

# Shortening of Voice Onset Time in Korean Aspirates: Phonetic OCP or Timing Regulation?

Mira Oh and Dahee Kim

Chonnam National University and Kyungbuk National University  
[mroh@jnu.ac.kr](mailto:mroh@jnu.ac.kr) and [inureyes99@naver.com](mailto:inureyes99@naver.com)

## ABSTRACT

The Voice Onset Times of word-initial Korean aspirated stops vary systematically as a function of the laryngeal feature of the onset of the following syllable. Precisely, VOT of a word-initial aspirated stop is shorter when the next syllable begins in an aspirated stop than when the next syllable begins in a lenis stop. The current study is aimed at testing two competing hypotheses to account for such VOT shortening in Korean aspirated stops, namely phonetic OCP[1, 2] or conforming to language-specific isochrony[3, 4]. VOT,  $f_0$ , and spectral tilt were measured from productions of  $C_1$  in  $/C_1VC_2Vta/$ , where the laryngeal properties of  $C_1$  and  $C_2$  were orthogonally varied among lenis, tense, and aspirated. Results suggest that isochrony can account for VOT shortening, while no phonetic dissimilation was found from phonetic measures other than VOT.

**Keywords:** VOT, Korean three-way contrast, phonetic OCP, interval, speech timing.

## 1. INTRODUCTION

Avoidance of similarity (e.g., OCP) and its relevance has been an important focus in the phonological literature, in particular, to account for phonotactic constraints against identical phonemes occurring within a certain phonological domain [1]. In monosyllabic native-Korean, aspirated consonants may not co-occur within a stem [5], and the author accounted for this laryngeal cooccurrence restriction as aspirated  $C_2$  blocking aspirated  $C_1$  in  $C_1VC_2$  stems. Laryngeal co-occurrence restrictions are widely attested across languages [6, 7]. Gallagher [7] identified three patterns of laryngeal cooccurrence restrictions, namely assimilatory (tautomorphic stops must have the same laryngeal feature), dissimilatory (stops of the same laryngeal feature do not occur within a root morpheme), and mixed patterns (homorganic stops must have the same laryngeal feature but non-homorganic stops must not have the same laryngeal feature). Avoidance of Asp-V-Asp sequences in native Korean monosyllabic stems would be one case of dissimilatory laryngeal cooccurrence.

However, avoidance of Aspirated stop(henceforth Asp)-V-Asp in native Korean stems may qualitatively differ from laryngeal cooccurrence restrictions found from other languages. First, the constraint against two consecutive aspirated stops is only found in one specific stratum of the lexicon. In other strata of the lexicon, a sequence of aspirate onsets within a monomorphemic word is widely found from other strata of the lexicon, such as loanwords (e.g.,  $/k^h\Lambda mp^hjut^h\Lambda/$  “computer”) or Sino-Korean words (e.g.,  $/p^hok^h\ae\eta/$  “violence”). In addition, the constraint against Asp-V-Asp is valid only for monosyllabic stems thus morphologically complex words that are of native Korean origin may still have an Asp-V-Asp sequence.

A recent study by Oh and Kim [2] addressed the question of how Asp-V-Asp sequences are phonetically realized. In particular, they focused on the marked status of Asp-V-Asp sequences in the native stratum of the Korean lexicon [5] and examined whether such sequences are “phonetically repaired.” They found that Oejeol-initial Asps have shorter VOTs when followed by another Asp, suggesting that the shortening of VOT might suggest dissimilation or phonetically repairing a marked structure. In the current study, we argue that the shortening of VOTs in the first Asps in the Asp-V-Asp sequences can be better explained by an account appealing to the timing regularity in the language, rather than phonetic OCP.

The rest of the paper is organized as follows. In section 2, we reinterpret the data in [2] and provide pieces of evidence suggesting that dissimilation does not fully account for the phonetic variability of Korean stop production. In section 3, we provide an alternative account for the observed variability, and argue that the timing account is simpler and more comprehensive. Section 4 concludes the paper.

## 2. REVIEW OF OH AND KIM (2016)

Oh and Kim [2] had 18 Korean speakers (10 Seoul speakers and 8 Gwangju speakers) produce three-syllable nonsense words in carrier phrases,  $/iketto C_1aC_2ata/$  or  $/iketto C_1alata/$ .  $C_1$ , and  $C_2$  had same place and laryngeal features. They measured VOT of  $C_1$ , VOT of  $C_2$  (Not discussed in [2]),  $f_0$  and spectral tilt of  $/a/$  between  $C_1$  and  $C_2$ . Both measures were

made at 10% point of the vowel. VOT of  $C_1$  is summarized as Table 1 below.

**Table 1:** VOT of  $C_1$  stops, data from [2].

Dialect	$C_1$	$C_2$	$C_1$ VOT (ms)
Seoul	Lenis	Lenis	62.73
		Lateral	76.36
	Aspirated	Aspirated	43.10
		Lateral	81.06
	Tense	Tense	20.04
		Lateral	25.12
Gwangju	Lenis	Lenis	59.37
		Lateral	76.01
	Aspirated	Aspirated	42.33
		Lateral	73.93
	Tense	Tense	20.88
		Lateral	28.02

As can be seen from Table 1 above, VOT of aspirated  $C_1$  is shorter when  $C_2$  was an aspirated stop than when  $C_2$  was a lateral stop in both dialects. VOTs were submitted to a mixed-effects linear models where  $C_1$  and  $C_2$  were fixed effects and talker and place of articulation were random effects. A series of pairwise comparisons using TukeyHSD tests revealed that the ~33ms difference in VOTs of Asp  $C_1$  between Asp( $C_1$ )-V-Asp( $C_2$ ) and Asp( $C_1$ )-lateral( $C_2$ ) was statistically significant at alpha level of 0.05 ( $\beta = -33.90$ ;  $z = -4.25$ ;  $p < 0.001$ ), confirming that the VOT of Asp( $C_1$ ) is shorter before Asp( $C_2$ ) compared to lateral ( $C_2$ ). In contrast, for lenis and tense stops, VOTs did not differ as a function of  $C_2$ .

Readers may wonder whether the observed pattern is due to the fact that  $C_1$  and  $C_2$  were identical and the repetition of the same aspirated stop (i.e., repetition of the identical segment, as opposed to the same laryngeal feature) was causing VOT shortening in Asp( $C_1$ )s. In [2], the authors reported that they found a similar magnitude of VOT shortening from a spontaneous speech corpus of Seoul Korean, even  $C_1$  and  $C_2$  were not identical, suggesting that the effect is likely to be due to the repetition of laryngeal feature, not the repetition of an identical segment. Apparently, the “shortening” of  $C_1$  VOT in Asp( $C_1$ )-V-Asp( $C_2$ ) sequences seems to suggest that the dissimilation account in [2] is accurate. However,  $f_0$  and H2-H1 measured at 10% point of the vowel between  $C_1$  and  $C_2$  summarized in Table 2, may suggest otherwise.

A series of comparable mixed-effects models tested whether and to what extent  $f_0$  and H2-H1 of  $C_1$  varied as a function of  $C_2$ . Interestingly, none of the two phonetic properties differed as a function of  $C_2$ , suggesting that no dissimilative effects were found. In other words, an OCP-style account (i.e.,

dissimilation) is burdened to explain why only VOT was affected by a nonlocal  $C_2$  but no other phonetic properties were affected by  $C_2$ .

**Table 2:**  $f_0$  and spectral tilt of  $C_1$  stops, data from [2]

Dialect	$C_1$	$C_2$	$f_0$ (Hz)	H2-H1
Seoul	Lenis	Lenis	170	11.55
		Lateral	170	10.91
	Aspirated	Aspirated	227	11.36
		Lateral	232	11.10
	Tense	Tense	216	8.39
		Lateral	213	7.04
Gwangju	Lenis	Lenis	130	8.26
		Lateral	125	8.43
	Aspirated	Aspirated	183	9.49
		Lateral	186	10.65
	Tense	Tense	158	4.65
		Lateral	171	2.69

Yet an alternative explanation is possible. One possible explanation for this pattern is that the primary cue— $f_0$ —to laryngeal distinction in Korean [8] stays constant, while secondary cues vary as a function of other properties. Still, such an account does not predict why H2-H1, which is a secondary cue compared to  $f_0$ , stays stable across the  $C_2$  conditions. For these reasons, we argue that dissimilation does not provide a simple and comprehensive account for VOTs in Korean. In Section 3, we provide an alternative explanation for the reported variability.

### 3. ISOCHRONY IN SPOKEN LANGUAGES

In this section, we argue that an account based on the speech timing can better explain the VOT modulation found in [2] and summarized in section 2. First of all, the appeal to timing removes the theoretical burden to explain why VOT of  $C_1$  was the only phonetic property affected by  $C_2$ . Second, independent evidence suggests that  $C_1$  affects  $V_1$  duration [9, 10] and  $C_2$  affects  $V_1$  duration in  $C_1$ - $V_1$ - $C_2$ - $V_2$ -sequences [11]. If this is the case,  $C_2$  may influence duration of  $V_1$ , and possibly, duration of  $C_1$  as well. In order to examine whether  $C_1$  and  $C_2$  predicts duration of neighboring segments, we measured durations of /a/ between  $C_1$  and  $C_2$ , closure duration of  $C_2$ , and VOT of  $C_2$  from data generated in [2], Experiment 2 of which the participants were 10 Gwangju Korean speakers and the task was to read /iketto  $C_1$ a $C_2$ ata/ or /iketto  $C_1$ alata/ three times in a random order, where  $C_1$  and  $C_2$  had same or different laryngeal features but had identical place feature. (i.e., thus, when  $C_1$  was

/k/, there were four different types of stimuli: /kakata/, /kak'ata/, /kak<sup>h</sup>ata/, and /kalata./ Table 3 summarizes the duration of V<sub>1</sub> and C<sub>2</sub> closure; Table 4 summarizes VOTs of C<sub>2</sub>.

**Table 3:** Duration of V<sub>1</sub> and C<sub>2</sub> closure

C <sub>1</sub>	C <sub>2</sub>	V <sub>1</sub> (ms)	C <sub>2</sub> closure (ms)
Lenis	Lateral	89.27	NA
	Lenis	67.42	45.90
	Aspirated	52.86	111.29
	Tense	52.32	141.70
Aspirated	Lateral	85.59	NA
	Lenis	82.38	47.52
	Aspirated	46.45	103.71
	Tense	67.19	135.47
Tense	Lateral	140.10	NA
	Lenis	124.40	45.85
	Aspirated	108.44	111.34
	Tense	76.47	126.40

Duration of V<sub>1</sub> was found to differ systematically as a function of C<sub>1</sub>. Vowels following lenis (M = 65.39 ms) and aspirated (M = 70.58 ms) stops were shorter than vowels following tense stops (M = 112.18 ms) and pairwise comparison revealed that all three levels were significantly different from each other at alpha level of 0.05.

V<sub>1</sub> duration also differed as a function of C<sub>2</sub>. Vowels followed by laterals were, overall, longest (M = 104.97 ms); vowels followed by a lenis stop (M = 90.52 ms) were longer than vowels followed by aspirated (M = 69.12 ms) or tense (M = 65.21 ms) stops. Pairwise comparisons revealed that V<sub>1</sub> duration did not differ between when C<sub>2</sub> was aspirated and when C<sub>2</sub> was a tense stop, but all other differences were found to be statistically significant. These results confirm that aspirated and tense C<sub>2</sub>s shorten the duration of preceding V<sub>1</sub> [11].

Variation in V<sub>1</sub> duration caused by neighboring segments, C<sub>1</sub> and C<sub>2</sub>, suggests that the motivation for duration modulation in Korean is not limited to the domain of a syllable. In the stimuli, C<sub>1</sub> and C<sub>2</sub> are onsets of two different syllables yet C<sub>2</sub> affected the duration of the vowel, which is the nucleus of a syllable preceding C<sub>2</sub>. Moreover, limiting the domain to a syllable cannot account for why C<sub>2</sub> conditions VOT of C<sub>1</sub>. Considering these observations, we also measured closure duration and VOTs of C<sub>2</sub>.

Closure duration of C<sub>2</sub> was found to be conditioned by C<sub>2</sub> (M = 46.43 ms for lenis C<sub>2</sub>; M = 108.80 ms for aspirated C<sub>2</sub>; M = 134.57 ms for tense C<sub>2</sub>; pairwise comparisons revealed significant differences across all levels) as well as C<sub>1</sub> (M =

100.15 ms for lenis C<sub>1</sub>; M = 95.41 ms for aspirated C<sub>1</sub>; M = 95.93 ms for tense C<sub>1</sub>; pairwise comparisons revealed significant differences between tense and lenis C<sub>1</sub> conditions), suggesting that duration of C<sub>1</sub> influences that of C<sub>2</sub> vice versa. To further examine durational properties of C<sub>2</sub>, as a function of C<sub>1</sub> and C<sub>2</sub>,

**Table 4:** VOT of C<sub>2</sub>

C <sub>1</sub>	C <sub>2</sub>	C <sub>2</sub> VOT (ms)
Lenis	Lenis	15.69
	Aspirated	62.30
	Tense	14.44
Aspirated	Lenis	15.97
	Aspirated	54.94
	Tense	15.74
Tense	Lenis	16.02
	Aspirated	69.01
	Tense	14.78

As can be seen from Table 4, VOT of aspirated C<sub>2</sub>s differ as a function of C<sub>1</sub>. Similarly to the shortening of aspirated C<sub>1</sub> VOT reported in [2], VOT of aspirated C<sub>2</sub> was also shorter after an aspirated C<sub>1</sub>, suggesting that the influence of non-local Cs is bidirectional. Statistical analyses revealed that the VOTs of aspirated C<sub>2</sub> after an aspirated C<sub>1</sub> was significantly shorter than VOTs of aspirated C<sub>2</sub> after a lax C<sub>1</sub> ( $\beta = -7.20$ ;  $z = -3.19$ ;  $p < 0.01$ ) and VOTs of aspirated C<sub>2</sub> after a tense C<sub>1</sub> ( $\beta = 13.82$ ;  $z = 6.07$ ;  $p < 0.001$ ).

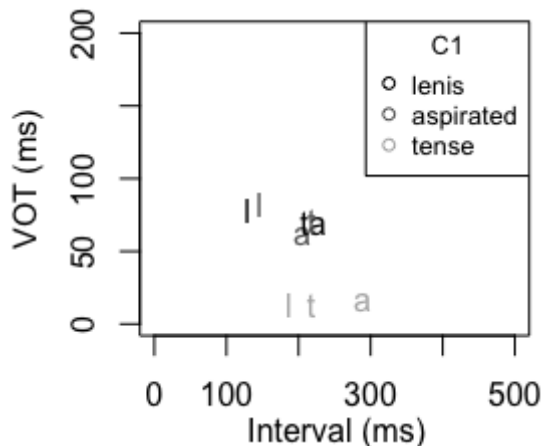
An account based on dissimilation cannot account for this bidirectional “shortening” of VOTs of aspirated stops without stipulation, since VOT of C<sub>1</sub> and C<sub>2</sub> eventually became similar to each other via shortening. One could potentially theorize the VOT patterns by first positing a VOT shortening, dissimilation rule of which the trigger is aspirated C<sub>2</sub> and target is aspirated C<sub>1</sub>, which feeds assimilatory shortening of C<sub>2</sub> VOT. However, such an account lacks a consistent motivation for duration modulation.

To summarize, we found that duration modulation in Korean stops and intervening vowels. To account for such modulation, a domain that is longer than a syllable is required, since onsets of one syllable condition duration of onset of a following syllable.

There have been proposals suggesting that vowel to vowel interval forms an integral unit in phonetics and phonology [3, 4]. For instance, [4] suggested that phonetic duration of vowel to vowel interval predicts stress placement in American English. Similarly, interval was found to be a better predictor of stress in Portuguese than syllables [12]. Although not much is known regarding the rhythmic unit of spoken Korean, there have been debates as to whether Korean is stress-time, mora-timed, or

syllable timed. Results are inconclusive, as different measures led to different conclusions [13, 14]. We focused on the shortening of aspirated C<sub>1</sub> VOT before tense and aspirated C<sub>2</sub>, and hypothesized that V to V interval, which is the sum of V<sub>1</sub> duration, C<sub>2</sub> closure, and C<sub>2</sub> VOT may predict VOT of C<sub>1</sub>. Figure 1 summarizes how V-to-V interval and VOT are related.

**Figure 1:** V-to-V interval and VOT of C<sub>1</sub>. Letters on the plot corresponds to C<sub>2</sub>.



As can be seen from Figure 1, we find that the longer the V-to-V interval is, the shorter C<sub>1</sub> VOT is within the same C<sub>1</sub>, suggesting that the inverse relationship might help V-to-V interval predict VOT of C<sub>1</sub>. However, in order to evaluate whether this trend is a reliable predictor of C<sub>1</sub> VOT, a future study focusing on the variation of V-to-V interval (e.g., VOT of C<sub>1</sub> in C<sub>1</sub>VCCV vs. C<sub>1</sub>VCV) is needed.

#### 4. CONCLUSIONS

In this study, we reexamined VOT shortening of Korean aspirated stops. Aspirated stops are typically considered as a stop category that is distinguished by long VOT and the long VOT of aspirated stops have been confirmed in productions of onset of monosyllables. However, in this study, we showed that in word initial positions, due to non-local C to C coarticulation or timing modulation, VOT of aspirated stops can be shorter than VOT of lenis stops. An account that is based on dissimilation cannot account for bidirectional shortening of VOTs of aspirated stops and does not predict why VOT, but not other phonetic properties, are modulated by laryngeal features of C<sub>1</sub> and C<sub>2</sub>. In contrast, appealing to timing such as V-to-V interval predicts why VOT is modulated by C<sub>1</sub> and C<sub>2</sub>. However, further research is needed to determine why such relationship between timing units (or some type of isochrony) is found from speech. We leave this question for future research. (We are in the process of examining the

extent to which V-to-V interval predicts segment duration in read speech as well as in spontaneously spoken present day Seoul Korean.)

#### 7. REFERENCES

- [1] Liberman, M., Schultz, M., Hong, S., & Okeke, V. 1993. The phonetic interpretation of tone in Igbo. *Phonetica* 50(3), 147-160.
- [2] Oh, M., & Kim, D. 2018. Long-distance effects on the VOT variation of Korean stops. Poster presented at the 16<sup>th</sup> Conference on Laboratory Phonology.
- [3] Steriade, D. 2012. Intervals vs. syllables as units of linguistic rhythm. Handouts, EALING, Paris.
- [4] Hirsch, A. 2014. What is the domain for weight computation: the syllable or the interval? *Proc. 2013 Annual Meetings on Phonology*, 1-12.
- [5] Ito, C. 2007. Morpheme structure and co-occurrence restrictions in Korean monosyllabic stems. *Studies in Phonetics, Phonology and Morphology* 13, 373-394.
- [6] MacEachern, M. 1999. *Laryngeal Cooccurrence Restrictions*. New York: Garland.
- [7] Gallagher, G. 2010. Perceptual distinctness and long distance laryngeal restrictions. *Phonology* 27, 435-480.
- [8] Silva, D.. 2006. Acoustic evidence for the emergence of tonal contrast in contemporary Korean, *Phonology* 23, 287-308.
- [9] Pae, J., Shin, J., & Ko, D-H. 1999. Some acoustical aspects of Korean stops in various utterance positions, *Speech Science* 5, 139-159.
- [10] Chung, H., Kim, K., & Huckvale, M. 1999. Consonantal and prosodic influences on Korean vowel duration. *Proc. of Eurospeech*, 1-4.
- [11] Sohn, H S., & Ahn, M A. 2011. Voice onset time differences in Daegu Korean stops as a function of their position in words. *The Journal of Linguistics Science* 59, 149-180.
- [12] Garcia, G. D. 2016. The computation of weight in Portuguese: syllables and intervals. *Proc. of the 33rd West Coast Conference on Formal Linguistics*, 137-145.
- [13] Arvaniti, A. 2009. Rhythm, timing and the timing of rhythm. *Phonetica* 66, 46-63.
- [14] Cho, M-H. 2004. Rhythm typology of Korean speech. *Cognitive Processing* 5, 249-253.