

## L1-L2 Transfer in VOT and f0 Production by Korean English Learners: L1 Sound Change and L2 Stop Production

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### ABSTRACT

Recent studies have shown that the stop system of Korean is undergoing a sound change in terms of the two acoustic parameters, voice onset time (VOT) and fundamental frequency (f0). Because of a VOT merger of a consonantal opposition and onset-f0 interaction, the relative importance of the two parameters has been changing in Korean where f0 is a primary cue and VOT is a secondary cue in distinguishing lax from aspirated stops in speech production as well as perception. In English, however, VOT is a primary cue and f0 is a secondary cue in contrasting voiced and voiceless stops. This study examines how Korean English learners use the two acoustic parameters of L1 in producing L2 English stops and whether the sound change of acoustic parameters in L1 affects L2 speech production. The data were collected from six adult Korean English learners. Results show that Korean English learners use not only VOT but also f0 to contrast L2 voiced and voiceless stops. However, unlike VOT variations among speakers, the magnitude effect of onset consonants on f0 in L2 English was steady and robust, indicating that f0 also plays an important role in contrasting the [voice] contrast in L2 English. The results suggest that the important role of f0 in contrasting lax and aspirated stops in L1 Korean is transferred to the contrast of voiced and voiceless stops in L2 English. The results imply that, for Korean English learners, f0 rather than VOT will play an important perceptual cue in contrasting voiced and voiceless stops in L2 English.

**Keywords:** VOT, f0, L1 Korean and L2 English stops, and the sound change of the Korean stop system

### 1. Introduction

In many studies in the past decade, voice onset time (VOT) has been solely examined to investigate cross-language phonetic influences or interferences among stops in the world's languages. Stop consonants in the world's languages are realized with one of three modal VOT categories: lead (pre-voiced), short-lag, and long-lag (Flege, 1995, 2002; Fowler et al, 2008; M.-R. Kim, 2011a, 2011b). Most stops produced by the English monolinguals had the voicing lead or short-lag VOT values that are typical for English /b, d, g/ or the long-lag VOT values that are typical for

English /p, t, k/ (Lisker & Abramson, 1964, Flege, 2002). In English and many other languages, VOT is a primary cue and f0 is a secondary cue in contrasting voiced and voiceless stops (Keating, 1984; Kingston & Diehl, 1994).

In some languages, VOT is not enough to contrast stops. Korean is the only language that does not fit into three VOT categories well (Lisker & Abramson, 1964; M.-R. Kim, 2000). In many early studies, most stops produced by the Korean monolinguals had the short-lag VOT values for Korean tense stops /p\*, t\*, k\*/, intermediate-lag VOT values for Korean lax stops /p, t, k/ or long-lag VOT values for Korean aspirated stops /p<sup>h</sup>, t<sup>h</sup>, k<sup>h</sup>/ (Lisker & Abramson, 1964 and among others). In recent studies such as Silva (2006) and M.-R. Kim (2008, 2011a, 2011b, 2012a, 2012b), stop consonants in Korean are realized with one of two VOT categories: short-lag and long-lag, because of the VOT merging between aspirated and lax stops. Kim et al (2002) reports that in Korean, fundamental frequency (f0) plays a greater role in contrasting Korean stops than VOT (see also

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M.-R. Kim, 2000, 2008; Kim & Duanmu, 2004). Unlike English, in Korean,  $f_0$  or tone<sup>2)</sup> is a primary cue and VOT is a secondary cue in contrasting voiced and voiceless stops (Keating, 1984; Kingston & Diehl, 1994). One question arises: how these two parameters in L1 speech play a role in L2 speech production<sup>3)</sup>.

1.1 The sound change of the stop system of Korean

Recent studies have shown that the stop system of Korean is undergoing a sound change in terms of the two acoustic parameters, VOT and  $f_0$  (or tone) (Silva, 2006; Wright, 2008; Kang & Guion, 2008; M.-R. Kim, 2008, 2011b, 2012a, 2012b). The sound change was characterized by two phonetic facts, VOT merging of aspirated and lax consonants and onset-tone interaction. Because of this, the relative importance of the two acoustic parameters in Korean has been switching in that  $f_0$  is a primary cue and VOT is a secondary cue in distinguishing lax from aspirated stops. It would be interesting to see how the ongoing sound changes of the two acoustic parameters in L1 Korean are phonetically implemented in L2 English.

With respect to the effect of onset consonants on  $f_0$  contour,  $f_0$  contours following aspirated and tense consonants are relatively higher than those following lax and other counterparts. The rising and lowering effect of onset consonant types on  $f_0$  contour in Korean remarkably differs from the intrinsic effect of onset voicing on  $f_0$  contour in English and other languages. The difference between English and Korean can be clearly seen in Figure 1.

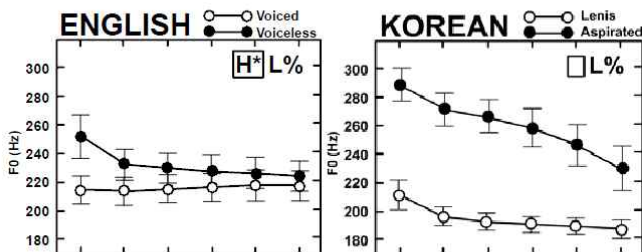


Figure 1. Mean  $f_0$  measurements at 20 ms interval into 100 ms in the vowel in English and Korean stops. From Jun (1996).

2) Following a common approach in generative phonology (Pierrehumbert, 1980), both tone and intonation are represented with the same phonological features H (high) and L (low). In addition, the term “tone” refers to all pitch patterns whether they are used to distinguish word meaning (as in Chinese) or not (as in English) (Kim & Duanmu, 2004, 61).

3) L1 is used as a cover term referring to a native language, mother tongue, or first language and L2 as a target language or second language. Throughout the whole paper, L1 refers to Korean and L2 refers to English.

In English, the rising and lowering effect of onset voicing on  $f_0$  disappears at 20 ms after onset voicing whereas, in Korean, the effect persisted till 100 ms. The effect of onset consonants on  $f_0$  contour in both spectral (Hz) and temporal magnitude (ms) was confirmed by M.-R. Kim’s (2000) large quantitative data. Comparing the intrinsic effect of onset voicing on  $f_0$  in English, M.-R. Kim (2000) introduced the effect for Korean in terms of ‘consonant-tone interaction’ where aspirated and tense consonants were correlated with H tone and lax and other consonants were correlated with L(H) tone (see also Kim & Duanmu, 2004). The important role of vocalic portion (i.e.  $f_0$ ) in contrasting Korean stops in speech perception has also been reported in studies such as M.-R. Kim (2000), Kim et al. (2002) and M. Kim (2004).

With respect to VOT, a number of recent studies have reported that VOT values between lax and aspirated stops in Korean are merging or neutralized (Choi, 2002; Silva, 2006; M.-R. Kim, 2008, 2011b; Wright, 2008; Kang & Guion, 2008; Oh, 2011). The merging of aspirated and lax consonants has occurred in that mean VOT values of lax stop are getting longer whereas those aspirated ones are getting shorter (Silva, 2006; M.-R. Kim, 2008). In other words, there was a VOT lengthening for lax stops whereas a VOT shortening for aspirated stops. The ongoing VOT merger or overlap between aspirated and lax consonants can be clearly seen in Figure 2 (from M.-R. Kim, 2008: 8).

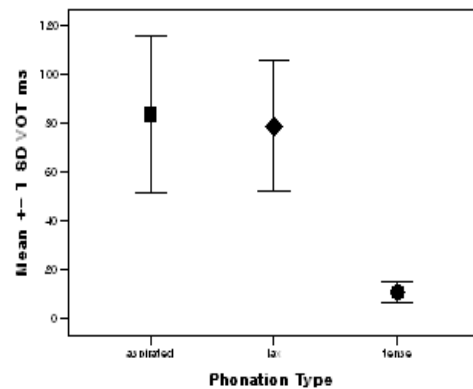


Figure 2. Overall mean VOT values (ms) and range (within 1 standard deviation) aggregated from nine Korean female speakers according to aspirated, lax, and tense targets in initial position, averaged across speakers in the 20’s, 40’s, and 50’s.

With respect to the merger phenomena, remarkable speaker variations were found in terms of a number of factors such as age, dialect, gender, and L2 proficiency. Silva (2006) examined the effect of age and provided evidence VOT merger between aspirated and lax stops among younger speakers. He found that the VOT differences are getting shorter in younger speakers than

those in older speakers. As a result, it was expected that the merger mainly occurred among younger generation born after 1965. The effect of age on the merger was confirmed in studies such as Wright (2008: 74) and Kang & Guion (2008: 3913). However, the effect of age was not consistent with that of M.-R. Kim (2008). M.-R. Kim (2008) showed evidence of the merger across generation from twenties to fifties. In her study, speakers in their twenties produced a shorter VOT values for both aspirated and lax stops than those in their forties and fifties. In addition, speakers even in their 20s show remarkable VOT variations on the merger. As can be seen in Figure 2 from, the pool data overall show the partial or complete merger between the two stop types.

With respect to the effect of dialect, the merger is different from dialect to dialect (Choi, 2002; Kenstowicz & Park, 2006; Silva, 2006, M.-R. Kim, 2008; Wright, 2008; Kang & Guion, 2008; cf, Cho et al, 2002). Choi (2002) found that Seoul Korean showed relatively more overlapping distribution in VOT than Chonnam Korean. One of the two Seoul speakers showed a substantial VOT overlap between lax and aspirated stops (2002, p. 17). However, Cho et al (2002) reported a different pattern: the Cheju dialect exhibited more overlap in VOT ranges than the Seoul dialect.

Recently, Oh (2011) found the effect of gender in that the merger phenomenon is stronger for females than males: overall means of percent overlap between the two stops were approximately 35.1% for males and 70.6% for females in isolation, and 45% for males and 76% for females in sentences. A recent study by M.-R. Kim (2011b) provided evidence of the effect of L2 proficiency on VOT: for both L1 and L2 stops, the more proficient, the shorter VOTs. The merger was more frequent among advanced L2 speakers than among L2 beginners.

The aforementioned studies overall show that there is a partial or complete VOT merger between aspirated and lax stops in Korean and the length of VOT for both stops are in the progress of changing. The results suggest that the sound change of the Korean stop system is still in progress. Speaker variations in terms of various factors described above imply that a question of which can be the main factor to trigger the change remains unsolved.

This study was designed to answer the questions of how Korean English learners employ the two acoustic parameters, VOT and f0 contours, in producing L2 English stops and whether or how the sound change of acoustic parameters in L1 affects or transferred to L2 speech production.

## 2. Methods

### 2.1 Participants

Speech data were collected from six adult Korean English learners who served as L2 speakers. They are all females in their twenties. The mean age was 28 years, 6 months and the individuals ranged from 25 years, 6 months to 29 years, 4 months. They grew up in Seoul and spoke a standard Seoul dialect. All of them had learned English since middle school in Korea. All of participants were asked to fill out their background and a self-reported questionnaire about their L2 English proficiency according to a typical five-level Likert item. Their Likert scales were slightly varied from 1.8 to 3.2 out of five. Although there were speaker variations in terms of the Likert scale, their proficiency level in L2 English could be determined as beginners based on the reasons as follows: First, all of the participants didn't use English in their daily life and had a difficulty in communicating with a native speaker of English. Second, they all had no experience in living in an English speaking country more than 1 month. As a result, for participants employed in the current study, factors such as age, gender, and dialect, and L2 English proficiency were controlled.

### 2.2 Speech materials and procedure

In order to compare the production of L2 English stops with the L1 Korean counterparts, speech materials for the two languages were constructed in similar contexts. The target words for each language were balanced for phonation types (voiced, voiceless, and voiceless unaspirated (e.g. s/ptk/) stops for English and lax, aspirated, and tense stops for Korean), vowel context (/a/ and /ai/), and syllable types (CVC and CVCV). All were real words, as presented in (1).

#### (1) English and Korean words

**English (18):** pot, bot, spot, tot, dot, stot, cot, got, scot, pie, buy, spy, tie, die, sty, kye, guy, sky

**Korean (18):** /p<sup>h</sup>aj/ 'bang', /pai/ 'room', /p\*aj/ 'bread', /t<sup>h</sup>al/ 'mask', /tal/ 'moon' /t\*al/ 'daughter', /k<sup>h</sup>aj/ 'proper name', /kan/ 'river', /k\*aj/ 'percussion cap', /p<sup>h</sup>ada/ 'dig out', /pada/ 'sea', /p\*ada/ 'to grind', /t<sup>h</sup>ada/ 'to ride', /tado/ 'tea ceremony', /t\*ada/ 'to pick', /k<sup>h</sup>adi/ 'card', /kada/ 'to go', /k\*ada/ 'to peel'<sup>4)</sup>

4) The stop series in Korean are typically described as tense or fortis /p\*, t\*, k\*/, lax or lenis /p, t, k/, and aspirated /p<sup>h</sup>, t<sup>h</sup>, k<sup>h</sup>/.

In order to record the target words in a constant prosodic environment, each word was presented in a carrier sentence. The carrier sentence for the English data was “\_\_\_\_\_ is the word.” The carrier sentence for the Korean data was “[\_\_\_\_\_ has<sup>ə</sup>jo]” (“Say \_\_\_\_\_”). For the target words, they were located in utterance-initial position. In utterance-initial position, the target words were expected to be fully stressed and emphasized. Overall, a total of 648 tokens (18 words x 2 target language x 3 repetitions x 6 Korean speakers) were obtained for analysis.

Each target word was presented with the carrier sentence on a flashcard in the orthography of each language. Participants first read English sentences and then Korean ones five times in the flash cards in randomized blocks. The first and last randomizations were discarded, and three tokens of each target words, extracted from the carrier sentence, were selected as stimuli. All participants were instructed, in their native languages, to read the cards at a comfortable and normal speaking rate and loudness level and to repeat any utterance when they were not satisfied with their production. Before the recording session began, speakers were given a chance to be familiarized with target words. All speakers reported familiarity with the target words.

Recordings were made in a sound-attenuated booth in the Phonetics Lab at the University of Oregon using a Shure (model SM 10A) head-mounted microphone and a Marantz digital recorder (PMD 670) at a sampling rate of 22,500 Hz. All recorded utterances were analyzed using Praat 4.6.40, a speech analysis program (Boersma & Weenink, 2005).

VOT was measured from the release burst to the onset of periodicity in the waveform (Lisker & Abramson, 1964). The onset of the vowel in the waveform was determined by the onset of the first full glottal pulse of the vowel as well as the pitch of the spectrogram. The onset of the voicing energy in the second formant shown in a time-locked spectrogram was used to help determine voicing onset in conjunction with the waveform.

In order to capture the  $f_0$  contour of the syllable,  $f_0$  was measured at a 20 ms interval from the onset of voicing to 100 ms into the vowel. The onset of voicing (=vowel onset) was defined as the first and periodic pulse of a vocalic waveform that show features typical of a vowel.

Acoustic measurements were statistically tested using repeated measures analysis of variance (ANOVA) in the context of a mixed linear model (SAS Institute, 1996). Our main goal was to examine whether there is the effect of onset consonants on VOT and the  $f_0$  of its following vowel and whether VOT and  $f_0$

differences between target languages (i.e., L1 Korean and L2 English) and within the language are significant. A repeated measures ANOVA includes both “between” subjects effects (i.e., target language: L1 Korean vs. L2 English) and “within” subject effects (i.e., phonation type). Their main and interaction effects were statistically analyzed.

Post hoc test were run to answer the following questions: (i) whether any differences in pairs between the target languages were significant and (ii) whether any differences in pairs within each language were significant. For statistical analysis, we will focus on those that involve the factors of most central interest to the present paper: target language and VOT and  $f_0$  differences between cross-linguistics phonation types.

### 3. Results

#### 3.1. VOT production in L1 and L2 stops

Table 1 presents the mean VOT values and ranges of the L2 English and L1 Korean stops produced by adult Korean English speakers. A significant main effect of target language confirmed the expected VOT differences between L1 Korean and L2 English ( $M_{L1Korean} = 59.6$  ms;  $M_{L2English} = 62.5$  ms). The differences were mainly due to the fact that lax stops were realized with long-lag VOT values whereas voiced stops were realized with short-lag VOT values.

Table 1. Mean (*M*: italicized) VOTs, range, and standard deviations (SD) of Korean speakers’ productions of Korean and English in initial position (n=6).

	Type	<i>M</i>	Range	SD
<b>L2 English</b>	<b>Vl</b>	79.1	27~145	28
	<b>Vd s/ptk/</b>	21 .9	4~65	17
		27.3	11~58	14
<b>L1 Korean</b>	<b>Asp Lax Ten</b>	80.8	40~114	16
		84.3	40~118	37
		13.8	5~30	6

In L2 English stop production, most of stops produced by L2 Korean English speakers had either short-lag VOT values that are typical for English /b, d, g/ or the long-lag VOT values that are typical for English /p, t, k/ (Flege, 2002). No speakers here were able to produce voiced stops with some voicing-lead. In some studies, English voiced stops are realized with either voicing-lead or short-lag VOT (Lisker & Abramson, 1964; Keating, 1984;

M.-R. Kim, 20011a). For adult L2 learners who were beginners, voiceless stops were well-distinguished from voiced or s/ptk/ stops in terms of VOT. The results are analogous to those of early and bilingual data (Kang & Guion, 2006; Oh & Dalland, 2011).

In L1 Korean stop production, both aspirated and lax stops were produced with the long-lag VOT values and tense stops were produced with the short-lag VOT values. As expected from previous studies (Choi, 2002; Silva, 2006; M.-R. Kim, 2008, 2011b; Wright, 2008; Kang & Guion, 2006, 2008; Oh, 2011; Oh & Dalland, 2011), tense stops were well-distinguished from either aspirated or lax stops whereas aspirated stops were not distinguished from lax stops in terms of VOT. There was an apparent merger between aspirated and lax stops.

To help visualize the merger in pairs between target languages and within the language, Figure 3 was plotted with the mean VOT values according to each phonation type in the target language.

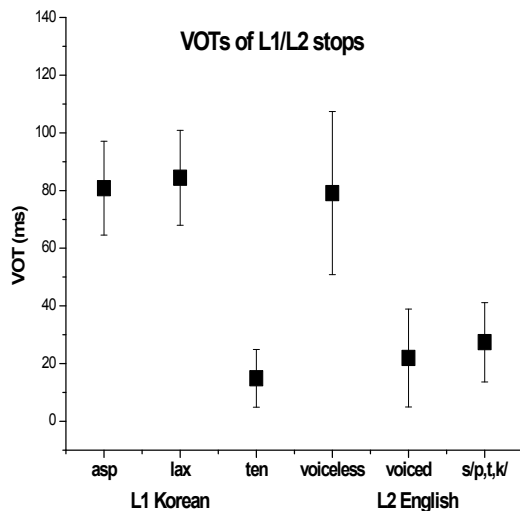


Figure 3. The mean VOT values in six phonation types in the initial position of Korean and English words spoken by adult Korean English learners. Error bar indicates  $\pm 1$  standard deviation.

Figure 3 show that, although there are slight differences, there are roughly two VOT categories: the short-lag VOT categories for tense, voiced, and s/ptk/ stops (tense<voiced<s/ptk/) and the long-lag VOT categories for aspirated, lax, and voiceless (voiceless<lax<aspirated). Table 2 presents the statistical results of each pair between the target languages and within the target language.

Table 2. All 15 pairs across L1 and L2 phonation types according to the target language in terms of VOT. Cases that are significantly different ( $p < 0.01$ ) are in bold.

Between (n=9)	Within (n=6)	
vl-asp, <b>vl-lax</b> , <b>vl-ten</b> vd-asp, <b>vd-lax</b> , vd-ten s/ptk/-asp, s/ptk/-lax, s/ptk/-ten	vl-vd, <b>vl-s/ptk/</b> , vd-s/ptk/	L2 English
	asp-lax, <b>asp-ten</b> lax-ten	L1 Korean

Post hoc results ‘between’ the target languages that there was no significant differences between L2 voiceless and L1 aspirated stops and between L2 voiced and L1 tense stops. The rest pairwise comparisons showed significant differences for the pairing of the other stop types ( $p < 0.01$ ). Post hoc results ‘within’ the target languages that there was no significant differences between aspirated and lax stops and between voiced and s/ptk/ stops. The rest pairwise comparisons showed significant differences for the pairing of the other stop types ( $p < 0.01$ ).

One of the research questions in the present study is whether the sound change (i.e., VOT merger) in L1 Korean is transferred to L2 speech production. If there is, we can expect that, similar to the merger between aspirated and lax stops in L1 Korean, there can be some merger between L2 voiced and voiceless stops. If there isn’t, the opposite pattern can be expected. Unlike merging of aspirated and lax stops in L1 Korean, the VOT merger between voiced and voiceless stops in L2 English did not occur because most L2 voiced stops produced by Korean speakers had the short-lag VOT values that are typical for English /bdg/ and most L2 voiceless stops produced by Korean speakers had the long-lag VOT values that are typical for English /p, t, k/ (see also M.-R. Kim, 2011a, 2011b; Oh & Daland, 2011). The English stop categories between voiced and voiceless stops were distinguished from each other even for L2 beginners. The results suggest that the VOT change in L1 stop production did not affect that in L2 stop production.

With respect to the VOT productions of L1 and L2 stops, speaker variations were noticeable in three aspects. First, some speakers produced relatively longer VOTs than others for both L1 and L2 stops (i.e. the VOT shortening phenomenon) (M.-R. Kim, 2011b). Second, some speakers showed a VOT merger between aspirated and lax stops whereas some did not. Third, some speakers showed a VOT merger between L2 voiceless and L1 aspirated stops whereas some did not. The VOT length in stop production was not stable among L2 speakers.

### 3.2. F0 contours in L1 and L2 stops

Repeated Measures ANOVA were run over f0 measurements at 0 ms (the onset), 20 ms, 40 ms, 60 ms, 80 ms, and 100 ms to see whether there was a main effect of onset consonants on f0. There was a significant effect of onset consonants on f0 at all six measurement points due to the rising effect of aspirated and tense initial consonants in Korean (i.e., lax < tense < aspirated). As can be seen in Figure 4, the effect holds the three-way contrast of the stop onsets across all six measurement points.

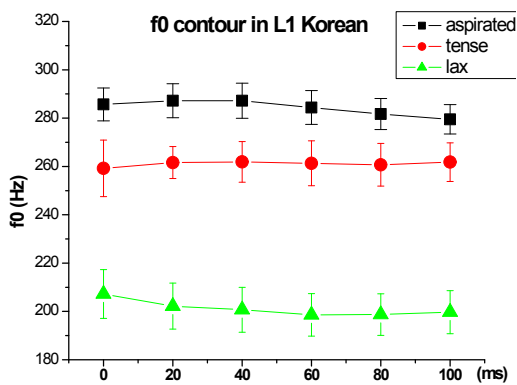


Figure 4. Korean speakers' mean f0s ( $\pm 1$  standard error) at 20 ms intervals from the onset of the first regular vocal pulse till the 100 ms into the vowel of the target syllable, averaged across repetitions.

The post hoc results showed that the f0 differences in pairs between aspirated and tense stops, between aspirated and lax stops, and between tense and lax stops were all statistically significant throughout six measurement points ( $p < 0.01$ ). The present results correspond to earlier findings that f0s is the highest for aspirated stops, intermediate for tense stops, lowest for lax stops (Han & Weitzman, 1970; Kim, M.-R. Cho, 1994). The results reported here suggest that there is little f0 overlap between aspirated and tense stops. However, the f0 overlap between aspirated and tense stops was found in M.-R. Kim (2000: 68). Based on the three f0 measurements (i.e., onset, midpoint, and offset in the vocalic portion) with a large quantitatively balanced data, M.-R. Kim (2000) obtained of VOT overlap between tense and aspirated stops. She found that, at rime onset, there was a 20 Hz f0 difference between aspirated and tense consonants (with higher f0 after aspirated consonants than after tense counterparts), but the difference is much narrower (about 8 Hz) at midpoint and offset. M.-R. Kim (2000) suggests that f0 contours following onset consonants in Korean fall into two tonal groups, high (H) and low (L): H following aspirated and tense stops vs. L

following lax and voiced stops (see also Jun, 1993, 1996; Kim & Duanmu, 2004).

Now, let's move on to the f0 production in L2 stop production to see how the onset-tone interaction in L1 Korean plays a role in L2 speech production and whether the effect in L1 is transferred to that in L2. Figure 5 presents the mean f0 values of six measurements starting from 0 ms (onset voicing) till 100 ms into the vowel.

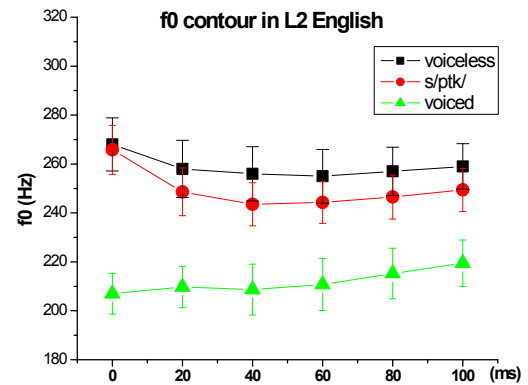


Figure 5. Korean speakers' mean f0s ( $\pm 1$  standard error) at 20 ms intervals from the onset of the first regular vocal pulse till the 100 ms into the vowel of the target syllable, averaged across repetitions.

The results of a repeated measures ANOVA with onset consonants at each measurement point showed that there was a main effect of onset voicing on f0s at all six measurement points between voiced and voiceless stops (i.e., voiced < s/ptk/ < voiceless). The post hoc results showed that the f0 differences in pairs between voiceless and voiced stops were significant throughout six measurement points ( $p < 0.001$ ) whereas those in pairs between voiceless and s/ptk/ were not ( $p > 0.05$ ). In Figure 5, there is about 30-60 Hz difference between voiced and voiceless stops: f0s following voiceless stops are remarkably higher than voiced counterparts. The results can be comparable to the intrinsic effect of onset voicing on f0 produced by native speakers of English in Figure 1 (M.-R. Kim, 2000, 2003). The English results in Figure 5 are analogous to the Korean results in Figure 4. The onset-f0 effect in L2 English corresponds to the temporal (ms) and spectral (Hz) magnitude effect of onset consonants on f0 in Korean. The f0 results of L2 voiced stops are similar to the results of L1 lax stops and L2 voiceless stops are similar to those of L1 aspirated. The results suggest that, similar to the onset-tone interaction in Korean, in L2 English, voiced stops are correlated with low tone whereas voiceless are correlated with high tone (Kim & Park, 2001).

Figure 6 was plotted to collapse the results of Figures 4 and 5 for the direct comparison of the target languages. The post hoc tests were run over the f0 measurements at each point to see whether the f0 differences in pairs between L1 and L2 stops were significant. Among pairs, we focus on pairs such as L2 voiceless and L1 aspirated or tense stops and L2 voiced and L1 lax stops that involve the main concern of the current study. The post hoc results showed that the differences in pairs between voiceless and aspirated stops or tense stops were statistically significant at all measurement points except for onset whereas those between voiced and lax stops were not at all measurement points except for 100 ms.

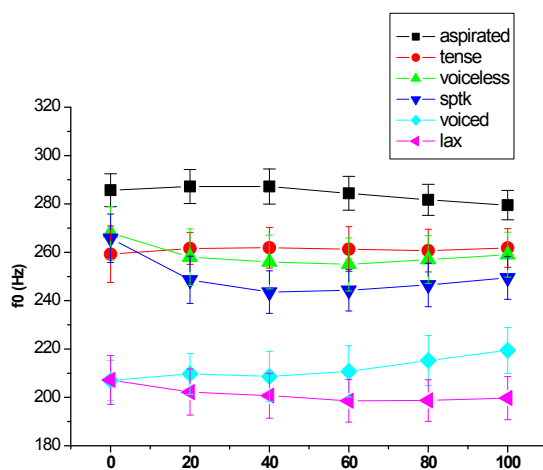


Figure 6. Korean speakers' mean f0s ( $\pm 1$  standard error) at 20 ms intervals from the onset of the first regular vocal pulse till the 100 ms into the vowel of the target syllable, averaged across repetitions. Error bar indicates  $\pm 1$  standard deviation.

Figure 6 represents two tonal groups of f0 contours: high tone following aspirated, tense, voiceless, and s/ptk/ stops and low tone following lax and voiced stops. The high-low f0 dichotomy is symmetrical for both L1 Korean and L2 English. Although there were slight f0 differences between pairs in each tonal group (i.e., s/ptk/ < voiceless < tense < asp vs. lax < voiced), the results suggest that the onset-f0 interaction in L1 is transferred to that in L2 stop production.

One anonymous reviewer points out that it is hard to tell L1 to L2 transfer on the effect of onsets on f0 because of the two reasons. First, it is possible to carry f0 perturbation into the vowel even in English produced by native speakers of English (Kingston & Diehl, 1994). It is true that there can be f0 differences between the two types even into the vowel. However, the f0 differences between English stops are much smaller than the Korean counterparts (under 20 Hz difference vs above 50 Hz

difference) and intrinsically localized before vowel midpoint. It is called 'intrinsic f0 perturbation' (M.-R. Kim, 2000: 116-118). Second, the f0 patterns between the two languages are slightly different: falling pattern for all Korean stops vs. fall for English voiceless but rise-fall pattern for voice stops. The reviewer describes that the rise-fall pattern can be observed from the speech of native speakers of English. However, M.-R. Kim (2000) reports the similar rise-fall pattern for Korean lax stops as well as English voiced stops. The f0 patterns, either fall or rise-fall, can differ, depending on various factors such as speech rate, types of target words, and different carrier sentences. The issue of whether the f0 patterns are common might be a different question from the magnitude of the effect of onset consonants on f0 contour.

#### 4. Discussion

According to Grosjean's (1989) view that interference is bidirectional (L1 <-> L2), the two language systems are influenced with each other (Flege, 1995, 2002; Fowler et al, 2008). The results reported here suggest that the phonetic systems between L1 Korean and L2 English stops were influenced with each other. The L1-L2 transfer (or cross-linguistic influences between L1 and L2) would be assimilatory or dissimilatory. The Speech Learning Model (SLM) (Flege, 1995, 2002) proposes that both patterns were found in literature. By the category assimilation hypothesis, L2 sounds are assimilated to native sound categories with or without modification. According to the SLM, it is hypothesized that dissimilation between L1 and L2 sounds only occurs when the L2 sound was perceived as different enough from the closest L1 sound to have formed its own category. The SLM posits that new phonetic categories for L2 sounds are established less often as age of L2 learning increases, suggesting that dissimilation is less likely to happen in adult learners.

##### 4.1. L1-L2 transfer in VOT and f0

The results reported here suggest that there is an L1-L2 transfer in terms of VOT and f0: L1 to L2 transfer and L2 to L1 transfer. As expected from previous findings (Flege, 1995, 2002), for adult learners, the influence of L1 on L2 was robust. For example, the behaviors of the two acoustic parameters for L2 voiceless stops corresponded to those of L1 aspirated counterparts in that both stops were realized with long-lag VOT values and high tone. The influence in this case can be explained well in term of an assimilatory process (i.e., L1 to L2).

However, some speaker variations suggest that there is an L2

influence on L1. As found in M.-R. Kim (2011b), the two speakers produced both L1 aspirated and L2 voiceless stops with much shorter VOT values than others (e.g., 27-60 ms vs. 70-145 ms). The VOT shortening for L1 aspirated stops were reported in previous studies (Silva, 2006, M.-R. Kim, 2008). It was not clear which factor triggers the shortening. Recently, M.-R. Kim (2011b) found that there was VOT shortening across L1 and L2 stop types. She suggests that more proficient speakers tend to produce stops shorter than less proficient speakers. Although L2 speakers employed in the current study were identified as beginners, their L2 proficiency might slightly differ from speaker to speaker (e.g., 1.8 to 3.2 from self-reported scale). With VOT shortening, if there is an effect of L2 proficiency on L1 stop production (i.e., L2 to L1 transfer), the influence in this case would be dissimilatory. In addition to L1 aspirated and L2 voiceless stops, the speakers produced all other stop types (i.e., L1 lax and tense, and L2 voiced and s/ptk/) with short-lag VOT values than others.

The cross-linguistic influences between L1 and L2 stops can be also found from the behaviors of the two acoustic parameters for L2 voiced stop. With respect to  $f_0$  contours, L2 voiced stops corresponded well to those of L1 lax counterparts in terms of low  $f_0$ . As a result, L2 voiced stops were realized with low  $f_0$  contours and L2 voiceless stops with high  $f_0$  counterparts (Kim & Park, 2001; M.-R. Kim, 2005). The effect of onset consonants on  $f_0$  contour in L2 English was not intrinsic but interaction in terms of the spectral (Hz) and temporal (ms) magnitude (M.-R. Kim, 2000). The voiced-low and voiceless-high  $f_0$  dichotomy in L2 stop production are analogous to the lax-low and aspirated (or tense)-high counterparts in L1 stop production. The findings suggest that there is an influence of L1 on L2 speech on  $f_0$  (i.e. L1 to L2 transfer). The influence in this case would be assimilatory (Flege, 1995).

With respect to VOT, however, L2 voiced stops did not correspond to those of L1 lax counterparts because L2 voiced stops are realized with short-lag VOT values whereas L1 lax stops with long-lag counterparts. The influence in this case cannot be explained in term of an assimilatory process. With the behaviors of the two acoustic parameters for L2 voiced stops, some speculations are possible. First, the influence in this case would also be assimilatory. According to the SLM, L2 sounds are assimilated to native sound categories with modification. It is possible for L2 speakers to modify or control the amount of VOT values from long-lag to short-lag because they identify L2 voiced stops as tense or lax (Schmidt, 1996; Kingston & Diehl, 1994).

Second, the influence would be dissimilatory, assuming that L2 voiced stop is a new category distinguished from L1 stops. This speculation is not consistent with Flege's dissimilation process that is less likely to happen in adult learners. Third, since L2 voiced stops correspond to native-like English voiced counterparts in terms of VOT and  $f_0$ , it is possible to speculate that there can be an influence of L2 on L1. Further quantitative data are necessary to generalize.

#### 4.2 Merged or new category for L2 voiced stops

According to Kang & Guion's (2006) findings, the late bilinguals showed the merged system between the two languages. It is highly expected that L2 speakers employed in this study produce the merged system between L1 and L2 stops. There was a merger between L1 aspirated and L2 voiceless stops. However, there was an  $f_0$  merger between L1 lax and L2 voiced stops whereas there was no VOT merger between them. The two parameters were behaved in a different manner for the production of L2 voiced stops. Thus, the results reported here suggest that the two parameters together must be taken into consideration. In some languages, VOT alone is not enough to examine cross-language phonetic influences. Table 3 presents four different categories among L1 and L2 stops in terms of VOT and  $f_0$ .

Table 3. L1 and L2 stops in terms of VOT and  $f_0$  contour

		$f_0$	
		Low	High
VOT	Short-lag	voiced <sub>L2</sub>	tense <sub>L1</sub> s/ptk <sub>L2</sub>
	Long-lag	lax <sub>L1</sub>	voiceless <sub>L2</sub> aspirated <sub>L1</sub>

Voiced English consonants can be produced or perceived as either tense or lax consonants<sup>5)</sup> (Schmidt, 1996; Kang & Guion, 2006). If this is correct, voiced stops might be assimilated to either lax or tense counterparts. If L2 voiced stops are produced as tense stops, they must be realized with short-lag VOT values and high  $f_0$  contours. If they are produced as lax stops, they must be realized with long-lag VOT values and low  $f_0$  contours. The present findings do not correspond to this expectation.

5) According to the researcher's labeling, 90% of the voiced English stops were labeled or perceived as lax rather than tense counterparts. Unlike lax stops, however, the lax-like English voiced stops did not have long-lag VOT values but relatively low  $f_0$  contour (section 3.2).



Interestingly, although voiced stops were mostly produced as lax-like voiced stops (see footnote 5), they were in fact realized with short-lag VOT values and low f0. The VOT values of voiced stops were much shorter than the lax counterparts (22 ms vs. 84 ms). How can we explain this? Can we say that L2 speakers develop a new L2 category for L2 voiced stops? If then, L2 speakers have four different stop categories, as can be seen in Table 3. According to Fowler et al (2008), even simultaneous bilinguals are hard to develop a new or distinct L2 stop category different from L1 counterparts because of phonetic interactions between L1 and L2 stops. It is controversial whether L2 voiced stops produced by L2 speakers can be treated as a merged or new category.

The results reported here suggests as follows. First, for Korean speakers, in contrasting voiced and voiceless stops, the role of VOT is not stable. For example, the three of the speakers was able to produce voiced tokens from 10 ms to 65 ms in VOT. Even for the word with 10 ms, the sound was identified as lax-like stops because of low f0. This supports that, in Korean, VOT is a secondary cue and f0 is a primary cue. Regardless of the amount of VOT length, L2 voiced stops are almost always determined as lax ones whenever they were realized with low f0 (Kim et al, 2002).

Second, there might be a relationship between the production of voiced stops and L2 proficiency. M.-R. Kim (2011b) reports that more proficient L2 speakers tend to produce voiced stops as tense-like stops. If this is correct, we can expect that less proficient speakers produce L2 voiced stops with lax-like ones whereas more proficient speakers tend to produce them with tense-like ones because of the SLM's assimilation theory (Flege, 1995).

Third, there might also be a relationship between VOT length and L2 proficiency. M.-R. Kim (2011b) reports that more proficient speakers tend to produce VOT shorter for both L1 and L2 stops than less proficient speakers. She suggests that the VOT shortening phenomenon might be related with the influence of L2 on L1 speech. Further study is necessary to generalize.

#### 4.3. Phonological features and phonetic implementation

Cross-linguistically, voiceless stops (either aspirated or unaspirated) raise the f0 of their following vowel while voiced stops lower f0. This is expected by the phonology view that f0 difference between a voiceless and voiced stop can be attributed to the phonetic implementation of the phonological [+stiff] feature for voiceless stops and [-stiff] (or [voice]) for voiced stops. The

dichotic f0 pattern is also compatible with the phonetic view which holds that f0 rising after a voiceless stop is due to the stiffness of vocal folds to suppress voicing (Halle & Stevens, 1971). In this view, the phonetic implementation is directly connected to its phonological feature. In the present results, for example, corresponding f0 values between voiceless and aspirated/tense stops are expected because of their phonetic implementation of the phonological [+stiff] feature for voiceless stops. However, it is problematic to account for corresponding f0 values between voiced and lax stops according to the phonetic implementation of the phonological feature.

For lax and voiced stops, they have different phonological features, [-voice] for lax stop but [+voice] for voiced stops. However, their phonetic implementations on f0 between the two stops are similar to each other, as seen in Figure 6. In contrast, their phonetic implementations on VOT between lax and voiced stops are different, as seen in Figure 3. How can we account for the phonetic implementations of L2 voiced stops produced by Korean English learners? Two approaches are conceivable. One is to take the traditional view that the Korean stop system is unique and its phonetic implementation requires a language-special mechanism. According to Kingston & Diehl (1994), the phonetic implementation of the feature can be automatic as well as controlled. In one hand, L2 speakers produced voiced stops with a short voicing lag different from lax stops because of their controlled implementation of the [voice] feature in L2 stop production. On the other hand, the onset-f0 interaction in L1 speech is automatically implemented in L2 speech because of the primary characteristics from L1 stop. The effect cannot be controlled even with the phonological [voice] feature. According to the traditional phonology, the onset-tone interaction in Korean can be accounted for under the language-special mechanism. Instead of voice-tone interaction, there can other laryngeal features-tone interaction in Korean (Jun, 1996; Silva, 2006).

The other possibility is to view that the languages do share the same phonological feature(s) and their phonetic implementation can be cross-linguistically accounted for. According to Kim & Duanmu (2004) and M.-R. Kim (2012a, 2012b), the three Korean stops are described in terms of voicing and aspiration, voiced for lax stops, voiceless unaspirated for tense stops, and voiceless aspirated for aspirated stops. They argue that sound change in the Korean stop system can be viewed as undergoing tonogenesis where there was a loss of voicing and a consonantal opposition in initial position. Their basic assumption is to view that Korean does not have an unusual stop system. According to the standard

tonogenesis theory, the development of tone is initially triggered by the intrinsic effect of onset voicing on  $f_0$  in initial position, and by the loss of onset voicing, and then by the loss of a consonantal opposition. Since Korean is undergoing its sound change in terms of an onset-tone interaction as well as a merger of a consonantal opposition, it is possible to speculate that the nature of the Korean sound change can be related with its tonogenesis. The former approach introduces that the Korean phenomena must be accounted for under the language-special mechanism. Under the approach, Korean can be the only language that have occurred a consonant-tone interaction as well as the merger of a consonantal opposition between lax and aspirated stops without any [voice] feature. Thus, it is burdensome to account for all phonetic implementations according to language-special mechanisms. The latter approach adopts an idea of a cross-linguistic or language-universal mechanism in that their phonetic implementation can be phonologically accounted for. The questions that still remain open are whether L1 Korean and L2 English stops share the same features or not and how their phonetic implementation in L1 and L2 speech production can be accounted for under certain phonological feature(s). It would be important to gather further data to confirm which approach is better to account for phonetic implementation and phonological features.

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