Early Korean bilingual children's production of English stressed vowels in multisyllabic words*

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Oh, Eunhae. 2012. Early Korean bilingual children's production of English stressed vowels in multisyllabic words. *Studies in Phonetics, Phonology and Morphology* 18.2. 279-295. The effect of age of acquisition and amount of experience on the production of English stressed vowels in multisyllabic words was investigated. Twenty Korean-speaking children varying in age of second-language (L2) exposure and the amount of experience (6 months vs. 6 years) were compared to ten age-matched native English speaking children. English multisyllabic words containing stressed syllables were elicited. The results for Korean children who were exposed to the L2 before the age of three returned a native-like production of stressed vowels. The native Korean-speaking children with shorter L2 exposure were unable to produce distinctive phonemic categories, indicating a strong L1 interference on L2. The early learners of English, however, were comparable to the native English-speaking children in producing stressed vowels. Furthermore, the early bilingual children's native-like perceptual distance between stressed and unstressed vowels was interpreted as their early mastery of English vowel spectral qualities that are prosodically conditioned at the lexical level. **(Hyupsung University)**

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1. Introduction

The examination of bilingual's production of the first (L1) and second language (L2) has allowed researchers to gain insight into several factors affecting the degree of native-likeness in the production of L2. In the course of language learning, many variables such as the age at time of L2 exposure (Guion 2003, Baker and Trofimovich 2005), the amount of L1 and L2 use (MacKay et al. 2001, Piske et al. 2002, Flege et al. 2003), and cross-language similarity (McAllister et al. 2002, Baker et al. 2008, Oh et al. 2011) were shown to play significant roles in shaping the ultimate attainment of L2. While some studies have reported that early bilinguals are more likely to acquire L2 in a native-like manner than late bilinguals (Aoyama et al. 2004, Tsukada et al. 2005, Kang and Guion 2006), others have argued that even early bilinguals produce foreign accents as the effect of prior L1 experience (Guion et al. 2000, Kehoe 2002, Baker and Trofimovich 2005). For instance, Oh et al. (2011) examined Japanese-speaking children's and adults' production of English vowels in a longitudinal study and found that

* The current paper is an extended study of my dissertation undertaken at the University of Oregon in 2011. Please refer to Chapter 5 for the report on unstressed vowel production. Responsibility for any errors of interpretation remains mine alone.

the children not only outperformed the adults but also showed a native-like accuracy within a year's time of English exposure. Similarly, Tsukada et al. (2005) compared the vowel production of native Korean adults and children with that of the age-matched native English speakers. The results showed no significant difference across the child, but not adult, groups, suggesting that the early L2 learners are likely to acquire L2 in a native-like manner.

On the other hand, Baker and Trovimovich (2005) found a significant L1-L2 interaction in the Korean and English vowel production by late as well as early bilinguals with 7 years of experience in the L2 speaking country. Interestingly, the L1-L2 interaction was bidirectional for the early bilinguals, whereas the late learners showed a unidirectional interaction (i.e., L1 effect on L2 vowel production). In Kehoe's (2002) longitudinal study on the vowel systems of early bilinguals, German-Spanish bilingual children were shown to acquire the German vowel length contrasts significantly later than monolingual German-speaking children. The bilingual children's performance, however, gained more accuracy as they became more experienced in German. Although early learners were shown to have a notable L1 influence, the amount of L1 use can also be an important factor determining the degree of foreign accents in the L2 (Guion et al. 2000).

The early bilinguals' delayed L2 acquisition of language-specific features is also evident in the domain of prosody. Lee, Guion, and Harada (2006) examined the effect of L1 prosody on the acquisition of English stressed and unstressed vowel contrasts produced by Korean-English bilingual adults who were exposed to English in their early age. They found that the prior exposure to L1 negatively affected the acquisition of L2 prosody. They argued that greater knowledge of L1 is likely to give rise to a greater interference in learning L2 (Oyama 1979, Flege 1987, Bialystok 1997, Iverson, Kuhl, Akahane-Yamada, Diesch, Tohkura, Kettermann, and Siebert 2003). On the assumption that the interference gets stronger as L1 develops, early bilingual children who were exposed to L2 around school-age children and thus have a well-established L1 system compared to simultaneous bilingual children are expected to show greater L1 influence on the L2.

In so far, the effect of age on L2 acquisition have been presented through the comparisons of early versus late bilinguals who are mostly in the age range of one to six years for early bilinguals and 15 to 35 years for late bilinguals (see Flege 1991, Kang and Guion 2006, Guion, Harada, and Clark 2004). However, considering that most children have acquired the major components of their native language by age six (Li, Zhao, and McWhinney 2007), the extent of L1 influence on L2 learning are likely to differ significantly across children who were exposed to the L2 at one and those around six years old. In this respect, greater attention to the subdivision of children's age categories is necessary. Due to the fairly wide age range that has defined "early" for early bilinguals and a relatively under-researched area in the language behavior of second generation immigrant children, it is less clear whether children who were born in the L2 speaking country but were raised by their L1 speaking parents are able to acquire the L2 in a native-like manner. U.S.-born Korean children are mostly exposed to Korean (L1) by their Korean caregivers before the age of three. When these children start attending kindergarten or a child day care center at the age of three and thereafter, they are predominantly exposed to English (L2). If early bilinguals are introduced to a second language before the first language wins out as a dominant language, the native-like attainment of the L2 is likely. More investigation is needed as the early form of these bilingual children's speech production of Korean and English provides the interim state of language development and interaction of the two phonological systems (Oh 2012).

The current study examined English stressed vowels in multisyllabic words. Despite the extensive research, studies on stressed vowels have often been restricted to the production of monosyllabic words and its segmental features at a lexical level (Munro 1993, Flege et al. 1999, Baker and Trofimovich 2005, Tsukada et al. 2005, Baker et al. 2008, Tomita et al. 2009, Oh et al. 2011). As for the suprasegmental features, stressed vowels in multisyllabic words have rarely been considered separately from unstressed vowels (see Trofimovich and Baker 2006, Lee et al. 2006, Oh 2011). The relative duration, pitch and amplitude of English stressed and unstressed syllables have long been the topic of interest for assessing the acquisition of prosody and the acquisition of stress has often been researched through the vowel quality of unstressed vowels alone. In Lee et al. (2006), the production of English unstressed vowels by Korean learners of English was examined with the aim of finding the influence of the L1 prosodic system on the L2. More specifically, the differential rhythmic features (stress-timing vs. syllable-timing) were expected to create challenges for Koreans to produce reduced vowels. Although the early bilinguals were overall more accurate than the late bilinguals in producing unaccented vowels, the authors proposed that the early bilinguals may have substituted a Korean mid-high vowel, /ɨ/, for English reduced vowels.

The findings on nonnative-like unstressed vowel quality produced by early bilinguals suggested that the prosodic features are likely to be under-attended by L2 speakers when they are not phonologically meaningful in their native language. If unstressed vowels produced by early Korean bilinguals showed low production accuracy due to the lack of vowel reduction in Korean, the following question is whether the early bilinguals would show greater accuracy for English stressed vowels in multisyllabic words. As stressed vowels are produced with fuller vowel qualities than unstressed vowels (Sluijter and Van Heuven 1996), it is less likely to be under the effect of a L1 prosodic system. Differently from stressed vowels in monosyllabic words, however, stressed vowels in multisyllabic words should be accounted with respect to the acquisition of lexical stress patterns. The current study compared early and late bilingual children's stressed vowel qualities to native English-speaking children's production with the goal of understanding the effect of age of L2 exposure and L2 experience on the acquisition of prosodically-conditioned stressed vowels in multisyllabic words.

2. Experiment

2.1 Method

2.1.1 Participants

A total of thirty children varying in age, length of residence (LOR) and overall English use participated. These children were divided into three groups and each group consisted of ten children (4 male, 6 female) with the average age of 7 years: Native English-speaking Children (NEC), Early Korean-English Bilingual Children (EBC), Native English-learning Korean Children (NKC). None of the thirty children reported being diagnosed with hearing or speech disorders. As shown in Table 1 below, early and late child groups differed in the age of English exposure as well as LOR in the U.S. The NEC and EBC groups were all recruited from Northwest area of the U.S. The bilingual children were born and raised to a Korean-speaking family who were all maintaining a close contact with Korean community through church or local associations. The NKC group had resided in the U.S. approximately 6 months at the time of testing, but they reported to have learned English in Korea for less than a year. Four out of ten bilingual children were the sisters or brothers of the other four participants in the group. For additional information, participants were given language background questionnaire which included the question on the percentage of English use at home, at school, and language spoken to family. The percentage of English use shown below is their overall use of English on a daily basis.

Table 1. Language backgrounds of Native English-speaking children, Early Korean-English bilingual children and Native English-learning Korean children, in years are shown with standard deviation in parentheses.

Group	Age	LOR	AOA	English use
NEC (4m, 6f)	7.5(1.2)	-	-	100%
EBC (4m, 6f)	7.1(1.2)	7.1(1.2)	2.4(1.6)	62%(18%)
NKC (4m, 6f)	7.3(1.3)	0.5(0.1)	6.7(1.5)	42%(8%)

* Note that AOA for the NKC groups indicates the age of L2 acquisition in Korea.

2.1.2 Stimuli

A total of seven frequently used English 3-syllabic words that share the same number of syllables and stress pattern were presented. With two multisyllabic words exemplifying three vowel categories (/ɛ/, /æ/, /ɑ/) and one word representing one vowel category (/u/), a total of four vowel categories were produced by the three child groups. The speech stimuli are shown in Table 2. Each stressed vowel of interest is marked in bold.

Table 2. Speech stimuli

Stressed vowels	Target words
/ɛ/	***e**lephant, **te**lephone*
/æ/	***a**nimal, **fa**mily*
/ɑ/	*cr**o**codile, **o**ctopus*
/u/	*c**u**cumber*

2.1.3 Procedure

A picture task was conducted in a quiet room in the home of the children. Similar to the procedure shown in Oh (2011), pictures representing the seven target words were presented in a random order to the children on the screen of a laptop computer. The Korean and English-speaking adult and child participants wore a head-mounted Shure microphone (Model SM 10A) and the speech was recorded on a flash digital recorder (Marantz PMD670) at a 22.05 kHz sampling rate with 16 bit quantization.

English production that had been prerecorded by a female native English speaker was presented along with the corresponding picture and children were asked to listen and repeat the auditory cue. Each word was elicited three times including the repetition, but only the second and third tokens of each word were analyzed.

2.1.4 Measurements

A total of 420 tokens (7 words x 2 repetition x 3 groups x10 participants each) for the English stressed vowel productions were analyzed using Praat. The first syllable of the seven words was measured for stressed vowels. First and second formant frequencies of each vowel were measured at the temporal midpoint of each vowel. Because of the difference in the vocal tract length across participants, F1 and F2 frequency measurements were normalized for the spectral analyses.

Although the number of female and male participants is controlled across the groups, individual differences in the vocal tract lengths and shape are likely to affect the formant frequencies. Thus, first (F1) and second formant (F2) frequency measurements were normalized for vowel spectral quality comparisons. All formant values of the EBC, NKC, NEC groups were normalized to one child of each group. Using the average F3 frequency of the child's low back English vowel /ɑ/ as a reference point, the mean F3 of this speaker was divided by the mean F3 for each speaker. Then, the F1 and F2 frequencies for each speaker were multiplied by the factor derived from dividing the mean F3 by their own F3 frequency. The normalized measurements were used for between-group analyses (see Lee et al. 2006, Guion 2003, Yang 1996, Oh 2011 for the same normalization method). The seven stressed vowels were analyzed and compared separately across the groups.

2.1.5 Statistical Analyses

Three adult (or child) groups were compared using MANOVAs in SPSS. If the group (3) by word (7) interaction was significant, 3-way comparisons were conducted. Although some words contain the same vowel quality in the first syllable, seven words were analyzed separately due to the different syllabic structures, different consonantal contexts, and different vowel quality in the following syllable.

First, in order to determine whether the effect of L2 experience was significant, MANOVAs examined English vowels produced by the EBC and NKC groups were conducted. Also, the EBC and NKC groups were separately compared to the NEC group to assess the native-likeness of their productions. The NKC and NEC groups were treated as control groups, representing native Korean speaking- and English-speaking children, respectively. For each comparison, the dependent variables for all comparisons were F1 and F2 frequency and the independent variables were word (7), submitted as repeated measures, and group (2). In the case of a significant interaction between group and word, 7 MANOVAs were conducted to test the effect of group on each vowel. A traditional Bonferroni procedure was used and each ANOVA was tested at the alpha level of 0.007 for 7 comparisons (.05 divided by the number of ANOVAs conducted). The univariate tests for F1 and F2 are reported for each significant MANOVA comparison.

Next, the similar or overlapping vowels within the group's production were examined. Three vowel pairs with the same orthographic spelling (i.e., [ε^1]*lephant* - *t*[$\boldsymbol{\varepsilon}^2$]*lephone,* [$\boldsymbol{æ}^1$]*nimal* - *f*[$\boldsymbol{æ}^2$]*mily*, *cr*[$\boldsymbol{ɑ}^1$]*codile*- [$\boldsymbol{ɑ}^2$]*ctopus*) were compared with repeated measures. The same three pairs were examined first, followed by the additional neighboring vowel pairs. The neighboring vowel pairs varied by groups and they were determined by examining the adjacent vowels shown in vowel space (Figure 1). The alpha level was adjusted to 0.013 for the NEC and EBC groups for 4 comparisons and 0.006 for the NKC group for 8 comparisons. Partial eta squared (η_p^2) values are indicated to provide information on the effect size.

2.2 Results

The group analysis revealed a significant group effect [$F(4,54) = 4.297$, $p < 0.05$, $\eta_p^2 = 0.241$] as well as a significant group by word interaction [$F(24,34) = 4.581$, $p < 0.05$, $\eta_p^2 = 0.764$]. Thus, 3-way comparisons for the

EBC and NKC groups, the EBC and NEC groups as well as the NKC and NEC groups were submitted. First, the EBC and NKC groups were compared to investigate to what extent bilingual children differ from native Korean-speaking children in producing stressed vowels in multisyllabic words. Namely, the effects of age and length of L2 exposure on the acquisition of stressed vowel quality were examined.

The EBC and NKC groups returned no significant group effect [$F(2,17) = 2.664$, $p > 0.05$, $\eta_p^2 = 0.239$], but a significant group by word interaction [$F(12,7) = 4.416$, $p < 0.05$, $\eta_p^2 = 0.883$]. To further examine which vowels differed across the two groups, seven MANOVAs were conducted. A significant group effect was returned for *cr*[**ɑ^1**]*codile* [$F(2,17) = 14.286$, $p < 0.007$, $\eta_p^2 = 0.627$], [**ɑ^2**]*ctopus* [$F(2,17) = 10.880$, $p < 0.007$, $\eta_p^2 = 0.556$] but not for the rest of the vowels: [**ɛ^1**]*lephant* [$F(2,17) = 4.057$, $p > 0.007$, $\eta_p^2 = 0.323$], *t*[**ɛ^2**]*lephone* [$F(2,17) = 8.337$, $p > 0.007$, $\eta_p^2 = 0.495$], [**æ^1**]*nimal* [$F(2,17) = 2.773$, $p > 0.007$, $\eta_p^2 = 0.246$], *f*[**æ^2**]*mily* [$F(2,17) = 4.321$, $p > 0.007$, $\eta_p^2 = 0.337$], *c*[**u**]*cumber* [$F(2,17) = 1.604$, $p > 0.007$, $\eta_p^2 = 0.159$].

The univariate tests showed a significantly higher F1 frequency (lower in vowel space) for *cr*[**ɑ^1**]*codile* [$F(1,18) = 21.780$, $p < 0.007$, $\eta_p^2 = 0.548$], [**ɑ^2**]*ctopus* [$F(2,17) = 16.425$, $p < 0.007$, $\eta_p^2 = 0.447$] and higher F2 frequency (further fronted) for *cr*[**ɑ^1**]*codile* [$F(1,18) = 11.821$, $p < 0.007$, $\eta_p^2 = 0.396$] in the EBC than the NKC group's production. As shown in Figure 1(a) and (b), EBC group's vowel, /ɑ/, is further fronted and also significantly lower in vowel space than NKC group's production which created greater distinctiveness from the adjacent vowel category, /ɛ/.

The EBC and NEC groups returned a significant group effect [$F(2,17) = 4.016$, $p < 0.05$, $\eta_p^2 = 0.321$]. However, there was no significant group and word interaction [$F(2,17) = 2.610$, $p > 0.05$, $\eta_p^2 = 0.817$], which suggested that seven stress vowels were not significantly different between the two groups. This result is surprising given that the NEC group showed overall greater distinctiveness across the vowel categories than the EBC group in Figure 1(b) and (c). Thus, to compare the NEC and EBC groups' dispersion of the ten vowel points within each vowel category, the average F1 and F2 value for each vowel category for each subject was taken. Then, the average value was subtracted from the F1 and F2 values of ten speakers of that group. The absolute values of the difference scores for the NEC and EBC groups were compared using Welch *t*-test. The results revealed that the distance scores for each vowel category did not significantly differ across the two groups. Although the vowels produced by the NEC group appeared to be more distinctive, the similar variances and vowel qualities between the NEC and EBC groups may be interpreted to suggest that the bilingual children have acquired all seven stressed vowels in a native-like manner.

On the contrary, the NKC and NEC groups showed a significant effect of group [$F(2,17) = 8.714$, $p < 0.05$, $\eta_p^2 = 0.506$] as well as group by word interaction [$F(2,17) = 10.582$, $p < 0.05$, $\eta_p^2 = 0.948$]. Separate MANOVAs on each word showed a significant group effect on [**æ^1**]*nimal* [$F(2,17) =$

16.988, $p < 0.007$, $\eta_p^2 = 0.667$], *f*[**æ²**]*mily* [$F(2,17) = 29.737$, $p < 0.007$, $\eta_p^2 = 0.778$], *cr*[**ɑ¹**]*codile* [$F(2,17) = 15.703$, $p < 0.007$, $\eta_p^2 = 0.649$], [**ɑ²**]*ctopus* [$F(2,17) = 12.431$, $p < 0.007$, $\eta_p^2 = 0.594$], but not on [**ɛ¹**]*lephant* [$F(2,17) = 1.228$, $p > 0.007$, $\eta_p^2 = 0.126$], *t*[**ɛ²**]*lephone* [$F(2,17) = 0.698$, $p > 0.007$, $\eta_p^2 = 0.076$] and *c*[**u**]*cumber* [$F(2,17) = 0.715$, $p > 0.007$, $\eta_p^2 = 0.078$].

The univariate tests showed a significantly lower F1 frequency for *cr*[**ɑ¹**]*codile* F1 [$F(1,18) = 31.948$, $p < 0.007$, $\eta_p^2 = 0.640$], [**ɑ²**]*ctopus* [$F(1,18) = 21.022$, $p < 0.007$, $\eta_p^2 = 0.539$], lower F2 frequency for *cr*[**ɑ¹**]*codile* F2 [$F(1,18) = 12.763$, $p < 0.007$, $\eta_p^2 = 0.415$], [**æ¹**]*nimal* [$F(1,18) = 22.440$, $p < 0.007$, $\eta_p^2 = 0.555$], *c*[**u**]*cumber* [$F(1,18) = 55.201$, $p < 0.007$, $\eta_p^2 = 0.754$] and higher F1 for *c*[**u**]*cumber* [$F(1,18) = 40.726$, $p < 0.007$, $\eta_p^2 = 0.693$] in the NKC group than in NEC group's production. Table 3 summarizes the results of all group comparisons. stressed vowel of interest is marked in bold.

Table 3. Significantly different stressed vowels between the child groups are shown. The results of a more native-like group (marked in bold) are given in comparison to a corresponding group. The significant differences are marked with an arrow indicating significantly high or low F1 and F2 frequencies.

Group	Significantly different stressed vowels
EBC vs. NKC	*cr*[ɑ¹]*codile* (F1↑,F2↑) [ɑ²]*ctopus* (F1↑)
EBC vs. NEC	
NEC vs. NKC	[**æ¹**]*nimal* (F2↑) *c*[**u**]*cumber* (F1↓, F2↑) *cr*[ɑ¹]*codile* (F1↑, F2↑) [ɑ²]*ctopus* (F1↑)

Both EBC and NEC groups produced stressed vowels for *crocodile* with higher F1 frequency and *octopus* with higher F2 frequency. However, NKC group showed greater differences with NEC group than EBC group. Specifically, stressed vowels for *animal* and cucumber were produced with the tongue further forward in the mouth. Interestingly, NKC group's vowels in Figure 1(a) showed a tendency to center around /ɛ/ in e*lephant* except for /u/. The concentration of English stressed vowels is consistent with the pattern shown in the late Korean children's production of English unstressed vowels (see Oh (2011: 153)). Relatively less experienced NKC group's smaller and more crowded use of vowel space for stressed (and unstressed) vowels is clearly demonstrated in Figure 1. In this and the following figures, the mean is represented by the placement of the vowel symbol and the ellipses enclose +/- 2 standard deviations.

(a) (b) (c)

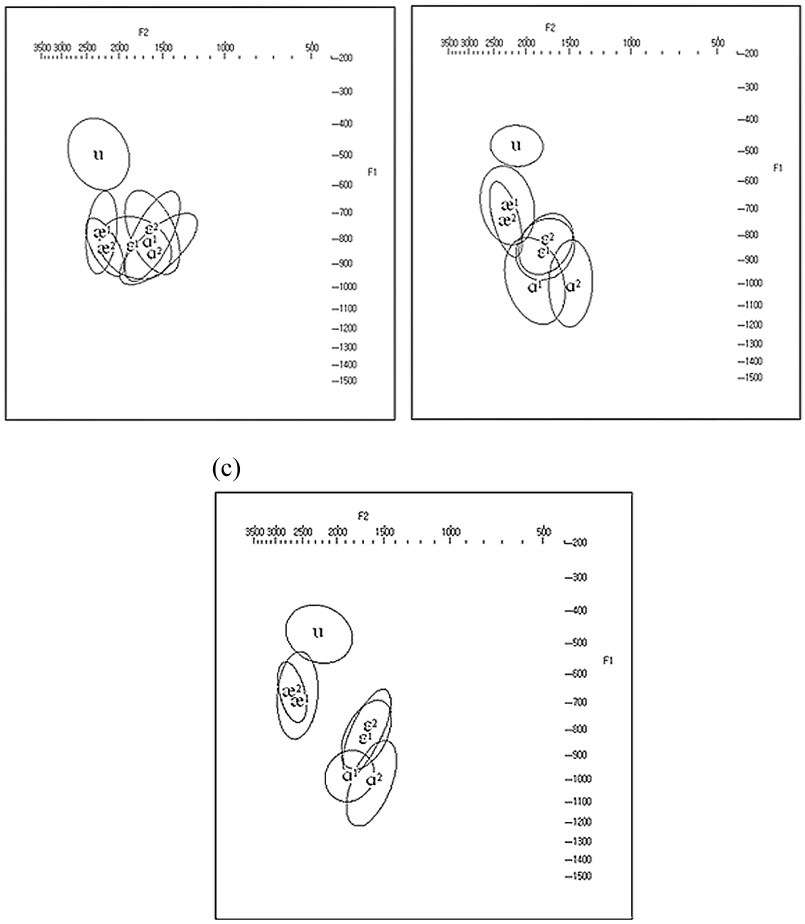

Figure 1. Normalized F1 and F2 frequencies of seven English stressed vowels in the first syllable produced by (a) Native Korean learners of English Child (NKC), (b) Early Bilingual Child (EBC) and (c) Native English-speaking Child (NEC) groups are shown. The target stressed vowels are indicated with phonetic symbols: ε^{1} – *elephant*, ε^{2} – *telephone*, æ^{1} – *animal*, æ^{2} – *family*, ɑ^{1} – *crocodile*, ɑ^{2} – *octopus,* u – *cucumber.*

As presented in Figure 1, there was a tendency that less L2 experienced group showed greater overlapping within and across vowel categories (NEC < EBC < NKC). The vowel category, [u], is located in high-front vowel position as an effect of the preceding palatal consonant [j]. With the aim of assessing the category separability, the seemingly adjacent vowels were examined. As for the NEC group, [ε^{1}] in *elephant* and its closest vowel, [ɑ^{1}] in *crocodile*, was significantly different from one another [$F(2,8) = 15.658$, p

< 0.013, $\eta_p^2 = 0.797$]. The univariate test showed that the F1 frequency for [**ɛ**[1]]*lephant* was significantly lower (higher in vowel space) than that for *cr*[**ɑ**[1]]*codile* [$F(2,8) = 35.229$, $p < 0.013$, $\eta_p^2 = 0.797$]. When the vowel pairs that share the same orthographic spelling were compared, only one pair, *cr*[**ɑ**[1]]*codile* and [**ɑ**[2]]*ctopus* [$F(2,8) = 23.269$, $p < 0.013$, $\eta_p^2 = 0.853$], differed significantly from one another. The F2 frequency for *cr*[**ɑ**[1]]*codile* was higher (more fronted) than [**ɑ**[2]]*ctopus* [$F(1,9) = 38.203$, $p < 0.013$, $\eta_p^2 = 0.809$]. The other two pairs, however, were not significantly different: [**ɛ**[1]]*lephant* - *t*[**ɛ**[2]]*lephone* [$F(2,8) = 0.119$, $p > 0.013$, $\eta_p^2 = 0.029$] and [**æ**[1]]*nimal* - *f*[**æ**[2]]*mily* [$F(2,8) = 1.024$, $p > 0.013$, $\eta_p^2 = 0.204$].

The EBC group revealed the same results. The [**ɛ**[1]]*lephant* and *cr*[**ɑ**[1]]*codile* showed a significant difference [$F(2,8) = 37.908$, $p = 0.014$, $\eta_p^2 = 0.654$] in F1 frequency [$F(1,9) = 9.739$, $p < 0.014$, $\eta_p^2 = 0.520$]. Also, there was a significant difference between *cr*[**ɑ**[1]]*codile* and [**ɑ**[2]]*ctopus* [$F(2,8) = 37.908$, $p < 0.013$, $\eta_p^2 = 0.905$] with [**ɑ**[2]]*ctopus* produced with the tongue further back in the mouth than its counterpart [$F(1,9) = 52.945$, $p < 0.013$, $\eta_p^2 = 0.855$]. However, [**ɛ**[1]]*lephant* - *t*[**ɛ**[2]]*lephone* [$F(2,8) = 0.241$, $p > 0.013$, $\eta_p^2 = 0.057$] and [**æ**[1]]*nimal* - *f*[**æ**[2]]*mily* [$F(2,8) = 3.268$, $p > 0.013$, $\eta_p^2 = 0.450$] were not statistically different.

Out of the eight overlapping vowel pairs shown in NKC group's production, only one pair returned a significant difference [$F(2,8) = 16.370$, $p < 0.006$, $\eta_p^2 = 0.804$]. *f*[**æ**[2]]*mily* was produced with significantly higher F2 frequency (more fronted) [$F(1,9) = 36.152$, $p < 0.006$, $\eta_p^2 = 0.801$] than [**ɛ**[1]]*lephant*. However, the rest of the vowel pairs were not distinctive from each other: [**ɛ**[1]]*lephant* - *t*[**ɛ**[2]]*lephone* [$F(2,8) = 6.771$, $p > 0.006$, $\eta_p^2 = 0.629$], [**æ**[1]]*nimal* - *f*[**æ**[2]]*mily* [$F(2,8) = 0.883$, $p > 0.006$, $\eta_p^2 = 0.181$], *cr*[**ɑ**[1]]*codile*- [**ɑ**[2]]*ctopus* [$F(2,8) = 3.984$, $p > 0.006$, $\eta_p^2 = 0.499$], [**ɛ**[1]]*lephant* - *cr*[**ɑ**[1]]*codile* [$F(2,8) = 1.771$, $p > 0.006$, $\eta_p^2 = 0.307$], [**ɛ**[1]]*lephant* - [**ɑ**[2]]*ctopus* [$F(2,8) = 3.230$, $p > 0.006$, $\eta_p^2 = 0.447$], *t*[**ɛ**[2]]*lephone* - *cr*[**ɑ**[1]]*codile* [$F(2,8) = 0.201$, $p > 0.006$, $\eta_p^2 = 0.048$], *t*[**ɛ**[2]]*lephone* - [**ɑ**[2]]*ctopus* [$F(2,8) = 8.130$, $p > 0.006$, $\eta_p^2 = 0.670$]. As shown in the figure, [ɛ] were differentiated from [æ] but it was [ɛ] and [ɑ] vowel categories that showed the greatest overlap due to the high [ɑ] vowel production. Although the adjusted alpha level ($p < 0.006$) was stricter for the NKC group, it should be noted that none of the above vowel pairs passed the alpha level ($p < 0.013$) set for the other child groups.

The extensive overlap among stressed vowel categories found in the NKC group showed that, unlike the NEC and EBC groups, the Korean children with the least L2 exposure were unable to execute distinctive vowel targets. Considering the centralization of stressed vowels in NKC group's production, it is likely that they will show an extensive overlap with the following unstressed vowels.

With the goal of examining the separability between stressed and following unstressed vowels, the spectral qualities of the six words representing the three vowel categories ([ɛ] '*elephant*, *telephone*', [æ] '*animal*, *family*', [ɑ] '*octopus*, *crocodile*') were further investigated. The F1 and F2 frequency values of the following unstressed vowels were taken from the previous study (Oh 2011). In Figure 2, the following unstressed vowels are indicated by grey shades. Note that each unstressed vowel is indicated with the same phonetic symbol as the corresponding stressed vowel (e.g., [æ^1] for '[**æ**]*nimal*' and [æ^1] for an[**ə**]mal).

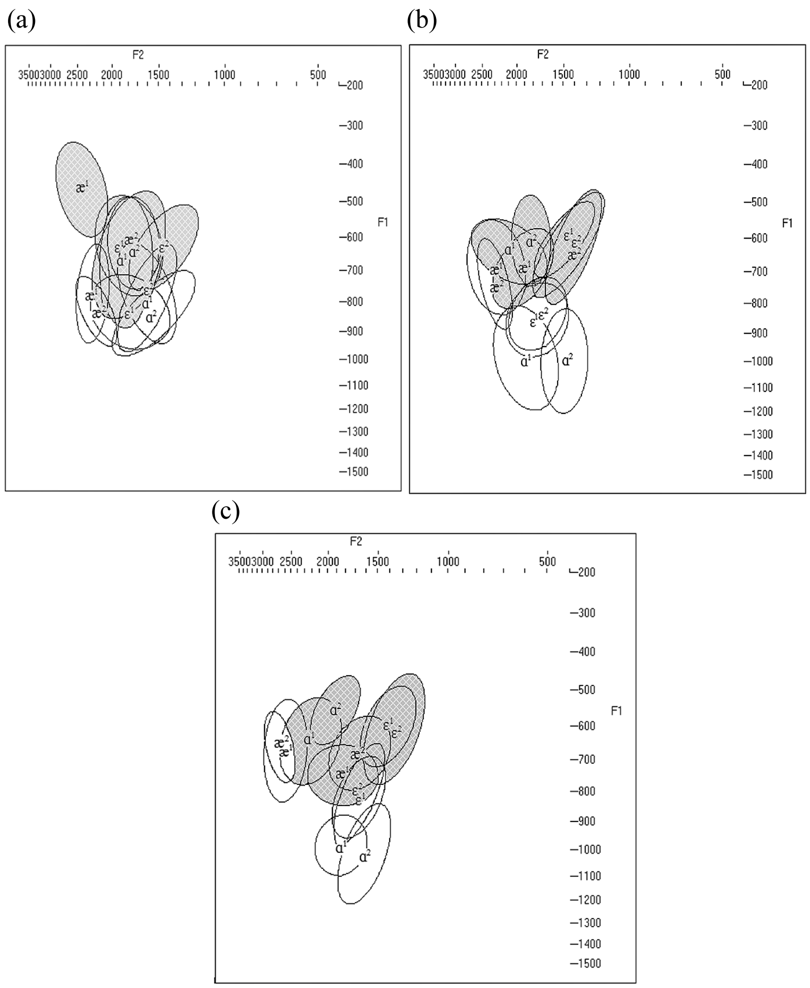

Figure 2. Normalized F1 and F2 frequencies of seven English stressed and unstressed (shaded grey) vowels in the first and second syllables produced by (a) Native Korean learners of English Child (NKC), (b) Early Bilingual Child (EBC) and (c) Native English-speaking Child (NEC) groups are shown. Six target stressed and unstressed vowels (shaded) are indicated with the same phonetic symbols as below:
ε^1 – *elephant*, ε^2 – *telephone*, æ^1 – *animal*, æ^2 – *family*, ɑ^1 – *crocodile*, ɑ^2 – *octopus*

Figure 2 shows that the degree of overlap between stressed and the following unstressed vowels among the three child groups' production decreases with increase in the amount of English experience. The vowels produced by the NEC group showed the least overlap between the stressed and the following unstressed vowels compared to the other two groups. To investigate the perceptual contrasts between the stressed and unstressed vowels produced by the three groups, the perceptual distance between the two consecutive (stressed and unstressed) vowels was calculated. As suggested in Yang (1996), the acoustic differences across vowels should be converted and evaluated to better approximate the perceived distances among the vowels. Greater perceptual distance between stressed and unstressed vowels suggests greater perceptual differences, and thus greater distinctiveness between the two speech sounds. The equation used to estimate the distance is as follows (see Lindblom (1986), Lee et al. (2006)):

$$D_{ij} = \sqrt{(M1_i - M1_j)^2 + (M2_i - M2_j)^2}$$

This equation transforms the M1 and M2 frequencies of stressed and unstressed vowels, i and *j*, into *mel*. F1 and F2 were converted to M1 and M2 respectively, using the conversion formula (1000/log(2)) (log(f/1000+1)) (Fant 1968). A perceptual distance of the six pairings of stressed and unstressed vowels (i.e., *elephant*, *telephone*, *animal*, *family*, *crocodile*, *octopus*) was averaged for each participant and compared across groups. Larger distance indicated more dispersion between stressed and unstressed vowels in vowel space. The average acoustic distance between unstressed vowels is presented for each group in Table 4.

Table 4. Average perceptual distance (in *mel*) between stressed and unstressed vowel pairs (standard error is shown in parentheses)

Words /Group	NEC	EBC	NKC
Animal	355(42)	178(30)*	301(20)
Family	475(38)	468(23)	307(23)*
Elephant	244(29)	267(18)	199(15)
Telephone	248(25)	248(22)	161(20)
Crocodile	329(17)	344(24)	162(26)*
Octopus	415(15)	375(33)	232(30)*
Average	344(28)	314(25)	227(22)*

A significantly different group is indicated with *. ($p < .01$)

As shown in Table 4, the smallest perceptual dispersion was found for the NKC group. The significant difference was found between the NEC and NKC as well as between the EBC and NKC groups. However, the NEC and EBC groups did not show any statistical difference (p=.309). When each word was examined independently, the stressed and unstressed vowels in ***tele**phone* and ***ele**phant* did not return a significant group effect ($p > .01$) as the stressed vowel [ɛ] is more centrally located, and thus intrinsically closer to unstressed vowels in vowel space. The other four words, however, significantly differed across the three groups: *animal* [$F(2,27) = 8.088$, $p = 0.002$, $\eta_p^2 = 0.375$], *family* [$F(2,27) = 10.760$, $p = 0.000$, $\eta_p^2 = 0.444$], *crocodile* [$F(2,27) = 19.672$, $p = 0.000$, $\eta_p^2 = 0.593$], *octopus* [$F(2,27) = 12.619$, $p = 0.000$, $\eta_p^2 = 0.483$]. As the result of EBC group's production of lower F2 for stressed vowels and higher F2 for unstressed vowels, *animal* returned a significantly smaller perceptual difference compared to the other groups. Except for the word *animal*[1], however, the perceptual difference between the stressed and unstressed vowels was mostly found between the NEC/EBC groups and NKC groups. The smaller perceptual distance in the NKC group reflects a smaller perceptual difference and smaller use of vowel space between the stressed and unstressed vowels of the six words.

3. Discussion

In the comparison of the three child groups differing in their age of L2 exposure and the amount of L2 experience, the bilingual children were comparable to the NEC group in producing the stressed vowels of multisyllabic words. The two groups showed a greater separability across all the vowel categories than the NKC group. As for the NKC group, four vowels [**æ**^{1}]*nimal*, *f*[**æ**^{2}]*mily*, *cr*[**ɑ**^{1}]*codile*, [**ɑ**^{2}]*ctopus,* differed from the NEC group while the remaining three vowels, [**ɛ**^{1}]*lephant*, *t*[**ɛ**^{2}]*lephone,* *c*[**u**]*cumber*, revealed greater accuracy. Considering the frequency of the stimuli (taken from COCA: Corpus of Contemporary American English), the least frequent word was *octopus*, following the next infrequent words such as *cucumber* and *crocodile*. NKC group's inaccurate production of *crocodile, cucumber*, and *octopus* (see Table 3) may be attributed to the low word frequency in input. The most frequent words such as *animal* and *family*, however, appeared to have a different reason for their nonnative-like production. Especially, distinctively low F1 and high F2 frequencies of the unstressed vowels for *animal* suggest that NKC children show a strong influence of orthographic symbols (i.e., 'i' in animal produced as [i]). Acquiring L2 words that are frequently used the L1 speaking environment can affect the phonetic representations of the L2 sounds. What this suggests is the importance of considering L2 learners' length of L2 experience in the L1-speaking country.

In the previous experiment, when the NKC group was asked to produce monosyllabic words containing stressed vowels, [ɛ] and [ɑ] (e.g., *pet*, *box*),

[1] Although the perceptual distance between the stressed and unstressed vowels for *animal* was not significantly different between the NEC and NKC groups, the low F1 and high F2 values for the unstressed vowel *an*[ə]*mal* was likely to be produced as /i/ as an effect of orthographic symbols. Thus, the similar perceptual distance should not be seen as native-like.

the two vowels were shown to be native-like (Oh 2011: 55). When the same stressed vowels were produced in multisyllabic words by the same children, however, they were produced with greater variance and less accuracy. As manifested in Figure 1(a), NKC group's stressed vowels tended to merge into the mid-central area in vowel space. In addition, the overlap occurred to the greatest extent, and consequently the distance between stressed and unstressed vowels was the shortest for the NKC group (see Figure 2(a)). Unlike EBC and NEC groups who showed strong coarticulatory effects on the unstressed vowels (Browman and Goldstein 1992), NKC group's unstressed were more concentrated around the center of the vowel space. The smaller effect of the surrounding consonants and the convergence of the unstressed vowels may indicate that KE adults have created an acoustic target for English unstressed vowels in the vicinity of schwa /ə/ (Oh 2011) or even Korean high-central vowel /ɨ/ (Lee et al. 2006). Consequently, inaccurate articulatory targets for the stressed vowels and a strong convergence and overlapping across the following unstressed vowels led to the smallest perceptual distinction between the successive vowels.

The result is consistent with Kondo's (2009) study on Japanese speakers' production of English stressed and unstressed vowels. The merged F1 and F2 values of stressed and unstressed vowels were interpreted to indicate Japanese speakers' insensitivity to the changes in vowel qualities associated with the presence or absence of stress (Kondo 2009: 111). Because the Japanese pitch accent system has little effect on vowel quality, even Japanese speakers with extensive amount of English experience (up to 10 years) were unable to differentiate stressed and unstressed vowels in production. On that same note, the concentration of stressed and unstressed vowels shown in the NKC group may be attributed to the different phonological system between Korean and English. Especially for the later Korean learners of English, the smaller differentiation between stressed and unstressed vowels reflects the under-attended phonetic features in the English prosodic system.

As previously stated, the acquisition of reduced vowel qualities has been viewed as an important yardstick for assessing the native-likeness of lexical prosody in English (Lee et al. 2006, Zuraiq and Soreno 2007, Kondo 2009). However, distinctive vowel qualities of the stressed vowels in multisyllabic words should also be accounted in relation to the following unstressed vowels to determine the native-like acquisition of prosodic properties in English. This study contributed to a better understanding of early bilinguals' L2 acquisition of prosodic features. Although the use of highly frequent stimuli and a small sample size calls for a careful interpretation of the general trends, the results argue for the early bilinguals' native-like acquisition of stressed vowels in multisyllabic words. Taken together with the production and perceptual results, the early bilinguals have not only acquired the native-like spectral qualities in the segmental domain but also in the prosody at the lexical level.

There are over 450,000 U.S.-born ethnic Koreans residing in the U.S. and the abundant resources these immigrants provide for linguistic research on bilingualism have been led to the increasing demands on areas of research in second language acquisition. Examining the early form of bilingual children's speech productions of the two languages is expected to provide a multifarious and integrated view on the effect of age and experience on the L1-L2 interaction in bilinguals' speech production.

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