THE SECONDARY ROLES OF AMPLITUDE AND F0 IN THE PERCEPTION OF WORD-INITIAL GEMINATES IN KELANTAN MALAY

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ABSTRACT

This study examines the extent to which amplitude and F0 play secondary roles in perceptually cueing the word-initial singleton/geminate consonant contrast in Kelantan Malay (KM). Three voiceless stop word-pairs produced in isolation, i.e. utterance-initial position, were chosen for manipulation in three perception experiments involving KM native listeners. Results show that amplitude and F0 have limited perceptual functions on their own, although the combined values of the two parameters do have some effect on the perception of the consonant contrast. These results are expected for the utterance-initial voiceless stop pairs given the absence of closure duration information as a perceptual cue in this context. The findings support the view that the consonant length distinction in word-initial position, particularly for voiceless stops, can be potentially cued by a set of secondary parameters, e.g. amplitude and F0, alongside the primary acoustic parameter of closure duration.

Keywords: amplitude, F0, word-initial consonant contrast, geminate perception, Kelantan Malay

1. INTRODUCTION

Closure duration has been established as a powerful cue to consonant gemination across languages, e.g. [11, 12]. However, many studies suggest that there may be additional acoustic cues that influence the perception of word-initial geminates, particularly in the case of voiceless stop geminates produced in utterance-initial position in which closure duration is acoustically unavailable and, therefore, potentially perceptually indiscernible. In this context, amplitude and F0 have been shown to be potential perceptual cues to the word-initial consonant contrast, such as in Pattani Malay (henceforth PM), which is closely related to KM (see also [9, 10]).

In a perception experiment in PM [2], amplitude was manipulated involving a voiceless stop word-pair produced in isolation. The results show that the amplitude modification of the first syllable of a word beginning with a singleton or a geminate, respectively, brings about different responses. Nevertheless, the response curves never cross the perceptual boundaries at 50%, suggesting that, in PM, amplitude variation alone is a weak cue to consonant gemination. In a subsequent experiment in PM [3], F0 values were modified in the first syllable of a voiceless stop word-pair produced in isolation. The results indicate that F0 shifts have some perceptual effect on PM listeners. However, like the previous experiment, the curves do not cross over the 50% perceptual boundaries. In the final perception experiment in PM [4], both amplitude and F0 values were co-varied in the first and second syllables of isolated tokens. The results reveal that the amplitude/F0 variation is sufficient to cause perceptual crossovers to the opposite categories.

In KM, the primary role of closure duration in the production and perception of the word-initial singleton/geminate contrast has been demonstrated in earlier acoustic studies, e.g. [6, 7]. With regard to amplitude and F0, their potential secondary functions in characterising such a contrast have been shown to be reliable in KM, as reported in [8]. The current study aims to examine whether and how controlled changes in amplitude and F0, both on their own and in combination, may also serve as perceptual cues to word-initial geminates among KM native listeners, especially in utterance-initial voiceless stops in which closure duration information is not present. Findings will confirm the relative saliency or otherwise of these non-durational acoustic cues that have also been observed in PM.

2. METHOD

2.1. Materials

The voiceless stop word-pairs chosen for manipulation in three perception experiments in this study are displayed in Table 1. The word-pairs in all experiments were produced in isolation, i.e. utterance-initial position. Although different minimal pairs were used for different experiments, the acoustic findings reported in [8] confirm the general patterns of potential acoustic properties of consonant gemination associated with utterance-initial voiceless stops.

Table 1: Sources of stimuli.

Experiment	Singleton		Geminate	
	Word	Gloss	Word	Gloss
1 (amplitude)	/pagɪ/	morning	/ppagɪ/	early morning
2 (F0)	/pɪtʊ/	door	/ppɪtʊ/	at the door
3 (amplitude & F0)	/tɪdo/	sleep	/ttɪdo/	sleep by chance

The procedures for manipulation were achieved by using the manipulation editor in Praat version 6.0.43 [5]. In Experiment 1, following the previous work on PM [2], the amplitude at vowel onset was either increased (after singletons) or decreased (after geminates) in five 2-dB steps. In Experiment 2, motivated by [3], the F0 at vowel onset was either increased (after singletons) or decreased (after geminates) in five half-semitone steps. In Experiment 3, following [4], both amplitude and F0 values at vowel onset were either incremented (after singletons) or decremented (after geminates) in three 2-dB steps and three half-semitone steps (see Table 4 in Section 3.3 for details). Twelve stimuli including their original words were each created for the word-pairs in Experiments 1 and 2, while 32 stimuli were created for the word-pair in Experiment 3. All stimuli were presented three times to the listeners, creating a total of 168 manipulated trials for all three experiments.

2.2. Listeners and data collection

The participants for all experiments were 30 undergraduate students (15 males, 15 females), all native speakers of KM, at the Universiti Malaysia Kelantan. Their ages ranged between 20 to 25 years (mean age: 21.2). All of the listeners were born and raised in Kelantan, Malaysia. The perception experiments began with Experiment 1, followed by Experiment 2 and then Experiment 3. The listeners participated individually in each experiment in a quiet room at the Universiti Malaysia Kelantan. They were seated at a desk and were fitted with a stereo headphone. All the stimuli were presented through a computer using Praat's Experiment Multiple Forced Choice listening experiment (version 6.0.43). The participants listened to a sound and chose the word that most closely resembled to what they listened. Since there is no written counterpart of KM, all words were written in Standard Malay. In each experiment, only one word-pair was tested at a time. All experiments lasted for approximately 30 minutes for each participant. All listeners were financially compensated for their participation.

2.3. Data analysis

The responses for each listener and each stimulus were processed using Microsoft Excel (Office 365). Since the stimuli were presented three times in each experiment, the scores for the correct responses ranged from 0 to 3. These scores represented the correct responses for geminates. The total scores for each stimulus were then converted into percentages and plotted into response curves. Geminate responses to each series of stimuli made from original singletons or geminates were submitted to one-way ANOVA tests using SPSS (version 25.0.0.0) to determine their significance levels. Following [1], the differences observed between the two series of stimuli in the 50% crossover points were calculated and compared statistically using ANOVA. Samples paired *t*-tests were also employed to test the level of significance of geminate responses between the two groups of stimuli at a specific step on a duration continuum.

3. RESULTS

3.1. Experiment 1

The perception results of the word-pair /pagɪ/-/ppagɪ/ in Experiment 1 are demonstrated in Figure 1, showing mean percentages of geminate responses to the stimuli made from the original /p/ (blue line) and the original /pp/ (red line). The horizontal line shows the crossover zones at 50%, while the vertical lines indicate the 50% crossover points between the two series of stimuli. Detailed measurements are provided in Table 2. It can be seen that increased amplitude following the original /p/ leads to more geminate responses, while decreased amplitude following the original /pp/ generates fewer geminate responses. Further, both response curves cross over the category boundaries with a particularly more rapid rise for the stimuli made from the original /p/. The crossovers, however, are incomplete, i.e. the mean percentages never reach 0% nor 100%.

ANOVA results reveal that the differences in geminate responses across the stimuli are statistically significant for the original /p/ ($F(5,220.5)=15.01$, $p<.001$) and also for the original /pp/ ($F(5,225.6)=9.618$, $p<.001$), suggesting that amplitude has a strong additional cue-value in geminate perception in KM. There are also ambiguous zones in the middle of the response curves. ANOVA results indicate that the difference between the two crossover points is significant ($F(1,536)=35.122$, $p<.001$), suggesting that, when amplitude is increased, listeners tend to perceive geminates much faster in the stimuli made from the

original /p/ (i.e. a 2-dB increase) than those made from the original /pp/ (i.e. a 6-dB increase).

Figure 1: Mean percentages of geminate responses to the voiceless stop stimuli in Experiment 1 (original /p/=blue line; original /pp/=red line).

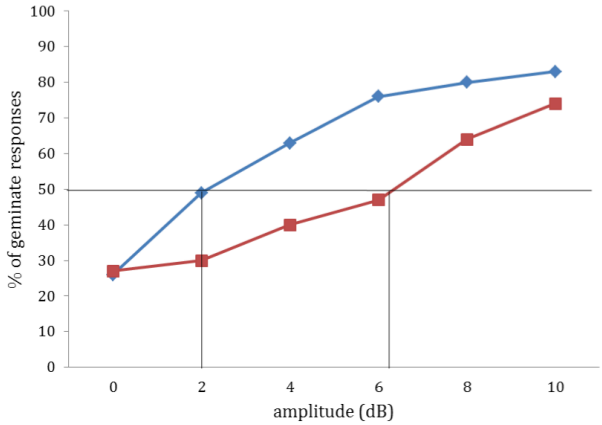


Table 2: Number of tokens and mean percentages of geminate responses to the voiceless stop stimuli in Experiment 1.

Amplitude (dB)	n	Originally /p/ (%)	n	Originally /pp/ (%)	Sig.
0	90	26	90	27	0.891
2	90	49	90	30	<0.05
4	90	63	90	40	<0.05
6	90	76	90	47	<0.01
8	90	80	90	64	0.075
10	90	83	90	74	0.333

Figure 2: Mean percentages of geminate responses to the voiceless stop stimuli in Experiment 2 (original /p/=blue line; original /pp/=red line).

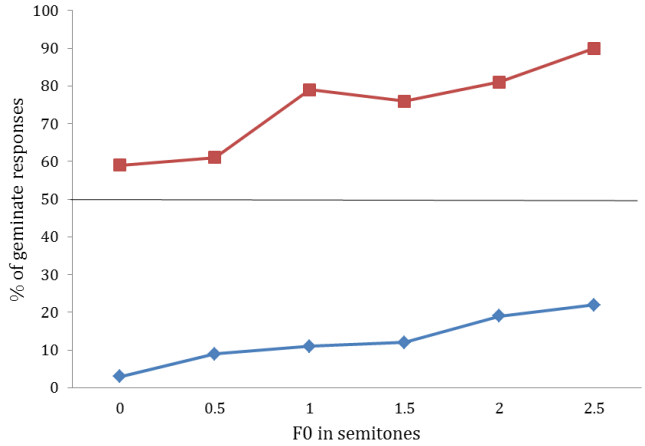


Table 3: Number of tokens and mean percentages of geminate responses to the voiceless stop stimuli in Experiment 2.

F0 in semitones	n	Originally /p/ (%)	n	Originally /pp/ (%)
0	90	3	90	59
0.5	90	9	90	61
1	90	11	90	79
1.5	90	12	90	76
2	90	19	90	81
2.5	90	22	90	90

3.2. Experiment 2

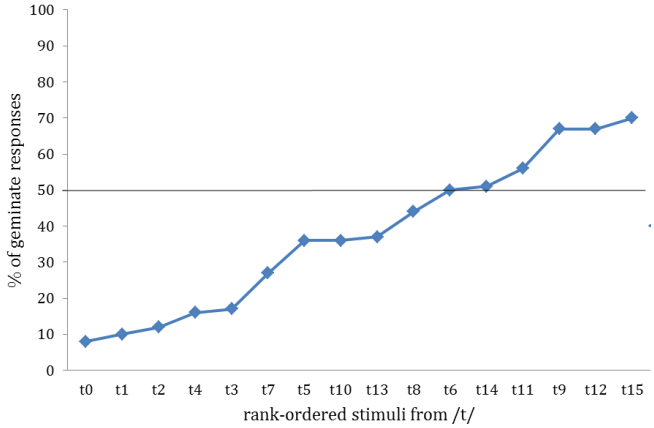
The perception results of the word-pair /pɪtʊ/-/ppɪtʊ/ in Experiment 2 are illustrated in Figure 2 and summarised in Table 3. It can be observed that increased F0 following the original /p/ causes more geminate responses, while lowered F0 following the original /pp/ results in fewer perceived geminates. Although there are no crossovers, both response curves converge gradually toward the perceptual boundary at 50%, especially in the case of the stimuli created from the original /pp/ in which the mean percentage of geminate responses is reduced from 90% to 59%. The results of one-way ANOVA reveal that the differences across the stimuli are just significant for the original /p/ ($F(5,82.55)=2.884$, $p<.05$) and highly significant for the original /pp/ ($F(5,157.7)=4.948$, $p<.001$), suggesting some perceptual cue-values of F0 on geminate perception in KM for both groups of stimuli.

3.3. Experiment 3

The perception results of the word-pair /tɪdo/-/ttɪdo/ in Experiment 3 are demonstrated in Figure 3 and summarised in Table 4.

Figure 3: Mean percentages of geminate responses to the voiceless stop stimuli in Experiment 3.

(a) Originally /t/



(b) Originally /tt/

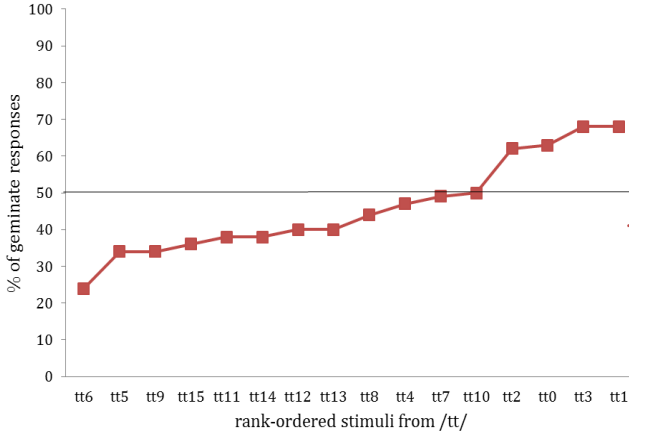


Table 4: Mean percentages of geminate responses to the voiceless stop stimuli in Experiment 3.

(a) Originally /t/		(b) Originally /tt/	
Stimuli (n=90) (amplitude/F0 variation)	**%**	**Stimuli (n=90) (amplitude/F0 variation)**	**%**
t0 (+0 dB, +0 ST)	8	tt6 (-6 dB, -0 ST)	24
t1 (+0 dB, +0.5 ST)	10	tt5 (-4 dB, -0 ST)	34
t2 (+0 dB, +1.0 ST)	12	tt9 (-6 dB, -0.5 ST)	34
t4 (+2 dB, +0 ST)	16	tt15 (-6 dB, -1.5 ST)	36
t3 (+0 dB, +1.5 ST)	17	tt11 (-4 dB, -1.0 ST)	38
t7 (+2 dB, +0.5 ST)	27	tt14 (-4 dB, -1.5 ST)	38
t5 (+4 dB, +0 ST)	36	tt12 (-6 dB, -1.0 ST)	40
t10 (+2 dB, +1.0 ST)	36	tt13 (-2 dB, -1.5 ST)	40
t13 (+2 dB, +1.5 ST)	37	tt8 (-4 dB, -0.5 ST)	44
t8 (+4 dB, +0.5 ST)	44	tt4 (-2 dB, -0 ST)	47
t6 (+6 dB, +0 ST)	50	tt7 (-2 dB, -0.5 ST)	49
t14 (+4 dB, +1.5 ST)	51	tt10 (-2 dB, -1.0 ST)	50
t11 (+4 dB, +1.0 ST)	56	tt2 (-0 dB, -1.0 ST)	62
t9 (+6 dB, +0.5 ST)	67	tt0 (-0 dB, -0 ST)	63
t12 (+6 dB, +1.0 ST)	67	tt3 (-0 dB, -1.5 ST)	68
t15 (+6 dB, +1.5 ST)	70	tt1 (-0 dB, -0.5 ST)	68

Figure 3 shows mean percentages of geminate responses to fifteen stimuli made from the original /t/ (upper panel) and the original /tt/ (lower panel). In the response curves, following [4], the data are displayed as a rank-ordering of the perceptual effects, i.e. they are rank-ordered from the lowest (at the beginning of the continuum on the *x*-axes) to the highest mean percentage (at the right end of the continuum). Generally, it can be seen that there are more geminate responses when the amplitude and F0 values following the original /t/ are systematically increased (upper panel), while, by contrast, there are fewer geminate responses when the same values following the original /tt/ are carefully reduced (lower panel). Both response curves cross over the 50% category boundary, although the perceptual shift to the opposite category is incomplete. ANOVA results indicate that the differences in geminate responses across the stimuli are highly significant for the original /t/ ($F(15,585.2)=14.12$, $p<.001$) and also for the original /tt/ ($F(15,603.0)=4.053$, $p<.001$), indicating that the combined effects of amplitude and F0 can influence listeners' percepts of the consonant contrast in KM.

4. DISCUSSION AND CONCLUSIONS

This study has investigated the degree to which amplitude and F0 can influence the perception of the word-initial singleton/geminate contrast in KM, focusing on voiceless stops in which the primary acoustic cue of closure duration is unavailable. The results reported from Experiments 1 and 2 have shown that amplitude and F0, when modified on their own, manage to provide secondary cues to word-initial geminates in KM. However, the effect is relatively stronger in amplitude modification in which there are perceptual crossovers for both series of stimuli. In the final experiment, it was revealed that the combined effects of amplitude and F0 provide a better cue-value to the perceptual separation of the contrast in KM. The perceptual changes, nevertheless, are not necessarily brought about by systematic variation in both parameters. In some cases, amplitude variation alone is enough to cause significant geminate responses. That is, amplitude has a larger perceptual effect than F0.

The results in Experiment 1 require some comment; listeners respond differently to modified singletons and geminates, implying additional cues besides amplitude that may potentially influence listeners to perceive the stimuli created from the original /p/ as geminates. One of the most probable cues is the amplitude ratio across syllables. That is, when amplitude is gradually increased in the first syllable beginning with singletons, it may be potentially heard as similar to or louder than the second syllable, leading listeners to perceive manipulated singletons as geminates.

These perception results lend support to the KM production data on amplitude and F0, as reported in [8]. First, the results closely match the acoustic results found for the mean amplitude difference between KM voiceless stop singletons and geminates (5 dB). Second, as also reported in [8], the mean F0 differences between KM voiceless stop singletons and geminates (12 Hz for males and 13 Hz for females) are relatively small to have a large perceptual effect, which has already been proven in the current study. The KM perception results are partially in agreement with comparable experiments in PM; the individual effect of amplitude seems to be much stronger in KM than in PM [2], while F0 shows a similar weak effect in both Malay varieties [3]. With respect to the joint modification of amplitude and F0, like KM, the word-pairs in PM show perceptual crossovers in identification, which can be attributed to the manipulation of both syllables of disyllabic words in PM.

With regard to the wider implications of this study, the findings constitute important additions to the phonetic literature on consonant gemination. In particular, the perception results have shown that word-initial consonant gemination can be characterised by a complex interplay of secondary acoustic cues in addition to the primary cue, i.e., closure duration, particularly in the case of voiceless stops. Further examination is warranted to determine whether similar perceptual effects across syllables are also present in KM consonant gemination. Also, as to whether the effects of manipulation are present at other consonant types, this is subject to future experimental confirmation.

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