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The Effect of Age-of-L2 Onset on Ultimate L2 Production: The English /i-ɪ/ Distinction Made by Korean Speakers*

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This instrumental phonetic study investigated a relationship between age-of-L2 onset and ultimate L2 vowel production. Korean speakers' production of English vowels /i/ and /ɪ/ was recorded and analyzed acoustically. It was found that those who began learning English in the United States by the age 15 were able to make a distinction between /i/ and /ɪ/ in terms of formant frequencies and vowel durations. However, those whose English acquisition occurred at age 16 or above failed to make a formant-based distinction of the vowels by producing /ɪ/ with almost /i/-like formant frequencies. Their differentiation of the vowels was excessively based on vowel length with their /ɪ/ being much shorter than the /ɪ/ produced by native English speakers. This shows that the phonetic cues used by late L2 learners in making phonemic contrasts are different from those used by native speakers. The findings here support the sensitive period hypothesis by showing that late L2 learners cannot achieve native-like production ability even after they have been exposed to authentic L2 input in a target country for quite a long period of time (13 years in this case).

I. INTRODUCTION

Some scholars refer to an L2 system as an "approximative" system, a notion similar to that of "interlanguage." A language system created by

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L2 learners is an interlanguage in that it resembles neither a target language nor a native language (Selinker, 1972). Such an independent system, however, approximates the target language system gradually as experience with the target language increases (Nemser, 1971), and in this way, L2 learning occurs. It seems, however, that for most L2 learners, the interlanguage system does not continue to approximate that of the target language indefinitely as a function of experience with it, but usually "fossilizes" at some point and thus can never develop into a perfect or native-like system. This is precisely what the sensitive period hypothesis (Oyama, 1979, hereafter SPH) predicts for late L2 learners.

Fossilized interlanguage involving pronunciation--i.e., a fossilized L2 phonetic system--is characterized by foreign accents. Foreign accents are derived from cross-language differences of phonological/phonetic aspects. To be specific, foreign accents result from L2 learners' maintaining at least some of their native language (L1) phonetic characteristics which are different from L2 phonetic characteristics in their L2 production. To borrow a definition from Flege (1988), a foreign accent is detected by native speakers when L2 production by L2 learners diverges from L2 phonetic norms and thus is not "authentic" in native speakers' judgment even if it is correctly identified and thus deemed adequate.

The present study was undertaken to test the SPH in relation to L2 production. The phonological/phonetic dimension of interest in the present study is the English /i-ɪ/ distinction made by Korean speakers, who began learning English in the United States at varying ages. In order to investigate the ultimate outcome of L2 learning, not the process of it (Krashen et al., 1979), only those Korean learners who are in the final stages of L2 learning were recruited. The study asks the following research question: Does the age at which one began learning a second language in a target country--i.e., age-of-L2 onset--affect second language acquisition such that early L2 learners have an advantage over late L2 learners in terms of eventual L2 production? And, if so, at what

age does L2 learning ability start to decline (i.e., age-of-first decline)?

The reason that the English vowels /i/ and /ɪ/ were chosen as phonological/phonetic dimensions of interest is as follows. The /i/ and /ɪ/ are differentiated in English speech primarily by spectral differences, rather than durational differences, with the vowel /i/ being a high front unrounded tense vowel and the vowel /ɪ/ being a high front unrounded lax vowel (Benett, 1968). Meanwhile, there is no phonemic contrast in Korean between the two vowels, with Korean lacking the /ɪ/. According to traditional approaches to the phonetic and phonological aspects of foreign accent, most difficulties experienced by L2 learners come from crosslinguistic differences in phonemic contrasts, as presented in the contrastive analysis hypothesis (Lado, 1957). Thus, difficulties involving the /i-ɪ/ distinction for Korean speakers of English, if found, would be derived from lack of a corresponding distinctive opposition between these two vowels in Korean. So, it would be of interest to determine if Korean speakers of English differ in differentiating one vowel from the other according to their age-of-English onset. Specifically, a question can be asked as to whether Koreans make use of spectral features as Americans do in their differentiation of the two vowels. One study (Mack, 1985) showed that Korean speakers who began English rather late simply substituted /i/ for /ɪ/. However, this finding was based on impressionistic judgment of the experimenter.

Unlike most previous studies on the SPH, which have focused on global L2 pronunciation requiring native speakers' judgment in assessment (Asher and García, 1969; Seliger et al., 1975; Oyama, 1976; Tahta et al., 1981), the present study used computer-based instrumental methods. It is hoped that the instrumental method adopted in the present study provided a measure of testing the SPH more rigorously in relation to L2 production than has previously been done.

II. EXPERIMENT

1. Subjects

30 Korean speakers of English participated in the experiment as paid subjects. They were first exposed to native English input in the United States at the age of birth to 25 and have stayed in the country for about 15 years on the average, ranging from 8 years to 21 years. Their mean age was 20 years old with the youngest being 17 and the oldest being 42. The majority of the subjects were either studying at the University of Illinois or graduated from university at the time of testing.

The Korean subjects were divided into 5 groups with the age-of-English onset for each group being 0-3, 4-7, 8-11, 12-15, and 16+. Each group consisted of 3 males and 3 females. Length of stay in the U.S. was held constant across the groups in order to investigate non-confounding age effects.

The subjects were all fluent in both Korean and English. Screening was made of them initially through self-evaluation and next through a short interview with the experimenter. After a final selection was made, they filled out a questionnaire asking demographic profiles about them. 3 male and 3 female native English speakers (monolinguals) were also recruited as a comparison group.

2. Materials

Materials consisted of a list of 12 English words. All were of the CVC syllable type (and thus monosyllabic), beginning with a variety of stop consonants and all ending with voiceless stops. Half of the test words contained /i/ (*beat, peak, peep, deep, teak, keep*) and half contained /ɪ/ (*bit, pick, pip, dip, tick, kick*).

3. Procedure and Measurement Methods

The subjects were tested individually in the Phonetics Laboratory at the University of Illinois. Their production was recorded in a sound-attenuated room of the lab using high-quality recording equipments. They read the test words which were presented to them one at a time and in random order. They read them, first, in isolation form and, then, in carrier-sentence form, in which the words were embedded in the carrier sentence, "He knew — was the right word." Each subject read the words and sentences three times, and the presentation of the words with the /i/ and /ɪ/ was done in a counterbalanced order across the subjects. So, some subjects read the words with /i/ first and others read the words with /ɪ/ first.

The number of words used for analysis amounted to 48 words for each subject and 1,728 words in total (12 words x 2 trials x 2 contexts x 36 subjects). The analysis involved the words produced on the first and second trials. Words produced on a third trial were used if any words were unacceptable from the first and second trials.

A waveform computer program designed by Cheng et al. (1988) was used for acoustic analysis. Direct measurements were made from the waveforms of the stimuli words and sentences on the screen which were sampled at 20 kHz. Durational measurements had a sampling accuracy of a tenth of a millisecond.

Vowel durations were first measured by determining the vowel onset and the vowel offset using two vertical cursors placed at each point. The vowel onset was considered at the point at which vowel voicing occurs signalled by a localized increase in the amplitude and regular periodicity. Since all the stimulus words were preceded by stops, the visual location of the vowel onset did not present much of a problem. No aspiration and prevoicing associated with the stops were included as part of the vowel. The vowel offset were also relatively easy to determine as all the stimulus words ended with voiceless stops. It was signalled by a relative

decrease in the waveform amplitude and/or a decrease in complexity followed by a period of silence before the voiceless stop release.

Vowel formants were obtained by placing the left cursor at the midpoint of the vowels as it was believed that the midpoint reflected the steady-state portion of vowels most accurately. The vowel midpoint was determined by calculation once the vowel onset and offset points were obtained.

4. Results

1) Formant Frequencies of the Vowels /i/ versus /ɪ/

Group mean values were computed for formant frequencies--F1, F2, and F3--measured at the midpoint of the vowel /i/ and the vowel /ɪ/. These values are shown in Table 1 and Table 2 for the /i/ and Table 3 and Table 4 for the /ɪ/. It appears that all the subject groups, except the 16+ Korean group, produced /i/ and /ɪ/ with little or no different formant values from one group to another for each vowel and with systematically different formant values between the two vowels. At first glance, it can be seen that the 16+ group produced the /ɪ/ in a way that the formant frequencies of the vowel were quite different from those of the same vowel produced by the rest of the groups (see Table 3 and Table 4). Not only that, it seems that their /ɪ/ had formant values which were not so different from those of the vowel /i/ produced by the same group. These observations have been supported by statistical tests conducted as reported below.

TABLE 1

Mean Frequencies (in Hz) of F1, F2, and F3 at the /i/ Mmidpoint in the Isolation Form

Age-of-L2 Onset Group	F1	F2	F3
		Males	
Native	322.58 (17.25)	2230.75 (21.75)	2912.92 (81.47)
0-3	339.22 (42.56)	2377.61 (176.07)	3099.58 (134.65)
4-7	300.86 (20.46)	2125.06 (161.40)	3120.72 (154.37)
8-11	314.53 (25.36)	2284.69 (279.75)	3127.33 (190.01)
12-15	324.97 (23.25)	2210.50 (244.00)	3236.00 (147.25)
16+	337.44 (8.22)	2225.89 (56.41)	3121.92 (186.49)
		Females	
Native	407.58 (72.79)	2785.33 (138.19)	3411.75 (197.35)
0-3	376.97 (49.30)	3009.53 (51.31)	3648.42 (99.28)
4-7	387.58 (11.16)	2783.11 (141.36)	3413.89 (88.13)
8-11	370.92 (26.31)	2880.08 (70.33)	3426.31 (250.62)
12-15	397.72 (55.33)	2813.75 (67.16)	3596.00 (143.18)
16+	358.31 (33.87)	2911.28 (48.31)	3740.89 (69.27)

TABLE 2

Mean Frequencies (in Hz) of F1, F2, and F3 at the /i/ Midpoint in the Carrier-sentence Form

Age-of-L2 Onset Group	F1	F2	F3
		Males	
Native	328.39 (4.48)	2278.22 (25.96)	2967.92 (25.92)
0-3	334.92 (34.22)	2370.50 (140.28)	3001.00 (180.22)
4-7	303.50 (8.11)	2112.17 (173.81)	3165.58 (82.79)
8-11	307.61 (5.59)	2286.81 (290.61)	3036.25 (182.29)
12-15	342.42 (29.11)	2174.75 (190.45)	3157.19 (197.50)
16+	338.61 (7.08)	2163.78 (115.02)	2975.28 (47.60)
		Females	
Native	361.42 (72.38)	2787.56 (175.58)	3403.81 (152.21)
0-3	332.69 (29.17)	2965.17 (85.59)	3515.19 (175.31)
4-7	363.86 (33.03)	2823.64 (113.22)	3420.22 (85.37)
8-11	328.14 (31.23)	2747.69 (154.35)	3397.61 (224.67)
12-15	374.67 (57.93)	2784.00 (84.65)	3577.97 (173.86)
16+	330.78 (24.75)	2841.78 (100.40)	3593.36 (218.61)

TABLE 3

Mean Frequencies (in Hz) of F1, F2, and F3 at the /ɪ/ Midpoint in the Isolation Form

Age-of-L2 Onset Group	F1	F2	F3
		Males	
Native	469.00 (28.60)	1805.42 (31.57)	2522.06 (23.33)
0-3	493.94 (9.62)	1879.33 (172.56)	2636.56 (192.15)
4-7	457.06 (27.50)	1746.86 (18.04)	2432.36 (134.78)
8-11	465.14 (21.41)	1878.53 (122.35)	2645.67 (155.55)
12-15	451.22 (14.43)	1946.83 (267.88)	2739.61 (100.88)
16+	404.33 (41.74)	2015.28 (91.01)	2738.03 (30.55)
		Females	
Native	563.42 (47.15)	2269.81 (124.27)	2961.00 (213.84)
0-3	534.97 (57.27)	2343.19 (98.82)	3212.50 (47.98)
4-7	572.67 (6.17)	2206.58 (147.52)	3087.81 (69.48)
8-11	587.42 (63.02)	2134.78 (177.61)	3023.64 (168.46)
12-15	572.08 (82.11)	2226.44 (270.91)	3112.19 (200.05)
16+	362.36 (18.17)	2828.69 (60.96)	3525.47 (136.48)

TABLE 4

Mean Frequencies (in Hz) of F1, F2, and F3 at the /ɪ/ Mmidpoint in the Carrier-sentence Form

Age-of-L2 Onset Group	F1	F2	F3
		Males	
Native	471.67 (14.81)	1808.75 (55.90)	2471.03 (45.00)
0-3	458.22 (8.97)	1923.31 (101.32)	2632.14 (93.59)
4-7	447.53 (46.20)	1722.06 (34.78)	2371.89 (111.24)
8-11	445.25 (18.28)	1905.64 (91.74)	2622.28 (193.17)
12-15	446.36 (6.19)	1901.11 (228.76)	2630.86 (61.87)
16+	369.89 (45.31)	2078.08 (131.44)	2803.72 (39.32)
		Females	
Native	551.64 (33.71)	2340.22 (81.61)	3042.19 (178.18)
0-3	486.78 (44.82)	2409.44 (72.92)	3166.78 (116.14)
4-7	494.39 (11.05)	2217.86 (95.17)	3079.61 (25.03)
8-11	558.00 (27.49)	2116.75 (200.50)	3003.92 (175.51)
12-15	512.97 (82.68)	2364.72 (344.16)	3149.14 (281.76)
16+	372.50 (35.26)	2743.08 (75.07)	3540.58 (167.92)

First, the results of three-way ANOVAs and subsequent two-way ANOVAs conducted showed that some groups produced the vowel /i/ and the vowel /ɪ/ with no different formant values (except for the F3 in the isolation form). So a series of one-way ANOVAs were then carried out as tests of simple main effects for each of mean F1, F2, and F3 frequencies: the results are summarized below. Males and females were treated separately due to inherent systematic differences between them. When significance was reached, an LSD test was adopted as a post-hoc test to locate the observed difference.

As for the tense vowel /i/, no significance was reached in terms of F1, F2, and F3 frequencies in both the isolation and carrier-sentence forms (see Table 1 and Table 2). This shows that all of the Korean groups produced the /i/ in a native English-like manner regardless of the context in which the stimuli words were read.

The statistical tests conducted for the production of the lax vowel /ɪ/ showed that the 16+ male group differed significantly from the rest of the groups including the native group in terms of F1 in the isolation form [$F(1,16)=3.8824$, $p<.05$] and in terms of F1[$F(1,16)=4.7230$, $p<.01$] and F3[$F(1,16)=6.6119$, $p<.001$] in the carrier-sentence form. As for females, in the isolation form, statistical significance was reached for F1[$F(1,16)=7.8373$, $p<.001$], F2[$F(1,16)=7.3195$, $p<.001$], and F3[$F(1,16)=5.1932$, $p<.01$]. The same was found for the values observed in the carrier-sentence form (for F1[$F(1,16)=6.7137$, $p<.001$], for F2[$F(1,16)=4.4450$, $p<.025$], and for F3[$F(1,16)=3.7050$, $p<.05$]). According to the LSD test, the 16+ female group differed from the rest of the subject groups in terms of all the dependent variables concerned. These show that the 16+ Korean group, regardless of gender, failed to produce the /ɪ/ authen- tically.

An interesting observation here is that, when compared with the frequency values of the /i/ produced by the 16+ female group, there were few or no differences in F1, F2, and F3 values of the two vowels /i/ and /ɪ/ whether the words were read in the isolation form or in the carrier-sentence form. The same was true of the 16+ male group especially in the carrier-sentence form, in which they produced the /ɪ/

much like the vowel /i/ with almost similar formant values being observed for the two vowels.

In order to make clearer the point that the latest (16+) English-onset Korean group (both male and female) failed to differentiate the /i/ and the /ɪ/ spectrally, an F1-F2 vowel chart is provided here for each form. As can be seen in Figure 1, in which the English tense and lax vowels produced by the subjects in the isolation form are plotted with the composite values of F1 and F2, the /ɪ/ vowel produced by the 16+ male group occurs somewhere between the vowel space for the /i/ and the vowel space for the /ɪ/, although it appears to be a bit closer to the /ɪ/ vowel space. This indicates that the male subjects in this group were making an attempt to differentiate between the two vowels with no success: They produced the non-authentic /ɪ/, which led to an incomplete differentiation of the vowels. The same vowel chart shows that the vowel /ɪ/ produced by the 16+ female group occurs in the vowel space of the /i/, rather than in the /ɪ/ vowel space. This seems to show a failure in making a spectral distinction between the /i/ and the /ɪ/ on the part of the 16+ female Korean subjects.

Figure 2 shows an F1-F2 vowel chart for the vowels /i/ and /ɪ/ produced by the subjects in the carrier-sentence form. In this case, the /ɪ/'s produced by both the 16+ male group and the 16+ female group appear far outside the vowel space occupied by the /ɪ/'s produced by the other groups, including the native English group. Rather, they appear within the vowel space for the tense vowel /i/. It is clear that the latest Korean groups failed to distinguish the /ɪ/ from the /i/.

2) Vowel Durations of the Vowels /i/ versus /ɪ/

(1) The Isolation Form

As is apparent in Table 5, /ɪ/ was consistently shorter than /i/ across groups. The 16+ group, in particular, produced /ɪ/ much shorter than /i/. These have been substantiated by statistical tests as shown below. A two-way (Group x Vowel) repeated measures ANOVA revealed no significant group difference, a highly significant durational difference

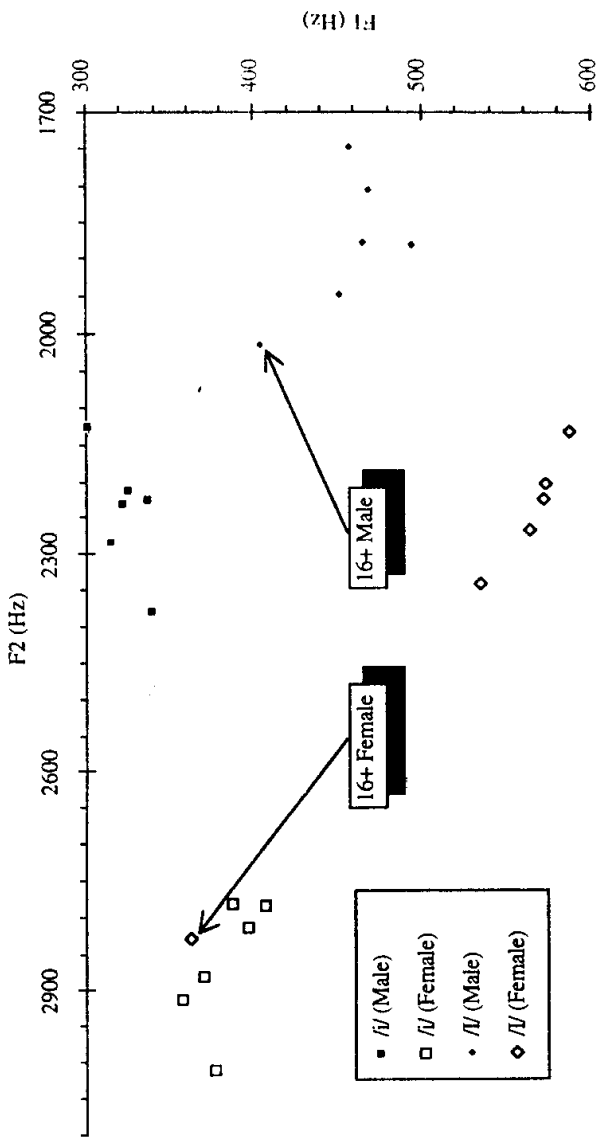

FIGURE 1
The F1-F2 Vowel Chart for /i/ and /ɪ/ for All Groups in the Isolation Form

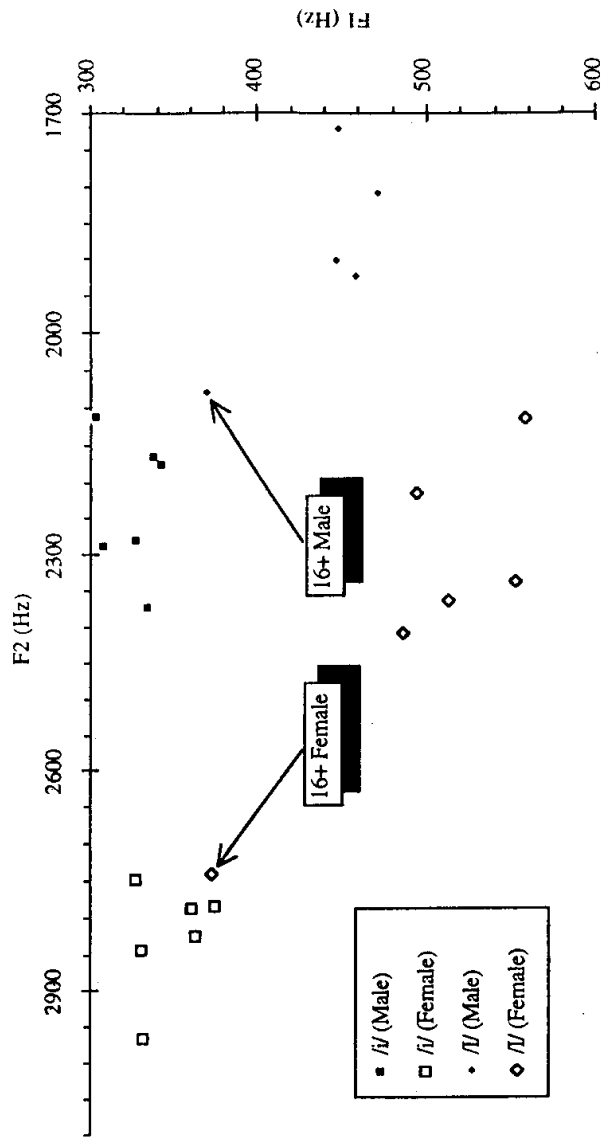

FIGURE 2
The F1-F2 Vowel Chart for /i/ and /I/ for All Groups in the Isolation Form

between /i/ and /ɪ/ (as expected) [$F(1,34)=162.45$, $p<.001$], and a significant group x vowel interaction [$F(1,34)=2.95$, $p<.05$]. The significant group x vowel interactional effect observed here can be interpreted as suggesting that durational difference between /i/ and /ɪ/ varied depending on group. Indeed, there was observed a significant difference between the native English group and the 16+ Korean group in terms of the absolute durational difference of /i/ minus /ɪ/ (i.e., the mean duration of /ɪ/ subtracted from the mean duration of /i/) [$F(1,34)=2.9494$, $p<.05$] and the durational /ɪ/-to-/i/ ratio (i.e., the mean duration of /ɪ/ divided by the mean duration of /i/) [$F(1,34)=3.6796$, $p<.025$]. (The durational ratio was computed in order to control for differences in speech rate.)

The results of one-way ANOVAs and post-hoc tests showed that the 16+ group did not differ much from the native group for the /i/ with a 6.86 msec difference, but it differed significantly for the /ɪ/ with a 40.77 msec difference [$F(1,34)=2.7515$, $p<.05$] . This would suggest that the subjects in this group in general attempted to differentiate /ɪ/ from /i/ by shortening the duration of the former vowel.

TABLE 5

Mean Vowel Durations (in msec) of /i/ and /ɪ/, Absolute Durational Differences (in msec) between /i/ and /ɪ/, and Durational Ratios (in %) by Group in the Isolation Form

Age-of-L2 Onset Group	/i/	/ɪ/	/i/-/ɪ/	/ɪ/ / /i/
Native	157.12 (35.46)	119.58 (22.51)	37.54 (15.77)	77.01 (5.13)
0-3	140.98 (16.16)	113.62 (20.09)	27.36 (11.11)	80.85 (8.39)
4-7	166.38 (47.24)	123.77 (21.55)	42.61 (28.58)	77.53 (13.60)
8-11	170.65 (22.54)	113.50 (17.88)	57.15 (16.45)	67.97 (7.20)
12-15	162.04 (27.89)	102.37 (32.47)	59.66 (11.52)	62.81 (10.08)
16+	150.26 (46.49)	78.81 (26.86)	71.45 (40.48)	56.38 (21.74)

(2) The Carrier-Sentence Form

The absolute length of the two vowels was shorter than the isolation-form context regardless of group (see Table 6). Thus, it appears that the subjects read words relatively rapidly when the words were embedded in sentences. The absolute durational difference decreased, and the durational ratio increased to a greater or lesser extent depending on groups compared to the isolation form. However, unlike in the isolation form, there does not seem to be much durational difference among the groups.

A two-way (Group x Vowel) repeated measures ANOVA resulted in a significant difference for groups [$F(1,34)=3.79$, $p<.01$], a highly significant difference for vowels [$F(1,34)=144.98$, $p<.001$], and no group x vowel interaction. This means that the vowel /i/ was longer than the vowel /ɪ/ regardless of group. A significant group effect observed here means that the absolute length of each vowel varied depending on groups. The Korean groups tended to produce the vowel /i/ shorter than the native English group with marginally significant differences being observed for the 0-3, 12-15, and 16+ Korean groups and the native English group [$F(1,34)=2.4352$, $p=.06$]. All the Korean groups produced /ɪ/ significantly shorter than the native English group [$F(1,34)=4.0794$, $p<.01$].

TABLE 6

Mean Vowel Durations (in msec) of /i/ and /ɪ/, Absolute Durational Differences (in msec) between /i/ and /ɪ/, and Durational Ratios (in %) by Group in the Carrier-Sentence Form

Age-of-L2 Onset Group	/i/	/ɪ/	/i/-/ɪ/	/ɪ/ / /i/
Native	139.14 (14.98)	113.32 (20.09)	25.82 (7.03)	81.65 (6.55)
0-3	112.71 (11.37)	89.05 (7.48)	23.66 (9.43)	79.93 (7.36)
4-7	119.30 (13.10)	91.99 (15.86)	27.31 (19.68)	79.62 (15.99)
8-11	121.15 (23.16)	88.30 (13.51)	32.84 (14.25)	74.34 (7.67)
12-15	117.25 (20.13)	83.13 (14.24)	34.12 (13.21)	72.94 (8.08)
16+	105.87 (19.52)	74.70 (19.32)	31.17 (19.06)	73.01 (18.82)

No significant difference was observed among the groups in terms of durational difference nor in terms of durational ratio. Apparently, the L2 Korean groups kept the durational distance between /i/ and /ɪ/ as did the native English group, although their absolute vowel length of both vowels, on the whole, was shorter than that for the native group.

III. DISCUSSION

The native English speakers of the present study made a primary spectral distinction between /i/ and /ɪ/ in addition to a temporal distinction, although the latter type of distinction might not be as important as the former in differentiating the two vowels (or any other English vowels) phonemically in English speech. The Korean groups whose age-of-English onset ranged from age 0 to age 15 exhibited the same pattern of performance as the native English speakers. They produced the vowels /i/ and /ɪ/ with F1, F2, and F3 values which were not different from those observed for the native English group. Also, their differentiation of the two vowels based on vowel length was similar to that of the native group in spite of the nonnative-like short /ɪ/ produced in the carrier-sentence form: The average durational ratios for these groups as a whole were 72.29% in the isolation form and 76.46% in the carrier-sentence form.

The way the 16+ Korean group made a distinction between the /i/ and the /ɪ/ is worthy of special attention here. This group, regardless of gender, produced the vowel /ɪ/ much like the vowel /i/ with little or no spectral distinction made between the two vowels.

Although the 16+ Korean group did not differentiate the two vowels in terms of formant frequencies, they did so in terms of vowel length by producing the /ɪ/ much shorter than the /i/. This was true at least for the isolation form. The degree of their /ɪ/ shortening was considerably greater than that of the native English group when words were read in isolation with the durational ratio of 56.38%. The phonemic distinction

between the /i/ and /ɪ/ made by the 16+ group was thus based on vowel length, not on vowel formant frequency, which contrasts with the formant-based phonemic distinction made by the native English group as well as the earlier age-of-English onset Korean groups.

If we consider the fact that Korean has no phonemic contrast between /i/ and /ɪ/ based on vowel formants but has phonemic contrasts between its vowels based on vowel length, the kind of performance observed here is not entirely unexpected. It seems that the subjects in the 16+ group have perceived the difference between the /i/ and the /ɪ/ as one of vowel length, rather than one of formant frequency as a result of reinterpreting the distinction.

A strategy of reinterpretation employed by L2 speakers in an attempt to distinguish between novel phonemic L2 contrasts has also been reported in other L2 production studies. In the studies of Mitleb (1981) and Suomi (1976), native Arabic speakers (in Mitleb's study) and native Finnish speakers (in Suomi's study) produced English tense and lax vowels (/i, u, e/ versus /ɪ, ʊ, ɛ/ in Mitleb's study and /i/ versus /ɪ/ in Suomi's study) with far greater durational differences than did the native English speakers in the studies. In addition, the magnitude of the vowel length difference in the English production of these subjects much resembled that of the phonemic vowel length difference found in their native languages. These results were thus interpreted by the authors as evidence that the L2 learners not only reinterpreted the formant-based phonemic distinction between the English vowels as a duration-based one but also maintained the timing pattern of their native languages. The same interpretation might be applicable to the Dutch speakers of English in Elsendoorn's (1980) study. In this study, the temporal distinction made by the Dutch subjects between English /i/ and /ɪ/ was similar to that observed between Dutch /e:/ and /ɪ/, which contrast with each other phonemically on the basis of vowel length.

In the present study, the 16+ Korean group might have reinterpreted the phonemic spectral distinction between English /i/ and /ɪ/ as a phonemic length distinction. However, it is not certain whether they actually maintained the L1 habit of using a temporal distinction —i.e.,

the magnitude of L1 temporal difference—between long vowels and short vowels in Korean. (No careful studies have yet been conducted investigating the vowel length difference between long and short Korean vowels.)

The findings of the above studies, and those of the present study, seem to suggest that L2 learners resort to some other cues, which are familiar to them from their L1 experience, in order to distinguish L2 vowel sounds, which are similar enough to them. This in turn suggests that phonetic cues which are used by L2 learners for the differentiation of L2 sounds might differ depending on which L1 is involved (e.g., Munro, 1990). Alternatively, it might be that L2 sounds which are close to each other in an F1-F2 vowel space and thus are similar spectrally force L2 learners to differentiate these vowels on the basis of additional, though not familiar, phonetic cues (e.g., Flege and Bohn, 1989). In any case, late L2 learners seem to make excessive use of such phonetic cues as manifested in the hypercorrect, duration-based /i-ɪ/ distinction made by the Korean speakers whose English acquisition occurred as late as 16 or above.

The use of familiar or additional acoustic/phonetic cues by the 16+ Korean group in the present study is worthy of further mention. It seems that not all the subjects in this group were making use of the durational cue to differentiate the /i/ and the /ɪ/, although the group, as a whole, was resorting to this cue rather excessively. This statement is based on the finding that there was great between-subject variability for this group: The durational ratio ranged from 37.86% to 91.12% in the isolation form and from 51.80% to 103.10% in the carrier-sentence form among the individual subjects of this group.

Here, special attention should be given to those who produced both vowels with little or no durational difference. They are also the same subjects who made no spectral distinction between the two vowels. This means that, for them, the English vowels /i/ and /ɪ/ were virtually the same vowels: That is, no phonemic contrast exists in these vowels for them. It seems that, as with the syntactic level (Johnson and Newport, 1989; Kim, 1993), production ability of late L2 learners fluctuate a great

deal among themselves. In relation to this, Patkowski (1990) found that the population curves were skewed in one direction (in the direction of high proficiency) for child learners and were normally distributed (i.e., bell-shaped) for adult learners. This might suggest that early L2 learners go through the same biological, acquisitional process. On the other hand, late learners might be subject to multiple factors—social, cultural, and psychological—which can be manifested variedly from one individual to another.

IV. CONCLUSION

The Korean speakers of English whose English acquisition occurred by age 15 succeeded in making a spectral and temporal distinction between /i/ and /ɪ/ in a native-like manner regardless of the context in which the words were read. These results show that an age-of-L2 onset of 15 or under is early enough to enable learners to achieve native-like ability to produce and differentiate L2 vowel sounds.

Those Korean speakers who began learning English in the U.S. as late as 16 or above were able to produce an authentic /i/ spectrally but were unable to produce an authentic /ɪ/, whose formant frequencies were nearly /i/ like. As a result, their differentiation of the /ɪ/ from the /i/ was solely based on vowel duration, with the former vowel being much shorter than the latter vowel compared to the native English subjects. Moreover, some subjects in this group totally failed to differentiate the two vowels spectrally or durationally.

Thus, it seems that L2 acquisition which occurs as late as 16 leads to irrevocably nonnative-like L2 production performance. That is, the age-of-L2 onset of 16 seems to be a turning point which determines whether one can achieve a native-like ability to produce new L2 vowel sounds and/or to differentiate novel L2 phonemic contrasts. The age-related limitations observed here provide some support for the SPH, a weak version of the critical period hypothesis (Lenneberg, 1967). It appears that late L2 learners cannot overcome the biological barriers in

learning a language even after they have lived in a target country long enough. A word of caution is in order here: Only with the evidence from psychological and neurological studies can the SPH gain full support.

The age-of-first decline observed here in relation to English vowels /i/ versus /ɪ/ can be said to be age 16, which is much later than that cited in L2 production studies investigating the SPH. Perhaps it might be that age-of-first decline depends on what phonological/phonetic aspects of the L2 are examined. For example, studies suggest that nonsegmental- level, rather than segmental-level, crosslinguistic differences such as voicing-dependent vowel duration present more problems to L2 learners (Mitleb, 1981; Port and Mitleb, 1983). Actually, Kim (1994) found that not all Korean speakers whose English acquisition started at age 8 or above were successful in lengthening pre-voiced vowels in the same degree as native English speakers. There might be different ending points for the sensitive period for different language components as suggested by the multiple critical periods hypothesis (Seliger, 1978).

Finally, future studies can investigate the relationship between various L2 phonological/phonetic aspects and the age-of-first decline observed among L2 learners of various native languages. It is surely not the case that L2 learners with different L1 backgrounds experience difficulties in producing the same aspects of L2 sounds and/or to the same degree.

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