DURATIONAL CORRELATES OF WORD-INITIAL VOICELESS GEMINATE STOPS: THE CASE OF KELANTAN MALAY

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ABSTRACT

This paper investigates the production of word-initial geminate consonants in Kelantan Malay with a focus on voiceless stops. It presents an acoustic phonetic analysis examining two acoustic parameters: closure duration and voice onset time (VOT). Evidence from a production experiment indicates that there is a clear durational contrast between word-initial voiceless geminate stops and their singleton counterparts. Closure duration is found to be the most robust acoustic correlate for the singleton-geminate contrast in Kelantan Malay, while VOT shows highly significant effects.

Keywords: acoustic phonetics, geminate, voiceless stops, duration, speech production

1. INTRODUCTION

The acoustic correlates of voiceless stops have been a subject of some debate in the field of acoustic phonetics, especially when it comes to geminate stops that occur in initial position. The fact that there is a lack of voicing in word-initial voiceless geminate stops which are, therefore, potentially perceptually less salient, especially at the start of utterances, poses a challenge as to how speakers produce and perceive this particular contrast [2].

To date, the phonological representation and phonetic characterization of word-initial voiceless geminate stops still remain an empirical issue and there are questions of cross-linguistic consistency. Most empirical studies suggest that closure duration is the universal attribute of such segments across many language families and their members. In Tarifit Berber [5], for example, closure duration was found to be the major acoustic parameter. Other acoustic correlates, on the other hand, were language-specific and less universal. In Cypriot Greek [12], VOT was an important secondary acoustic cue that accompanies the production of geminate stops. In Pattani Malay [3], the amplitude and fundamental frequency (F0) of the following vowels were considered weak markers on their own. However, if closure duration was absent, they were found to be sufficient cues to the singleton-geminate contrast.

Earlier work (e.g. [6, 9]) on Kelantan Malay (KM) was mainly based on impressionistic evaluation, in which word-initial voiceless geminate stops were described as a phonological event but with no actual phonetic evidence provided. Recent experimental examination [7] in this area only presented the durational properties of the entire stop articulation. The current study aims to test the claims of previous acoustic studies by investigating two acoustic features: closure duration and VOT, with the purpose of contributing to a better understanding of word-initial voiceless geminate stops in both KM and in other languages.

2. METHOD

2.1. Materials

An acoustic phonetic experiment was designed to investigate the production of singleton and geminate stops. A list of twelve tokens was prepared consisting of six minimal pairs (See Table 1).

Table 1: The KM tokens and their glosses.

	Singleton		**Geminate**	
	Word	**Gloss**	**Word**	**Gloss**
/p/	/pitu/	door	/ppitu/	at the door
	/pagi/	morning	/ppagi/	early morning
/t/	/tido/	sleep	/ttido/	sleep by chance
	/tanɔh/	land	/ttanɔh/	outside
/k/	/kiɣi/	left	/kkiɣi/	to the left
	/kabo/	blurry	/kkabo/	a beetle

All tokens were disyllabic words with either C(C)VCV or C(C)VCVC structures. Three phonemes were chosen: /p/-/pp/, /t/-/tt/, and /k/-/kk/. Each phoneme was followed by two distinct vowels: high front vowel /i/ and low back vowel /a/.

2.2. Participants and data collection

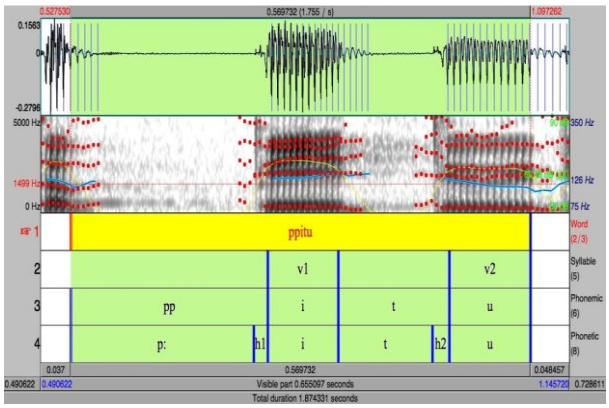
The participants were six native speakers of KM (three males, three females) whose ages ranged from 24 to 28 years. They were all students from several universities in Melbourne. The data were recorded in a professional recording studio at the University of Melbourne.

In all sessions, participants were asked to repeat each token in two different contexts: in isolation (the target word was preceded by a long silent pause); and in a carrier sentence (the target word was preceded by a vowel). The carrier sentence used was /diɔ katɔ (the target word) tigɔ kali/ (he said (the target word) three times) (adapted from [1]). All tokens were randomly presented through powerpoint slides on a notebook using the Standard Malay orthography. The carrier sentence was written separately on a piece of A4 paper. Six repetitions were recorded from each participant with a total of 864 utterances. The experiment took approximately thirty minutes for each participant.

2.3. Data analysis

The waveform files were digitized at 44.1 kHz, segmented into single utterances for each participant and then coded accordingly. The annotation was conducted using Praat [4] following standard segmentation and labeling procedures (See Figure 1).

Figure 1: An example of a sound file in a Praat window (a target word in a carrier sentence).



The Praat template includes four tiers: the word tier, the syllable tier, the phonemic tier and the phonetic tier. The word tier (top tier) shows the segmentation and labelling of the target word. The syllable tier (second tier) highlights the vowels in a disyllabic word. The underlying tier (third tier) represents the phonemic representation of the target word, and the surface tier (bottom tier) is the phonetic representation of the target word. VOT was marked as either 'h1' or 'h2' on the surface tier.

Closure duration was measured intervocalically in tokens produced in the carrier sentence. It was calculated from the offset of regular formant energy of the preceding vowel until the stop burst. VOT duration was measured in both isolated and sentence-medial tokens. The interval between the release burst and the onset of the first formant of the following vowel was measured. All closure and VOT duration values were extracted and analyzed statistically using the database analysis software EMU-R [8]. An analysis of variance (ANOVA) was performed on the data set to test the significance of three factors: Category (singleton or geminate); Phoneme (/p/-/pp/, /t/-/tt/, /k/-/kk/); and Participant (six speakers).

3. RESULTS

3.1. Closure duration

The overall closure duration results are shown in Figure 2 and Table 2.

Figure 2: Mean closure duration values (ms) in sentence-medial tokens.

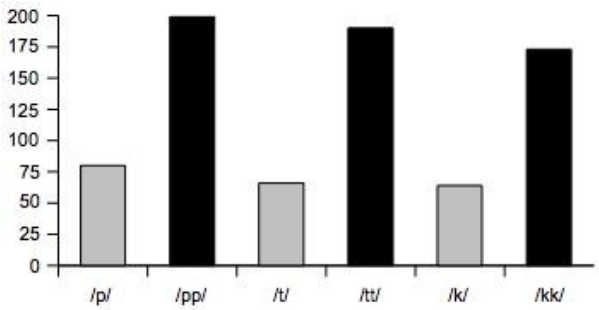


Table 2: Mean closure duration values (ms) and duration ratios for all word-initial voiceless singleton and geminate stops. Standard deviations are in parentheses.

Singleton	Mean (SD)	Geminate	Mean (SD)	Ratio
/p/	80 (13)	/pp/	199 (39)	2.51
/t/	66 (13)	/tt/	190 (39)	2.93
/k/	64 (15)	/kk/	173 (41)	2.84

The results show that geminate stops produced by all speakers across all three places of articulation are clearly distinguished from singleton stops (*t*-ratio=-25.49 to -21.17, $p<.001$). The ratios of closure duration are all more than double. ANOVA results indicate that all three factors (Category, Phoneme and Participant) have a significant effect on closure duration. The differences in closure duration due to Category, i.e.

singleton or geminate, are highly significant (F(5,396)=122.54, p<.001), as is the effect of Phoneme (F(4,396)=33.96, p<.001). Bilabial stops have longer closure duration than velar stops, in general, but Tukey's multiple comparison of means show that the singleton-geminate contrast is highly significant in all three consonant pairs. The effect of Participant is also highly significant (F(5,396)=122.54, p<.001), suggesting that some speakers show longer closure duration than others. There are also highly significant interactions between Participant and Category (F(5,396)=63.92, p<.001); and Participant and Phoneme (F(20,396)=3.03, p<.001). In general, it was observed that male speakers tend to produce voiceless stops with longer closure duration than female speakers, which is consistent across both singleton and geminate stops. Some speakers even produce geminate stops three times longer than singleton stops.

3.2. Voice onset time

The overall VOT duration results measured in isolated tokens are shown in Figure 3 and Table 3.

Figure 3: Mean VOT duration values (ms) in isolated tokens.

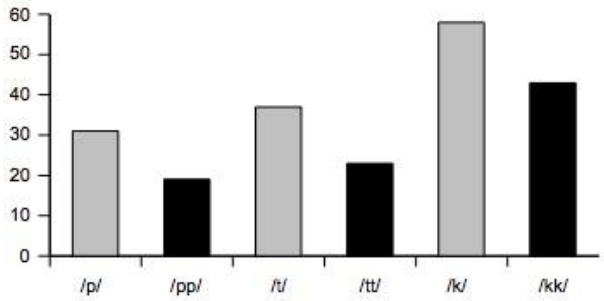


Table 3: Mean VOT duration values (ms) for all word-initial voiceless singleton and geminate stops. Standard deviations are in parentheses.

Singleton	Mean (SD)	Geminate	Mean (SD)
/p/	31 (9)	/pp/	19 (5)
/t/	37 (12)	/tt/	23 (6)
/k/	58 (18)	/kk/	43 (15)

The results show that the singleton-geminate contrast is reflected in VOT values. They are all significantly longer for singleton stops than geminate stops (t-ratio=5.57 to 9.72, p<.001). The results indicate that there are highly significant effects of Participant (F(5,396)=24.45, p<.001), Category (F(1,396)=203.99, p<.001) and Phoneme (F(4,396)=129.99, p<.001). There is a strong effect of place of articulation, with VOT much longer in velar stops. The interactions between Participant and Category (F(5,396)=2.27, p<.01), and Participant and Phoneme (F(20,396)=2.15, p<.01) are also significant. Nevertheless, Tukey's multiple comparison of means indicate that the singleton-geminate contrast is highly significant in all three consonant pairs for all speakers.

As for the sentence-medial tokens, the overall VOT duration results are shown in Figure 4 and Table 4.

Figure 4: Mean VOT duration values (ms) in sentence-medial tokens.

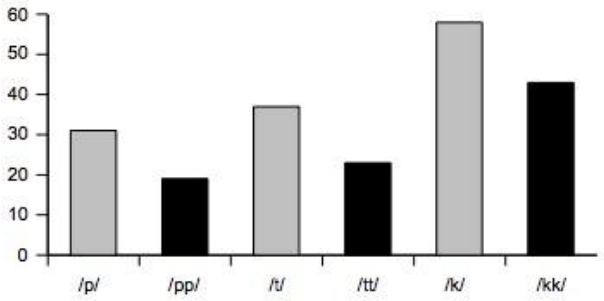


Table 4: Mean VOT duration values (ms) for all word-initial voiceless singleton and geminate stops. Standard deviations are in parentheses.

Singleton	Mean (SD)	Geminate	Mean (SD)
/p/	25 (11)	/pp/	19 (7)
/t/	29 (10)	/tt/	22 (8)
/k/	47 (16)	/kk/	43 (17)

As in isolated tokens, VOT values are significantly longer for singleton stops than geminate stops across all places of articulation, (t-ratio=4.21 to 5.35, p<.001), with the exception of velar stops (t-ratio=1.31, p=.193). While the effects of Category (F(1,396)=34.93, p<.001), Phoneme (F(4,396)=102.36, p<.001) and Participant (F(5,396)=24.83, p<.001) are highly significant, there is no interaction between Participant and Category (F(5,396)=1.38, p>.01), suggesting that VOT values for the singleton-geminate contrast are consistent among all participants. There is, however, a significant interaction between Participant and Phoneme (F(20,396)=2.18, p<.01). For example, some speakers produce consistently longer or shorter VOT in velar stops than others.

A comparison of VOT values in isolated and sentence-medial tokens shows that geminate stops have similar values across both utterance conditions. However, the VOT values are significantly shorter for singleton stops in sentence-medial tokens than in isolated tokens [e.g. 25 ms (sentence-medial) vs. 31 ms (isolated)

for /p/]. Although the VOT differences were found to be significant in the singleton-geminate contrast for both environments, they are all below the expected +/-20 ms threshold of just noticeable difference (JND) for VOT [14] (e.g. there was a 12 ms difference between /p/ and /pp/ in isolated tokens). However, it remains to be investigated as to why speakers would increase VOT duration in initial position, if it has potentially not reliably perceived.

4. DISCUSSION

The results show that closure duration, when measured intervocalically, is a robust parameter for word-initial voiceless geminate stops in KM, as it is in other languages (e.g. [5, 12]). As to whether or not closure duration contrasts are also maintained in absolute initial position, this can only be ascertained through other analyses, such as fiberscopic measurements [13].

With regard to VOT, the findings show that, in KM, its duration is also an important acoustic correlate for the singleton-geminate contrast in both absolute initial and intervocalic positions. This is in tandem with Cypriot Greek [11] in which VOT plays a significant role. There is, however, an inverse pattern in which VOT duration is significantly longer following geminate stops in Cypriot Greek, which is not the case for KM. In other languages, VOT does not contribute to the acoustic difference between word-initial voiceless singleton and geminate stops, such as Swiss German [10], given the absence of VOT duration differences. This cross-linguistic divergence indicates that VOT has language-specific functions in this context.

Further investigations will explore the relative perceptual weight of closure duration as a primary acoustic cue while, at the same time, investigating the potential contribution of other possible acoustic parameters, such as VOT, to the perception of word-initial voiceless geminate stops in KM.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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