VOT and Its Effect on the Syllable Duration in Busan Korean

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ABSTRACT

Two identical experiments are conducted at a six month interval in order to examine the VOT and its effect on the whole syllable duration or the rest portion of the syllable in Busan Korean. Just like the general characteristics of VOT, the aspirated stops consistently exhibit the longest VOT while tense stops have the shortest VOT. However, alveolar stops exhibit shorter VOT than labial stops, and it is contrary to the previous studies which claim that VOT values of labial stops are shorter than VOT values of alveolar stops. Moreover, there is a relationship between VOT and syllable/VC duration across stops. While VOT and syllable/VC duration have symmetric relationship for the aspirated velar and bilabial stops, other lax and tense stops exhibit the inverse relationship between the VOT and syllable/VC duration.

Keywords: VOT, duration, stop, tense, aspirated, lax

1. Introduction

The voicing feature for syllable-initial stops can be characterized by the interval between the articulatory release of the stop and the onset of the vocal fold vibrations. This time interval is called the voice onset time (VOT hereafter). The VOT differences among stops are generally contributed by the different place of articulation. As the point of articulation is further back in the mouse, the VOT gets longer (Fischer Jorgensen 1954, Peterson & Lehiste 1960). Lisker & Abramson (1964) show that velar stops have the longest VOT and bilabial stops have the shortest VOT among aspirated stops in Cantonese, English, Eastern Armenian, and Korean, and so do they among the unaspirated stops in

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Dutch, Puerto Rican Spanish, Hungarian, Cantonese, Eastern Armenian, Tamil, and Korean. In addition to the place of articulation, VOT is also affected by glottal opening and aerodynamics. The aspirated stops have the widest aperture of the glottis and the tense stops the narrowest aperture (C. W. Kim 1970, Hirose et al 1974, Kagaya 1974, Jun et al, 1998). As the glottal aperture gets wider, the rate of air flow increases. Consequently, aspirated stops have the longest VOT while tense stops have the shortest VOT (Lisker & Abramson 1964, C. W. Kim 1965, Han & Weitzman 1970, Abramson & Lisker 1972, Hardcastle 1973, Kagaya 1974, Silva 1992, Cho Kim 1994, Cho 1996, Han 1996a, Shimizu 1996). Though the VOT differences among stops can be generalized as argued by many researchers above, the clear cut distinctions of VOT among stops are not always available. The VOT values of lax and tense stops overlap and so do lax and aspirated stops (C. W. Kim 1965, Han & Weitzman 1970, Abramson & Lisker 1972, Cho Kim 1994, Shimizu 1996). However, according to Kim *et al*'s study (2002), alveolar stops are consistently shorter than labial stops, which is contradictory to the findings of the previous studies.

VOT is also known to affect the duration of the following vowel. Cho (1996) claimed that the duration of the following vowel is the longest after tense stops and the shortest after aspirated stops: the VOT in Korean stop is inversely related to the duration of the following vowel. Kim *et al.* (2002) also show that the duration of vowel /a/ was the shortest after aspirated stops and the longest after tense stops while the duration of vowel /i/ is not affected by the property of the preceding stops.

Based on the above studies, this paper first examines the duration of VOT in stops of Busan Korean, investigates if it follows the general tendency that the aspirated velar stop has the longest VOT while the tense bilabial stop the shortest VOT, or it exhibits different characteristics of VOT as Kim *et al.* (2002) found. Thirdly, it investigates the relationship between VOT and a following vowel and a coda consonant duration or a whole syllable duration.

2. Experiment 1

In order to achieve the above three objectives, the production of VOT and duration of following syllable elements were examined.

2.1 Stimuli

Nine monosyllabic words, shown in Table 1, are used in this experiment and they have a Consonant-Vowel-Consonant (CVC) syllable structure of which onset consonants is one of the voiceless stops: /p*/, /p/, /p^h/, /t*/, /t/, /t^h/, /k*/, /k/, /k^h/ (The asterisk, *, represents the acoustic feature of tense stops in Korean, following Cho & Keating (2001), and Kim *et al.* (2002) since there is no official IPA transcription for Korean tense stops.). They differ not only in the place of articulation but also in the degrees of aspiration or tenseness of vocal fold and VOT. Except these onset consonants which are the only variables in these stimuli, each syllable has the same vowel and the same coda consonant: a tense mid back vowel /o/ followed by a velar nasal /3/. Though Vowel-Consonant (VC) portion of a syllable is considered a constant, it remains to be seen whether their duration can be affected by the preceding stops.

Table 1. Individual tokens used in the experiment

Word	p*o3	po3	p^ho3	t*o3	to3	t^ho3	k*o3	ko3	k^ho3
Meaning	mulberry leaves	bar	splashing sound	dung	bronze	container	lie	ball	bean

2.2 Subjects

Seven subjects - three male and four female college students - participated in this experiment. They are native Busan-Koreans and their parents too. They range in age from 20 to 26 and they have lived in Busan all their lives. They fully understand the meanings of each word and can naturally produce the words.

2.3 Procedure

Subjects spoke each word, written in Korean Hangul orthography, in isolation at a natural speaking rate. Each word was spoken five times. Subjects were instructed to stop completely right after the utterance of each word to avoid any prosodic effects such as rising intonation when uttering the list of words. Each word in the list was recorded directly onto the Computerized Speech Lab (CSL) 4500 at 44.1 KHz sampling rate using Shure SM48 microphone.

2.4 Acoustic Analyses

The recorded 315 speech signals (7 subjects x 9 tokens x 5 repetitions) were measured using CSL 4500. The main interests of the measurement are VOT and durations of vowels and coda consonants, and whole syllables. VOT was measured in milliseconds (ms) from the onset of the stop consonant release burst to the onset of the first complete vibration of the vocal folds as indicated on the waveform and the remaining parts of a syllable - a vowel and a coda consonant - was measured as shown in Figures 1 to 3.

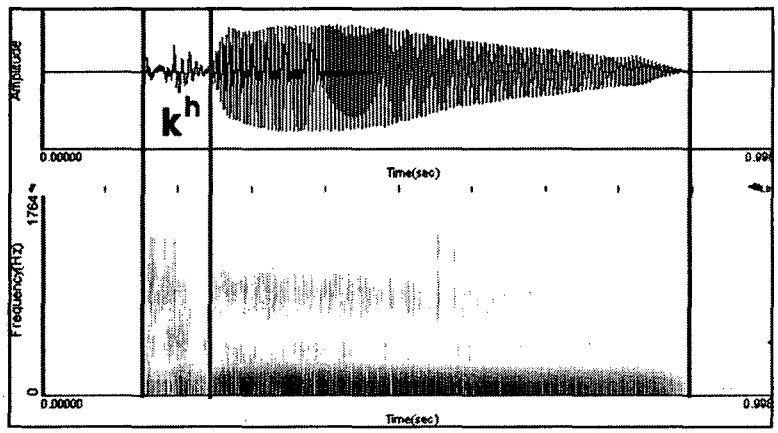

Figure 1. Spectrogram and waveform of /kʰo3/ 'bean'.

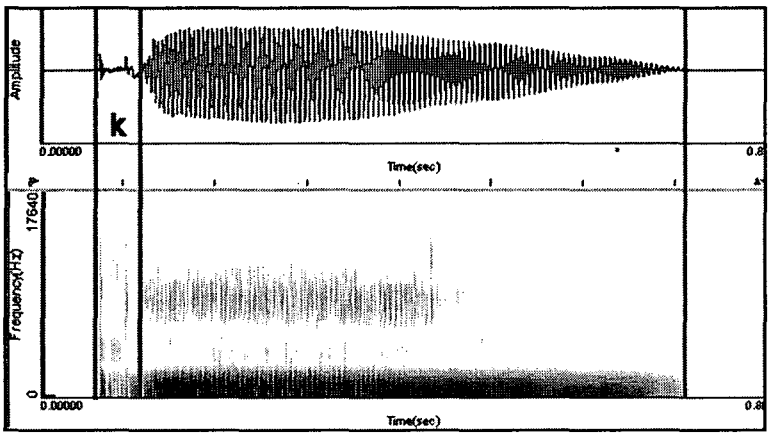

Figure 2. Spectrogram and waveform of /ko3/ 'ball'.

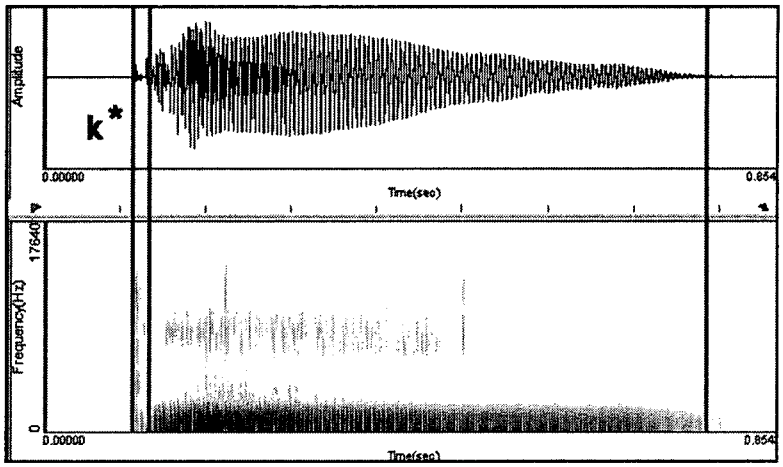

Figure 3. Spectrogram and waveform of /k*o3/ 'lie'.

3. Results

The results of the measured VOT values of each word token are shown in Table 2. As can be predicted from the previous studies, aspirated stops consistently exhibit the longest VOT while tense stops have the shortest VOT. The differences in VOT values across stops are significant [$F(8,261) = 71.4$, $p < 0.0001$]. However, in line with Kim *et al*'s study (2002), alveolar stops exhibit shorter VOT than labial stops, as shown in Figure 4, and it is contrary to the previous studies which claim that VOT values of labial stops are shorter than VOT of alveolar stops. The cause of idiosyncratic difference in VOT values between alveolar stops and bilabial stops are not specifically discussed in Kim *et al*'s study and it is not explicitly explained in the literature. Another interesting result is that the VOT of tense velar stop /k*o3/ is longer than the VOT of lax alveolar stop /to3/, and the VOT difference is statistically significant [$F(1,58)=70.5$, $p < 0.0001$]. The result is an exception to the generalization that lax stop has longer VOT than tense stop.

Table 2. VOT values of individual word tokens. VOT values in millisecond.

Word Tokens	Average	Distribution Range (Minimum ~ Maximum)	Standard Deviation
k*o3	26	17 ~ 45	8
ko3	54	26 ~ 103	23
k^ho3	86	49 ~ 156	28
t*o3	11	7 ~ 17	2
to3	25	14 ~ 49	10
t^ho3	61	30 ~ 99	21
p*o3	15	9 ~ 26	4
po3	32	16 ~ 73	15
p^ho3	61	36 ~ 95	15

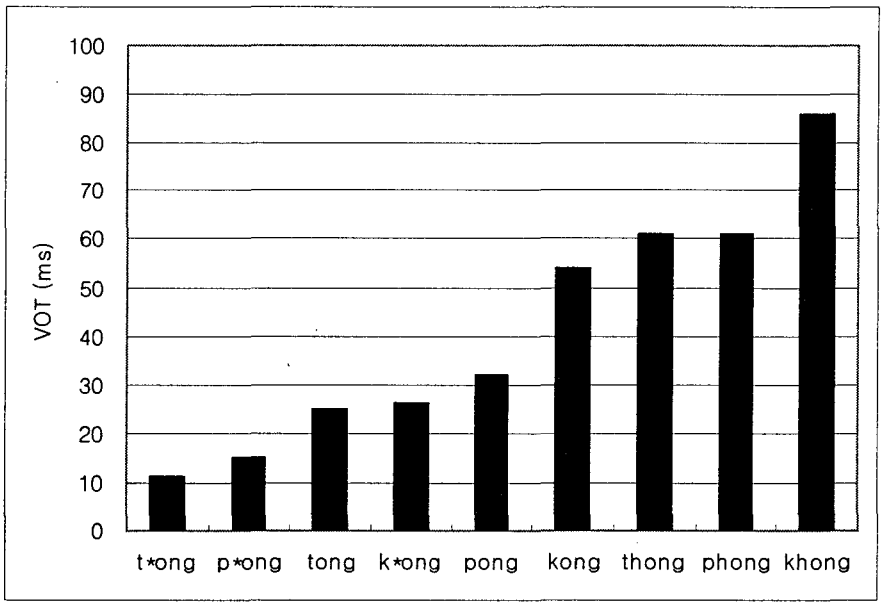

Figure 4. Bar chart illustrates the VOT values across stops. Aspirated stops exhibit the longest VOT.

Scatter plots of individual tokens in Figure 5 and 7 represent the relationship between VOT and syllable duration (CVC) and Figure 6 and 8 represent the relationship between VOT and CV duration for velar stops. Since the syllable structures are the same, that is, a

CVC structure, and vowels and coda consonants are the same - a vowel /o/ followed by a coda /4/ - across word tokens, the relationship between VOT and syllable duration can be manifested clearly on the scatter chart. Although the R^2 value, which is an indicator of how much of the variation in the data is explained by the model, is closer to 0 rather than to 1 when attempted to explain the variation in terms of a power model, and the trend explained by the model is almost insignificant, all of the scatter charts except Figure 7 show the inverse relationship between VOT and syllable/VC duration; as the VOT gets longer, the whole syllable/VC duration gets shorter. (Though only four scatter charts are shown in this paper, other stops exhibit the same trend.) It is contrary to the prediction that the syllable duration will systematically increase as VOT increases. However, for the aspirated velar stop as shown in Figure 7 and the aspirated bilabial stop, the whole syllable duration gets longer as VOT increases, indicating that the VOT is great enough to affect the whole syllable duration. Among velar stops, tense alveolar stop is the only exception to this phenomenon – a whole syllable/VC duration decreases as VOT increases. Moreover, as mentioned at the beginning of this paper, some of VOT ranges overlap across stops, too.

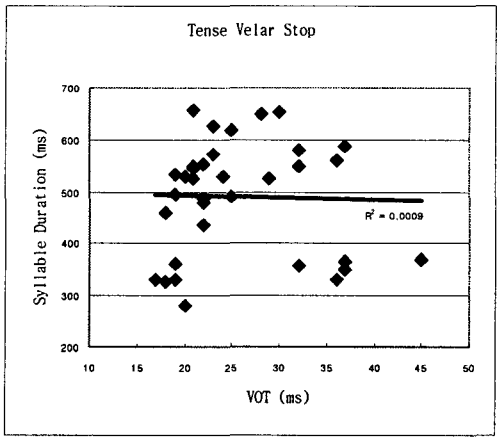

Figure 5. Relationship between VOT and a whole syllable duration for tense velar stop.

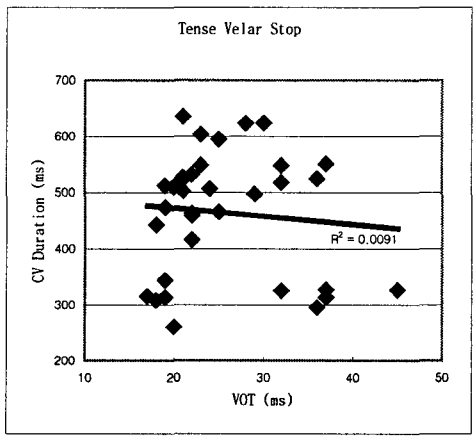

Figure 6. Relationship between VOT and CV duration for tense velar stop.

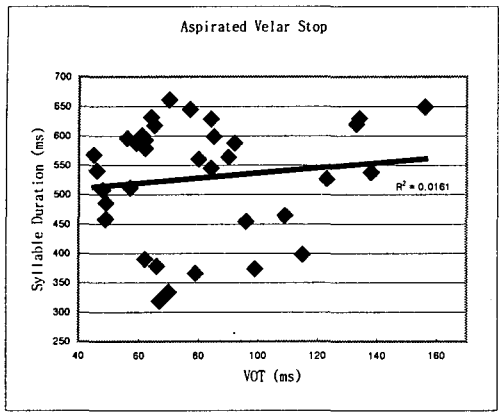

Figure 7. Relationship between VOT and a whole syllable duration for aspirated velar stop.

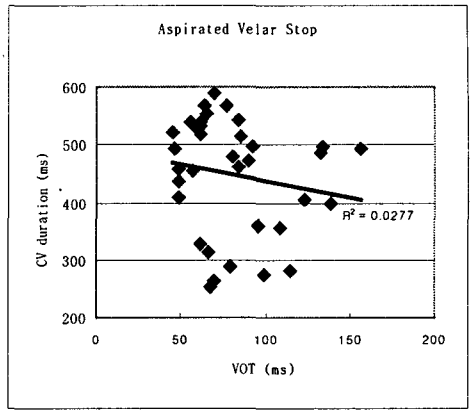

Figure 8. Relationship between VOT and CV duration for aspirated velar stop.

4. Experiment 2

In order to obtain more reliable experiment result, the same experiment as the first experiment is conducted after six months of the first experiment: the same word tokens, the same subjects, the same recording procedures, and the same analysis techniques are used.

Table 3 shows the results of the second experiment. Except the fact that the VOT value of /to3/ is longer than that of /k*o3/, the results of the second experiment are the same as the first experiment; aspirated stops exhibit the longest VOT while the tense stops the shortest VOT, and the VOT values of the alveolar stops are shorter than those of the bilabial stops, and the differences in VOT values across stops are significant [$F(8,261) = 112$, $p < 0.0001$].

For the relationship between VOT and syllable duration, as in the first experiment, whole syllable duration is inversely related to VOT values except aspirated stops; as the whole syllable duration or vowel and coda consonant duration increases, VOT values decreases.

If there are different experiment results from the first experiment, first, a whole syllable duration increases as VOT increases for the aspirated alveolar stop /t^ho3/. Second, for the aspirated stops, the duration of both a whole syllable and VC portion increase as VOT increases.

Table 3. VOT values of individual word tokens. VOT values in millisecond.

Word Tokens	Average	Distribution Range (Minimum ~ Maximum)	Standard Deviation
k*o3	24	16 ~ 49	8
ko3	50	25 ~ 85	14
k^ho3	83	46 ~ 119	18
t*o3	11	8 ~ 14	2
to3	26	14 ~ 45	8
t^ho3	58	21 ~ 105	22
p*o3	15	8 ~ 22	4
po3	30	17 ~ 51	8
p^ho3	69	43 ~ 95	16

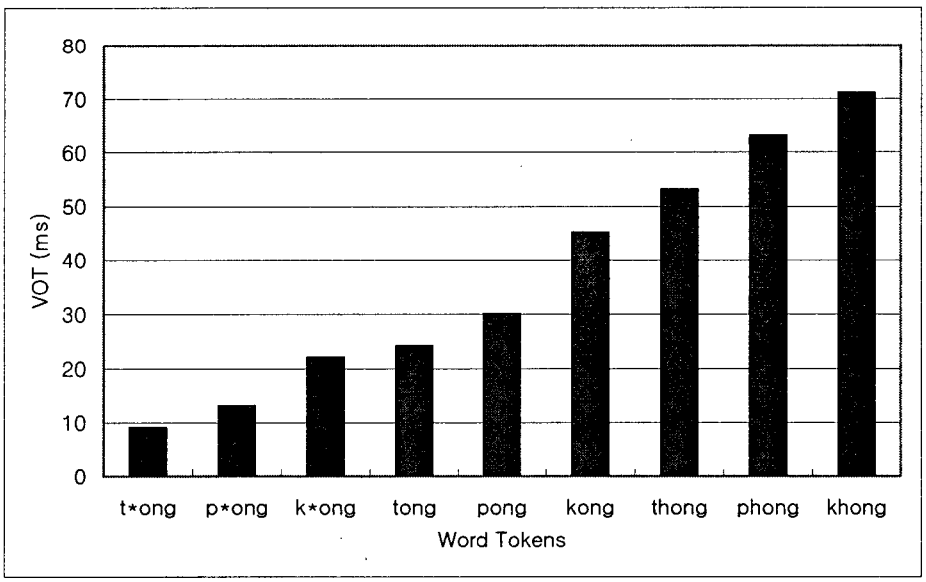

Figure 9. Bar chart illustrates the VOT values across stops. Aspirated stops exhibit the longest VOT while tense stops exhibit the shortest VOT.

5. Conclusion

To summarize, aspirated stops exhibit the longest VOT while tense stops have the

shortest VOT in Busan Korean. However, there is a different experiment result between the two experiments. In the first experiment, the VOT of tense velar stop /k*o3/ is longer than the VOT of lax alveolar stop /to3/ while in the second experiment the lax alveolar stop exhibits longer VOT than the tense velar stop. It leaves some room for further investigation for the non-coherent experiment result, though the difference is statistically significant in each experiment.

One of the interesting fact found in both experiments is that alveolar stops of Busan Korean exhibit shorter VOT than labial stops. It is contrary to the previous studies which claim that VOT values of labial stops are shorter than VOT of alveolar stops. This finding is in line with Kim et al's study (2002). It also needs further research to investigate the cause of the unique difference from other languages.

When the relationship between VOT and syllable/VC duration is considered, there is an inverse relationship between VOT and syllable/VC duration; as the VOT gets longer, the whole syllable/VC duration gets shorter. Contrary to this relationship, the whole syllable duration gets longer as VOT increases for the aspirated velar stop and the aspirated bilabial stop except for the aspirated alveolar stop of which whole syllable/VC duration decreases as VOT increases. However, in the second experiment, a whole syllable duration increases as VOT increases for the aspirated alveolar stop /t^ho3/, brining in the same trend for aspirated stops. Although some relationship is found between VOT and syllable/VC duration, the relationship is not statistically significant and it needs further study to validate the relationship.

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