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# Acoustic Properties of Korean Stops as L1 Produced by L2 Learners of the English Language

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**Objectives:** The present study examines whether Korean children and adults who have learned English as a second language (L2) produce Korean stops differently from Korean monolingual (KM) children with respect to voice onset time (VOT) and fundamental frequency (F0) and whether the age of L2 exposure is a critical factor in determining the L2-to-L1 influence. **Methods:** Eighteen Korean-English bilingual (KEB) children and adults and eighteen KM children produced nine monosyllables /$p^h$ɛ, pɛ, $p^*$ɛ, $t^h$ɛ, tɛ, $t^*$ɛ, $k^h$ɛ, kɛ, $k^*$ɛ/ twice in a row. A total of 1,890 tokens were acoustically analyzed with Praat to obtain VOT and F0 values and were subjected to statistical analysis for group comparison. **Results:** Two three-way ANOVAs and follow-up statistics revealed that the VOT values of aspirated and lenis stops were significantly longer in KEB children and adults than in KM children and that normalized F0 values of lenis stops were significantly higher in bilingual than in monolingual individuals. Nonetheless, no significant group difference was found between KEB children and adults. **Conclusion:** The acquisition of L2 English appears to disturb a tertiary contrast of Korean stops in terms of VOT and F0, in a way that bilingual individuals produced lenis stops more aspirated-like, with increased VOT and F0 values, and aspirated stops with increased VOT values. The L2-to-L1 influence may not be significantly different between early and late L2 learners, if their length of residence in a L2 speaking community is similar.

**Keywords:** Voice onset time, Fundamental frequency, Korean stops, L2 influence, English learners

The majority of studies on bilingualism focus on how a first language (L1) inhibits the acquisition of a second language (L2) in such a way that L2 learners produce ungrammatical sentences with a heavy foreign accent. In contrast, a relatively small body of literature has investigated the influence of L2 on L1, although the loss of L1 in an L2 environment, or L1 attrition, substantiates the bidirectional relationship between L1 and L2 (Cook, 2003; Hoff-Ginsberg, 1986; Jarvis & Pavlenko, 2008; Kaufman, 1991; Major, 1992; Schmid & Köpke, 2007). L1 attrition refers to the declining ability in L1 with the diminished exposure and use of L1 but with the increased exposure and use of L2. For example, a proficient L2 learner struggles with finding appropriate words in his or her native language or pronounces words in L1 with L2 rather than L1 phonology (Ok-Kim, 2007; Shim, 1994). Research on the L2-to-L1 influence as well as research on the L1-to-L2 influence is necessary in order to complete the understanding of how bilingual persons organize two languages in their mind. The objective of this study is to examine whether the acoustic properties of Korean stops produced by native Korean speakers who learned English as L2 are different from those produced by monolingual Koreans. The review of the literature focuses on research findings pertaining to acoustic characteristics of Korean stops and to the L2-to-L1 influence that are relevant to the present study. The values of voice onset time (VOT) and fundamental frequency (F0) for nine Korean stops were compared among three groups: (1) children and (2) adults who speak Korean as L1 and English as L2, and (3) children who speak only Korean and cannot communicate in English. Finally, the results of the acoustic and statistical analysis in this study were

compared with previous studies and the crosslinguistic influences of L2 English on L1 Korean were discussed.

English makes a distinction between voiceless and voiced stops. Early research on English word-initial stops has shown that the ranges of VOT are from 40 to 100 ms for voiceless stops but from 0 to 30 ms for voiced cognates (Docherty, 1992; Kang & Guion, 2006; Klatt, 1975; Lisker & Abramson, 1964; MacKay, 1987; Oh & Daland, 2011). Unlike English, Korean stops are distinguished by three laryngeal features: aspiration /$p^h$, $t^h$, $k^h$/, lenis /p, t, k/, and fortis /$p^*$, $t^*$, $k^*$/. This unique contrast system of Korean stops has been investigated in terms of the following articulatory and aerodynamic characteristics: suppression of adductor muscle activity (Hirose, Lee, & Ushijima, 1974; Jun, Beckman, & Lee, 1998; Kagaya, 1974), lingual-palatal contacts (Cho & Keating, 2001), intraoral pressure (Cho, Jun, & Ladefoged, 2002; Dart, 1987), F0 (Cho et al., 2002; Han & Weitzman, 1970; Jun, 1993; Kim & Duanmu, 2004), and VOT (Cho et al., 2002; Han & Weitzman, 1970; Hardcastle, 1973; Kim, 1965; Kim, 2008; Lisker & Abramson, 1964). In general, VOT has been discussed as a primary acoustic cue for distinction among the three categories of voiceless stops, where the average VOT of aspirated stops are approximately 2 to 4 times longer than the average VOT of lenis stops, which are, in turn, 1.5 to 5 times longer than that of fortis stops (Cho et al., 2002; Choi, 2002; Han & Weitzman, 1970; Kang & Guion, 2006; Kim, 2008; Lisker & Abramson, 1964; Oh & Daland, 2011). Figure 1 is a summary of the VOT of Korean stops which appear in the reviewed literature. Nonetheless, research on the VOT of Korean stops has revealed considerable individual variance among participants and among studies. For example, VOT values of lenis stops range from 10 to 65 ms (Lisker & Abramson, 1964), whereas they range from 80 to 90 ms (Choi, 2002). Similarly, VOT values of aspirated stops range from 58 to 163 ms (Han & Weitzman, 1970), whereas the average is only 68 ms (Kang & Guion, 2006).

Studies on voicing perception found that F0 at the onset of the vowels after the stop release provides an additional acoustic cue to laryngeal features, such as aspiration, voicing, and so on. According to Whalen, Abramson, Lisker, and Mody (1993), listeners make full use of F0 in perceiving voicing contrasts even when VOT is unambiguous—where VOT is only enough to identify a voicing feature of the given stop. As reported by the literature, a vowel after a voiceless stop has a slightly higher F0, with the range of 110 to 170 Hz, than a vowel after a voiced stop, with the range of 100 to 160 Hz (House & Fairbanks, 1953; Martin & Bunnell, 1981; Ohde, 1984; Tomiak, Mullennix & Sawusch, 1987; Whalen et al., 1993). Löfqvist, Baer, McGarr, and Story (1989) demonstrated how the contraction of cricothyroid muscle involves increasing F0 and producing voiceless and voiced stops. Increased vocal fold tension due to cricothyroid muscle movement usually results in small but statistically significant increases in F0 immediately before and after the closure interval. Nonetheless, some studies on English stops argued that F0 values with voiced obstruents did not show significant differences from F0 values with voiceless obstruents (Gruenenfelder & Pisoni, 1980 for negative results for postvocalic consonant; Silverman, 1986). Unlike English, most studies on Korean obstruents researchers found that F0 at the vowel onset plays an important role in distinguishing laryngeal features. It appears that F0 values are relatively higher at the onset of vowels preceded by aspirated and fortis obstruents than those at the onset of vowels following lenis obstruents (Cho et al., 2002; Choi, 2002; Han & Weitzman, 1970; Jun, 1993; Silva, 2006).

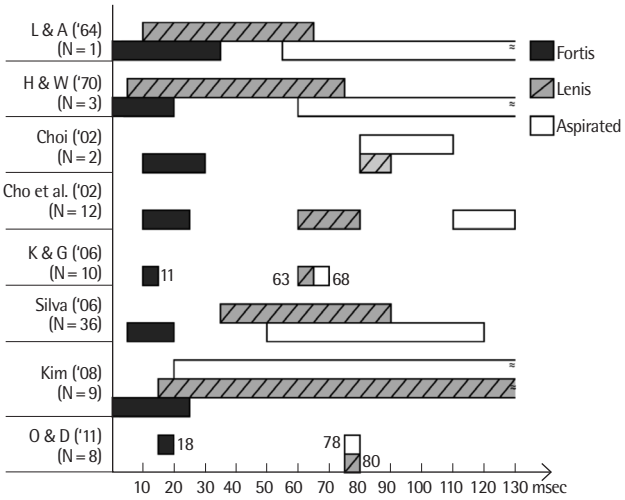


**Figure 1.** Summary of the reviewed literature on ranges or averages of voice onset time for the Korean stops in word-initial position produced by Korean monolinguals. L & A ('64) = Lisker & Abramson (1964); H & W ('70) = Han & Weitzman (1970); Choi ('02) = Choi (2002); Cho et al. ('02) = Cho, Jun, & Ladefoged (2002); K & G ('06) = Kang & Guion (2006); Silva ('06) = Silva (2006); Kim ('08) = Kim (2008); O & D ('11) = Oh & Daland (2011).

The influence of L2 on L1 can be found at various linguistic levels, such as articulation, phonology, morphology, syntax, semantics, and pragmatics. Caramazza, Yeni-Komshian, Zurif, and Carbone

(1973) demonstrated cross-linguistic interference within the domain of articulation and phonology in bilingual French-English speakers (FEB). It is known that the VOT values of French voiceless stops are shorter than the VOT values of English voiceless stops. In a production task, monolingual French speakers (FM) produced English voiceless stops with shorter VOTs than monolingual English speakers (EM). Interestingly, FEBs who are native French speakers but learned English before age 7 produced English voiceless stops with shorter VOTs than EMs did but with longer VOTs than FMs did. Similarly, their perception task showed that the VOT value for the phonetic boundaries of English voiceless stops in FEBs were shorter than in EMs but longer than in FMs. These results implicate that early exposure to L2 English may influence the speech production of L1 French in terms of VOT. Flege (1987) also investigated VOT differences between the French and English alveolar stops produced by FEBs. Native French speakers who were experienced learners of L2 English produced a French /t/ more English-like with a significantly longer VOT than FMs, and native English speakers who were experienced learners of L2 French produced an English /t/ more French-like with a shorter VOT than EMs. Similarly, Major (1992) demonstrated that bilingual English-Portuguese speakers who have been exposed to Portuguese as L2 for at least 12 years produced English voiceless stops more Portuguese-like with a significantly shorter VOT than EMs. These results collectively suggest that the early and extensive exposure to L2 may affect speech production of L1, where acoustic properties of L1, such as VOT, become similar to those of L2. Would this hold true for bilingual Korean-English speakers (KEBs)? In other words, would any Korean stops become similar to acoustic properties of English stops?

Kang and Guion (2006) investigated the acoustic characteristics of Korean stops produced by KEB adults and compared Korean stops produced by monolingual Korean speaking (KM) adults. In their study, the KM group consists of 10 native Korean speakers who attended the English institute with a length of residence (LOR) of less than 5 months; the early group consists of 10 KEBs who began learning English between 1 and 6 years; and the late group consists of 10 KEBs who had moved to the United States at the age of 15 or older (N = 30). The VOT and F0 values of Korean stops in the early group were not significantly different from the values in the monolingual group. On the other hand, VOT values of fortis stops produced by the late bilingual group (M = 14, SD = 1) were significantly different from those produced by KM adults (M = 11, SD = 1). They argued that the early bilingual group maintained a distinction between the two phonological systems of the Korean and English showing no interaction between L1 and L2, but that the late bilingual group merged the three contrasts of Korean stops into two contrasts, in a way that Korean aspirated stops were produced similarly to English voiceless stops and Korean lenis and fortis stops were blended in English voiced stops.

More recently, Oh and Daland (2011) examined acoustic characteristics of Korean stops produced by 6 early KEB adults, 7 late KEB adults, 5 simultaneous KEB adults, and 7 KM adults (N = 25). Simultaneous KEB adults acquired English at birth, early KEB adults acquired English as L2 at the age of 6 years on average, and late KEB adults acquired English at the age of 12.5 years on average. Stimuli in their study were nine nonsense monosyllabic words with onset stops followed by the vowel /a/ (e.g., /pa/). Statistical significance was found only for normalized F0 in % of fortis stops, indicating that the ratio in late KEB adults is lower than in KM adults (M = 106 vs. M = 119). Despite the lack of statistical significance, results of their study implicate that late KEB and KM adults make a distinction between aspirated and lenis stops in terms of F0 rather than VOT, but that simultaneous and early KEB adults make a distinction between aspirated and lenis stops in terms of both VOT and F0. In both the studies of Oh and Daland (2011) and Kang and Guion (2006) are in that KMs in both studies depend more on F0 difference than VOT difference for a distinction between aspirated and lenis stops, and the acoustic properties of Korean fortis stops produced by monolinguals are different from those by L2 English learners. Would bilingual children who learned L2 early in life and bilingual adults who learned L2 later in life show similar patterns of L2 influence with adult participants in these studies?

Numerous findings from cross-linguistic studies have demonstrated that perceptual and production performance of nonnative speech sounds are closely related to the age at which the participant began to learn L2 (i.e., age of arrival, AOA; Baker, Trofimovich, Flege, Mack, & Halter, 2008; Johnson & Newport, 1989; Mayberry & Eichen, 1991; Ploog, 1984; Yeni-Komshian, Flege, & Liu, 2000). Previous studies of L1 attrition also suggest that children or early

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bilinguals who were exposed to L2 with limited L1 exposure before the age of 7 years are more susceptible to L1 attrition than adults or late bilinguals speakers (Birdsong, 1992; Caramazza et al., 1973; Fillmore, 1991; Ventureyra, Pallier, & Yoo, 2004). Ventureyra et al. (2004) demonstrated that age and exposure factors are closely related to L1 attrition. They examined whether Korean adults, who were adopted into French families between the ages of 3 and 9 years (M=5;8, presented as year;month) and completed higher-education in France with no exposure to Korean after adoption, were able to detect Korean phonemes. The performance of these Korean adults was not significantly different from the performance of French monolingual adults who had never been exposed to Korean.

The objective of the present study is to examine whether bilingual speakers who learned L2 English produce Korean stops differently from monolingual speakers in terms of VOT and F0 and whether bilingual children who were exposed to L2 English early in life perform differently from bilingual adults who were exposed to L2 English later in life with a similar length of residence in an English-speaking community. The following are the research questions in this study:

1) Do bilingual speakers, who learned English as L2, produce Korean stops differently from monolingual speakers with respect to VOT and F0?
2) Do Korean children who were exposed to English intensively before age 6 exhibit the L2-to-L1 influence differently than Korean adults who were exposed to English after age 12 with a similar length of residence?

In order to answer to these research questions, the VOT and normalized F0 of Korean stops produced by the participants were investigated. The results of acoustical and statistical analysis in this study were discussed and compared to the previous studies done by Kang and Guion (2006) and Oh and Daland (2011) to conclude the research questions addressed above.

## METHODS

### Participants

The definition of bilingualism is a controversial issue. A dictionary might define a bilingual person as someone who speaks two languages with equal proficiency; however, in reality most bilingual speakers tend to have a dominant language (Grosjean, 1992). Therefore, many researchers in this field take a broader view of bilinguals as defined by Haugen (1953), where bilingual individuals are able to "produce complete meaningful utterances in the other languages (p.7)." In the present study, a holistic approach was employed and people who are able to communicate and interact with L2 speakers with receptive and productive linguistic competence are regarded as bilingual. The three experimental groups consisted of nine KEB adults age 21 years and older and nine KEB and eighteen KM children between the age of 8 and 13 (N=36). The number of females in each group is: 4 in the KEB adult group, 4 in the KEB child group, and 6 in the KM child group. All participants had normal hearing sensitivity and no emotional, psychological or neurological problems, as reported by the participants or their parents. The averages of AOA and LOR in bilingual adults were 18;9 and 4;4 (year;month), respectively, and all these adults were enrolled in colleges or universities in the United States as full-time students at the time of participation (i.e., their English proficiency meets at least the criteria to be accepted to the US colleges attested by TOEFL— an abbreviation for 'Test of English as a Foreign Language and an English language examination for foreign students who want to study at universities in the United States—and/or GRE—an abbreviation for 'Graduate Record Examination' and is the only admissions test for most graduate schools in the United States, which consists of three or more subjects including verbal reasoning, quantitative reasoning, and analytical writing). Bilingual children were born in Korea but moved to the United States at the age of 5;8 on average and had lived in the United States for 4;7 on average. KM children had never lived in an English-speaking community, had never attended an English language institute, and had never been exposed to native English speakers at the time of participation. All participants were given two standardized tests of English articulation, the Goldman-Fristoe Test of Articulation 2 (GFTA-2), expressive English vocabulary, the Expressive Vocabulary Test (EVT), and a language survey asking 4 scales of language proficiency questions in English and Korean (Table 1).

### Stimuli and task procedure

The stimuli in the syllable imitation task included 9 Korean stops

**Table 1.** Characteristics of KEB children, KEB adults, and KM children

| Characteristic | KEB adults (N=9) | KEB children (N=9) | KM children (N=18) |
|---|---|---|---|
| Age (yr;mo) | 23;3 (4;4) | 10;3 (2;1) | 11;0 (0;6) |
| Age of arrival | 18;9 (3;0) | 5;8 (3;7) | N/A |
| Length of residence | 4;4 (0;9) | 4;7 (1;7) | N/A |
| GFTA-2 | 5.7 (2.2) | 3.1 (2.2) | 13.9 (5.5) |
| EVT | 98.1 (12.2) | 80 (10) | 60 (7) |
| Self-reported or perceived proficiency in English | 2.8 (0.4) | 2.8 (0.4) | 1.3 (0.4) |
| Self-reported or perceived proficiency in Korean | 4 (0) | 2.6 (0.2) | 4 (0) |

Values are presented as mean (standard deviation).
KEB adults were 21 to 33 years old and KEB and KM children were 8 to 13 years old. Perceived proficiency in English and Korean was measured on the four scales of speaking, listening, writing, and reading (1=beginners' level; 2=intermediate level; 3=advanced level; 4=native level). The given value of GFTA-2 is the number of sound errors on average and the given value of EVT is the average standard score.
KEB=Korean-English bilingual; KM=Korean monolingual; GFTA-2=Goldman-Fristoe Test of Articulation 2; EVT=Expressive Vocabulary Test.

/$p^h$, p, $p^*$, $t^h$, t, $t^*$, $k^h$, k, $k^*$/ followed by the vowel /ɛ/. In Klatt (1975), the vowel context effect was established, where VOT values before high vowels were longer than VOT values before low vowels. Because vowels have an effect on the preceding consonants, the present study controlled for the vowel context where the three laryngeal categories of Korean stops emerge. If bilingual speakers produce the Korean vowel /u/ more English-like, the VOTs before the Korean vowel /u/ and the VOTs before the English vowel /u/ would reveal the vowel context effect. Therefore, the Korean vowel /ɛ/ was chosen because it resembles the acoustic characteristics of the English vowel /ɛ/ more than any other vowel. The author performed a pilot study to compare the English vowel /ɛ/ as produced by 5 male and 5 female EMs along with the Korean vowel /ɛ/ produced by 5 male and 5 female KMs A statistical analysis indicated that the vowel formants of the English vowel /ɛ/ were not significantly different from those of the Korean vowel /ɛ/ either in the male group ($t$=.332, $p$=.756 for the first formant; $t$=.207, $p$=.215 for the second formant) or in the female group ($t$=.120, $p$=.907 for F1; $t$=.444, $p$=.669 for F2).

The participants were asked to imitate each stimulus two times in succession immediately after hearing the sound and seeing the orthographic letters of the stimuli on the monitor (e.g., '캐,' /$k^h$ɛ/ in the Korean alphabet). Providing both auditory and visual stimuli to the participants ensures thorough familiarity with the stimulus and induces correct speech production as much as possible. The stimuli were presented in a random order. The oral responses were audio recorded on a laptop computer. The headset microphone which was used maintained a constant distance to the speaker's mouth and allowed for high quality recording of spontaneously produced of speech sounds. Values of VOT and F0 in Korean stops produced by the participants were analyzed via Praat (http://www.fon.hum.uva.nl/praat/).

### Measurements

If the stimulus was produced incorrectly by the participant, that consonant was excluded from further analysis. On average, KEB children produced the stimuli correctly 94% of the time, and both KEB adults and KM children produced the stimuli correctly 99% of the time. In total, 1,890 out of 1,944 tokens (9 stimuli × 2 times × 36 participants × 3 measures) were subjected to acoustical and statistical analyses. To obtain VOT values, the span between the stop release and the beginning of voicing for each consonant was measured. The values of F0 were taken from the onset of the vowels at the beginning of the second formant after the stop release. To minimize variables such as sex and age, raw F0 values were normalized by dividing F0 values by the average F0 at the midpoint of the vowel (Kang & Guion, 2006). With regard to VOT, a few studies have reported that aspirated voiceless plosives in English are produced with longer VOT in females than in males; however, other studies showed contradictive results. Particularly, Oh and Daland (2011) demonstrated VOT values of Korean stops produced by males are longer than those produced by females. Swartz (1992) argued that speech rate rather than gender induce greater variability in VOT. Thus, age or gender effect is not conclusive and there is no consensus standard for normalizing VOT values. Furthermore, the two previous studies on the L2 English influence on

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Korean stops reported raw VOT values although participants in their studies include both males and females. Therefore, the present study reported raw VOT values and raw VOT and normalized F0 values for the nine Korean stops which were statistically analyzed for a group comparison to determine main effects and interactions (i.e., three groups × three laryngeal categories × three places of articulation).

## RESULTS

Descriptive statistics for raw VOT and normalized F0 values of the nine stops are presented by group in Tables 2, 3 and Figure 2. Two three-way analysis of variances (ANOVAs)—group × laryngeal category × place of articulation—were conducted to determine significant main effects and interactions for VOT and normalized F0, respectively. The statistical analysis for VOT revealed significant main effects for group ($F_{(2,34)} = 28.236$, $p = .000$), place of articulation ($F_{(2,103)} = 38.856$, $p = .000$), and laryngeal category ($F_{(2,103)} = 372.837$, $p = .000$). The only significant interaction was found between laryngeal category and group ($F_{(4,101)} = 8.735$, $p = .000$, $\eta_p^2 = .108$, $p = .999$). According to a Scheffe post-hoc test, the group difference was found between KM children and KEB children ($p = .000$) and between KM children and KEB adults ($p = .000$) but not between the two bilingual groups. Several *t*-tests were also conducted to examine significant interactions between group and laryngeal category. According to the three independent *t*-tests, VOT values of aspirated stops in KM children was significantly smaller than those in KEB adults ($t = 2.192$, $p = .038$) and KEB children ($t = 2.566$, $p = .017$), and VOT values of lenis stops in KM children was significantly smaller than KEB adults ($t = 3.778$, $p = .001$) and

**Table 2.** Averages of voice onset time for nine Korean stops by group

| Stops | KEB adults (N = 9) | KEB children (N = 9) | KM children (N = 18) |
|---|---|---|---|
| $p^h$ | 79 (28) | 76 (22) | 62 (18) |
| p | 41 (12) | 54 (17) | 25 (7) |
| $p^*$ | 12 (3) | 10 (4) | 13 (6) |
| $t^h$ | 79 (28) | 81 (21) | 63 (18) |
| t | 44 (18) | 53 (21) | 31 (10) |
| $t^*$ | 15 (3) | 15 (4) | 14 (4) |
| $k^h$ | 100 (24) | 100 (21) | 78 (21) |
| k | 69 (24) | 70 (25) | 46 (10) |
| $k^*$ | 26 (5) | 24 (15) | 26 (7) |

Values are presented as mean (standard deviation).
KEB and KM children were 8 to 13 years old, and KEB adults were 21 to 33 years old.
KEB = Korean-English bilingual; KM = Korean monolingual.

**Table 3.** Averages of normalized fundamental frequency for nine Korean stops by group

| Stops | KEB adults (N = 9) | KEB children (N = 9) | KM children (N = 18) |
|---|---|---|---|
| $p^h$ | 1.22 (0.16) | 1.23 (0.12) | 1.23 (0.07) |
| p | 1.17 (0.05) | 1.19 (0.11) | 1.10 (0.08) |
| $p^*$ | 1.17 (0.11) | 1.15 (0.12) | 1.21 (0.12) |
| $t^h$ | 1.25 (0.14) | 1.26 (0.16) | 1.21 (0.07) |
| t | 1.15 (0.05) | 1.18 (0.11) | 1.09 (0.09) |
| $t^*$ | 1.19 (0.07) | 1.19 (0.11) | 1.21 (0.09) |
| $k^h$ | 1.25 (0.21) | 1.23 (0.05) | 1.23 (0.10) |
| k | 1.17 (0.04) | 1.22 (0.13) | 1.11 (0.09) |
| $k^*$ | 1.16 (0.14) | 1.20 (0.09) | 1.23 (0.09) |

Values are presented as mean (standard deviation).
KEB and KM children were 8 to 13 years old, and KEB adults were 21 to 33 years old.
KEB = Korean-English bilingual; KM = Korean monolingual.

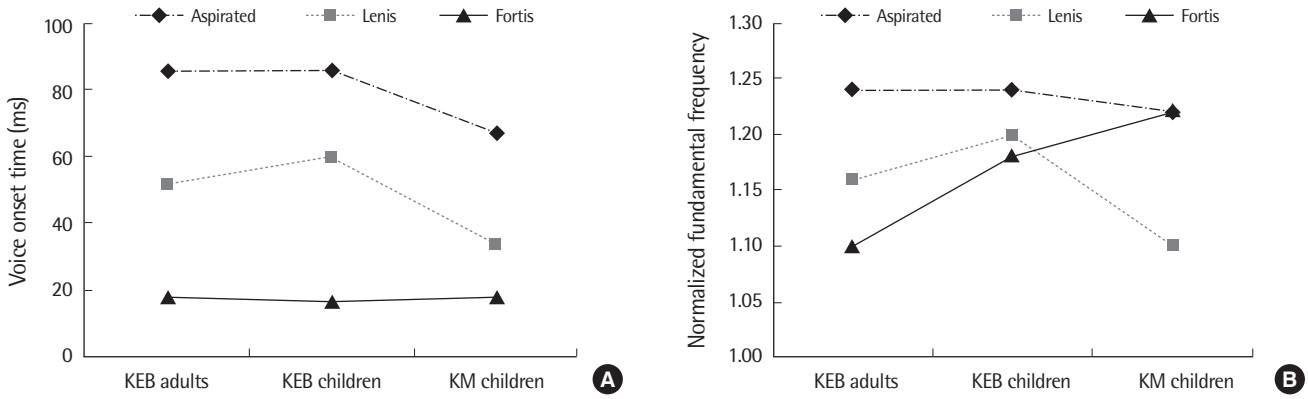


**Figure 2.** Averages of voice onset time (A) and normalized fundamental frequency (B) for Korean aspirated, lenis, fortis stops by Korean-English bilingual (KEB) adults, KEB children, and Korean monolingual (KM) children.

KEB children ($t = 4.993$, $p = .000$). In sum, VOT values in monolingual children were shorter for aspirated and lenis stops than those in the bilingual speakers.

A three-way ANOVA for normalized F0 revealed a significant main effect in the laryngeal category ($F_{(2,103)} = 12.877$, $p = .000$) and a significant interaction between laryngeal category and group ($F_{(4,101)} = 4.515$, $p = .001$). According to the following Scheffe test, normalized F0 values of the three laryngeal categories are significantly different from one another ($p = .000$ for aspirated vs. lenis stops; $p = .006$ for aspirated vs. fortis stops; and $p = .023$ for lenis vs. fortis stops). Three *t*-tests to follow-up the significant interaction showed that F0 values of lenis stops in KM children were statistically smaller than those in KEB adults ($t = 2.762$, $p = .011$) and KEB children ($t = 2.349$, $p = .027$). Overall, normalized F0 values in monolingual children were greater for fortis stops than those in the bilingual individuals. In both analyses, KM children differed from both KEB children and adults with respect to VOT and F0 for the three laryngeal categories but not for the three places of articulation.

## CONCLUSIONS

The present study examined VOT and F0 values of the nine Korean stops /$p^h$, $t^h$, $k^h$, p, t, k, $p^*$, $t^*$, $k^*$/ in order to explore whether English as L2 affects speech production of Korean as L1 and whether the age of exposure to L2 critically affects the L2-to-L1 influence. The first research question asked was whether bilingual speakers who learned English as L2 produce Korean stops differently from monolingual speakers with respect to VOT and F0. The VOT values of the aspirated and lenis stops produced by bilingual individuals were significantly longer, and their normalized F0 values of lenis stops were significantly. The second research question asked was whether KEB children who were early bilingual speakers of L2 English (mean LOR of 4;4) produce Korean stops differently from KEB adults who were late bilingual speakers (mean LOR of 4;7). No statistically significant difference was found between KEB adults and children, indicating that AOA alone is not enough to predict the L2-to-L1 influence.

In Kang and Guion (2006), a significant between-group difference was only found in VOT values of fortis stops where late KEB adults produced fortis stops with longer values than KM adults (M = 16, SD = 2 vs. M = 11, SD = 1). In contrast, the findings of the present study exhibit VOT values of aspirated and lenis stops which are significantly longer in KEB children and adults than KM children. Statistical analysis in Oh and Daland (2011) only revealed a significant group difference for F0 values of fortis stops between late KEB and KM adults. However, a significant group-difference in the present study was found for F0s of the lenis stops, in which KEB children and adults produced lenis stops with significantly higher F0 values than KM children. F0 values of fortis stops produced by bilingual speakers in Oh and Daland (2011) were higher than those of lenis stops; however, F0 values of fortis and lenis stops produced by bilingual individuals in the present study were reversed. Nonetheless, there are some similar trends between the present study and the two previous studies. VOT values of aspirated stops produced by the two bilingual groups in Kang and Guion (2006) are greater than those by the monolingual group although the difference did not reach the level of significance. This is accordance with the results of the present study. Oh and Daland (2011) concluded that late KEB adults and KM children distinguish aspirated stops from lenis stops in terms of F0 rather than VOT; whereas, early and simultaneous bilinguals make use of both VOT and F0 information. Similarly, the average difference between lenis and fortis stops is smaller in KMs than in KEBs, but the average F0 between lenis and fortis is greater in KMs than in KEBs. In other words, bilingual speakers use VOT differences rather than F0 differences alone when producing lenis stops distinctively from fortis stops.

In order to confirm our findings, future research may replicate this study with larger populations with either similar or different L2 variances, such as L2 language, AOA, and LOR. Numerous findings on the L1-to-L2 influence demonstrated that LOR in an L2-speaking community is a crucial factor in predicting the degree of crosslinguistic effect (Baker et al., 2008; Flege & MacKay, 2004; Goldstein & Washington, 2001; Yoon, 2014). Flege and MacKay (2004) examined discrimination of English vowel pairs by native Italian speakers with similar AOA but with different LOR. The results of their study revealed a substantial difference between the group with a smaller LOR and the group with a larger LOR; however, no sufficient difference was found for early vs. late L2 learners. Similarly, KEB children and adults with similar LOR but with

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different AOA in Yoon (2014) showed no significant group difference for any of the language measures including the number of different words, the number of total words, the mean length of utterance, words per minute, mazes, and abandoned utterances. A number of studies with such results argued that AOA alone cannot predict one's L2 proficiency. The same assumption seems to hold true for the L2-to-L1 influence based on the results of the present study. In other words, AOA alone is not sufficient to predict one's L1 attrition at phonetic level.

In addition, future research may focus on how the degree of L1-L2 interference differs between bilingual children and adult or how monolingual children acquire Korean phonemes with respect to acoustic properties such as in Kim (2013). Compared to VOT differences between the aspirated and lenis stops produced by KM adults in Kang and Guion (2006) and Oh and Daland (2011), the differences in KM children of the present study are greater. The developmental changes in the acquisition of Korean word-initial stops may contribute to such differences between KM children and adults. Kim and Stoel-Gammon (2009) and Kim (2013) explored the developmental patterns of the acquisition of Korean word-initial stops. Both studies demonstrated that the F0 distinction of lenis stops from aspirated and fortis stops emerges as early as 2 years 6 months in Korean children and that VOT differences between aspirated and lenis stops increases with age. Unfortunately, there is little research on how a child acquires Korean stops with respect to acoustic properties. Accordingly, developmental studies on the acquisition of Korean speech sounds with regard to acoustic properties are required to more fully understand the significance of the current results.

In conclusion, bilingual speakers who learned English as L2 differentiate three categories of Korean stops differently from monolingual speakers with respect to VOT and F0. The age of exposure to L2 English was not a critical factor in determining the L2-to-L1 influence on the speech production of Korean stops at the phonetic level. Unlike Kang and Guion (2006) who argued that lenis and fortis stops become more like English voiced stops and aspirated stops become more like English voiceless stops, the results of the present study suggest that lenis stops become approximate to English aspirated stops with increased VOT and F0 values. For a better interpretation of the results of the present study, values of VOT and normalized F0 were presented in two scatter plots as shown in Figure 3: one for monolingual and the other for bilingual speakers. Patterns in the plots and statistical analysis affirm that VOT values for aspirated and lenis stops are greater in the bilingual speakers, as also observed in Kang and Guion (2006). Reorganization of VOT and F0 intervals among the three laryngeal categories implies the two contrast systems of each language are mixed, supporting the L2-to-L1 influence. The F0 boundary that separates lenis stops from aspirated and fortis stops in monolingual speakers is blurred in their bilingual counterparts but the VOT boundary between lenis and fortis stops is clearer in bilingual speakers. Particularly, bilingual individuals tend to produce Korean lenis stops with higher VOT and F0 values, which might explain why Korean lenis stops produced with an English accent sound like aspirated stops to na-

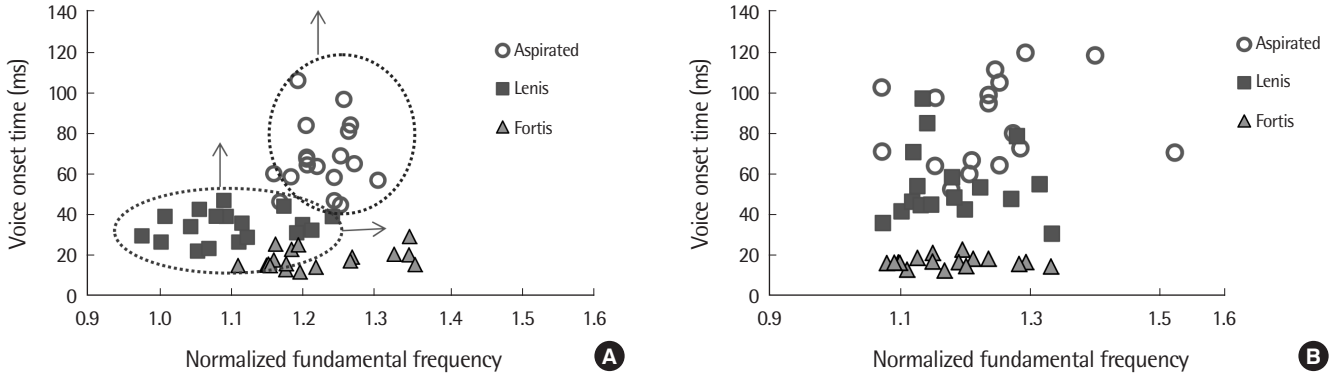


**Figure 3.** Voice onset time and normalized fundamental frequency for Korean aspirated, lenis, fortis stops produced by Korean monolingual children (A) and by Korean-English bilingual adults and children (B). Arrows and circles represent statistically significant differences, where voice onset time and normalized fundamental frequency of lenis stops and voice onset time of aspirated stops are greater in the bilingual than monolingual speakers.

tive Koreans. In addition, bilingual individuals tend to depend more on VOT as well as F0 information when producing lenis stops distinctively from aspirated and fortis stops. This aspect was also observed in Oh and Daland (2011).

To complete the understanding of how two languages are organized in one mind, bilingual research should focus not only on L1-to-L2 influence but also on L2-to-L1 influence. In this regard, the results of the present study may contribute to strengthen the foundation for speech production studies of Korean phonemes produced by children and adults who are exposed to languages other than Korean.

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## 국문초록

### 제2언어인 영어 습득자가 산출한 한국어 폐쇄음의 음향적 특성

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**배경 및 목적:** 제2언어로 영어를 습득한 한국인 아동과 성인이 한국어 폐쇄음을 산출했을 때 음성개시시간(voice onset time, VOT)과 기본주파수(fundamental frequency, F0)에 있어서 한국어만 사용하는 아동과 어떠한 차이를 보이는지, 또한 영어노출시기가 제1언어인 한국어 산출에 결정적 영향을 미치는 요인인지 알아보고자 한다. **방법:** 18명의 한국어-영어 이중언어 아동과 성인, 18명의 한국어 단일어 아동은 한국어 폐쇄음이 포함된 9개의 음절(/$p^h$ɛ, pɛ, $p^*$ɛ, $t^h$ɛ, tɛ, $t^*$ɛ, $k^h$ɛ, kɛ, $k^*$ɛ/)을 두 번씩 반복하여 산출하였다. Praat을 이용하여 산출 된 총 1,890개 음절의 VOT와 F0의 정격값을 측정하였고, 통계분석을 통해 집단 간 차이를 비교 분석하였다. **결과:** 두 개의 3-way ANOVAs 결과에 따르면, 이중언어 아동과 성인이 산출한 격음과 평음의 VOT와 평음의 F0는 단일어 아동보다 유의하게 큰 값을 가졌다. 하지만, 영어에 노출된 기간은 유사하나 노출시기가 다른 아동집단과 성인집단 간의 차이는 통계적으로 유의하지 않았다. **논의 및 결론:** 제2언어로 영어를 습득한 아동과 성인이 산출한 평음의 VOT와 F0가 통제집단의 격음과 닮아갔고 또한 이로 인해 격음의 VOT도 증가했다는 점에서, 제2언어습득이 한국어 폐쇄음의 음향적 특성에 변화를 가져오는 것으로 보인다. 하지만, 영어에 노출된 기간이 비슷한 아동집단과 성인집단의 차이가 없다는 것으로 미루어, 노출시기만으로는 제1언어에 대한 제2언어의 간섭효과를 예측하기에 부족한 것으로 사료된다.

핵심어: 음성개시시간, 기본주파수, 한국어 폐쇄음, 제2언어 영향, 영어습득자

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