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Korean and English affricates in bilingual children

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Abstract

This study examined how early bilingual children produce sounds in their two languages articulated with the same manner of articulation but at different places of articulation. English affricates are palato-alveolar and Korean affricates are alveolar. This study analyzed the frequencies of center of gravity (COG), spectral peak (SP), and the second formant (F2) of word-initial affricates in English and Korean produced by twenty-four early Korean-English bilingual children (aged 4 to 7), and compared them with those of monolingual counterparts in the two languages. If early Korean-English bilingual children produce palato-alveolar affricates in English and alveolar affricates in Korean, they may produce Korean affricates with higher COGs, SPs, and F2s than English affricates. The early Korean-English bilingual children at the age of 4 produced English and Korean affricates with similar COGs, SPs, and F2s, and the COGs, SPs, and F2s of their Korean affricates were similar to those of the Korean monolingual counterparts. However, the early bilingual children at the age of 5 to 7 had lower COGs and SPs for English affricates with higher F2s compared to Korean affricates, and the COGs, SPs, and F2s of their English affricates were similar to those of the English monolingual counterparts.

Keywords: Korean, English, affricate, bilingual, children

1. Introduction

The question whether bilinguals use two distinct language systems or only one language systems has previously been discussed. Many studies have compared speech sounds produced by bilinguals with those by monolinguals in the two languages and looked at how bilinguals categorize sounds in their second language from those in their first language that they learned from birth (Flege, 1995; MacLeod & Stoel-Gammon, 2010; Sundara *et al.*, 2006). For Korean-English bilinguals, the early Korean-English bilingual children in Lee & Iverson (2011) and Yu (2016) did not distinguish English and Korean stops regarding VOT, F0, and H1-H2 at an early stage. However, along with age they gradually separated English and Korean stop systems. The early Korean-English bilingual adults in Kang & Guion (2006) completely separated English and Korean stops in terms of VOT, F0, and H1-H2. Like these studies, most inquiring whether bilinguals use one or two phonetic language systems have examined phonetic properties of speech sounds produced by bilinguals and compared them with those of monolinguals in the two languages.

In general, consonants are categorized by manner and place of articulation. The bilabial, alveolar, and velar stops in Korean are produced at almost the same place of articulation as those in English. Korean fricatives are produced in alveolar ridge, and they are articulated between the back of the upper teeth and the front part of the alveolar ridge (Kim, 2001; Sohn,1987, 1999; Anderson *et al.*, 2004; Kang, 2006). However, English alveolar fricatives are articulated in the middle or forward part of the alveolar ridge (Ladefoged, 2005). Also, English affricates and Korean affricates are not produced at the same place of articulation. English affricates are palato-alveolar sounds articulated between the tongue blade and the back of the alveolar ridge (Ladefoged, 2005). Korean affricates are alveolar sounds articulated with the tongue blade (or the tongue tip) and the alveolar region (Kim, 2001, 1999; Anderson *et al.*,

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2004). This study was interested in how early bilingual children produce sounds in their two languages articulated at different places of articulation, but with the same manner of articulation. English and Korean affricates produced by early Korean-English bilingual children and their counterparts in the two languages were examined. Like stops, English palato-alveolar affricates have a two-way laryngeal contrast (voiceless /ʧ/ and voiced /ʤ/) and Korean alveolar affricates have a three-way laryngeal contrast (aspirated /tɕʰ/, lax /tɕ/, and tense /tɕ*/).

Center of gravity, spectral peak, and the second formant refer to functions of place of articulation. Center of gravity (hereafter COG) is defined as a weighted average of frequency over the entire frequency domain. COG quantifies the region where most of the linguopalatal contact is occurring by assigning progressively greater weight to a more anterior row of the electrode. COG is related to the length of the back cavity. As a place of articulation moves further forward, COG is raised by increased intensity of the anterior cavity resonances (Gordon *et al.*, 2002). According to Hwang (2004), COG is lower for affricates compared to fricatives in Korean, and COG is highest for tense affricate, intermediate for aspirated affricate, and lowest for lax affricate. Spectral peak (hereafter SP) is defined as the frequency that corresponds to the highest amplitude peak of the FFT spectrum. SP increases as a place of articulation moves further forward in the oral cavity. Jongman and his colleagues (Jongman *et al.*, 2000) conducted a large-scale acoustic comparative analysis to classify the places of articulation of English fricatives. SPs of the alveolar fricatives /s, z/ are higher than for the palato-alveolar fricatives /ʃ, ʒ/ in English. The direction of the second formant (hereafter F2) transition is also an important cue for a place of articulation of consonants. Bringing forward or raising the body of the tongue raises F2. According to Kim (1999, 2001), the F2s of Korean affricates are higher than for the alveolar stops and fricatives in Korean, indicating a more laminal articulation than in /t/ and /s/.

The specific questions pursued in the current study were whether early Korean-English bilingual children produce English and Korean affricates at different places of articulation from monolingual counterparts in the two languages and whether the place of articulation of English affricates influences that of Korean affricates or vice versa. Two hypotheses can be proposed for the development of articulatory gesture of English and Korean affricates in early Korean-English bilingual children. The early Korean-English bilingual children had separate English and Korean stops after a certain period of time in Lee & Iverson (2011) and Yu (2016). Early Korean-English bilingual children may produce English and Korean affricates at the same place of articulation during the initial period when they are exposed to English, but later they may produce English and Korean affricates at different places of articulation as their monolingual counterparts in the two languages do. Furthermore, to produce English affricates distinctly different from Korean affricates, early Korean-English bilingual children may produce English affricates somewhat behind the place of articulation where English monolinguals produce them and/or they may produce Korean affricates with bringing forward place of articulation compared to Korean monolinguals.

2. Method

2.1. Participants

Twenty-four children in each of the three language groups of English monolinguals and Korean monolinguals and Korean-English bilinguals participated in this experiment. In each language group, there were six children (three boys and girls) at each age from 4 to 7. As shown in <Table 1>, the Korean-English bilingual children were Early Second Language Acquisition children who learned Korean from birth (like Korean monolinguals) and then regularly learned English from at some point in the age range of 1;6 - 4;0 years (De Houwer, 2009). The Korean monolingual (hereafter KM) children lived in Seoul in South. Korea, and the English monolingual (hereafter EM) and the Korean-English bilingual (hereafter KEB) children lived in Buffalo, NY, USA. None of them was reported as having speech, hearing, or language problems.

Table 1. Age of exposure to English and extent of exposure to English in the KEB children.

Age of children	Age of exposure to English	Extent of exposure to English
4-year-olds	2;0 - 3;8	8 months - 2;0 years
5-year-olds	2;0 - 4;0	1;3 years - 3; 8years
6-year-olds	1;8 - 3;10	3;6 years - 4;8 years
7-year-olds	2;6 - 3;10	3;8 years - 5.6 years

2.2. Stimuli & Procedure

A set of words that contain word-initial affricates was conducted for English and Korean. The affricates were followed by the vowels /i, a, u/ in each language. Six words were selected for English affricates, and nine words were selected for Korean affricates. The selected words were nouns (for examples, 지도 /tɕi.to/ ‘map,’ 치마 /tɕʰi.ma/ ‘skirt,’ and 찌개 /tɕ*i.kɛ/ ‘stew’ in Korean, and cheese and jeans in English), except 쭉쭉 /tɕ’uk.tɕ’uk/ 'continuously' in Korean. 쭉쭉 /tɕ’uk.tɕ’uk/ is a mimetic word describing a continuous state. Pictures which directly remind a child of the selected words were used, all without written letters. A picture showing a cat stretching fully was presented to the children for the word 쭉쭉 /tɕ’uk.tɕ’uk/. The children were asked to say the words in the specific phrase; ‘this is a/an ___’ or ‘they are ___’ in English and ‘이것은 ___이에요’ /ikət-in ___-ieyo/ in Korean when the pictures were presented on a computer screen. Before the children recorded, they had a training session. The children recorded once in a quiet room in their house. The speech produced was recorded using a Pyle-Pro PMHM2 Omnidirectional Head Worn Microphone and Praat (version 5.1.29) signal processing software (Boersma & Weenink, 2010). The microphone placed about 3 cm away from a child’s mouth.

2.3. Analysis

This study conducted the acoustic analysis of the affricates by measuring COGs, SPs, and F2s in praat. COG and SP measurements were taken using a 20ms Hamming window placed in the middle of the frication noise in affricates to avoid the effect of vowels or aspiration. The children produced the shortest frication noise for Korean tense affricate. Since the average duration and shortest duration of frication noise of Korean tense affricate were 38ms and 21ms respectively, I chose a 20ms size of the window. F2 measurements were taken at the beginning of the following vowels.

For statistical analysis, COGs and SPs of English and Korean affricates were compared according to the categories and F0s of

English and Korean affricates were compared according to the following vowels. Linear Mixed Effect Regression model (LMER) was constructed in R using the lmerTest package (Kuznetsova *et al*., 2013) to estimate the differences in COGs, SPs, and F2 at each age between the EM and KEB children and between KM and KEB children, and between English and Korean affricates in the KEB children. The summary function was used to obtain the p-values. The factors of the category, age, and language group were fixed effects. Category and age were within-subject factors, language group was a between-subject factor, and subject was a random effect. The lowest significance level was displayed.

3. Results

3.1. Comparisons between the EM and KEB children and between the KM and KEB children

COGs, SPs, and F2s of the affricates produced by the KEB children were compared with those of the EM and KM children to ascertain whether the KEB children have differences in articulatory gestures from the EM and KM children. <Figure 1> shows the means and standard errors of the frequencies of COG, SP, and F2 for English affricates produced by the EM and KEB children.

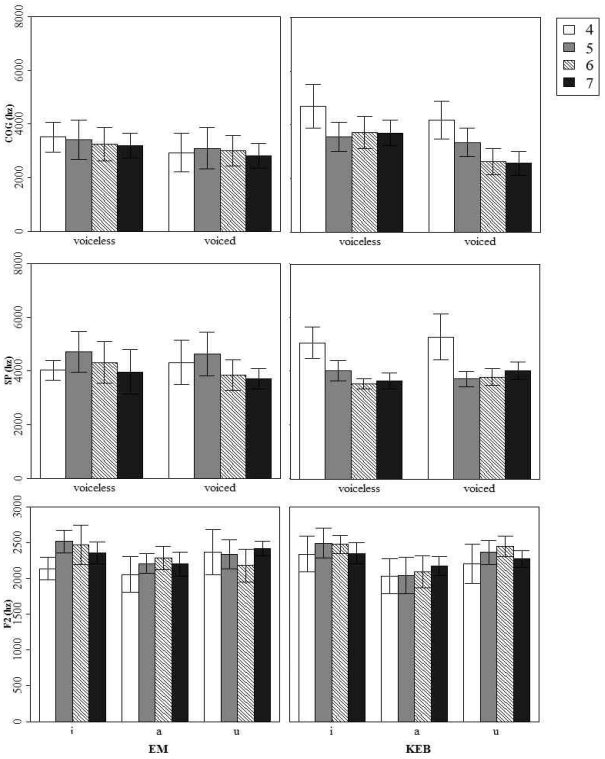

Figure 1. The means and standard errors of frequencies of COG, SP, and F2 for English affricates produced by the EM and KEB children

As shown in <Figure 1>, the EM and KEB children had overall higher COGs for voiceless affricate than for voiced affricate, and the COG differences between the two affricates were greater in the KEB children than in the EM children. The KEB children at the age of 4 had higher COGs for English affricates than those at the age of 5 to 7. In the LMER analysis, the KEB children at the age of 6 and 7 had significantly higher COGs for voiceless affricate than for voiced affricate [$\chi^2(4) = 37.149$, $p < .05$]. But, a significant COG difference between the two affricates was not found in the EM children at any age. The KEB children at the age of 4 had significantly higher COGs than those at the age of 5 to 7 [$\chi^2(3) = 11.18$, $p < .05$]. The KEB children had significantly higher COGs than the EM children at the age of 4 [$\chi^2(4) = 18.04$, $p < .001$], but significant COG differences between the EM and KEB children were not found at the age of 5 to 7. Furthermore, <Figure 1> shows that the SPs of English voiceless and voiced affricates were similar at each age in the EM and KEB children. However, the KEB children at the age of 4 had considerably higher SPs than those at the age of 5 to 7, and their SPs were also considerably higher than those of the EM children. In the results of LMER analysis, the KEB children at the age of 4 had significantly higher SPs for English affricates than those at the age of 5 to 7 [$\chi^2(6) = 26.04$, $p < .001$]. The SPs of the KEB children were significantly higher than those of the EM children at the age of 4 [$\chi^2(4) = 23.38$, $p < .001$]. As shown in <Figure 1>, the F2s after English affricates were compared by the following vowels. The EM and KEB children had little difference in F2s. No significant difference in F2s was found between the vowels and between the EM and the KEB children by the LMER analysis.

<Figure 2> displays the means and standard errors of the frequencies of COG, SP, and F2 for Korean affricates produced by the KM and KEB children.

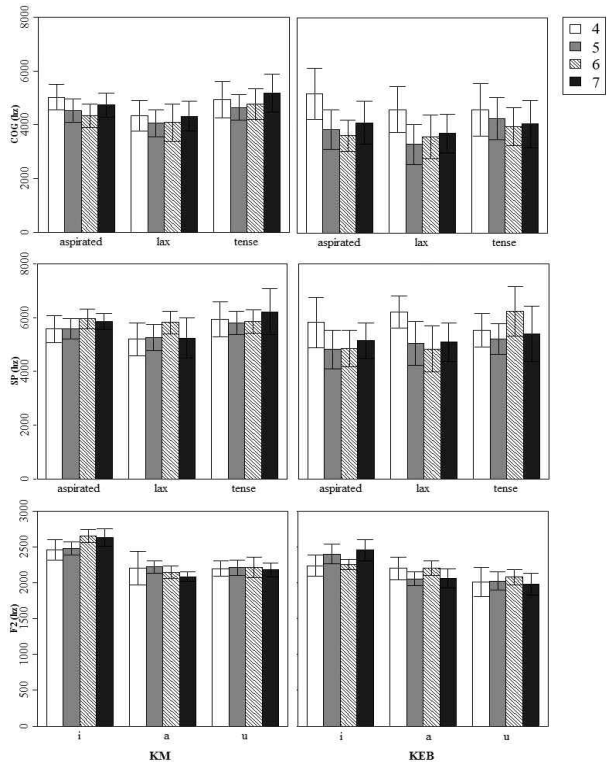

Figure 2. The means and standard errors of frequencies of COG, SP, and F2 for Korean affricates produced by the KM and KEB children.

As shown in <Figure 2>, the KM and KEB children had overall higher COGs for aspirated and tense affricates than for lax affricate. The KEB children at the age of 4 had higher COGs for Korean affricates than those at the age of 5 to 7, especially for aspirated and lax affricates. The KEB children had lower COGs than the KM children at the age of 5 to 7. In the LMER analysis, the KM children at the age of 7 had significantly higher COGs for tense affricate than

for lax affricate [$\chi^2(8) = 15.24$, $p < .05$], and the KM children at the age of 6 had almost significantly higher COGs for tense affricate than for lax affricate [$\chi^2(8) = 15.24$, $p = .06$]. However, the KEB children did not have a significant difference in COGs between Korean affricates at any age. There was no significant difference in COGs between the KM and KEB children, but the COGs of the KM children were almost significantly higher than those of the KEB children at the age of 5 [$\chi^2(4) = 12.02$, $p = .091$], at the age of 6 [$\chi^2(4) = 12.02$, $p = .075$], and at the age of 7 [$\chi^2(4) = 12.02$, $p = .068$]. <Figure 2> shows that the KM children had the lowest SPs for lax affricate and the highest SPs for tense affricate. The KEB children at the age of 4 had higher SPs for aspirated and lax affricates than those at the age of 5 to 7. In the results of LMER analysis, a significant difference in SPs between lax and tense affricates was found in the KM children at the age of 7 [$\chi^2(8) = 12.5$, $p < .05$]. However, SP differences between Korean affricates were not significant in the KEB children at any age. The SPs of the KM children were significantly higher than those of the KEB children at the age of 6 to 7 [$\chi^2(4) = 12.43$, $p < .05$]. In <Figure 2>, moreover, the KM children had higher F2s for the vowel /i/ than the KEB children. In the LMER analysis, the F2s of the vowel /i/ were significantly higher in the KM children than in the KEB children at the age of 4 to 7 [$\chi^2(4) = 26.96$, $p < .05$].

3.2 Comparisons of English and Korean affricates among the KEB children

In the KEB children, the COGs and SPs of Korean affricates were higher than those of English affricates, but the F2s of Korean affricates were lower than those of English affricates. <Table 2> shows t-values from the LMER analysis on the three acoustic parameters for English voiceless affricate and Korean affricates produced by the KEB children.

Table 2. Summary of the results in t-values from the LMER for three acoustic parameters for English voiceless affricate and Korean affricates produced by the KEB children.

	English voiceless					
	4			5		
Korean	COG	SP	F2	COG	SP	F2
aspirated	1.5	1.75	-0.32	0.64	1.81	-1.32
lax	-0.24	2.27***	0.8	-0.46	2.26*	-1.0
tense	-0.25	1.04	1.93	1.42	2.8**	0.03
	6			7		
Korean	COG	SP	F2	COG	SP	F2
aspirated	-0.07	2.95***	-1.34	0.88	3.48***	-1.82
lax	-0.14	2.91***	-0.62	0.01	3.35***	-1.61
tense	0.63	6.1***	-.024	0.77	4.07***	-0.46

In a comparison of English voiceless affricate with Korean affricates, the COGs of English voiceless affricate were not significantly different from those of the three Korean affricates at any age. The SPs of English voiceless affricate were lower than those of Korean affricates. At the age of 4, the SPs of English voiceless affricate were significantly lower than those of Korean lax affricate, and at the age of 5, they were significantly lower than those of Korean lax and tense affricates. At the ages of 6 and 7, the SPs of English voiceless affricate were significantly lower than those of all three Korean affricates. The F2s of English voiceless affricate were significantly different from none of the three Korean affricates at any age.

<Table 3> shows t-values from the LMER analysis on each of the three acoustic parameters for English voiced affricate and Korean affricates produced by the KEB children.

Table 3. Summary of the results in t-values from the LMER for three acoustic parameters for English voiced affricate and Korean affricates produced by the KEB children.

	English voiced					
	4			5		
Korean	COG	SP	F2	COG	SP	F2
aspirated	1.95*	1. 7	-2.64**	1.3	2.57*	-2.6**
lax	0.68	2. 2*	-1.55	0.19	3.01*	-2.26*
tense	0.64	0.39	-0.38	2.09*	3.57**	0.03
	6			7		
Korean	COG	SP	F2	COG	SP	F2
aspirated	2.14*	2.5**	-2.65**	3.42***	2.56*	-2.25*
lax	2.07*	2.46*	-2.4*	2.53*	2.43*	-2.03*
tense	2.84**	5.65**	-.1.56	3.31**	3.15**	-0.87

In a comparison of English voiced affricate with Korean affricates, the COGs of English voiced affricate were significantly lower than for all the Korean affricates at the ages of 6 and 7. The SPs of English voiced affricate were significantly lower than for all the Korean affricates at the age of 5 to 7. However, the F2s of English voiced affricate were significantly higher than for Korean aspirated and lax affricates at the age of 5 to 7.

4. Summary and Discussion

Results for the COGs, SPs, and F2s showed that assimilation of place of articulation occurred in the KEB children at the age of 4 and dissimilation of place of articulation occurred in the KEB children at the age of 5 to 7. At the age of 4, the COGs, SPs, and F2s of English affricates were little different from those of Korean affricates, although a significant difference was found in a few cases. However, the COG, SP, and F2 differences between English and Korean affricates gradually increased as the KEB bilingual children got older. Particularly, the differences were greater between English voiced affricate vs Korean affricates than between English voiceless affricate vs Korean affricates. As the KEB children got older, the COGs and SPs of English voiced affricates were significantly lower than those of Korean affricates, while only the SPs of English voiceless affricate were significantly lower than those of Korean affricates. These results show that the position of articulation for English voiced affricate moved from front to back, as the KEB children got older; while English voiceless affricate and all the Korean affricates were produced at almost the same place of articulation. Therefore, lower F2s were expected for English voiced affricate with backing of the tongue body than for Korean affricates, due to significantly lower COGs and SPs for English voiced

affricate than for Korean affricates. Little F2 difference was also expected for English voiceless affricate vs Korean affricates, due to little difference in COGs and SPs between English voiceless affricate vs Korean affricates. The F2 difference was not found between English voiceless affricate vs Korean affricates at all four ages. However, the F2s of English voiced affricate were higher than those of Korean affricates, and the F2s between English voiced affricate vs Korean aspirated and lax affricates were significantly different at the age of 5 to 7. In Lee & Iverson (2012), the F2s of English /a/ and /u/ were significantly higher than those of Korean /a/ and /u/ in the 5 and 10 years old Korean-English bilingual children. When comparing the F2s of the affricates for each vowel, the F2s of the vowel /u/ after English voiceless and voiced affricates were significantly higher than those after Korean affricates [$\chi^2(4) = 19.31$, $p < .001$] in the KEB children at the age of 5 to 7, and more significantly different F2s were observed between English voiced affricate vs Korean affricates than between English voiceless affricate vs Korean affricates. The F2s of the vowel /a/ were higher after English affricates than after Korean affricates, but a significant F2 difference was not found. These F2 results show a better distinction between English voiced affricate vs Korean affricates than between English voiceless affricate vs Korean affricates.

The KEB children had higher COGs and SPs for English affricates than the EM children at the age of 4, but the EM and KEB children at the age of 5 to 7 had little different COGs and SPs for English affricates. These results show that the KEB children produced English affricates with a shorter anterior cavity compared to the EM difference at the age of 4, but the EM and KEB children at the age fo 5 to 7 produced English affricates with a similar length of anterior cavity. On the other hand, the KM and KEB children at the age of 4 produced similar COGs and SPs, but the KEB children at the age of 5 to 7 produced lower COGs and SPs than their KM counterparts. These results show that the KM and KEB children at the age of 4 produced Korean affricates with a similar length of the anterior cavity. However, the KEB children at the age of 5 to 7 produced Korean affricates with a longer anterior cavity than the KM counterparts. It is likely that the KEB children at the age of 4 produced English affricates as they produced Korean affricates. However, from the age of 5 the KEB children moved the place of articulation for English affricates backward to produce English monolingual-like affricates. Furthermore, the place of articulation of Korean affricates also moved backward as the KEB children at the age of 5 to 7 moved the place of articulation for English affricates. Shifts in L1 phonological categories by the influence of L2 have been widely found in bilinguals. English-French and French-English bilinguals have been observed to modify L1 categories towards L2 norms in Flege (1987). In addition, the COGs of Korean tense affricate was significantly higher than those of Korean lax affricate in the KM children at the age of 7. But, no COG significant difference between the three Korean affricates was found in the KEB children. According to Hwang (2004), COGs of Korean tense affricate are significantly lower than for Korean lax affricate. Thus, it seems that the KEB children need more time to completely learn Korean affricates than the KM children, although they have heard Korean from birth like the KM children.

For F2, the F2s of the vowel /i/ after Korean affricates were lower in the KEB children than in the KM children, while the F2s of the vowels /a/ and /u/ were similar between the two children. This indicates that Korean affricates occurred with less laminal contact of the tongue in the KEB children than in the KM children. This may be due that the KEB children produced Korean affricates with less forward tongue body than the KM children. On the other hand, the F2s of English affricates produced by the EM and KEB children were similar. This shows that the KEB children raised the tongue blade together with raising the tongue body to produce English affricates, as the EM children did.

According to the Speech Learning Model (SLM) (Flege, 1995; Flege *et al.*, 2003), if L2 learners fail to perceive phonetic dissimilarity between an L2 sound and the most similar L1 category, a merged L1-L2 category is established. However, as the exposure to L2 increases, difficulties in perceiving an L2 sound may not persist. Thus, as L2 learners become more proficient in L2, they have a better perception of phonetic dissimilarity between an L2 sound and most similar L1 category (Flege, 1995). In Best's Perceptual Assimilation Model (PAM) (Best, 1995; Best, *et al.*, 1988; Best *et al.*, 2001), L2 learners assimilate an L2 sound to the most similar L1 category based on the information on articulatory gestures. Its extension to L2 learning (PAM-L2) (Best & Tyler, 2007) predicts that L2 learners perceive articulatory dissimilarities of an L2 sound and the most similar L1 category with increasing volume of vocabulary size. The results of the KEB children in this study paralleled these language learning models. From the results of COGs, SPs, and F2s, the KEB children at the age of 4 produced English affricates in the same place of articulation of their Korean affricates. From the age of 5, the place of articulation for English affricates gradually moved backward from their Korean affricates. Thus, it can be supposed here that early Korean-English bilingual children have difficulties in perceiving phonetical and/or articulatory dissimilarities between English and Korean affricates in the initial period when they are exposed to English affricates, and categorize English voiceless and voiced affricates as an exemplar of Korean affricates. However, with increasing language experience, they can detect the dissimilarities between English and Korean affricates and produce English and Korean affricates at the place of articulation where their monolingual counterparts produce them.

The COGs, SPs, and F2s in the KEB children in this study did not show that the KEB children at the age of 4 to 7 had two separate affricate systems. However, it was observed that the KEB children gradually separated the two systems, as they got older. English voiced affricate having less similarity with Korean affricates was earlier distinguished from Korean affricates than English voiceless affricate in the KEB children. A voicing contrast in English affricates might lead the KEB children to produce English voiced affricate with a different place of articulation from Korean affricates earlier. In English and Korean stops, the Korean-English bilingual children in Lee & Iverson (2011) and Yu (2016) showed the better phonetic distinction between English voiced stops vs Korean stops compared to between English voiceless stops vs Korean stops. However, the longer the KEB children are exposed to English, the better discrimination they may have between English voiceless stops vs Korean affricates, based on the SLM and PAM. Thus, the KEB children may eventually have two separate affricates systems. So, further study is needed to confirm that early Korean-English bilingual children completely produce the palato-alveolar English affricates and the alveolar Korean affricates after the age of 7, and is also needed to observe whether the shift of Korean affricates is kept after the KEB children fully distinguish the different places of articulation of English and Korean affricates.

References

Anderson, V., Ko, I., O'Grady, W., & Choo, M. (2004). A Palatographic Investigation of Place of Articulation in Korean Coronal Obstruents. *Korean Linguistics*, 12(1), 1-24.

Best, C. (1995). A direct realist view of cross-language speech perception. In W. Strange (Ed.), *Speech Perception and Linguistic Experience: Theoretical and Methodological Issues* (pp. 171-204). Timonium, MD: York Press.

Best, C., & Tyler, M. (2007). Nonnative and second language speech perception: Commonalities and complementaries. In O. Bohn, & M. Munro (Eds.), *Language Experience in Second Language Speech Learning: In Honor of James Emil Flege* (pp. 13-34). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Best, C., McRoberts, G., & Goodell, E. (2001). Discrimination of non-native consonant contrasts varying in perceptual assimilation to the listener's native phonological system. *The Journal of the Acoustical Society of America*, 109(2), 775-794.

Best, C., McRoberts, G., & Sithole, N. (1988). Examination of perceptual reorganization for nonnative speech contrasts: Zulu click discrimination by English-speaking adults and infants. *Journal of Experimental Psychology: Human Perception and Performance*, 14(3), 45-60.

Boersma, P., & Weenink, D. (2010). Praat: Doing phonetics by computer. Retrieved from version 5.1.29. http://www.praat.org/ on March 11, 2010.

De Houwer, A. (2009). *Bilingual First Language Acquisition*. Bristol, England: Multilingual Matters.

Flege, J. (1987). The production of "new" and "similar" phones in a foreign language: Evidence for the effect of equivalence classification. *Journal of Phonetics*, 15(1), 47-65.

Flege, J. (1995). Second language speech learning: Theory, findings, and problems. In W. Strange (Ed.), *Speech perception and linguistic experience: Issues in cross-language research* (pp. 233-277). Timonium, MD: York Press.

Flege, J., Schirru, C., & MacKay, I. (2003). Interaction between the native and second language phonetic subsystems. *Speech Communication*, 40(4), 467-491.

Gordon, M., Barthmaier, P., & Sands, K. (2002). A cross-linguistic acoustic study of voiceless fricatives. *Journal of the International Phonetic Association*, 32(2), 141-74.

Hwang, H. (2004). Spectral characteristics of frication noise in Korean sibilants. *Malsori*, 49, 31-50.

Jongman, A., Wayland, R., & Wong, S. (2000). Acoustic characteristics of English fricatives. *The Journal of the Acoustical Society of America*, 108(3), 1252-1263.

Kang, K. (2006). Are the Korean affricates alveolars or palato-alveolars?: Evidence from speech errors and loanwords. *Studies in Phonetics, Phonology and Morphology*, 12(3), 431-451.

Kang, K., & Guion, S. (2006). Phonological systems in bilinguals: Age of learning effects on the stop consonant systems of Korean-English bilinguals. *The Journal of the Acoustical Society of America*, 119(3), 1672-1683.

Kim, H. (1999). The place of articulation of the Korean affricates revisited. *Journal of East Asian Linguistics*, 8(4), 313-347.

Kim, H. (2001). The place of articulation of the Korean plain affricate in intervocalic position: An articulatory and acoustic study. *Journal of the International Phonetic Association*, 31(2), 229-257.

Kuznetsova, A., Brockhoff, P., & Christensen, R. (2013). lmerTest: Tests for random and fixed effects for linear mixed effect models (lmer objects of lme4 package). Retrieved from R package version 2.0-0. http://CRAN.R-project.org/package=lmerTest on June 5, 2013.

Ladefoged, P. (2005). *A Course in Phonetic.* Boston, MA: Heinle & Heinle

Lee, S., & Iverson, G. (2011). Stop consonant of English-Korean bilingual children. *Bilingualism: Language and Cognition*, 15(2), 275-287.

Lee, S., & Iverson, G. (2012). Vowel category formation in Korean-English bilingual children. *Journal of Speech, Language, and Hearing Research*, 55(5), 1449-1462.

MacLeod, A., & Stoel-Gammon, C. (2010). What is the impact of age of second language acquisition on the production of consonants and vowels among childhood bilinguals? *International Journal of Bilingualism*, 14(4), 400-421.

Sohn, H. (1987). *Underspecification in Korean Phonology*. Ph.D. Dissertation, University of Illinois at Urbana-Champaign.

Sohn, H. (1999). *The Korean Language*. NY: Cambridge University.

Sundara, M., Polka, L., & Baum, S. (2006). Production of coronal stops by simultaneous bilingual adults. *Bilingualism: Language and Cognition*, 9(1), 97-114.

Yu, H. (2016). *The Development of Obstruent Consonants in Bilingual Korean-English Children*. Ph.D. Dissertation, The State University of New York at Buffalo.

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