An Acoustic Study of the American English Pronunciation of Recently Arrived Korean Adult Immigrants*

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This research examines the production of English high and mid front vowels (/i ɪ e ɛ/) by three groups of male Korean speakers whose length of residence in the United States has been relatively short: less than 1 year, 1-5 years, and 5-8 years. Acoustic analyses reveal several statistically significant differences among the three groups. For example, the high front vowels /i/ and /ɪ/ of the 'less than 1 year' group are significantly lower in front tongue constriction than the other groups. Furthermore, the 'less than 1 year' and '1-5 years' groups produce American English /i/ with a shorter duration than that of the '5-8 years' group. When these L2-English production data are compared to those of the corresponding native Korean vowels /i e ɛ/, one finds interference effects: both the degree of fronting for English /i/ and /ɪ/ as well as the duration of English /i/ exhibit Korean-like characteristics. While these results confirm that L1 transfer effects can be documented in the English-language pronunciation of recently arrived Koreans, they are noteworthy in that they suggest that there is a significant reduction of these L1 interference effects in a relatively short period of time.

Key words: acoustic phonetics, English as a Second Language, interference, Korean, length of residence, vowel

1. Introduction

One of the recurring issues in the second language acquisition (L2)

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literature is the varying degree to which L2 learners successfully acquire native-like pronunciation of the target language. Many researchers have tried to explain this variability in pronunciation success in terms of non-linguistic factors such as the learner's sex, occupation, age of arrival in the L2 environment, and length of residence (LOR) in the L2 speech community (Asher & Garcia, 1969; Suter, 1976; Tahta, Wood & Loewenthal, 1981; Flege, Bohn & Jang, 1997; Larsen-Freeman & Long, 1997; Moyer, 1999; Piske, MacKay & Flege, 2001). LOR, the topic of this study, is one of the most controversial factors. Some studies suggest that LOR is not significant for any subjects (Fatham, 1975; Thompson, 1991; Munro, 1993) while others argue that the LOR effect is significant for many subjects, even for those who might enter the L2 environment after age 16 (Asher & Garcia, 1969; Flege, Bohn & Jang, 1997; Piske, MacKay & Flege, 2001). Flege and Fletcher (1992) claim that one possible reason that some researchers find an LOR effect whereas others do not is that each study examined different ranges of LOR. More specifically, Flege and Fletcher note that some of the studies that do not find a significant LOR effect on pronunciation performance have considered only a narrow range of LOR values (e.g., LOR < 10 years).

Anecdotal accounts, however, suggest that the most recently arrived learners to the L2 speech community (e.g., those for whom LOR is less than 1 year) speak with a more readily discernable "L1 accent" than do those L2 speakers who have arrived less recently. Such observations indicate that at least some details of phonological and phonetic L1 interference are dissipated soon after arriving in the L2 community: in a short period of time, a second language learner may have improved a particular aspect of his/her L2 pronunciation while still maintaining a more global L1 accent, an accent that quite often persists in the long-term.

With such an assumption in mind, this study focuses on more specific aspects of L2 pronunciation and illustrates how very subtle phonetic differences in L2 language output can be correlated with differences of even short lengths of residence. More specifically, this work examines the production of English front vowels by adult Korean learners whose relatively short length of residence in the United States differs: <1 year, 1-5 years, 5-8 years.[1] In seeking an explanation for the observed L2-speaker

1) There were three reasons for dividing LOR into these particular three groups. First, it was assumed that a subjects' language ability would be similar to his or her initial language

behaviors, the discussion turns to a comparison of data of L2-English front vowels[2)] and corresponding native Korean vowels. Acoustic analyses of the relevant data serve the aim of addressing the following three issues:

1. The ways in which English vowels produced by a Korean speaker differ from those produced by native English speakers;
2. The ways in which the English vowel pronunciations of more recently arrived Koreans differ from those of less recently arrived subjects; and
3. The extent to which Korean (L1) pronunciation manifests itself in the production of English (L2) vowels.

The results of the study indicate that while some L1 vowel characteristics transfer into the English production of recently arrived Koreans, these effects are reduced in a relatively short period of time.

2. Background

2.1. Acoustic and Articulatory Characteristics of Vowels

Central to any analysis of L2 vowel acquisition is the task of discerning the often complex relationship between phonological categories and their corresponding phonetic correlates. L2 vowel categories are frequently represented by the same symbol as putatively corresponding L1 vowels. Yet while one L2 vowel category might roughly correspond to a particular L1 vowel category, there are rarely exact phonetic similarities (Yang, 1996). Acoustically, each vowel has its own specific qualities, which can be defined in terms of its formant frequencies (usually first two formants, F1 and F2) and duration (Ladefoged & Broadbent, 1956; Yallop & Clark, 1990; Pickett, 1999). As has been amply attested in the linguistic literature, the values of vowel formants are reflections of the size and shape of the vocal tract. For example, the value of the first formant (F1) is inversely

learning during the first year abroad. Second, most subjects, who were university students, finish their studies in a five year period; during this time, it is expected that they will have established a consistent and reasonable oral proficiency in English. Third, Kim (1994) suggest that subjects who have been in the L2 area for at least 8 years may have reached the upper limits of second language acquisition.

2) Front vowels were chosen in anticipation of specific first language interference effects, as will be discussed in section 2.

correlated with articulatory vowel height: A lower F1 value corresponds to a higher tongue position in the oral cavity, while a higher F1 value corresponds to a lower tongue position. The value of the second formant (F2) is correlated with vowel fronting: a lower F2 value corresponds to a lower degree of vowel fronting (i.e., a more back vowel), while a higher F2 value corresponds to a greater degree of vowel fronting (Stevens, 1998; Pickett, 1999). By referencing these formant frequencies, the phonetic profile of the vowels in any language can be distinguished from one another. For example, the English high front vowel [i] manifests an F1 frequency around 250 Hz and F2 frequency around 2200 Hz (as spoken by a male speaker). In comparison, English high back [u] displays a similar F1 value-indicative of its height similarity-but a different F2 value (approximately 800 Hz for [u]), a physical reflex of [u]'s relatively more backed and rounded articulation (Pickett, 1999).

When comparing typical F1 and F2 values for vowels across two or more languages, consistent patterns are found, but only in the broadest sense. Between vowels in two languages that are said to represent the "same" linguistic category (and are thereby designated by the same phonetic symbol), the average formant values differ (to varying degrees). This reality serves as one source of what is commonly referred to as a "foreign accent:" Even in cases where it is said that L1 and L2 correspond to one another (in the sense of Stockwell and Bowen, 1983), L2 learners tend to pronounce target language vowels by adopting vocal tract configurations and durations for corresponding (or nearly-corresponding) L1 segments. As such, even when an L2 learner has successfully mastered the relevant phonemic distinctions in the target language, his/her pronunciation may still come across as "foreign" for purely phonetic reasons.

2.2. Korean Vowels Versus English Vowels

2.2.1. Vowel Quality of Corresponding L1 and L2 Vowels

What, then, is expected in the way of L1 interference on the pronunciation of English vowels by native speakers of Korean? An answer to this question must begin by acknowledging that the acoustic space occupied by phonemically "same" (or similar) vowels in English and Korean vowels differ. In a study that examines the native language vowel production of English and Korean male speakers, Yang (1990) finds that even though Korean manifests a distinction between /e/ and /ɛ/, neither of these are

exactly the same as English phonetic values corresponding to /e/ or /ɛ/: English /e/ as realized by native English speakers has a mean F1 of 469 Hz and a mean F2 of 2082 Hz; English /ɛ/ has a mean F1 of 531 Hz and a mean F2 of 1900 Hz. In contrast, Korean /e/ spoken by a Korean male speaker was reported to have a mean F1 of 484 Hz and a mean F2 of 1969 Hz while Korean /ɛ/ had mean F1 and F2 values of 612 Hz and 1879 Hz, respectively. In terms of each segments' location in the vowel space, Korean /e/ sits in a position lower than English /e/ but higher than English /ɛ/, while Korean /ɛ/ lies lower than English /ɛ/ and higher than English /æ/ (See also Ku, 1998).

2.2.2. Tense/Lax Contrast

One of the prominent differences between the English and Korean vowel systems is that English contrasts tense and lax vowels (e.g., /i/~/ɪ/ and/e/~/ɛ/)[3] while Korean does not. In the case of the English contrasting vowel pairs, the so-called "tense" vowel is higher and more fronted than the corresponding "lax" vowel. For example, Ku (1998) shows that the mean F1 and F2 values for /i/ produced by an American male native speaker of English are around 270 and 2270 Hz respectively, while the mean F1 of /ɪ/ is 390 Hz and the mean F2 is 1950 Hz. In addition, the higher and more fronted vowel is always longer than the lower and more backed vowel (Klatt, 1976; Bohn & Flege, 1990). Peterson & Lehiste (1960) report that lower and further back vowels (for example, /ɪ/ and /ɛ/ in context *h-V-d*) are shorter, ranging in duration from 180 to 200 msec, while the higher and more fronted vowels (/i/ and /e/ in the *h-V-d* context) are longer, with a durational range of 240 to 260 msec.

In Korean, the relationship between vowel formant frequencies and duration differs from that of English. Although the Korean high front vowel does not manifest a tense-lax formant distinction, most published sources claim that there is a phonemic length distinction: /i/ 'tooth' *vs.* /i:/ 'two,' and /pi/ 'rain' *vs.* /pi:/ 'ratio.'[4] Similar correspondences can be found for /e/ and /e:/ and /ɛ/ *vs.* /ɛ:/, for example, /ne/ 'your' *vs.* /ne:/

3) Here, the terms "tense" and "lax" are used as convenient cover terms for a distinction that is actually more complex.

4) Ingram and Park (1997), however, claim that this length contrast seems to be disappearing in the Seoul dialect, while an anonymous reviewer asserts that length contrasts have completely vanished in the standard language, especially among younger speakers.

'four,' and /mɛ/ 'whip (noun)' *vs.* /mɛ:/ 'each,' indicating that, in Korean, vowel duration is not (nor probably ever has been) correlated with differences in vowel formants. Based on these facts, it is not surprising that Korean speakers have difficulty in distinguishing and producing the tense/lax vowel distinctions of English.

2.2.3. Vowel Shift and Merge in Korean

Further complicating matters is that vowel shifts and mergers in contemporary Korean may affect Korean speakers' pronunciation of English vowels. One such change in Korean involves vowel rising, a phenomenon commonly found among speakers of the national standard, typically represented by speakers from Seoul (Kahng, 1990; Hong, 1991; Chai, 2001). For example, these researchers found that the Koreans frequently produce the vowel phoneme /e/ as [i] and /ɛ/ as [e]. This latter shift is a manifestation of more generalized merger of the non-high front vowels /e/ and /ɛ/: researchers claim that Seoul speakers do not distinguish /ke/ 'crab' and /kɛ/ 'dog' or /pe/ 'hemp cloth' and /pɛ/ 'pear' (Lee, 1998; Hong, 1991). Due to this merger, one can expect that many Koreans will have difficulty in producing (and, perhaps, perceiving) the contrast between English /e/ and /ɛ/.

3. Method

To investigate the questions posed in section 1, a two-part study was conducted. The first portion of the research examined the production of English (L2) vowels by Korean (L1) speakers; the second focused on the acoustic properties of Korean vowels as produced by native speakers, thereby allowing for a comparison of L2 English vowels with "corresponding" L1 vowels.

3.1. Subjects

For the English L2 vowel experiment, the subjects were thirty native speakers of Korean whose relatively short length of residence in the United States differed: <1 year, 1-5 years, 5-8 years. For the second experiment (i.e., that investigating Korean vowels produced by Koreans), the subjects consisted of a separate group of ten Korean male adults

whose LOR in the United States was less than 4 months and who shared similar backgrounds (e.g., age, education, dialect) with the Korean subjects in the English L2 experiment. All subjects were university students who were recruited by the first author through an approach that involved social networking and personal contacts. Except for the subjects' length of residence in the United States, other variables were controlled so as to minimize any confounding effects.[5] For example, by controlling the sex of speakers, the effect of sex-based biological factors, including the length of vocal tract, were minimized (Asher & Garcia, 1969; Hillenbrand *et al.*, 1995).[6] In addition, all subjects were between 19 and 30 years old, had spent their early-middle childhood years (age 6-9) in the Seoul area, speak the standard Seoul dialect,[7] and had arrived in the United States after age 16.

3.2. Materials and Procedure

To elicit the production of the English vowels /i/, /ɪ/, /e/ and /ɛ/, subjects were asked to read sentences each containing a word with the target vowel in the medial position of the context *h-V-d: heed, hid, hayed,* and *head.*[8] The reason for choosing the vowel in an *h-V-d* context is that the lax vowels are not produced in open syllables, and the fricative /h/ and alveolar /d/ have little influence on vowel formants (Yang, 1996). All words were embedded in a carrier sentence, "Say _____

5) Given that the samples are homogeneous, there is a limit to the generalizability of the sample to the population. However, to reduce the effect of other factors that might affect the L2 pronunciation acquisition, the analysis of data from such a homogeneous sample was deemed a necessary limitation.

6) According to Hillenbrand et al. (1995), the formant values of female speakers are higher than those of male speakers due to the differences in the length of vocal tract of the two genders. In addition to these biological differences, Asher & Garcia (1969) claim that women are better than men in acquiring native-like L2 accent. Therefore, controlling for the subjects' sex was deemed critical to this study.

7) Here, the standard Seoul dialect means "the speech of the educated adults who were born and lived or have lived from childhood in the Seoul area" (Lee, 1971).

8) As one anonymous reviewer noticed, the experiment described here does not include elicitation of the low front vowel of English, /æ/. Omitting this vowel from the present study was a conscious decision, done with an eye toward keeping the analysis focused on those English vowels that enter into a tense-lax relationship. Subsequent research on this topic would most certainly benefit by including /æ/ in the experimental design, thereby shedding light on learning and/or production difficulties with respect to this vowel, which is not found in Korean.

for me." For the Korean vowel experiment, each subject read sentences containing the Korean vowels /i/, /e/ and /ɛ/, also in the context *h-V-da* (i.e., 히다 [hida], 헤다 [heda], and 해다 [hɛda])[9], all nonsense words. These Korean words were embedded in a carrier sentence 이건 _____라고 해요 [igən _____ rago hejo?] 'This is called _____.'

Recording was conducted in a quiet room using a Sony cassette recorder (Sony Model TCM59V) and a high-quality microphone (Sony ECMT6). Before the recording, the speakers filled out a questionnaire, which included questions on age, sex, length of time in the U.S., age of arrival, education, history of English study. Assuming that the subjects needed time to become familiar with the test words, the test stimuli were presented and explained before the recording. The speakers then read a set of randomly ordered cards five times. The speakers were instructed to read the sentences at a self-selected, normal speed. If the speakers read at a non-optimal speed (either too fast or too slow), the speaker was re-instructed about the matter of speed. However, re-instruction was not provided more than once. For analysis, only those data collected for rounds two, three and four were analyzed; the first trial was expected to be somewhat unnatural, and the fifth trial was expected to be distracted.[10]

3.3. Acoustic Analysis

The recorded speech signals were digitized (11 kHz sampling rate and 4.5 kHz low pass filter) and the durations and formants of vowels were analyzed using Speech Analyzer software. The duration of each vowel was measured referencing both waveform and spectrogram displays. The vowel onset was determined at the point where (a) the amplitude suddenly rose in waveform, and (b) all clearly discernible structures for the first three formants (F1, F2 and F3) appeared in the spectrogram. Vowel offset was determined at the point where the amplitude suddenly fell and clear vowel formant structure disappeared (See Figure 1). Given that American English /e/ is most frequently produced as a diphthong, the decision was made to measure only the nuclear (non-glide) portion of

9) The /e/ in Korean in this study is different from the /e/ in American English in that /e/ in American English is a diphthong while the /e/ in Korean is a simple vowel.

10) One anonymous review characterized our policy of excluding rounds one and five as "excessively cautious." We respectfully stand behind our methodological decision.

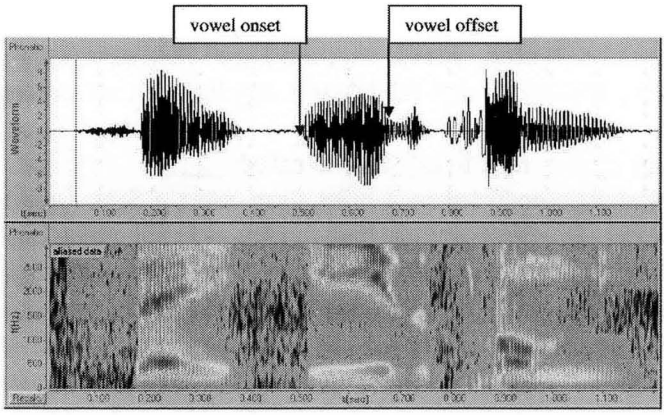

Figure 1. Waveform and spectrum for *Say heed for me* spoken by one subject. Vowel duration was determined by calculating the interval between vowel onset and offset.

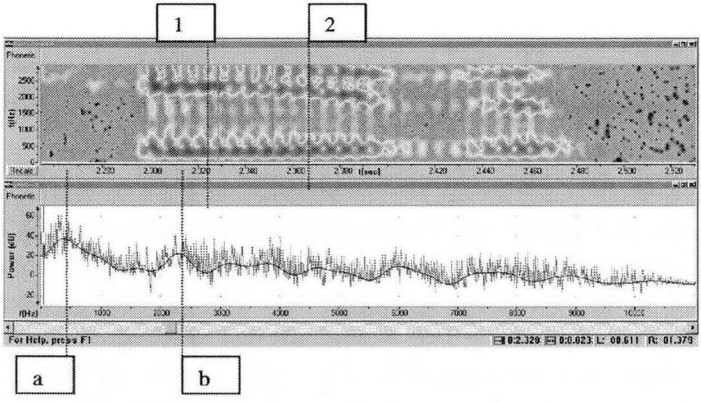

Figure 2. Partial spectrogram (upper) and spectrum (lower) for *say heed for me* spoken by one subject.

the segment; the duration of /e/ was determined by measuring the time between vowel onset and the point in the visual display at which the formant structure indicated the shift into the off glide.

F1 and F2 formant frequencies were measured using both spectrographic and spectral analysis of each vowel's steady state, which was taken as the middle of one-third portion of the total vowel duration (between point 1 and point 2 in Figure 2). From here the formant values in the spectrogram were measured by means of an automatically calculated

averaged spectral analysis. F1 and F2 were identified by placing the cursor on each of the first highest and the second highest amplitude points of the spectral display (a and b in Figure 2).

4. Results

4.1. English Vowel Production

As a summary of the results for Experiment 1, Table 1 presents the mean values for F1, F2, and duration for the L2 English vowels /i/, /ɪ/, /e/ and /ɛ/ as produced by the 30 native Korean-speaking subjects. Initial comparisons of the data associated with each of the study's three LOR groups suggests that for some vowels, there appears to be little change in their acoustic characteristics over time: both duration and format values for tense /e/ are similar across all three groups. Similarly, each vowel's F1 values are relatively stable over apparent time, with F1 values for /i/ and /ɪ/ bearing striking similarities in all cases, ranging from 342 Hz to 359 Hz. More variable are the values for vowel duration and F2, both among vowels and across LOR groups. For example, the duration of tense high /i/ is consistently longer than those of the other three vowels; in addition, the 5-8 years group produced the longest /i/

Table 1. Mean F1 and F2 formant values and durations of the English vowels /i/, /ɪ/, /e/ and /ɛ/ produced by Korean speakers

Mean Vowel Formants (Hz)

	/i/		/ɪ/		/e/		/ɛ/	
Years in U.S.	F1	F2	F1	F2	F1	F2	F1	F2
0~1	350	2071	344	2043	493	1921	571	1737
1~5	335	2193	342	2171	467	1932	542	1737
5~8	345	2309	359	2194	466	1912	588	1790

Mean Vowel Durations (msec)

Years in U.S.	/i/	/ɪ/	/e/	/ɛ/
0~1	91.13	71.00	66.17	90.53
1~5	84.33	64.10	69.27	81.47
5~8	115.27	78.53	68.37	99.26

segments (115 ms), with the <1 and 1-5 years groups producing noticeably shorter sounds (91 ms and 84 ms, respectively). With regard to the second formant, in all of the vowels except tense /e/, one observes a general trend whereby the F2 values increase as the speakers' length of residence increases: for tense high /i/, the mean F2 value for the <1 year group is 2071 Hz, while the mean F2 values for the 1-5 and 5-8 years groups are 2193 Hz and 2309 Hz. These initial overviews of the mean value data make clear that there are interactions between the two primary independent variables in this study--a speaker's LOR and the target vowel.

Confirming these observations are the results of a three multi-factor ANOVA performed using the "Generalized Linear Model" function of SPSS, one analysis for each of the three dependent variables: duration, F1, and F2. Table 2 summarizes the results of the statistical models, in which

Table 2. Summary of the result of ANOVA tests for Vowel Duration, F1, and F2. Degrees of Freedom (df), F-values, and significance (p) values are presented for each factor, both fixed (LOR and Vowel), random (Repetition), and all possible interactions. A "✓" marks those factors and interactions with a p-value less than 0.05.

Dependent Variable		Source	df	F	p
Vowel Duration	✓	LOR	2	26.97	0.005
	✓	Vowel	3	94.98	0.000
		Repetition	2	0.28	0.783
	✓	LOR * Vowel	6	5.88	0.005
		LOR * Repetition	4	1.14	0.383
		Vowel * Repetition	6	0.78	0.603
		LOR * Vowel * Repetition	12	0.38	0.971
First Formant (F1)	✓	LOR	2	08.58	0.036
	✓	Vowel	3	637.50	0.000
		Repetition	2	2.64	0.621
		LOR * Vowel	6	2.04	0.139
		LOR * Repetition	4	0.62	0.657
		Vowel * Repetition	6	0.68	0.673
		LOR * Vowel * Repetition	12	0.74	0.716
Second Formant (F2)	✓	LOR	2	86.35	0.001
	✓	Vowel	3	325.16	0.000
		Repetition	2	0.151	0.871
	✓	LOR * Vowel	6	3.77	0.000
		LOR * Repetition	4	0.57	0.690
		Vowel * Repetition	6	1.54	0.246
		LOR * Vowel * Repetition	12	0.41	0.960

LOR and the target vowel were treated as fixed factors while the three repetitions of each token were accounted for as random (repeated measure) factor. These data indicate that for each of the three dependent variables, both LOR and the quality of the target vowel play a significant role in accounting for the observed variation. Complicating matters, however, is the fact that for two variables, duration and F2, the interaction between LOR and Vowel is revealed as significant. Such a finding indicates that for these two variables, the effects of LOR on a speaker's production will vary depending on the vowel. As noted above, for example, LOR appears to have little effect on the acoustic properties of tense /e/, but seems to make a difference in the production of tense /i/. Given these statistically-determined interactions, it becomes useful to consider the results of two additional series of ANOVA: ANOVAs for each of the target vowels (treating LOR as the primary independent variable) and ANOVAs for each of the LOR groups (treating the target vowel as the primary independent variable).

4.1.1. ANOVAs for Each Target Vowel

Four separate sets of ANOVAs, one for each of the target vowels, reveal mixed results regarding the effects of LOR on duration, F1, and F2.[11] As the data in Table 3 indicate, LOR plays a significant role in five of twelve cases under investigation: duration and F2 of /i/, duration and F2 of /ɪ/, and F2 of /ɛ/. Subsequent *post hoc* tests on each of these five cases reveal the following[12]:

11) In each case, "repetition" was incorporated into the analysis as a random factor; in no case, either here or in section 4.2.2, was repetition or any interaction including repetition significant at the 95% confidence level. As such, we have not included these statistics in the summary tables.

12) Two post-hoc tests were employed in this study: Bonferroni and Dunnet's T3. In each case, the choice of post-hoc depended on whether Levene's Test of Equality of Error Variances indicated that the error of variance of the dependent variable was equal across groups. If so, Bonferroni was employed; if not, Dunnett's T3 was used.

Table 3. Summary of the result of ANOVA tests for the Four Target Vowels. For each of the target vowels, ANOVAs were performed to assess whether LOR was a statistically significant factor in determining duration, F1, and F2. A "✓" indicates significance at $p < 0.05$. Mean values for each dependent variable are provided for ease of reference.

Vowel	Dependent Variable		p	Mean Values for Each LOR Group		
				<1 yr	1-5 yrs	5-8 yrs
/i/	duration (ms)	✓	0.001	91	84	115
	F1 (Hz)		0.207	350	335	345
	F2 (Hz)	✓	0.001	2071	2193	2309
/ɪ/	duration (ms)	✓	0.016	71	64	79
	F1 (Hz)		0.344	344	342	359
	F2 (Hz)	✓	0.000	2043	2171	2194
/e/	duration (ms)		0.788	66	69	68
	F1 (Hz)		0.230	493	467	466
	F2 (Hz)		0.810	1921	1932	1912
/ɛ/	duration (ms)		0.087	91	82	99
	F1 (Hz)		0.074	571	542	588
	F2 (Hz)	✓	0.038	1737	1737	1790

(1) Duration

a. for tense /i/, mean vowel duration is significantly longer for those in the 5-8 years group (115 ms) as compared to the mean durations of /i/ for the <1 and 1-5 years groups (91 ms and 84 ms, no significant difference at $p \leq 0.05$)

b. for lax /ɪ/, mean vowel duration is significantly different between the 1-5 and 5-8 years groups, with mean duration value of the <1 year group falling in between (with no significant difference from the others)

(2) F2

a. for tense /i/, the mean value of F2 is significantly different for each of the groups, increasing with LOR: <1 year = 2071 Hz; 1-5 years = 2193 Hz; 5-8 years = 2309 Hz

b. for lax /ɪ/, the mean value of F2 is significantly lower for the <1 year group (2043 Hz); the mean values for the 1-5 and 5-8 years groups showed no significant difference between them (2171 Hz and 2194 Hz, respectively)

c. For lax /ɛ/, the mean value of F2 is significantly higher for the 5-8 years group (1790 Hz); the mean values for the <1 and 1-5 years groups were identical at 1737 Hz.

Table 4. Summary of the result of ANOVA tests for the Three LOR Groups. For each of the LOR groups, ANOVAs were performed to assess whether the quality of the target vowels was a statistically significant factor in determining duration, F1, and F2. A "✓" indicates significance at $p < 0.05$. Mean values for each dependent variable are provided for ease of reference.

LOR	Dependent Variable		p	Mean Values for Each Vowel			
				/i/	/ɪ/	/e/	/ɛ/
<1 yr	duration (ms)	✓	0.006	91	71	66	91
	F1 (Hz)	✓	0.000	350	344	493	571
	F2 (Hz)	✓	0.000	2071	2043	1921	1737
1-5 yrs	duration (ms)	✓	0.001	84	64	69	82
	F1 (Hz)	✓	0.000	335	342	467	542
	F2 (Hz)	✓	0.000	2193	2171	1932	1737
5-8 yrs	duration (ms)	✓	0.000	115	79	68	99
	F1 (Hz)	✓	0.000	345	359	466	588
	F2 (Hz)	✓	0.000	2309	2194	1912	1790

4.1.2. ANOVAs for Each LOR Group

In a manner parallel to that outlined above, three separate sets of ANOVAs were performed for each of the LOR groups, this time choosing the target vowels as the primary independent variable (see Table 4). Given the gross articulatory differences among the four target segments under investigation (issues of first language interference notwithstanding), it comes as no surprise that vowel quality appears to play a significant role in the realization of duration, F1, and F2 for all three LOR groups. Of more substance are the ensuing *post-hoc* analyses (Bonferroni or Dunnett's T3, as appropriate), whereby the following patterns are revealed:

(1) Duration

a. for all the LOR groups, the durations of /e/ and /ɪ/ are always the shortest and are never significantly different one from the other.

b. for both the <1 year and 1-5 years groups, there is no significant difference in the durations of /ɛ/ and /i/.

c. for the 5-8 years group, the duration of high tense/i/ (115 ms) is significantly longer than that of mid lax /ɛ/ (99 ms), which, in turn, is significantly longer than the duration values of /e/ and /ɪ/.

(2) F1

a. for all three LOR groups, values for F1 fall into three statistically significantly distinct categories: the highest for lax /ɛ/, next highest for tense /e/, and the lowest for /i/ and /ɪ/.

b. F1 values for /i/ and /ɪ/ are never statistically significantly different.

(3) F2

a. For the <1 and 1-5 years groups, F2 values pattern similarly to those for F1: F2 for /ɛ/ is significantly lower than that of /e/, which is significantly lower than those for the high vowels /i/ and /ɪ/.

b. Only for the 5-8 years group are F2 values for all four vowels statistically distinguished.

When the vowel qualities for the four target vowels are plotted in a F1 by F2 space (Figure 3) one can visually confirm the quantitative findings.

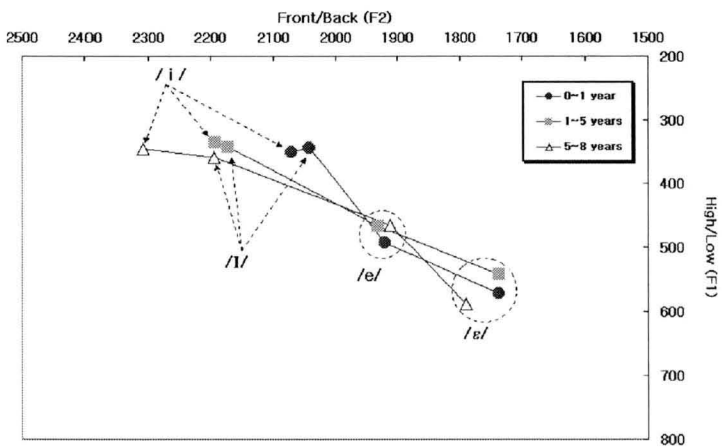

Figure 3. Mean F1 and F2 values for English /i ɪ e ɛ/ as produced by Korean subjects. Speakers in the most recently arrived group (<1 year) produce high vowels that are significantly further back.

One notices, for example, that the regions occupied by the mid vowels are well separated, with relatively small differences among the positions associated with each of the three LOR groups. More specifically, the values for tense /e/ are tightly clustered in the region of F1 = 475 Hz and F2 = 1920 Hz, while the values for lax /ɛ/ are somewhat more spread out in the region of F1 = 570 Hz and F2 = 1750. Each mid vowel occupies a distinct space. In contrast, the high vowels share much of the same acoustic space. Moreover, the locations of the high vowels /i/ and /ɪ/ are systematically shifted forward according to the speakers' increasing LOR. As a result, the front-back distance between the two most extreme vowels, /ɛ/ and /i/, is shortest for subjects in the <1 year group but becomes longer for the 1-5 years group and the 5-8 years group.

4.2. Comparing English and Korean Vowel Pronunciations

Given the reported effects of L1 interference in the production of L2 (Ingram & Park, 1997; Suter, 1976; Brown, 1994; LarsenFreeman & Long, 1997; Kim, 1999; Javis, 2000), the data discussed above were compared with the production of Korean vowels as produced by a separate group of native speakers of Korean. Table 5 represents the mean F1 and F2 formant values and durations of the Korean vowels /i/, /e/ and /ɛ/. Here, it is worth noting that there is no significant difference between the F1 and F2 values of Korean /e/ and /ɛ/.

When the Korean pronunciation data are compared to the English pronunciation data, one finds that the degree of fronting (manifested by F2 values) of the most fronted Korean vowel (/i/) is similar to that of English /i/ pronounced by speakers of <1 year group: this degree of

Table 5. Mean F1 and F2 formant values and durations of the Korean vowels /i/, /e/ and / ɛ / produced by Korean speakers

Mean Vowel Formants (Hz)

/i/		/e/		/ɛ/	
F1	F2	F1	F2	F1	F2
355	1973	544	1756	537	1669

Mean Vowel Durations (msec)

/i/	/e/	/ɛ/
31.10	43.70	40.60

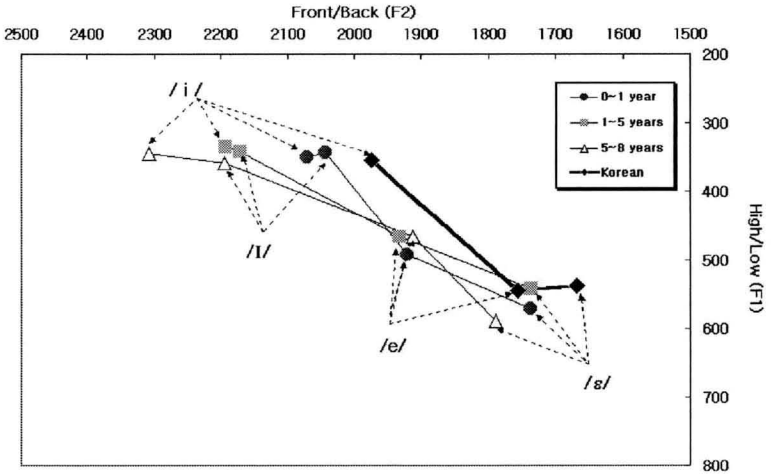

Figure 4. Mean F1 and F2 values for English /i ɪ e ɛ/ and Korean /i e ɛ/ as produced by Korean-speaking subjects. In considering the various manifestations of /i/, we notice that the L1 Korean form is pronounced further back than any of the corresponding L2 English variants.

fronting is less than that of the /i/ vowel pronounced by the speakers of the other Korean ESL groups. With regard to the duration, the duration of Korean /i/ and /ɛ/ is the shortest, and the duration of English /i/ and /ɛ/ produced by the 5-8 years speakers is the longest. Figure 4 plots the L2 English vowels /i/, /ɪ/, /e/ and /ɛ/ pronounced by the speakers of each group, and L1 Korean vowels /i/, /e/ and /ɛ/ pronounced by speakers whose LOR in the United States was less than 4 months. Here, the front/back distance between Korean /ɛ/ and /i/ is more similar to the distance of /ɛ/ and /i/ produced by the speakers in the <1 year group.

5. Discussion

There are three major findings of this study. The first concerns Length of Residence effects: certain details of L2 pronunciation are influenced by even very short LOR periods. Second, there is observable Korean L1 inference on English pronunciation. Third, the Korean front /i/ is pronounced more in a back position than has been previously reported.

Table 6. The average formant values of English vowels pronounced by American male speakers (Ku, 1998)

	/i/	/ɪ/	/e/	/ɛ/
F1	270	390	500	540
F2	2317	1950	1880	1800

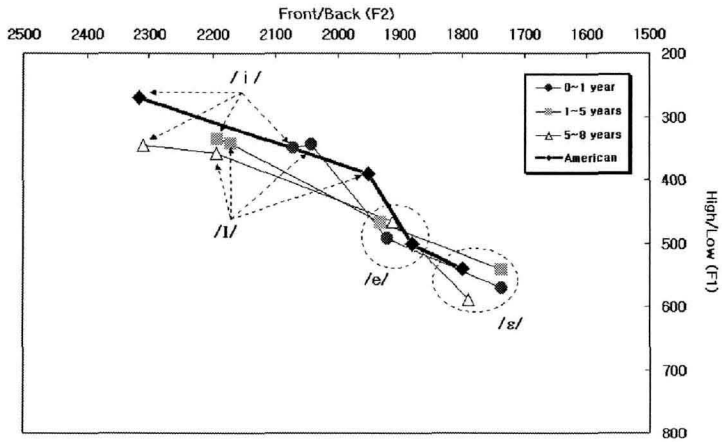

Figure 5. Comparison of the pronunciation of native speakers of American English with that of Koreans. Among the various manifestations of /i/, that pronounced by native speakers of American English is in the most front position. English /i/ produced by subjects in the Korean-speaking <1 year group is least like the English /i/ pronounced by native speakers of English. English /i/ produced by those in the Korean-speaking 5-8 years is noticeably more like the English /i/ pronounced by native speakers of English.

5.1. LOR Effects

While it has been well documented that LOR often influences the degree to which a second language learner accurately produces the L2, this study indicates lengths of residence as brief as one year make a difference in production. For example, the data reveal that for the front English vowels /i/ and /ɪ/, the <1 year speakers produced a significantly lower degree of front tongue constriction than did the speakers in the 1-5 years and 5-8 years groups (Table 1). When these values are compared to those produced by native speakers of American English (Table 6), the acoustic position of the most front vowel pronounced by the native

English speakers, /i/, is similar to those pronounced by the L2 English speakers in the 1-5 years and 5-8 years groups. The relevant comparisons between Korean and American male speakers of the English front vowels /i/, /ɪ/, /e/ and /ɛ/ are illustrated in Figure 5.

With regard to vowel duration, LOR effects are less clear. Speakers in the <1 year and 1-5 years groups manifest rather un-English duration patterns: statistically significant differences in vowel duration are not made along tense-lax lines, as is the case for native speakers of American English. Rather, for these more recently arrived immigrants, the duration of the highest and lowest vowels in the study (/i/ and /ɛ/) is significantly longer than those of the two more "interior" vowels (/ɪ/ and /e/). Additional differentiation among vowel durations appears in the production of speakers in the 5-8 years group. They produced instances of the vowel /i/ with significantly longer durations than those of the other vowels. Moreover, their production of the vowel /i/ was significantly longer than those produced by speakers in the other two groups.

When we compare these duration data with the duration of these vowels produced by American English speakers[13] the durations produced by the 5-8 year group are the most similar to those produced by the L1 English speakers. Here, the mean duration of /i/ vowel produced by native English speakers is 131ms (Bohn & Flege, 1990), and those of 5-8 years, 1-5 years and <1 year groups are 115ms, 84ms, and 92 respectively. These results agree with Asher and Garcia (1969), Flege, Bohn and Jang (1997), and Piske, MacKay and Flege (2001)'s suggestions that LOR has a significant effect on second language acquisition.

Just as this study shows how even short periods of LOR affect specific details of pronunciation in the L2, it also provides evidence that a short LOR does not necessarily affect the ultimate L2 pronunciation. In this study, all of the Korean speakers make a much smaller phonetic distinction between English /i/ and /ɪ/ than do native speakers of American English. This fact confirms a key finding obtained by Kim (1994): in general, Koreans whose English learning onset time is after age 16 find it difficult to successfully distinguish /i/ from /ɪ/. She adds that those Koreans whose L2 onset time is greater than age 16 tend to lack a native-like pronunciation of the lax vowel /ɪ/. However, the present study shows

13) That is, vowels produced in CVC tokens embedded in carrier sentences, i.e. circumstances analogous to those employed in the current study.

that the most recently arrived speakers (<1 year), fail to pronounce the tense /i/ in an Englishlike manner; they pronounce /i/ with significantly less front tongue constrictions than do American English speakers. Interestingly, they pronounce lax /ɪ/ more natively than did the other LOR groups.

5.2. Korean Interference

The results of this study lend additional support to the well-established claim that the native language is an influential factor in L2 pronunciation (Briere, 1966; Hammerly, 1973; Suter, 1976; Flege, 1981; Mitleb, 1984; Flege, 1987; Brown, 1994; Ingram & Park, 1997; LarsenFreeman & Long, 1997; Kim, 1999; Javis, 2000). More specifically, the current work supports claims regarding Korean vowel pronunciation interference in English: the lower degree of fronting of /i/ and /ɪ/ produced by the speakers in the <1 year group can be attributed to the tendency for Korean /i/ to be located further back in the acoustic space than the /i/ of American English. In a similar vein, Flege (1987) finds that English speakers who have less experience in French produce French /u/ with much greater fronting than French monolinguals and therefore produce a more English-like segment. Flege's interpretation suggests that in the case of a similar vowel (French /u/ and English /u/), L2 speakers tend to approximate L1 phonetic norms when they produce the L2 vowel.

Korean speakers also make a less clear distinction between the relative locations of English /i/ and /ɪ/, which again can be attributed to L1 interference. Because Korean manifests no such phonemic contrast, making the tense-lax differentiation is apparently difficult. This result corroborates a related finding of Flege, Bohn and Jang (1997), who claim that when compared to native speakers of American English, Koreans produce a much narrower distinction between the format frequencies of /i/ and /ɪ/.

In the present study, L1 interference also appears to manifest itself in terms of vowel duration: subjects in the <1 year and 1-5 years groups do not make statistically significant distinctions among the four target vowels, a situation that one might anticipate given the nature of Korean vowel duration (see section 2). Subjects in the 5-8 years group seem to have overcome this interference, however, as the data show that they make more English-like length distinctions.

5.3. The Backing of Korean /i/

This study presents the somewhat curious finding that Korean /i/, which has been generally believed to share a similar degree of fronting with the English /i/, is produced with a smaller degree of fronting. The Korean vowel experiment shows that the mean F2 value of Korean /i/ is 1973 Hz, a value that indicates the degree of fronting for Korean /i/ is less than those reported in previous studies. Yang (1990), for example, claims that the F2 value of Korean /i/ for male adults between 18 and 27 years is 2230 Hz. Similarly, Lee (1998) shows that the F2 value of Korean /i/ produced by Korean males (ages 20 to 30 and who live in Seoul) is 2176 Hz.

How can the differences between the results of previous studies and those of this study be understood? In the case of Yang's study, the only difference between the subjects of his study and this study is that his subjects were people who had been in the United States for more than 3 years, whereas the subjects of this study are those who have been in the United States less than 4 months. Therefore, one possibility is to consider that the Koreans who have been in the United States for several years learn the more tensed /i/ pronunciation and longer back/front tongue movement and pronounce the Korean vowel also with a more back/front movement. Additionally, when one considers that his study was conducted in 1990, one might entertain the possibility of language changes in Korean, a change whereby the relevant back/front distance has been reduced during the intervening dozen years. In the case of Lee's study (1998), one must consider the fact that the target vowels were not spoken in a natural context: in his data elicitation materials, Lee presented each vowel within a pair of single quotation marks and used a relatively formal carrier sentence 이것은 '이'라고 합니다 [igəsk n 'i' rago hamnida] 'It is called "i".' As such, there is a distinct possibility that speakers produced the target vowel /i/ in a way that was unnaturally stressed and tensed. In contrast, the vowels presented to subjects in this study appeared a fuller linguistic context (*h-V-da*), with the target words embedded in a more casual carrier sentence 이건 _____라고 해요[igən _____ rago hejo] 'This is called _____', thereby providing a relatively more naturalistic (though still experimentally controlled) situation.

6. Conclusion

Despite its modest scale, this study contributes to our understanding of both Length of Residence effects as well as the acoustic relationship between English and Korean. While most previous research has focused on the degree of native-like pronunciation in a global sense, this study is one of the few that focuses on more specific aspects of L2 pronunciation that might alter the L1 accent (i.e., duration, F1 and F2), and provides more detailed information on the production of L2 language learners. For the high front vowel /i/ and /ɪ/, the <1 year speakers produced a significantly lower degree of front tongue constriction (manifested in terms of F2 values) than did speakers who have resided in the United States for longer periods. When the English pronunciation data were compared to comparable Korean data, it was shown that the lowered degree of the fronting of the Korean /i/ was similar to the degree of fronting of English /i/ and /ɪ/ as pronounced by the most recently arrived (<1 year) speakers. In addition, those in the 5-8 years group appeared to produce the /i/ vowel with longer duration than did other groups. These findings suggest that even though one of the L1 effects-the reduced forward movement of the front vowel and short vowel duration-are directly transferred into the English production of recently arrived Koreans, these effects are reduced in a relatively short period.

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