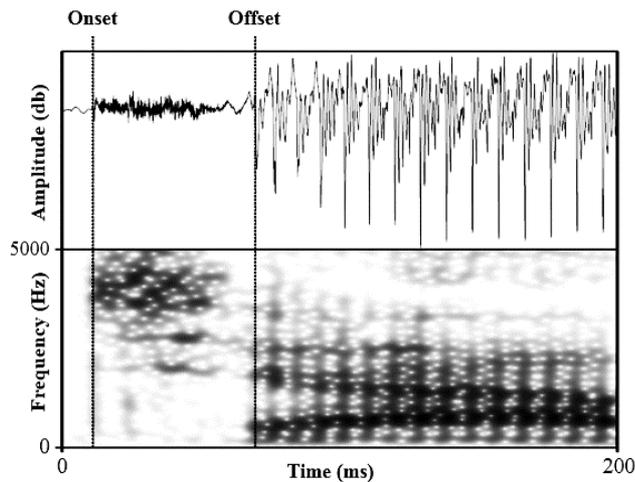
The participants were invited into a quiet room at the University of Agriculture, Faisalabad. Before the experiment, a practice session was conducted to familiarize participants with the task. Target words were written in Punjabi orthography (Shahmukhi script), and presented on a computer screen in three different random orders. Participants were asked to

read the words in citation form (single word productions). Each item was repeated five times, resulting in a total of 75 tokens per participant (12 participants, 15 items, 5 repetitions: 900 items). The recordings were made using a Zoom H2 digital voice recorder with an in-built microphone at a sampling rate of 44.1 KHz. The whole experiment took approximately 10 to 15 minutes.

2.4. Acoustic Coding

A total of 900 items were acoustically annotated in Praat. Thirteen items were excluded due to mispronunciation. The remaining 887 items were then automatically annotated using a Praat script, and manually corrected where needed. VOT was measured from the onset of the stop release burst to the beginning of the following vowel (Fig. 1).

Figure 1: Acoustic waveform and spectrum showing release of an onset palatal consonant and following vowel of the word /tʃap^ha/. Acoustic landmarks used to measure VOT (release burst onset and offset) are indicated.



We also measured first four spectral moments (CoG, variance, skewness and kurtosis) of the release bursts of word-initial Punjabi coronal stops. For the spectral moment analysis, the acoustic signal was downsampled from 44.1 KHz to 22 KHz [10]. Spectral moments of stop bursts were measured in FFT spectra over sliding 20ms Hamming analysis windows. The four spectral metrics capture the distribution of acoustic energy in the burst spectrum. CoG (Hz) is the mean energy distribution in the burst spectrum and variance (Hz) is related to the distribution of acoustic energy on both sides of the mean. Skewness (negative or positive) indicates whether the acoustic energy is skewed towards the left or right side of the burst spectrum. Kurtosis (negative or positive) refers to the peakiness or shape of the burst spectrum. Back articulations (retroflexes

and velars) have lower CoG, variance, and positive skewness and kurtosis [12, 13].

2.5. Statistical analysis

General Linear Model repeated-measures ANOVA was used with VOT and four spectral moments (CoG, variance, skewness, kurtosis) as dependent variables, place (three coronal stops /t̪ t̪ tʃ/) and following vowels (/i e a u o/) as within-subject factors. We also conducted separate repeated-measures ANOVA in each vowel context to evaluate whether there is reduction in the contrastiveness of coronals in each vowel context. The alpha value was set at 0.05.

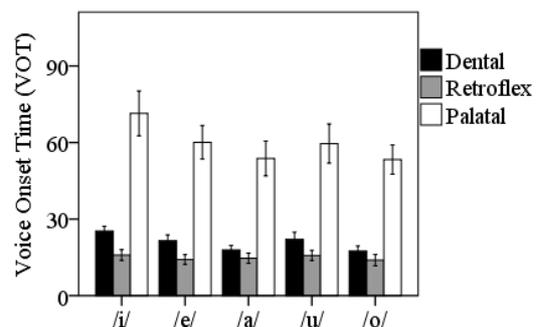
We predicted that temporal and spectral moment analysis would reliably differentiate the three-way coronal contrast of Punjabi, but there would be reduction in the acoustic cues of Punjabi coronals in the context of front /i e/, compared to the low /a/ and back /u o/ vowels.

3. RESULTS

3.1. VOT

Figure 2 presents mean VOTs for all coronal stops. VOT was significantly different among all coronals. The results of ANOVA indicated the main effects of place ($F(1.111, 12.220) = 241.904, p < .001$) and following vowels ($F(4, 44) = 20.626, p < .001$) on the VOT and a significant interaction between the two ($F(2.318, 25.493) = 5.835, p < .001$).

Figure 2: Mean VOT (ms) of the three coronal stops across vowel contexts. Error bars indicate standard error of the mean.



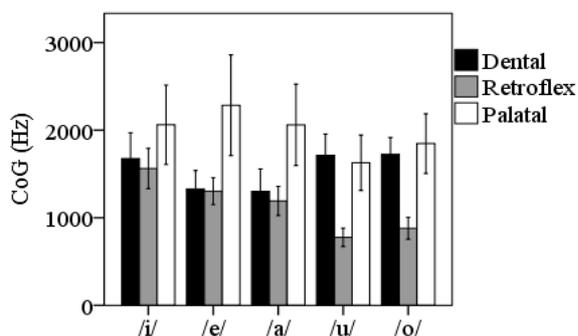
Unexpectedly, the results of separate repeated-measures ANOVA in each vowel context showed that VOT distinguished the coronal contrasts in all vowel contexts (/i/: $F(1.020, 11.216) = 139.943, p < .001$; /e/: $F(1.157, 12.725) = 173.884, p < .001$; /a/: $F(1.225, 13.476) = 140.258, p < .001$; /u/: $F(1.116, 12.276) = 136.821, p < .001$; /o/: $F(1.308, 14.393) = 179.235, p < .001$). The results suggest that VOT is a reliable cue to differentiate the coronal contrasts of Punjabi, even before front /i e/ vowels. As can be seen

in Figure 2, palatals are characterized by much longer VOT (60ms, collapsed across vowels), followed by dentals (21ms) and retroflexes (15ms). The results are in line with the previous studies showing that palatals have longer VOT among all coronals [1].

3.2. CoG

Centre of gravity (CoG) differed significantly across coronal stops. Figure 3 shows the mean CoG (Hz) values of stop release bursts produced before each of the five vowels.

Figure 3: Mean CoG (Hz) of the coronal stop release bursts across vowel contexts.



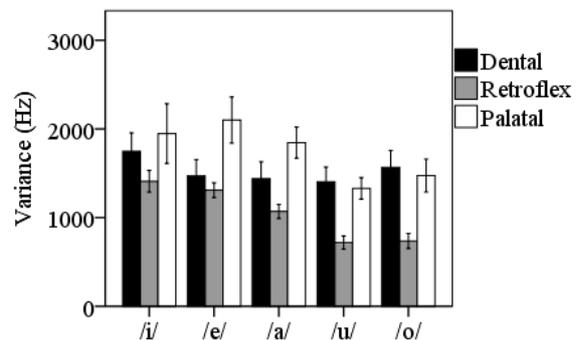
The overall ANOVA results showed a significant effect of place ($F(1.337, 14.705) = 11.951, p=.002$) and following vowels ($F(2.270, 24.973) = 7.216, p=.002$) on the centre of gravity, with a significant place by vowels interaction ($F(8, 88) = 7.196, p<.001$). As predicted, subsequent repeated-measures ANOVA in each vowel context indicated that, except for the high front vowel /i/, the CoG differentiated the Punjabi coronal stops in all vowel contexts (/i/: $F(2, 22) = 2.572, p=.099$; /e/: $F(1.268, 13.945) = 9.741, p=.005$; /a/: $F(2, 22) = 7.649, p=.003$; /u/: $F(2, 22) = 25.152, p<.001$; /o/: $F(2, 22) = 21.067, p<.001$). Surprisingly, the CoG also differentiated the coronal contrasts in the mid front /e/ vowel, which we did not expect. Similar to the results of VOT, the centre of gravity is higher for the palatal (1976Hz, collapsed across vowels), lowest for the retroflex (1142Hz) and intermediate for the dental (1547Hz). This suggests that the concentration of the acoustic energy for the palatal is higher than for the other two coronals, as found in Australian languages [11].

3.3. Variance

Figure 4 presents the mean spectral variance (Hz) of stop release bursts. The main effect of both place ($F(2, 22) = 29.276, p<.001$) and following vowels ($F(1.833, 20.718) = 49.694, p<.001$) on the variance was obtained. A place by vowel interaction was also observed for the variance ($F(3.507, 38.578) = 12.523, p<.001$). We expected that coronal stops

would not be distinguished in the context of front vowels, but this was not the case. The results from repeated-measures ANOVA in each vowel context showed that variance reliably distinguished the coronal stops in all vocalic environments (/i/: $F(2, 22) = 6.766, p=.005$; /e/: $F(2, 22) = 25.023, p<.001$; /a/: $F(2, 22) = 21.802, p<.001$; /u/: $F(2, 22) = 58.407, p<.001$; /o/: $F(2, 22) = 53.378, p<.001$). As can be seen in Figure 4, the spread of acoustic energy is higher for the palatal stop (1739Hz, collapsed across vowels) and lowest for the retroflex stop (1048Hz).

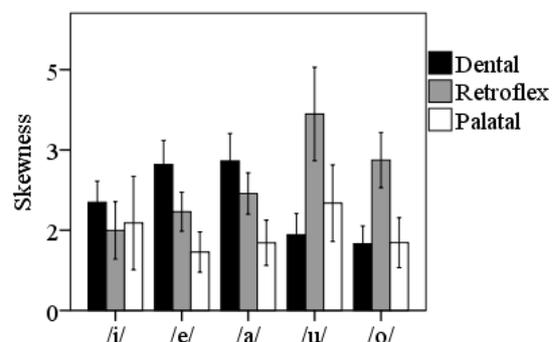
Figure 4: Mean variance (Hz) of the coronal stop release bursts across vowel contexts.



3.4. Skewness

Figure 5 illustrates spectral skewness in Punjabi stop release bursts. The overall results indicated that all coronal stops were differentiated by skewness. The ANOVA results showed the main effect of place ($F(2, 22) = 6.424, p=.006$) and following vowels ($F(4, 44) = 3.254, p=.020$) on the skewness and a significant interaction between the two ($F(8, 88) = 11.531, p<.001$).

Figure 5: Mean skewness (positive or negative) of the coronal stop release bursts across vowel contexts.



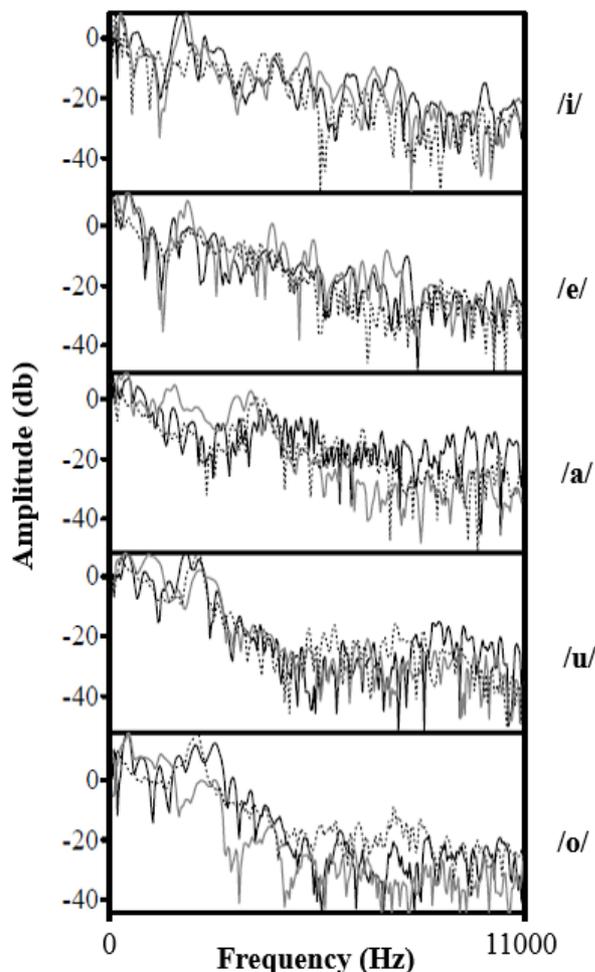
As predicted, the results of separate repeated-measures ANOVA in each vowel context suggested that skewness did not differentiate the coronal contrasts in the /i/ context ($F(2, 22) = .630, p=.542$). This means that the acoustic cues of coronals in the following high front vowel /i/ are reduced. However,

skewness differentiates the coronal stops in other vowel contexts (/e/: $F(2, 22) = 14.430, p < .001$; /a/: $F(2, 22) = 11.124, p < .001$; /u/: $F(2, 22) = 13.700, p < .001$; /o/: $F(2, 22) = 12.196, p < .001$). Retroflex and dental stops showed similar skewness, slightly higher for the retroflex (dental: 2.04; retroflex: 2.40; palatal: 1.45, collapsed across all vowels).

3.5. Kurtosis

Figure 6 depicts the spectral shapes of three coronal release bursts in all vocalic contexts. Similar to the previous results, the overall results showed a significant difference in kurtosis across coronal stops. There was a significant effect of place ($F(2, 22) = 5.201, p = .014$) and following vowels ($F(1.885, 20.737) = 5.597, p = .012$) on the kurtosis. The interaction between the place and vowels was also significant ($F(3.131, 34.446) = 5.945, p = .002$).

Figure 6: Representative spectral shapes of three coronal releases across vowel contexts (dental (black), retroflex (grey) and palatal (black dotted)).



As predicted, subsequent repeated-measures ANOVA in each vowel context indicated that kurtosis did not distinguish the three coronal stops in the /i/

context ($F(1.112, 12.230) = .616, p = .549$). In other vowel contexts, the kurtosis was significant across coronal stops (/e/: $F(2, 22) = 8.520, p = .002$; /a/: $F(2, 22) = 3.559, p = .046$; /u/: $F(2, 22) = 7.804, p = .003$; /o/: $F(1.230, 13.526) = 24.752, p < .001$). The coronal contrasts were distinguished in the context of mid front vowel /e/, which we did not predict.

4. DISCUSSION

Cross-linguistic phonological studies on retroflexes have provided substantial evidence regarding the avoidance of retroflexes before front vowels /i e/ but do not provide any phonetic data on whether following front vowels have an effect on the contrastiveness of the *word-initial* coronals in Indo-Aryan languages [2, 9]. Our findings on word-initial Punjabi coronals demonstrated that VOT and stop burst spectral variance reliably distinguished the three-way coronal contrast of Punjabi in all vocalic environments. Centre of gravity, skewness and kurtosis did not differentiate the Punjabi coronal contrasts before /i/, but reliably distinguished the three coronals in the other vowel contexts. The findings suggested that there is a contrast reduction among coronals but before [+front, +high] vowels, not before [+front, -high] and [-front, +high] vowels. As cues to contrastive retroflexion are limited in word-initial position [9], we argue that the contrast reduction among coronals that results from a following /i/ is probably a contributing factor to the common avoidance of retroflex contrasts when there is no preceding vowel information. The present study therefore contributes to the literature on word-initial contrast neutralization among coronals in Indo-Aryan languages.

5. REFERENCES

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