

The Interaction of the Bilingual's Two Phonetic Systems: Differences in Early and Late Korean-English Bilinguals

Wendy Baker
Brigham Young University

1. Introduction

One of the basic questions of bilingual research is to what extent the bilingual's two phonetic systems influence each other, a question that has occupied a prominent place in bilingual research almost from the outset of the field (see, for example, Weinreich, 1953). Recent studies in bilingual first language acquisition (BFLA) demonstrate that, at least in simultaneous bilingual acquisition, infants exposed to two languages are developing what appear to be two phonetic/phonological systems from the beginning (Johnson and Wilson, 2002; Kehoe, 2002; Bosch and Sebastian-Galles, 2001, Vihman, 2002), although their two systems may differ from monolinguals of either language (Mack, 1989; Bosch, Costa, & Sebastian-Galles, 2000).

In late bilingualism (i.e., when a second language is learned in adulthood), where one language system is already established when a second is learned, most likely a separate system for the second language does not develop in the beginning. In fact, most researchers agree, at least as initial stages of L2 learning, adults perceive and produce both native (L1) and second language (L2) vowels and consonants ("sounds" for short) as instances of similar L1 sounds. In fact, it is only after extensive exposure to the second language that separate long-term memory representations (categories) for L2 sounds are formed, if at all (Flege, Meador, & MacKay, 1999).

The differences between these two types of bilingualism indicate that several factors most likely influence both the extent the two languages influence each other and the direction of the influence (Flege, 1995; Piske, Flege, McKay, & Meador, 2002; Khatib, 2002). The purpose of this study is to examine how two factors, the amount of similarity between native (L1) and second-language (L2) sounds, and age at the time of second language learning, determine how the L1 and L2 phonetic systems interact both at initial and more advanced stages of L2 learning.

The first factor, the amount of similarity between L1 and L2 sounds (or cross-language similarity), at least in late L2 learning, heavily determines how much the L1 influences the L2 (Flege, MacKay, and Munro, 1999; Best, 1995; Flege, 1995). In particular, the more similar L2 sounds are to L1 sounds, the more likely the L1 will influence how L2 sounds are perceived and produced. For example, Flege, Bohn, & Jang (1997) showed that learners of English perceived and produced English vowels differently depending on their native language. In addition, Aoyama, Flege, Guion, Yamada, & Akhane-Yamada (2003) have determined that Japanese learners of English identify English /r/ as being more similar to Japanese /r/ than this Japanese consonant is to English /l/. These same Japanese learners are more likely to produce English /r/ more accurately than English /l/. These and many other studies indicate that cross-language similarity is an important factor in how much the L1 and L2 interact in bilinguals (Best, 1995; Guion, Flege, Akhane-Yamada, & Pruitt, 2000).

The second factor that may influence the organization of a bilinguals' L1 and L2 phonetic systems is the learner's age at the time of learning a second language. In particular, in early bilinguals (i.e., those that learn a second language in childhood), the native language seems to exert less of an influence on the perception and production of the L2, suggesting that cross-language similarity may play less of a role in early than in late bilinguals (Baker, Trofimovich, Mack, and Flege, 2001). . For example, Flege, MacKay and Meador (1999) found that early Italian-English bilinguals were more accurate in their perception and production of English vowels than were late Italian-English bilinguals,

regardless of the degree of similarity between English and Italian vowels. Similarly, Aoyama, Flege, Guion, Yamada, & Akhane-Yamada (2003) determined that early Japanese-English bilinguals over the course of 1 year were able to improve in the production of English /r/ and /l/ more than late bilinguals. These studies suggest that age at the time of learning a second language plays a significant role on how much of an influence the L1 has on the perception and production of the L2. That is, the L1 exerts a greater degree of influence on the L2 of late than early bilinguals (Munro, Flege, & MacKay, 1996; Mack & Trofimovich, 2001; Piske, Flege, MacKay, & Meador, 2002).

One hypothesis for these differences between early and late bilinguals is that, because their native language system is still developing, early bilinguals are less likely than late bilinguals to identify L2 sounds with L1 sounds at the onset of L2 learning (Baker, Trofimovich, Mack, & Flege, 2002). This may be because, as L1 segment categories develop through childhood (Ohde, Haley, & McMahon, 1996; Sharma, Kraus, McGee, & Nicol, 1997; Hazan and Barrett, 2001), they become more powerful attractors of L2 segments, exerting a greater influence on how the L2 is perceived and produced (Flege, 1992; Walley & Flege, 1999). Thus, adults, because their native system is fully developed, are more likely than children to equate L2 sounds with L1 sounds. If this is indeed the case, then it would explain why the two phonetic systems interact with each other less in early than late bilinguals. The purpose of this study is to test this hypothesis.

Thus this current study examines whether, because children's L1 sounds are less powerful attractors of L2 sounds, early bilinguals are less likely than late bilinguals to identify L2 with L1 segments at the onset of L2 learning and (2) whether this likelihood translates into the two phonetic systems interacting with each other less in early than late bilinguals. In particular, it was predicted that (1) for both early and late bilinguals the degree of influence of the two languages on each other would be greater for similar than less similar sounds, (2) early bilinguals would be less affected by the cross-language relationships in their production of English and Korean vowels than would late bilinguals in initial stages of L2 learning, and (3) in later stages of L2 learning early bilinguals would be more likely than late bilinguals to keep their two languages separate. To test these hypotheses, two experiments were conducted. In Experiment 1, early and late native Korean speakers with little English experience judged and rated the similarity between English and Korean vowels. In Experiment 2, beginning early and late native Korean learners of English, as well as more advanced early and late bilinguals produced six Korean and eight English vowels in CVC word contexts. The influence of the two languages on each other was investigated by comparing whether bilinguals were able to produce differences between English and Korean vowels.

2. Experiment 1: cross-language identification

The purpose of Experiment 1 was to determine whether children are less likely than adults to identify L2 sounds as L1 sounds, which in turn might explain why the L1 and L2 phonetic systems of children and adults influence each other differently. To explore this hypothesis, 20 native Korean speakers (10 children and 10 adults) were asked to judge the similarity between English vowels and Korean vowels in a cross-language perceptual identification task.

2.1 Participants

The participants of this experiment were 10 child (mean age: 8.8; range: 7-9 years) and 10 adult (mean age: 22.7; range: 20-23 years) native Korean speakers who had resided in the U.S. for on average less than 1 year. The participants were recruited based on their limited English ability, with the goal that both the children and adults would have as similar English experience to each other as possible. The participants completed a language background questionnaire that determined their English language experience. Answers to this language background questionnaire revealed that the children had, on average, 2.3 months in the United States (range: 2-16 months) and none had experience with English previously, whereas the adults had resided in the United States for 4.3 months (range: 1-18 months) and had limited exposure to native English speakers before coming to the United States. Participants also rated their ability to speak, comprehend, read, and write English on a 10-point Likert scale (where "1" = "I don't know any English" and "10" = "I am a native speaker of English).

The adults rated their ability to use English on average 3.2 and the children rated their ability on average 4.2. Participants (or their parents) also estimated the amount of time they spoke English daily. Adult participants spoke English on average 44% of the time and children on average 32% of the time. Statistical analyses indicated that the children and adults did not differ significantly from each other on any of these demographic variables. The answers on this language background questionnaire confirmed that the participants had limited English ability.

2.2 Stimuli

In order to examine how the participants judged the similarity between English and Korean vowels, 8 were selected because pairs of these vowels (English /i/-/ɪ/, /u/-/ʊ/, /æ/-/ɛ/, /ɑ/-/ʌ/) are often confused by Korean learners of English) and they are difficult to learn (Flege, Bohn, & Jang, 1997). These English vowels were placed in 3 phonetic contexts in English monosyllabic CVC words (Table 1).

Table 1: English stimuli used in Experiment 1

/i/	/ɪ/	/ɛ/	/æ/	/u/	/ʊ/	/ʌ/	/ɑ/
<i>beat</i>	bit	bet	bat	<i>boot</i>	book	but	<i>bought</i>
<i>neat</i>	knit	net	gnat	<i>nuke</i>	nook	nut	<i>not</i>
<i>heed</i>	hid	<i>head</i>	had	who'd	hood	<i>hut</i>	<i>hot</i>

The English words were recorded by 3 male monolingual English speakers (average age: 24) who were untrained in second language acquisition, linguistics, or phonetics. The stimulus words were recorded using a Shure unidimensional head-mounted microphone (model: SM10A) and Sony DAT tape recorder (model: TCD-D8). The monolingual speakers produced each word in a carrier phrase “I say ---- for you” in random order. Each word token was subsequently excised from the carrier phrase and the best token of each word (based on its clarity) was selected for inclusion in the experiment. The resulting 144 words (24 stimulus words × 3 speakers × 2 repetitions) were digitized at 16 kHz, ramped off during the first and last 15 msec to eliminate audible clicks, and normalized for peak intensity and perceived loudness.

2.3 Procedure

In this experiment, participants were tested individually in a quiet room and the stimuli were presented using presentation software (Smith, 1997). Over headphones, the participants heard each token twice in each trial. The first time the participants heard the English token (cross-language vowel identification), participants selected one of the 10 vowels of standard Korean (represented orthographically in Hangeul characters on a computer monitor) to which the English vowel in the token was most similar. The second time the participants heard the same English token (similarity-ratings), they rated the degree of similarity between the English vowel they heard and the Korean vowel they chose on a 7-point scale. On this scale a “1” indicated that the vowels across the two languages “sounded very dissimilar” and a “7” indicated that they “sounded very similar.” Importantly, the task required the participants to choose one of the Korean vowels and to guess if unsure. Participants had an unlimited time to choose the response alternative, but were unable to change their choice once it was made.

2.4 Results

The vowel-identification responses were analyzed by determining how many times each participant classified each English vowel with its modal (most frequent) Korean response alternative. For example, the Korean vowel chosen most in response to tokens of English /i/ (and therefore was the modal response alternative) was Korean /i/. Similarity-rating responses were analyzed by computing a participant’s mean similarity rating between each English vowel and its modal Korean response alternative.

The children and adults selected the same Korean vowel as the primary (modal) response

alternative in their classification of each English vowel. That is, for each English vowel, both children and adults chose one Korean vowel that they perceived as being most similar to the English vowel. The modal responses alternatives for each English vowel, as well as the percent of the time each was chosen, were as follows for both the adult [A] and child [C] groups: English /ɑ/—Korean /a/ (A: .73, C: .66); English /Δ/—Korean /Δ/ (A: .51, C: .42); English /i/—Korean /i/ (A: .92, C: .79); English /ɪ/—Korean /i/ (A: .68, C: .58); English /u/—Korean /u/ (A: .83, C: .61); English /ʊ/—Korean /u/ (A: .61, C: .39); English /æ/—Korean /ε/ (A: .67, C: .44); English /ε/—Korean /ε/ (A: .57, C: .39).

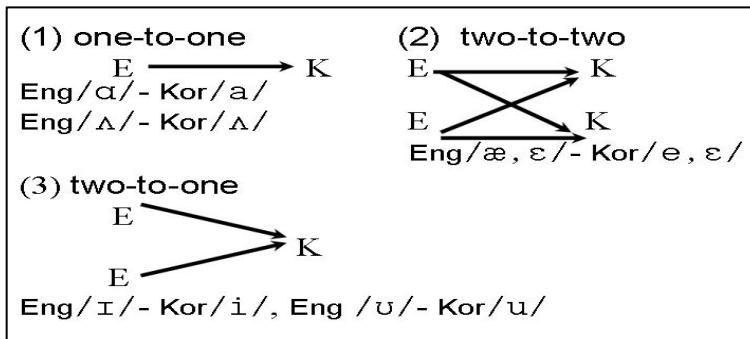


Figure 1: Cross-language relationships between English and Korean vowels

In addition, the English (E) and Korean (K) vowels fell into 3 types of cross-language perceptual relationships. The first type consisted of those vowels across the two languages that were perceived on a *one-to-one* basis. That is, one English vowel was identified with one Korean vowel, such as Eng /ɑ/—Kor /a/; Eng /Δ/—Kor /Δ/. These vowels were very similar across the two languages. The second type consisted of those vowels that were perceived on a *two-to-two* basis. In this case, two English vowels were identified with two Korean vowels: E /æ/, /ε/—K /ε/, /ε/. Because two vowels were chosen an almost equal number of times for both these English vowels, these vowels were considered highly dissimilar from a single Korean vowel. Finally, the third type were vowels that were perceived on a *two-to-one* basis. That is, two English vowels were identified with one Korean vowel: E /i/, /ɪ/—K /i/, E /u/, /ʊ/—K /u/. These vowel-pairs were highly confusable across the two languages, and one of the English vowels was perceived as being highly and one less similar to the same Korean vowel.

To determine whether children and adults differ in their judgments of similarity between L1 and L2 sounds, a two-way (group × vowel) ANOVA comparing the groups' frequency of identification of each English vowel with its modal Korean response alternative was performed. This analysis yielded a significant main effect for group [F(1,58)=7.72, p=.007] and vowel [F(7,406)=28.79, p=.001] and a significant group × vowel interaction [F(7,406)=2.45, p=.018]. Further tests of simple main effects demonstrated that the children were less likely than the adults to choose the modal Korean vowel response alternatives for 5 of the 8 English vowels—English /æ/, /ε/, /i/, /ʊ/, and /u/ (Bonferroni tests (t-tests with α adjusted for number of pairwise comparisons) indicated that these comparisons were significant (p<.05). A two-way (group × vowel) ANOVA was also performed on the cross-language similarity ratings. This analysis yielded a significant main effect for vowel [F(7,105)=3.08, p=.005] and a significant group × vowel interaction [F(7,105)=3.14, p=.005]. Further tests of main effects demonstrated that the children rated the similarity between English /ɑ/, /Δ/, /ε/ and Korean /a/, /Δ/, /ε/, respectively, lower than did the adults (p<.05). In summary, these results indicate that the children were less likely than the adults to identify English vowels as instances of Korean vowels. Moreover, children rated the similarity between English and Korean vowels lower than did the adults. This tendency reached significance for all English vowels except English /ɪ/. These findings suggest that children are less likely than adults to identify English vowels with Korean vowels. Importantly, these differences were maintained across all the cross-language vowel types identified above.

The findings that children were less likely to identify English vowels with Korean vowels, as well as the grouping of cross-language vowel pairs into these three types of relationships will provide the basis for examining the extent to which the L1-L2 interaction is determined by the perceptual similarity between these English and Korean vowels.

2.5 Discussion

The results of experiment 1 suggest that age may influence how the L1-L2 phonetic systems are organized. In particular, the native Korean children were less likely to identify English (L2) vowels with Korean (L1) sounds. These findings may provide at least one reason why the L1 and L2 influence each other differently in early than in late bilinguals. The results of this study also suggest that the cross-language similarity between L1 and L2 sounds also differs depending on the L1-L2 vowel pairs. That is, both the children and adults identified three different types of cross-language relationships between English and Korean vowels. In particular, some of the English vowels were judged more similar to their modal Korean vowel response alternative than were others. These findings provide the basis for testing the extent to which age and cross-language similarity influence how much the L1 and L2 influence each other.

3. Experiment 2: comparisons of English and Korean vowels

The purpose of Experiment 2 was to determine whether and how cross-language similarity (as determined in Experiment 1) influences how early and late bilinguals' two languages influence each other. In particular, three hypotheses were proposed. First, it was hypothesized that less similar vowels across English and Korean would be more likely to be produced differently from each other than those that were judged as being more similar to each other. Second, based on the results of Experiment 1, it was also hypothesized that late bilinguals' production of English and Korean vowels would depend more than early bilinguals' production upon the perceived cross-language similarity between these vowels. Moreover, it was hypothesized that, with extensive experience with English, early Korean-English bilinguals would be more likely than late bilinguals to separate their two languages, regardless of cross-language similarity. To test these three hypotheses, early and late Korean-English bilinguals with either 1 year or 7 years of English experience were asked to produce 24 English vowels and 14 Korean vowels in a picture-naming task.

3.1 Participants

Forty native Korean speakers participated in Experiment 2. These forty participants were divided into four groups depending on their age at the time of exposure to English and the amount of experience they had had with English (see Table 2). The first two groups, the "Late+1" and "Early+1" groups (where the "+1" indicates an average of 1 year of U.S. Residence), were recruited based on their similarity to those native Korean speakers who participated in Experiment 1. That is, both groups had been exposed to English in the U.S. for about 1 year (mean: Late+1, 0.6; Early+1, 0.8), but differed in their age of English acquisition: The Late+1 group had arrived in the United States on average at 24.3 years old (range: 21-25) and the Early+1 group had arrived on average at 9.9 years old (range: 7-13). The two groups also rated their ability to read, speak, write and comprehend English on a scale from 1 ("I don't know any English") to 10 ("I am a native speaker of English"). The Late+1 group rated their English ability on this scale on average 6.1 and the Early+1 group rated their ability on average 4.5. The two groups also estimated their amount of daily Korean use as on average 56% of the time. Based on these demographic characteristics, both the Early+1 and Late+1 groups were considered to be beginning English speakers.

Two other groups were also included in the experiment to test the hypothesis that more experienced early bilinguals would be more likely than late bilinguals to produce differences between similar English and Korean vowels (i.e., keep their two languages separate). The third group in this study, the "Late+7" group (where the "+7" indicates an average of 7 years of U.S. residence) had been exposed to English in the U.S. as adults (mean age of exposure: 22.6; range: 15-30). The fourth group, the "Early+7" group had been exposed to English in the U.S. as children (mean age of exposure: 8.8; range: 7-13). These two groups had considerably more experience with English than the first two groups (mean amount of exposure: Late+7, 6.9; Early+7, 8.0) but they differed based on their age of

arrival in the U.S. In addition, the two groups rated their English ability significantly higher than the Late+1 and Early+1 groups (Late+1, 6.7; Early+7, 7.8), but used Korean daily equally as often as did the less experienced groups (Late+1, 55%; Early+7, 40%). Based on these demographic characteristics, the Late+7 and Early+7 groups were considered to be advanced English speakers.

Table 2: Characteristics of participants in Experiment 2

		Age ^a	AOA ^b	LOR ^c	K. Use ^d	E. Rate ^e
Late+1	(10)	24.9 (1.5)	24.3 (1.7)	0.6 (1.5)	56%	6.1 (1.9)
Early+1	(10)	10.7 (2.2)	9.9 (2.3)	0.8 (0.6)	56%	4.5 (2.8)
Late+7	(10)	29.5 (6.8)	22.6 (5.1)	6.9 (3.3)	55%	6.7 (1.8)
Early+7	(10)	16.9 (3.3)	8.8 (2.9)	8.0 (0.7)	40%	7.8 (2.0)

^aCurrent age, in years. ^bAge of arrival in the U.S., in years. ^cLength of U.S. residence, in years. ^dPercent of daily Korean use. ^eEnglish self-rating from 1 to 10. (Standard deviations are in parentheses.)

3.2 Stimuli

The stimuli for this experiment consisted of the same 8 English vowels (/i/, /ɪ/, /ε/, /æ/, /u/, /ʊ/, /ʌ/, /ɑ/) used in Experiment 1 (see Table 3). The vowels were located in 24 monosyllabic words that differed slightly from the words used in Experiment 1. The words were changed slightly from those in Experiment 1 to make them representative of picturable concrete images, or more suitable for the picture-naming task. The words were elicited from a female native English speaker (age: 31) using the same procedures as those used to elicit the stimuli for Experiment 1.

Table 3: English stimuli used in Experiments 1 and 2

/i/	/ɪ/	/ε/	/æ/	/u/	/ʊ/	/ʌ/	/ɑ/
beat	bit	pet	bat	boot	book	bug	pot
bead	big	bed	bad	bood	good	bud	pod
heat	hid	head	had	hoop	hood	hut	hot

In addition, the stimuli for this experiment also consisted of 7 Korean vowels (/i/, /ɪ/, /ε/, /e/, /u/, /ʌ/, /ɑ/) in 14 mono- and bi-syllabic words (see Table 4—Korean words are written in transcribed English equivalents; English translations are listed below each word in parentheses). These Korean vowels were chosen because, of the 10 Korean vowels in Experiment 1, they were perceived to be the most similar to English vowels. The words were elicited from a female native Korean speaker (age: 26) using the same procedures as those used to elicit the stimuli for Experiment 1.

Table 4: Korean stimuli used in Experiment 2

/i/	/a/	/u/	/ʌ/	/ε/	/e/	/ɪ/
bihang (flying)	bap (rice)	bukchae (drumstick)	passot (mushroom)	paygay (pillow)	pekomp (bear)	Tungdae (lighthouse)
hita (heater)	hakyu (school)	hooshik (dessert)	hakgan (barn)	hayum (swim)	habit (sun)	hooksek (black)

3.3 Procedure

To elicit the 24 English and 14 Korean words, participants were asked to participate in a picture-naming task. In particular, participants were tested individually in a quiet room or sound-attenuated booth. Participants were randomly assigned to either produce all the Korean or all the English words first. The words were randomly presented three times to the participants. The first time the participants saw the pictures representing each of the Korean or English words, they heard the name of the picture over the computer's loudspeakers and were asked to repeat the word. The second and third

times they saw the pictures they were asked to remember the name of the picture and to repeat it as soon as they saw the picture. If they were unable to remember the name of the picture, they heard the name over the loudspeakers and then repeated the word. By the third time they saw the picture, most participants were able to repeat the name of the picture without a prompt. This allowed for spontaneous productions of the words. Participants were recorded using a Shure unidimensional head-mounted microphone (model: SM10A) and Sony DAT tape recorder (model: TCD-D8).

3.4 Acoustic measurements

Each participant's third production of each of the English and Korean words were used for the analysis. In most cases, these productions were spontaneously produced. The words were excised from the speech stream and were submitted to an acoustic analysis. The analysis included 960 English and 560 Korean word productions (40 native Korean participants x 14 Korean and 24 English words).

Acoustic analyses of the bilinguals' English and Korean words were performed to obtain an accurate measure of the interaction between the two languages. The English and Korean vowels were analyzed by measuring the first three vowel formants (F0, F1, F2) in two locations in each token, onset of vowel and vowel midpoint, although only the measurements at vowel midpoint were used in the analysis. The vowel formants were measured using Bliss (Brown Linguistics Speech Software, Mertus, 2001) and were measured both by hand and by using LPC measurements.

These measurements were then converted to Bark scale (B) to normalize for gender and age differences in vowel production (Syrdal & Gopal, 1986). The following formula was used to convert F0 values to Bark scale: $B0 = 26.81/(1+(1960/F0)) - 0.53$. The same formula was used to compute B1 and B2, where F1 and F2, respectively, were substituted for F0 in the preceding formula. Next, the formant frequencies were transformed to two values: B1-B0 and B2-B1. B1-B0 is an estimate of vowel position in the high-low dimension, where lower numbers represent low vowels and high numbers represent high vowels. B2-B1 is an estimate of vowel position in the front-back dimension, where lower values represent back vowels and higher values represent front vowels. Thus, the independent variables in the analysis were the participants' B1-B0 and B2-B1 measurements of each Korean and English words' vowel formant frequencies.

3.5 Results

The acoustic measurements were submitted to statistical analysis in order to explore the three hypotheses of this study. First, the four groups' B1-B0 (vowel height) values were submitted to a three-way (group x vowel x language) ANOVA which yielded a significant main effect for group, vowel and language (all $F's > 37.21$; $p < .0001$). In addition significant group x vowel, vowel x language, and group x language interactions were also obtained (all $F's > 2.3$; $p < .001$). A similar analysis of the four groups' B2-B1 (vowel frontedness) values also revealed a significant main effect for group, vowel, and language (all $F's > 36.66$; $p < .001$) and significant group x vowel, group x language, and vowel x language interactions (all $F's > 14.07$; $p < .001$). Further analyses explored how the inexperienced early and late Korean-English bilinguals' productions of English and Korean vowels differed from each other and from the more experienced bilinguals.

3.5.1 Hypothesis 1

First examined in the analyses was the hypothesis that more similar vowels across the two languages would influence each other more than would vowels that are less similar across the two languages. In particular, it was hypothesized that bilinguals should be less likely to produce differences between vowel pairs perceived on a one-to-one basis across the two languages (English-Korean vowel pairs that were highly similar to each other) than those that were perceived on a two-to-two basis (English-Korean vowel pairs that were relatively dissimilar to each other or those that were perceived on a two-to-one basis (English-Korean vowel pair where two English vowels were perceived as nearly equally similar to a single Korean vowel). A second hypothesis, based on the results of Experiment 1, was that the inexperienced early bilinguals (Early+1 group) would be less affected by the cross-

language relationships in their production of English and Korean vowels than would the inexperienced late bilinguals (Late+1 group). If this is indeed the case, it would suggest at least one reason for differences between early and late bilinguals.

To examine these hypotheses, B1-B0 (vowel height) and B2-B1 (front/back) values of the participants' production of English vowels and their modal Korean response alternatives (as determined by Experiment 1) were compared to each other to determine whether the bilinguals produced the two vowels differently. For example, the Korean vowel that was perceived (i.e., identified) as most similar to English /i/ was Korean /i/. Therefore, statistical analyses determined whether the participants produced Korean /i/ and English /i/ differently from each other. Table 5 lists all the English vowels, their modal Korean vowel response alternatives and their B1-B0, B2-B1 values.

Thus, the Early+1 groups' B1-B0 values (vowel height) for both English and Korean were submitted to a two-way (language x vowel pair) ANOVA, which yielded a significant main effect for vowel and group, and a significant group x vowel interaction (all $F's > 4.89$; $p < .0001$). A similar analysis examining the group's B2-B1 values (vowel front/backedness) yielded a significant main effect for vowel, group, and a significant group x vowel interaction (all $F's > 17.62$; $p < .0001$). Next, a similar analysis of the B2-B1 and B1-B0 values for the Late+1 group was conducted. These analyses for the Early+1 groups' B1-B0 values (vowel height) yielded a significant main effect group, vowel and a significant group x vowel interaction (all $F's > 3.34$; $p < .001$). Similarly for the group's B2-B1 (vowel front/backedness) values a significant main effect for vowel and group and a group x vowel interaction were obtained (all $F's > 6.76$; $p < .0001$).

Table 5: B0-B1/B2-B1 for English and Korean vowels of inexperienced bilinguals

	Early + 1	Late + 1
1. one-to-one		
Eng /i/ - Kor /i/	3.2/11.1-3.1/11.3	3.1/10.4-3.2/11.1
Eng /u/ - Kor /u/	4.0/5.1 - 3.7/6.8	3.1/5.2-3.1/5.5
Eng /ɑ/ - Kor /a/	7.3/3.0 - 7.2/2.9	6.7/2.9-6.2/3.8
Eng /ʌ/ - Kor /ʌ/	5.6/3.8 - 4.9/3.8	5.9/3.0-5.6/4.1
2. two-to-two		
Eng /æ/ - Kor /ɛ/	6.7/5.8-4.8/8.4*	6.1/6.4-4.7/8.6*
Eng /ɛ/ - Kor /ɛ/	6.3/6.2-4.8/7.9*	5.9/6.0-4.2/8.5*
3. two-to-one		
Eng /ɪ/ - Kor /i/	3.8/9.7-3.1/11.3*	3.3/10.1-3.2/11.1
Eng /ʊ/ - Kor /u/	4.6/5.4-3.7/5.3	3.3/5.9-3.2/5.5

* $p < 0.01$; ** $p < 0.001$

Further exploration of the main effects revealed that the neither of the two groups (Early+1 and Late+1) produced significant differences between any of the vowel pairs perceived on a one-to-one basis, such as English /i/ and Korean /i/, or those cross-language vowel pairs that were the most similar to each other across the two languages (Bonferroni adjustment, $p < .01$). (See Table 5, where the B1-B0 and B2-B1 values for both the Korean and English vowels are listed for both the Early+1 and Late+1 groups—where significant differences in the production of the English and Korean vowels occur, the values are listed in bold.) In contrast, both groups produced significant differences between those English-Korean vowel pairs perceived on a two-to-two basis, such as English /æ/ and Korean /ɛ/, those cross-language vowel pairs across the two languages that were least similar to each other; (Bonferroni adjustment, $p < .01$). These two findings confirmed the first hypothesis that less similar vowels across the two languages would be more likely to be produced with significant differences from each other than those that are more similar across the two languages, regardless of the age of L2 acquisition. (In all analyses, significance was reported only when both the B1-B0 and the B2-B0 analyses were $p < .01$.)

3.5.2 Hypothesis 2

Moreover, analyses of those vowels that are perceived on a two-to-one basis across the two languages demonstrated that the Early+1 group produced a difference between the confusable vowels English /ɪ/ and Korean /i/ (Bonferroni adjustment, $p < .01$) but the Late+1 group did not. Because the younger learners were able to produce differences between highly confusable vowels across the two languages, this finding seems to suggest that the younger L2 learners are less influenced by the cross-language similarity of the two languages than are the older L2 learners. These findings thus support the second hypothesis of this study.

3.5.3 Hypothesis 3

The final hypothesis examined in this study was that, with more experience, early bilinguals' two languages should interact with each other less than those of late bilinguals. This hypothesis was first examined by completing similar analyses to those performed on the inexperienced bilinguals' English and Korean vowel production. That is, the Early+7 and Late+7 groups' formant frequency values for similar English and Korean vowels were submitted to statistical analyses to determine if they were able to produce differences between them. In particular, a two-way (language x vowel pair) ANOVA on the Early+7 groups' B1-B0 values (vowel height) yielded a significant main effect for vowel and group and a significant group x vowel interaction (all F 's > 6.01 ; $p < .0001$). For the B2-B1 values (vowel front/backedness) similar results were obtained (all F 's > 6.43 ; $p < .0001$). Analyses examining the production of English and Korean vowels by the Late+7 group for the B1-B0 values (vowel height) also revealed a significant main effect for vowel and group (all F 's > 21.79), but no group x vowel interaction ($F = 1.10$; $p = .36$). For the B2-B1 values (vowel front/backedness), a significant main effect for group and vowel and a significant group x vowel interaction were obtained (all F 's > 3.47 ; $p < .001$).

Table 6: B0-B1/B2-B1 for English and Korean vowels of experienced bilinguals

	Early + 7	Late + 7
1. one-to-one		
Eng /i/ - Kor /i/	2.0/11.9-2.4/11.1	2.7/10.0-2.6/10.7
Eng /u/ - Kor /u/	2.8/ 6.5-2.7/6.5	3.1/6.2-2.9/5.3
Eng /ɑ/ - Kor /a/	6.8/2.5-6.2/3.4	6.6/3.2-5.5/3.9
Eng /ʌ/ - Kor /ʌ/	5.6/4.2-4.9/4.8	5.5/3.8-4.9/4.7
2. two-to-two		
Eng /æ/ - Kor /ɛ/	6.2/5.9-3.2/9.6*	5.4/6.1-4.2/8.2**
Eng /ɛ/ - Kor /ɛ/	5.1/7.4-4.2/8.4*	5.3/6.4-4.4/7.7*
3. two-to-one		
Eng /ɪ/ - Kor /i/	3.4/9.4-2.4/11.1*	2.9/9.9-2.6/10.7
Eng /u/ - Kor /u/	4.2/5.8-2.7/6.5*	3.4/5.7-2.9/5.3

* $p < 0.01$; ** $p < 0.001$

Further tests of main effects for vowel revealed that, like the Late+1 and Early+1 groups, the Late+7 and Early+7 groups did not differ in their production of highly similar English and Korean vowel pairs, such as English /i/ and Korean /i/, or those perceived on a one-to-one basis across the two languages (Bonferroni adjustment, $p < .01$). (See Table 6, where the B1-B0 and B2-B1 values for both the Korean and English vowels are listed for both the Early+7 and Late+7 groups—when significant differences in the production of the English and Korean vowels occur, the values are listed in bold.) Similarly, like the Early+1 and Late+1 groups, the Early+7 and Late+7 groups did produce differences between highly dissimilar English and Korean vowel pairs, such as English /æ/ and Korean /ɛ/, or those perceived on a two-to-two basis across the two languages (Bonferroni adjustment, $p < .01$).

Interestingly, the Early+7 group also produced differences between highly confusable English and Korean vowel pairs, such as English /ɪ/ and Korean /i/, as did the Early+1 group. The Early+7 group also produced differences between one English-Korean vowel pair that the Early+1 group did not,

English /u/ and Korean /u/. In contrast, the Late+7 group, as did the Late+1 group, did not produce any differences between either of the English-Korean vowel pairs perceived on a two-to-one basis across the two languages. Such findings suggest that early bilinguals are more likely than late bilinguals, with more experience, to separate their two language systems. That is, the native language of the early bilinguals exerted less of an effect on early than on late bilinguals. These findings support the hypothesis that early bilinguals two languages systems interact with each other less than do those of late bilinguals. One of the reasons why these differences occur, based on the findings of Experiment 1, is that younger bilinguals are less likely than older bilinguals to identify L2 sounds with L1 sounds in the initial stages of L2 learning.

3.6 Discussion

Acoustic analyses of early and late bilinguals' production of L1 and L2 segments confirmed the hypotheses proposed at the onset of this experiment. Examination of similar vowel pairs across the two languages confirmed the first hypothesis that bilinguals would be more likely to produce differences between very dissimilar than between very similar vowel pairs across the two languages, regardless of their age of L2 acquisition. Second, as was hypothesized, early bilinguals were more likely than late bilinguals to produce differences between English and Korean vowels, at least for those vowel pairs that were confusable across the two languages.

Finally, as was hypothesized, in later stages of L2 learning, early bilinguals were more likely than late bilinguals to maintain a distinction between their native and second language. In particular, the Late+1 and Late+7 groups did not differ in their ability to produce differences between English and Korean vowels, even though the Late+7 group had considerable more experience with the second language than did the Late+1 group. In contrast, the Early+1 and Early+7 did differ in their ability to produce differences between English and Korean vowels. The Early+7 group was able to produce differences between one more Korean-English vowel pair than was the Early+1 group. This difference between early and late bilinguals may have been because early bilinguals' L1 categories are still developing as they learn the second language. Thus, children are more likely than adult L2 learners to keep their two languages separate.

4. General discussion

This study examined the influence of cross-language similarity and age at the time of L2 acquisition on the organization of a bilinguals' L1 and L2 phonetic systems. In particular, this study tested three hypotheses. The first hypothesis was that more similar vowels across the two languages would be more likely to influence each other than those that are less similar across the two languages. The findings of this study indicated that this hypothesis was upheld: Both early and late bilinguals were more likely to produce differences between English and Korean vowel pairs that were relatively dissimilar from each other more than those that were relatively similar to each other. In fact, the extent to which L1 and L2 segments interacted depended on how perceptually similar those segments were.

The second hypothesis of this study was that, because early bilinguals are initially less likely than late bilinguals to associate L2 sounds with L1 sounds, they would also be more likely to maintain differences between L1 and L2 vowels even at initial stages of L2 learning. This hypothesis was also upheld by the results of this study: Even at beginning stages of L2 learning, early bilinguals were more likely than late bilinguals to produce differences between English and Korean vowels, especially those that were the most confusable across the two languages. Such findings suggest that, as occurs in bilingual first-language acquisition, younger L2 learners have two phonetic systems even at the onset of learning a second language.

The final hypothesis of this study was that, because they are less likely initially to identify L2 sounds with L1 sounds, with more L2 experience, younger L2 learners would be more likely than older L2 learners to keep their two languages separate. This hypothesis was also supported by this study. Early bilinguals were able to produce differences between highly confusable English and Korean vowel pairs after 7 years of L2 experience. In contrast, late bilinguals with a similar amount of English experience were not able to do so. These findings suggest that the native language exerts a lesser

degree on the second language for early than for late bilinguals, or that the early learners were better able to separate at least some L2 sounds from L1 sounds.

These findings suggest that late bilinguals maintain only one phonetic system (L1) even after several years of being exposed to and speaking the L2. In contrast, these findings seem to suggest that early bilinguals maintain two separate phonetic systems, and do so from the onset of L2 learning. Thus, early bilinguals, even those who learn their L2 in later childhood (like the participants in this study) learn sounds more similarly to simultaneous bilinguals than to adult L2 learners. Further analyses will reveal the extent to which these early and late bilinguals are able to maintain separate categories (long-term memory representations) for L1 and L2 sounds and the nature of these categories, providing greater insight in how cross-language similarity and age of L2 acquisition influence the organization of a bilinguals' two phonetic system. In addition, further analyses will explore the nature of the relationship between highly similar vowels across the two languages, or those sounds which neither the early nor the late bilinguals were able to separate across the two languages.

In summary, the findings of this study shed light on why there are differences between the two phonetic systems of early and late bilinguals. In particular, because the L1 categories are still developing when the second language is learned, early bilinguals develop a separate system for native- and second-language sounds. In contrast, adults, because their native-language system is completely developed by the time they learn a second language, develop categories that resemble a unidirectional influence from the L1 to the L2. In short, these findings demonstrate that the state of the bilinguals' native language system at the time of second-language learning and the amount of similarity between native- and second-language segments may explain why there are differences in how the two languages interact in early versus late bilinguals.

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