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The English Voicing-Dependent Vowel Duration Produced by Korean Speakers

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In English, words such as *pick* and *pig* are differentiated based on the vowel length rather than on the voicing of the final consonants. This study examined English production with respect to this voicing-dependent vowel duration. The subjects were 30 Korean speakers who began English as a second language in the United States at varying ages ranging from birth to 25 and stayed in the country for almost 15 years on the average. Computer analysis revealed that Korean speakers of English in general succeeded in lengthening vowels before /b d g/ to an equal degree as native English speakers in both isolation and carrier-sentence speech conditions. However, great intersubject variability was found among individuals whose English acquisition started at the age of 12 or above. Some late English learners exaggerated the English voicing-dependent rule by lengthening vowels preceding /b d g/ too much, while others even produced longer vowels before /p t k/, rather than before /b d g/. Age effects seem to be manifested in L2 production in a way that late second language acquisition leads to great variability among language learners, who either implement L2 production rules with hypercorrection or fail to internalize those rules. Acquisition of authentic L2 production seems to require explicit teaching of L2 production rules rather than mere exposure, albeit extensive and extended, to L2 input.

I. INTRODUCTION

It has been observed that vowels tend to be longer before a voiced consonant

than before a voiceless consonant in many languages, including English, French, Russian, and Korean (Chen, 1970), Dutch (Slis & Cohen, 1969), and Persian (Ghadessy, 1986). Some languages--Arabic (Flege & Port, 1981), Polish or Czech (Keating, 1979)--show little such voicing-dependent vowel duration, however. Thus, it is not clear whether vowel length variation as a function of the voicing feature of postvocalic consonants is a universal phonetic phenomenon or language-specific phenomenon. Meanwhile, it has also been observed that the extent to which vowels are lengthened in the voiced context varies from one language to another. This led Chen (1970) to conclude that the differential vowel duration phenomenon *per se* is universal, but the degree to which it is manifested is language-specific. For example, English appears to exhibit the strongest voicing effect among languages examined, at least for isolated monosyllabic words (e.g., Mack, 1982). The voicing effect in English is reduced to varying degrees in polysyllabic words (e.g., Klatt, 1973; Port, 1981) and/or in unstressed medial contexts (e.g., Luce & Charles-Luce, 1985). However, a stronger voicing effect has been observed in English than in French (Mack, 1982) or Arabic (Flege & Port, 1981) when comparable monosyllabic words have been used in the two languages. Thus, a phonological rule may be proposed for English that a vowel is lengthened before a voiced obstruent. To be specific, in English, vowels preceding a voiceless consonant are about one-half or two-thirds as long as those preceding a voiced consonant in stressed contexts (Peterson & Lehiste, 1960; Umeda, 1975; Klatt, 1976).

Examples of no physical voicing contrast during consonant closure are not uncommon in production (Lisker et al., 1969). Nevertheless, vowels are longer prior to phonologically voiced but phonetically voiceless consonants (Walsh & Parker, 1981). (In the same way, vowels have been found to be longer before word-final voiced consonants in Russian [Chen, 1970] and in German [Port et al., 1981], which are realized as voiceless consonants on the surface through a rule of final devoicing in these languages.) The significance of vowel duration as a cue for the voicing contrast of the following consonant in English has also been well documented in perceptual studies (Denes, 1955; Malécot, 1970; Raphael, 1972; Port, 1979). For example, in his perceptual experiments, Raphael (1972) observed that listeners perceived syllable-final consonants as voiced before longer vowels and as voiceless before shorter vowels regardless of the voicing quality of the consonant. He thus concluded that "the presence of

voicing during the closure period of a final consonant or cluster does have some cue value, although it is *minor* [emphasis added] compared to that of vowel duration" (p. 1301). Likewise, Ladefoged (1993) states that "the major difference between such pairs of words [*nap, nab; mat, mad; knack, nag*, for example] is in the vowel length, not in the voicing of the final consonants" (p. 51). It can be said that vowel duration is a major cue, though not a single primary cue, to a phonemic contrast between voiced and voiceless consonants in English.[1]

Patterns of temporal implementation such as differential vowel duration, which vary from one language to another can be a potential source of accentedness (Tarone, 1976) or even diminished intelligibility (Huggins, 1976) for L2 learners. If it is assumed that voicing-dependent vowel duration is a phonological rule more specific to English than to any other language, non-native speakers of English must utilize this phonological rule in order to pronounce English vowels authentically. That is, for the authentic pronunciation of English, if one's native language has less of a voicing-dependent vowel duration effect than does English, one must learn to increase the magnitude of such an effect found in the native language. If one's native language does not possess such a vowel duration effect, one must internalize the differential vowel duration rule of English.

A few studies have shown that second language learners fail to lengthen vowels preceding voiced consonants in English, or do not lengthen the vowels as much as native English speakers do, when they began to learn English at a later age (Crowther & Mann, 1992a, 1992b, 1994; Flege, 1993; Flege & Port, 1981; Flege et al., 1992; Fokes et al., 1985; Mack, 1982, 1992; Mitleb, 1981, 1984; Port & Mitleb, 1983; Suomi, 1976). According to this finding, there seem to be age-related limitations for language learners in acquiring native-like, "authentic" pronunciation: English differential vowel duration can present a problem for those learning English as a second/foreign language rather late, at least when the native language does not manifest a voicing effect comparable to

1) Some studies have shown that the consonant closure/vowel ratio (i.e., the relative duration of the vowel to the consonant closure) is a primary cue for hearing the final sound as voiced or voiceless in English, and that neither vowel duration nor consonant closure duration independently provides a reliable cue for the perception of a voicing contrast in consonants (Denes, 1955; Port & Dalby, 1982). The same was found by Kohler (1979) for German.

that of English. As for Korean, only one study provides data concerning vowel duration. Chen (1970) found that the vowel durational ratio in Korean is 78% compared to 61% in English. That is, the voicing effect manifested as differential vowel duration is greater in English monosyllabic words than in Korean disyllabic words. However, this study has a drawback in that syllable structure was not held constant between these two languages: measurements were made from monosyllables in English, but from disyllables in Korean (in which the critical voicing contrast occurred in the first segment of the second syllable as in [aga] '아가' and [ak'a] '악까'). This was unavoidable, because no monosyllabic words comparable to English ones exist in Korean. In any case, the difference in voicing effect between the two languages might create a problem for Korean speakers learning English as a second/foreign language.

The above studies all used subjects who either had never been in the United States or had stayed there for a rather short period of time (except for one subject in Mack's [1982] study). So, the possibility cannot be ruled out that, if nonnative speakers have been exposed to English in naturalistic settings for extended period of time and thus have received sufficient English phonetic input, they could make use of the English vowel-lengthening rule and produce native-like English voicing-dependent vowel duration. A stringent test of age effect on second language production can only be done when it involves those language learners who have lived in a target country long enough, so the final outcome of second language acquisition in its later stages, not the rate of it in the initial stages, is investigated (Krashen et al., 1979). It is of major interest to see if the age of learning (AOL hereafter) of Korean speakers has any influence on phonetic proficiency with respect to the voicing-dependent vowel duration such that late learners have more difficulty realizing this English phonetic fact compared to early learners.

II. EXPERIMENT

1. Subjects

Subjects in the present study consisted of 30 Korean speakers of English whose exposure to English as a second language in the United States was

begun at varying ages--from birth to age of 25. (They were the same subjects who participated in Kim's [1995] study.) They were divided into 5 groups of 6 subjects (3 males and 3 females) in each group according to their AOL--0-3, 4-7, 8-11, 12-15, and 16+. The mean chronological age of the subjects was 25, ranging from 17 to 42. All subjects were highly educated: the majority were undergraduate or graduate students at the University of Illinois at the time of testing, and the four who were an exception to this had had university-level (or above) education. Subjects were recruited through announcements and by word of mouth and were paid for their participation in the experiment.

Length of stay in the U.S. was controlled for across subjects to avoid confounding effects with AOL. The mean length of stay was 14 years and 10 months (minimum: 8 years, maximum: 21 years 4 months). Thus, all bilinguals had been in the target country for at least 8 years. This was to ensure that the ultimate outcome of second language acquisition, rather than the process of it, would be examined.

Subjects were initially screened through self-evaluation of fluency in English and Korean. Only those who claimed to express themselves in both languages to some degree were selected. Final selection was made by the experimenter, based on a short conversation (both in English and Korean) with candidate subjects. To obtain information about their demographic and linguistic background, subjects were required to fill out a written-form questionnaire.

To provide baseline performance, 6 English monolinguals (3 males and 3 females) were included. These monolinguals matched the bilingual subjects in terms of chronological age and educational level. Their mean age was 22, ranging from 18 to 27. They were studying at, or had graduated from the University of Illinois at the time of their participation in the experiment.

2. Materials

Stimuli consisted of a list of six minimal pairs which were monosyllabic words. Words began with /b, k, s, h/ and all ended with voiceless or voiced stops at three places of articulation. (Peterson and Lehiste [1960] had found the effect of voicing on vowel duration to be greater before final stops than in other environments.) Medial vowels were /i/, /u/, and /a/, with two pairs for each vowel: (None of the subjects had difficulty pronouncing "bock," which is a rare

word in English. Also, in spite of the dialectal variations of [a] and [ɔ] of the vowel in "bog," none of the subjects produced [ɔ] for the word.)

/i/		/u/		/a/	
seat	seed	boot	booed	bock	bog
beat	bead	hoot	who'd	cop	cob

Materials were prepared in two forms--one in the isolation form and the other embedded in the carrier-sentence, "He knew ____ was the right word."

3. Procedure and Measurement Methods

Subjects were recorded individually in a sound-attenuated room in the Phonetics Laboratory at the University of Illinois with a TASCAM 32 reel-to-reel stereo tape recorder and a SHURE unidirectional SM 94 microphone.

In the isolated word condition, subjects read words written (one word per card) in the center of a notecard. In the carrier-sentence condition, the same procedures were used except that subjects were asked to produce each word in the carrier-sentence. The isolation condition was presented first to all subjects. The order of presentation of the vowels in a voiceless context and a voiced context was counterbalanced across the subjects in both speaking conditions to minimize experimental design effect: so, in each speaking condition, some subjects read words with voiceless stops first and some read words with voiced stops first.

Each subject read each word and each sentence three times, although only the words produced on the first two repetitions were analyzed acoustically. Tokens judged as problematic or ambiguous (by two researchers, the experimenter and M. Mack) were not measured. In these cases, the corresponding tokens produced by that subject on the third repetition were analyzed instead. The presentation of each set of the words, one set with voiceless stops and the other set with voiced stops, was randomized by shuffling the cards before each repetition. 48 words were analyzed for each subject (12 words x 2 repetitions x 2 speaking conditions) for a total of 1,728 words across 36 subjects.

For acoustic analysis, the recorded speech signal was first converted into a digitized representation on an IBM AT. A computer program designed and

implemented by Cheng, Johnson, and Mertus (1988) was used. Words and sentences were sampled at 20 kHz and low-pass filtered at 9.0 kHz. Measurements were made from the waveforms displayed on the terminal screen; durational measurements had a sampling-period accuracy of .01 msec.

Vowel durations were measured by placing cursors (at the zero crossing) at vowel onset and offset. Vowel onset was defined as a relatively sudden increase in the amplitude and pitch-period regularity in the stimuli waveforms. Aspiration and prevoicing for the initial consonants (/k/ and /b/, respectively) were not considered as part of the vowel. For words ending with voiceless stops, vowel offset was defined as the point of a localized decrease in the waveform amplitude and/or complexity followed by a period of silence prior to the stop burst. For words ending with voiced stops, low amplitude phonation continuing after relatively high-amplitude pulsing was not interpreted as part of the vowel, but was rather attributed to consonant voicing.

4. Results

1) The Isolation Form

Mean durations of vowels preceding voiceless stops /p t k/ and homorganic voiced stops /b d g/ and mean durational differences of vowels in the two contexts (i.e., the mean durations of vowels preceding a voiceless stop subtracted from the mean durations of vowels preceding a homorganic voiced stop) were computed for each group.

All of the groups produced vowels preceding /b d g/ with longer durations than vowels preceding /p t k/ (see Table 1). A two-way repeated measures analysis of variance (ANOVA) was conducted with group as a between-subjects factor and voicing context as a within-subjects factor. There was a significant main effect for voicing context [$F(1, 34) = 133.70$, $p < .001$]. Neither a significant main effect for group nor a significant voicing context x group interaction was observed. This means that vowels were significantly longer before a voiced stop than before a voiceless stop regardless of age group. As for durational differences between voiceless and voiced contexts, the native group showed the greatest durational difference. However, a one-way ANOVA revealed no significant differences among groups. Figure 1 shows this graphically.

TABLE 1

Mean Durations of Vowels (in msec), Mean Durational Differences (in msec), and Mean Durational Ratios (in %) in the Isolation Form

Age Group	/p t k/	/b d g/	Durational Difference	Durational Ratio
Native	176.90	274.65	97.75	65.18
	(28.54)	(50.27)	(38.98)	(9.02)
0-3	154.19	223.50	69.31	69.43
	(19.75)	(26.62)	(19.90)	(6.93)
4-7	177.85	266.93	89.08	67.00
	(37.71)	(41.40)	(28.54)	(9.10)
8-11	171.73	242.13	70.39	71.39
	(19.67)	(25.87)	(13.58)	(4.01)
12-15	157.94	244.03	86.10	69.36
	(50.09)	(42.69)	(82.82)	(28.50)
16+	140.08	205.53	65.46	69.15
	(50.84)	(54.70)	(21.98)	(12.13)

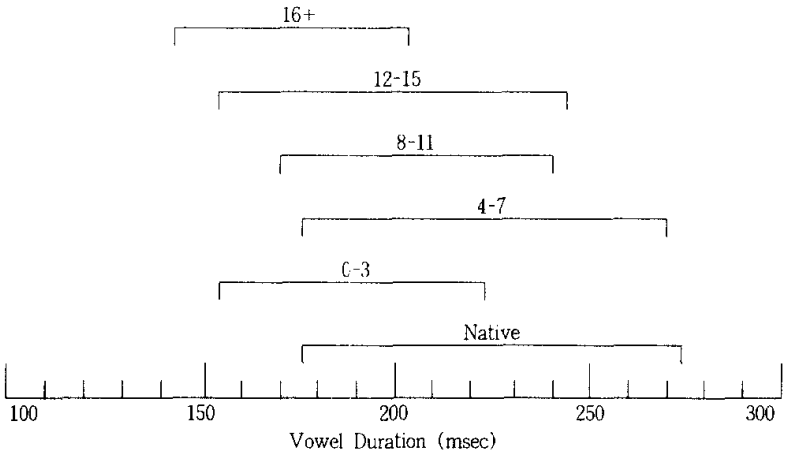
*Numbers in parentheses represent group standard deviations.

Next, ratios of vowel duration in the /p t k/ context to vowel duration in the /b d g/ context were also calculated for each group (see the right most column in Table 1) to control for the across-age group differences in absolute vowel length.[2] (The absolute vowel length differs across groups and it tends to be smaller for the Korean groups compared to the native English group as shown in Figure 1.) Again, although the native group showed the lowest average durational ratio of 65.18% (the minimum ratio of 54.19% and the maximum ratio of 75.34%), there did not seem to be much difference in durational ratio among the groups. Indeed, a one-way ANOVA showed no significant difference among the groups.

2) Research shows that the magnitude of voicing effects can vary as a function of vowel duration in the production of native English speakers (Crystal & House, 1982, 1988). Whether or not there were differences in speaking rates among groups, the differences in the absolute vowel length among them could have affected their voicing effects. So, more reliable results can be obtained by using ratios.

FIGURE 1

Vowel Durational Differences (in msec) in the Isolation Form



*The left endpoint of each line represents the mean vowel length in the voiceless context and the right endpoint of each line represents the mean vowel length in the voiced context [after Mack, 1989].

What is noteworthy here is that the group standard deviation in durational ratio is fairly large for the 12-15 group. The durational ratio of this group ranged from 29.72% (durational difference of 223.24 msec) to 115.91% (durational difference of -20.13 msec). This means that some subjects produced vowels before /b d g/ much longer than vowels before /p t k/ and some subjects produced vowels preceding /b d g/ even *shorter* than vowels preceding /p t k/. The 16+ group, whose durational ratios ranged from 56.98% to 84.34%, also appears to show rather large intersubject variability especially in the direction of high durational ratio. Actually, only two subjects in the 12-15 group and three subjects in the 16+ group performed such that their mean durational ratios fell within the mean durational ratio range of the native group, whereas all subjects in the 4-7 group and five subjects in each of the 0-3 and 8-11 groups did so.

2) The Carrier-Sentence Form

Average vowel durations and durational differences were also computed in the carrier-sentence form for each group (see Table 2). The absolute length of

vowels preceding both /p t k/ and /b d g/ was less to some degree compared to the isolation form. This might mean that the subjects' speech rate was faster in the carrier-sentence form. As in the isolation form, consistently longer vowels can be observed in the /b d g/ context than in the /p t k/ context regardless of group. Statistical tests yielded results similar to those in the isolation form. A two-way repeated measures ANOVA showed a significant main effect for voicing context [$F(1, 34) = 154.76$, $p < .001$], a significant main effect for group [$F(1, 34) = 4.85$, $p < .001$], and no significant voicing context x group interaction. This supports the observation that vowels are longer preceding a voiced stop than preceding a voiceless stop.

TABLE 2

Mean Durations of Vowels (in msec), Mean Vowel Durational Differences (in msec), and Mean Durational Ratios (in %) in the Carrier-Sentence Form

Age Group	/p t k/	/b d g/	Durational Difference	Durational Ratio
Native	165.19	223.34	58.15	74.63
	(18.74)	(24.70)	(20.40)	(7.65)
0-3	140.18	177.28	37.10	79.54
	(13.41)	(13.46)	(12.63)	(6.89)
4-7	150.86	191.13	40.26	79.19
	(16.94)	(14.17)	(7.82)	(4.96)
8-11	141.05	181.94	40.89	78.91
	(15.36)	(23.10)	(23.07)	(11.25)
12-15	130.56	178.43	47.87	76.13
	(20.61)	(23.76)	(32.44)	(13.79)
16+	116.65	170.24	53.59	69.40
	(28.12)	(40.37)	(27.78)	(12.45)

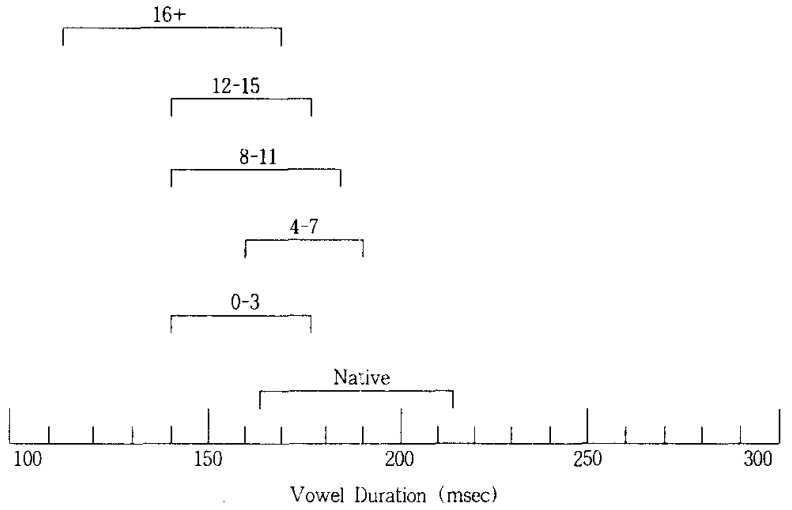
*Numbers in parentheses represent group standard deviations.

Relative to the isolation form, durational differences decreased to a considerable degree and consistently across groups, as indicated by the shorter horizontal bars in Figure 2. This suggests that (given the greater decrease of vowel length in the /b d g/ context than in the /p t k/ context) vowels are lengthened to a lesser degree before voiced stops when words are embedded in sentences and thus are read at a higher speed. The vowel durational difference

was greatest for the native English group compared to the Korean groups in general. However, a one-way ANOVA showed no significant differences among the groups. (Figure 2 also shows that, as in the isolation form, there is a tendency for smaller absolute vowel length for the Korean groups than for the native English group.)

FIGURE 2

Vowel Durational Differences (in msec) in the Carrier-Sentence Form



*The left endpoint of each line of represents the mean vowel length in the voiceless context and the right endpoint of each line represents the mean vowel length in the voiced context [after Mack, 1989].

There were some differences in durational ratios among the groups, with the native English group showing the durational ratio of 74.63% (minimum: 63.28%, maximum: 84.40%) and the latest Korean group exhibiting the smallest durational ratio of 69.40%. However, a one-way ANOVA did not reveal any significant group difference. When compared to the isolation form, durational ratios increased across the groups except for the 16+ group. The higher durational ratio, as well as the smaller durational difference, in the carrier-sentence form thus reveals that the effect of stop voicing on vowel duration seems to be much smaller in the carrier-sentence form than in the isolation form. Interestingly, however, the

16+ group did not show any appreciably lessened voicing effect: the durational ratio in both isolation and carrier-sentence forms were virtually the same for this group, although the absolute vowel length was decreased as for the other groups. Not only that, the durational ratio of this group was much lower than that of the native English group.

As for intersubject variability, the groups performed in a similar way as in the isolation form: the native English group and the 0-3, 4-7, 8-11 Korean groups performed with less variability compared to the 12-15 and 16+ groups. The latter groups showed either too much or too little voicing effect of stops on the preceding vowel: the durational ratios of the 12-15 and 16+ groups ranged from 50.26% to 86.28% and 59.01% to 93.54%, respectively. The number of those subjects in these groups whose mean durational ratios fell within the range of the mean durational ratio of the native group was three in the 12-15 group, and three in the 16+ group, while it was five in the 0-3 group, six in the 4-7 group and four in the 8-11 group.

3) The Isolation Form Versus the Carrier-Sentence Form

In order to determine if there was a significant difference, as observed in the above, for the isolation and carrier-sentence forms in the use of English voicing-dependent vowel durational rule by the subjects, additional statistical tests were carried out. A two-way repeated measures ANOVA for vowel durational difference resulted in a significant main effect for speaking condition [$F(1, 34) = 28.77$, $p < .001$] but neither a significant main effect for group nor a significant speaking condition x group interaction. A two-way repeated measures ANOVA for vowel durational ratio also revealed a significant main effect for speaking condition [$F(1, 34) = 14.59$, $p < .001$] but no significant main effect for group nor a significant group x speaking condition interaction. Thus, statistical analysis supported the observation that the subjects in all six groups produced vowels with a weaker voicing effect in the carrier-sentence form than in the isolation form.

In addition, vowel length, whether it was in the /p t k/ or /b d g/ context, was less variable in the carrier-sentence form, and the phenomenon of voicing-dependent vowel duration was realized with smaller intersubject (or between-subject) variability, at least for the native English group and those Korean groups whose AOL ranged from 0 to 11.

III. DISCUSSION

The present study was undertaken to examine whether AOL has any systematic influence on ultimate phonetic proficiency of L2 learners with the Korean speakers of English who had entered the final stage of language acquisition. The group data showed that the native Korean groups in general showed similar patterns of production as the native English group in some respects. The Korean groups produced vowels which were significantly longer before voiced stops /b d g/ than before voiceless stops /p t k/ and did so with no significant difference from the native English group in the voicing effect. (The mean durational ratio of the whole Korean groups was 72.95% and that of the native English group was 69.91% when the data were collapsed over the isolation speech condition and the carrier-sentence speech condition.) They also lengthened vowels in the /b d g/ context to a lesser degree in the carrier-sentence form than in the isolation form. It is all the more interesting to observe this native-like vowel differentiation on the part of the Korean subjects whose absolute vowel length was overall much shorter than that of the native English subjects. This seems to suggest that they succeeded in internalizing the English vowel-lengthening rule and also in implementing it.

The results here might lead one to conclude that learners with substantial L2 experience are eventually able to achieve native-like L2 production ability, no matter when L2 acquisition occurs (that is, at an early or later age). However, this conclusion seems premature at this point. This is so because it was also found that individuals who were first exposed to the English of native speakers in the United States at the age of 12 and beyond revealed certain characteristics in their performance which were not observed among the native group and the earlier AOL Korean groups. Unlike the native English subjects and the Korean subjects in the 0-3, 4-7, and 8-11 groups, those in the 12-15 and 16+ groups performed quite unlike one another: for example, some individuals had native-like performance in implementing the voicing-dependent vowel duration rule by lengthening vowels before /b d g/ to a degree equal to that observed for the native English group. Others even went beyond the average durational ratio of the native English group with a much lower durational ratio. Still others performed in an unusual way by producing shorter, rather than longer, vowels before /b d g/. Thus, the performance of the later AOL Korean groups is

characterized by being hypercorrect in some cases and being inverted in other cases.

Hypercorrection was observed in the performance of one male subject (TP), whose AOL of English was 13, in both the isolation and carrier-sentence forms, as indicated by his durational ratio of 29.72% and 50.26%, respectively. (For reference, the durational ratios of a native English speaker (LK) who showed the strongest voicing effect were 54.19% and 63.28%, respectively.) A close examination of the Korean speaker's demographic profile revealed that he had been in the U.S. for 25 years and 8 months at the time of testing, the longest of all the subjects. It might be that, in view of his consistent performance across the stimulus pairs, he had been in the target country long enough to be conscious about the vowel-lengthening rule of English and exaggerated it deliberately under testing situations. A tendency for hypercorrection was also observed among the 16+ group when the subjects in this group maintained virtually the same durational ratios in the isolation and carrier-sentence forms (69.15% and 69.40%, respectively). This group's ratio in the carrier-sentence form was actually much lower than that (74.63%) observed in the native English group. Hypercorrection or a hypercorrective tendency appears to be commonplace in the performance of L2 learners and is frequently mentioned in L2 literature (Richards et al., 1985).

Another subject (AL) in the 12-15 group, who had begun learning English at age 12 and had been in the U.S. for 11 years, produced vowels even shorter in the /b d g/ context than in the /p t k/ context, rather than vice versa, with a mean durational ratio of 115.91% in the isolation form. In the carrier-sentence form, she produced shorter vowels in the /b d g/ context for one stimulus token, although the mean durational ratio of 86.28% shows that her vowels were longer before /b d g/. The similar pattern of performance was observed for the other subjects in the 12-15 and 16+ groups: despite the overall longer vowels in the /b d g/ context observed in their production, two more subjects in the 12-15 group and two subjects in the 16+ group produced vowels longer in the /p t k/ context than in the /b d g/ context for one to three stimulus tokens. So, these subjects performed according to the native phonetic norm at one time but failed to do so at other times. What is noteworthy is that when they missed the native phonetic target, they did so not with a relatively smaller voicing effect but with no voicing effect or even a reversed voicing effect, which is quite

peculiar.

The point to be made here is that the overall native-like vowel durational difference in the production of the later Korean groups was only a pooling effect of extreme values. So, had the English production of a larger N in each group been examined, a significant difference might have been observed in performance for the native English speakers and the native Korean speakers whose English learning occurred rather late. (Indeed, Flege [1993] found that those Taiwanese learners of English who began learning English after the age of 9 showed smaller overall voicing effects than did his native English subjects or the earlier AOL Taiwanese subjects.) A caveat is in order, however, since the greater intersubject variability can be attributed to the idiosyncratic performance of some subjects. Again, a larger N per cell would resolve this question. Performance variability such as that observed in the late AOL Korean subjects of the present study is not unique with the phonetic level. It has been found to be manifested at the syntactic level also as found in the studies of Johnson and Newport (1989).

A question arises at this point as to why some later Korean learners of English in this study could not make authentic English production at all times, whereas the early learners could do. The reason might have the perceptual base (see Best, 1994). It might be difficult for native Korean speakers to differentiate English voiceless and voiced stops in word-final position, as Korean does not have voiced stops in its phonemic inventory, so voicing is not contrastive for word-final stops or for stops in any other positions, for that matter. On the other hand, crosslinguistic phonetic interference could occur so that Korean speakers might identify /p t k/ in English with /p^h t^h k^h/(i.e., ㅍ ㅌ ㅋ) in Korean and /b d g/ in English with /p t k/ (i.e., ㅂ ㄷ ㄱ) in Korean. This interlingual identification would go some way in helping Korean speakers distinguish between voiced and voiceless English stops. Still, in Korean the stop categories are neutralized into one stop category in word-final position in favor of the lax stop. (For example, /ip^h/ 'leaf' and /ip/ 'mouth' are both pronounced [ip].)[3] So Korean speakers might interpret both voiceless and voiced English stops in terms of /p t k/ in Korean, which would make it difficult for them to

3) Korean has three types of voiceless stops: heavily aspirated tense stops /p^h t^h k^h/, slightly aspirated lax stops /p t k/, and unaspirated tense stops /p' t' k'/ (Kim, 1965).

make a distinction between the two stop categories. Then, it is likely that they simply give up distinguishing them one from the other. Or, they would try to make a distinction by resorting to differential vowel duration or some other phonetic cues but they would do so only incompletely or inconsistently. Assuming that this is the case, then, why should this be true only for late learners and not for early learners? As Werker & Tees (1984) have noted, the child's innate perceptual ability seems to start undergoing reorganization due to experience with the native language within one year of birth, making it difficult to discriminate nonnative phonemic contrasts. Given the finding of the present study that the earlier AOL Korean subjects were able to produce native-like differential vowel duration, perceptual learning still seems to be possible with L2 experience even after the first year of life. However, perceptual learning appears to be incomplete when L2 learning occurs beyond a certain later age. The Korean subjects who were unsuccessful in implementing native-like vowel duration might have been unable to attend to the unfamiliar phonetic cue of vowel duration because they had begun to learn English rather late and so their perceptual learning was not complete. If perception indeed guides production, incomplete perception should lead to inaccurate production.

Alternatively, the nonnative-like English vowel duration of some late English learners in this study might result from their inability to control the timing appropriately in their articulation of English stops. That is, speech learning difficulties should exist at a motoric level for late L2 acquisition. Whichever explanation--perceptual or motoric--might be chosen, the inconsistent and unstable pattern of production of some late Korean subjects seems to point to the fossilized L2 phonetic system. L2 learning can occur as experience with a target language increases (Nemser, 1971), but, for most late L2 learners, learning cannot continue indefinitely and usually stops at some point. Such a fossilized L2 system is characterized by language performance errors which seem to have disappeared at one point but won't easily disappear and reoccur intermittently (Selinker, 1972).

Another question to be asked is whether the failure of some late Korean learners of English to realize voicing-dependent vowel duration in a native like manner leads to the fact that native English listeners cannot identify their English production appropriately. The answer to this question depends on whether some other phonetic/acoustic cues, such as F1 offset frequency,

duration of closure voicing, and intensity of final release bursts are available in the Koreans' production to help identify word-final stops as voiceless or voiced. Unfortunately, no systematic study was done on this. (Schmidt [1989] observed, however, that native Korean speakers who began learning English at ages of 10 to 13.5 years produced word-final, utterance-medial /t d/ without bursts.) Still, given that the vowel durational difference is a major cue in differentiating the voiceless and voiced consonants in English, Korean speakers could be at disadvantage in making themselves understood in the language.

A lot of research has shown that AOL of second language determines how well L2 sounds are produced by language learners. L2 learning which started by a certain early age leads to L2 production without a detectable accent given sufficient experience with L2. On the other hand, when L2 learning happened rather late in life, one can hardly overcome foreign accents in L2 production. This age-related limitation in L2 production suggests that there is a sensitive period (Oyama, 1979) or a critical period (Lenneberg, 1967) for speech learning, although a mechanism behind the period phenomenon is not yet known. This finding came mainly from studies which investigated the overall accentedness in L2 production using native listeners' ratings or sometimes self-assessment as a measurement method (Asher & García, 1969; Seliger et al., 1975; Oyama, 1976; Tahta et al., 1981). However, this kind of study has its limits in that it cannot provide insights into when and how L2 production deviates from native speakers' phonetic norm. It is necessary to employ instrumental methods and investigate age effects across a wide range of segments for L2 learners of diverse language backgrounds. This would help look into precise characterisitics of the sensitive period phenomenon in L2 speech learning. The present study was one such attempt.

VI. CONCLUSION

In terms of ultimate L2 production proficiency, one conclusion to be made based on the results here is that early L2 acquisition guarantees native-like production provided sufficient L2 input, whereas late L2 acquisition--English acquisition at the age of 12 and beyond, in this case--does not always result in the achievement of native-like production proficiency even after an extended

period of exposure to the L2. Some late L2 learners might be able to achieve a native-like phonetic norm, but some might not. The latter also display inconsistent and unstable production performance. Thus, age effects seem to prevail over language experience effects: an extensive, prolonged L2 experience is not of much help in overcoming the deficiencies of late L2 acquisition.

The present study has important pedagogical implications: first, teaching of English pronunciation will be more effective if it begins at an earlier age. Second, English voicing-dependent vowel duration should be isolated and taught to Korean learners of English explicitly. Simply having them exposed to English input without any explanation about the phenomenon would not be sufficient to make them aware of the rule. If Korean speakers who lived in the U.S. surrounded by native English speakers for as long as 15 years cannot produce authentic voicing-dependent vowel duration, the majority of Korean speakers, most likely confined in classrooms where authentic L2 input is scarce, would be much less likely to do so. It is the English teacher's job to impress upon them that the voicing contrast of syllable-final obstruents in English is made primarily on the basis of the length of preceding vowels, and so vowels should be lengthened before voiced consonants in English. Actually, in most cases, English pronunciation books are urging us to teach the rule with clear explanation and ample practice exercises (for example, Improving Oral Communication [Handschuh & Simounet de Geigel, 1985]; Phrase by Phrase [Chan, 1987]; Clear Speech [Gilbert, 1994] to name a few).

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