# A Study on Korean Students' Production and Perception of English Word-final Stop Voicing*

**Seok-Han Kang****


## ABSTRACT

The purpose of this study is to examine Korean students' production and perception of word-final stop voicing in light of their overseas experience. Subjects were English native speakers, Korean university students with residence experience in America, Korean university students without residence experience in America, and Korean elementary school students. They participated in both production and perception tests. Results showed that the students' production and perception with residence experience in America appeared quite similar to those of the English native speakers. In the production tests, we noticed somewhat different results in temporal and frequency features. The one-year residence in America had some influence on their frequency features, but not the temporal features in the word final stop production. That difference could be seen in the perception tests, too. We could not find any difference in the identification test of the final release environment between the Korean university students who had studied abroad and those who didn't. Rather the difference could be found in the cue influence test in both the final release and non-release environments.


**Keywords: stop, production, perception, temporal, frequency, cue identification**

## 1. Introduction

In the field of SLA (Second Language Acquisition), researchers have paid attention to what factors influence on the L2 learners' production and perceptual system when they learn foreign languages. L2 learners' developmental pattern has been studied in light of age (Flege, Mackay & Meador, 1999; Flege, Yeni-Komshian & Liu, 1999; Gordon-Salant, Yeni-Komshian, Fitxgibbons & Barrett, 2006), amount of exposure (Werker & Tees, 1984), background language (Crowther & Mann, 1992; Abramson & Tingsabadh, 1999; Tsukada et al., 2005), and training (Flege & Wang, 1990; Kang, 2006a). Arsland and Hansen (1997) studied foreign accent by analyzing temporal features, intonation patterns, and frequency characteristics for

* This work was supported by the Korea Research Foundation Grant funded by the Korean Government (KRF-2006-321-A00563).

** Language Institute, University of Incheon

native-produced versus Mandarin-, German-, and Turkish-accented English speaking. They found that the temporal features including word-final stop closure duration were especially important in distinguishing Mandarin-accented versus native English. This study implies the influence of the subjects' native language on production and perceptual pattern in the second language acquisition. In a recent study, MacKay et al. (2001) have examined the identification of English consonants by native speakers of Italian who immigrated to Canada. Considering two effects of AOA (age of arrival) and amount of L1 use, they reached the result that the effect of AOA was not significant for distinguishing English word-final stops, while the amount of L1 use in their home played a primarily negative role. This implies some limitation to the L2 developmental change even under conditions of early age of acquisition and rather importance to the amount of their target language use.

A few factors have been examined on a change of the L2 developmental system for ESL (English as a Second Language). Relatively little research, however, has been carried out on the production and perceptual structure by the effect of temporary residence experience in English speaking countries for adult L2 learners of EFL (English as a Foreign Language). This study originates from the question about whether Korean university students who had studied in America for approximately one year have changed their L2 (English) production or perceptual system. If we find the changing pattern, further questions are what is the first and/or the last factor to lead their L2 frame change in both sides and what differences between production and perception come out.

The study focuses on the L2 phonetic developmental pattern in English word-final stops. For this study, the word-final stops are favored because L2 learners can find some difficulty in "producing and identifying word-final rather than word-initial consonants" (Mackay et al., 2001) and also show some particular characteristics clearly "depending on their background language" (Abramson & Tingsabadh, 1999). The purpose of the study is to suggest a better understanding on the developmental pattern of Korean L2 English learners by the effect of residence experience in America during the university life. For that purpose, the study includes English native speakers, Korean university students with residence experience in America, Korean university students without residence experience in America, and Korean elementary school students. All of them participated in both production and perception tests. This study also examines some factors which affect the subjects' production and perceptual system and any difference that exists among the various subject groups.

## 2. Production

### 2.1 Subjects

Four native speakers of English (2 Americans, 2 Canadians), four Korean university students

with residence experience in America (hereafter, KUS with residence experience), four Korean university students without residence experience in America (hereafter, KUS without residence experience), and four Korean elementary school students (hereafter, KES students) took part in the experiment. The native speakers of English were English instructors of a Korean university. Their mean age was 28.1 years and their stay in Korea was around 23 months. Four KUS with residence experience had the experience of studying English in America or Canada for approximately 14 months. Four KUS without residence experience had never been to American countries. Subjects of these two university groups were selected based on TOEIC test taken in 2005. Because the test scores of both groups ranged from 600 to 700, it is safe to say that their English ability is almost at the same level. Four KES students who were in the 5th grade from various elementary schools in Incheon Educational District were another participant. Their English ability was unknown, but they had studied English for over three years in both public elementary schools or private institutions. The subjects' information is as follows:

Table 1. Subjects' Information

| Group | Native Language | Members | Mean Age (yr.) |
|---|---|---|---|
| Native speakers | English | 2 American males<br>2 Canadian males | 28.1 |
| KUS with residence experience | Korean | 4 Korean university male students | 22.9 |
| KUS without residence experience | Korean | 4 Korean university male students | 21.1 |
| KES students | Korean | 4 Korean elementary school male students | 10.6 |

Note: *KUS* stands for *Korean university students* and *KES* for *Korean elementary school students.*

2.2 Procedure

All subjects had no history of speech disorders and no problems in pronunciation. Minimal pairs of English plosives were selected across places of articulation (bilabial, alveolar, and velar) in the initial and final positions and analyzed only in the part of the pre-consonantal vowel, the stop closure and the release burst. The minimal pairs were embedded in the frame sentence to minimize the effect of other factors. The minimal pairs and the frame sentence used in the present study were provided below:

(1) words: bap, bab, bat, bad, back, bag, pap, pab, pat, pad, pack, pag, dap, dab, dat, dad, dack, dag, tap, tab, tat, tad, tack, tag, gap, gab, gat, gad, gack, gag, cap, cab, cat, cad, cack, cag

frame sentence: 'Say ____.'

Most of the selected words were real English words. The selected words were under the same condition except for the voicing contrast. All subjects were asked to read the words embedded in the frame sentence randomly ordered three times. Recording was done in a sound-proof broadcasting booth at the University of Incheon. Sounds were recorded with a Shure SM 50 microphone on computer with a Sound Blaster card. Recorded sounds were digitalized at a sampling rate of 44,100 Hz and a quantization rate of 16 bits.

### 2.3 Results and Discussion

#### 2.3.1 Temporal feature

Studies have shown that duration is an important feature in foreign language speaking. Crowther and Mann (1992) investigated native language factors affecting use of vocalic cues to final consonant voicing. They found that Japanese and Mandarin speakers of English show less difference in F1 offset frequencies in their token *pod* compared to their token of *pot*. In another study, Flege et al. (1992) reported significantly longer closure durations in final stops produced by Mandarin and Spanish speakers when compared to native English speakers. Clearly an L2 learners' background language has some influence on their English acquisition in temporal features. In my analysis on temporal features, I observed that the pre-consonantal vowel at the end of a word is in general longer for native speakers than for non-native speakers, while the stop closure duration prior to the stop release is generally longer for non-native speakers than for native speakers. The results are summarized in <Table 2>.

Table 2. The mean and standard deviation (in parenthesis) of word-final pre-consonantal vowel duration, stop closure, and release burst (ms).

| | pre-consonantal vowel | | stop closure | | release burst | |
|---|---|---|---|---|---|---|
| | voiceless | voiced | voiceless | voiced | voiceless | voiced |
| Native speakers | 184(28) | 262(63) | 103(45) | 58(22) | 70(52) | 48(37) |
| KUS with residence experience | 188(41) | 218(56) | 196(78) | 110(81) | 69(53) | 53(44) |
| KUS without residence experience | 192(35) | 224(48) | 144(68) | 107(101) | 71(62) | 52(55) |
| KES students | 188(37) | 198(42) | 136(91) | 93(59) | 24(35) | 22(19) |

Note: Null hypothesis represents the case where the averages of pre-consonantal vowel ([$F(3, 1012) = 10.9$, $p < .001$)]), stop closure ([$F(3, 775) = 28.6$, $p < .001$)]), and release burst ([$F(3, 746) = 26.1$, $p < .001$)]) are equal across four groups. *KUS* stands for *Korean university students* and *KES* for *Korean elementary school students*.

The first temporal features considered here are average duration, the mean difference, and the ratio difference for the pre-consonantal vowel. There have been a few studies on vowel

duration as a speech cue to the voicing feature produced by native speakers of English (Raphael, 1972; Kang, 2005b) as well as by non-native speakers (Crowther & Mann, 1992). Vowel duration is measured from the first glottal peak in the periodic portion of the voiced speech until the point where peak disappeared. The mean difference of the voicing duration for English native speakers is the longest of all groups as 78 ms, compared to KUS with residence experience as 30 ms, KUS without residence experience as 32 ms, and KES students as 10 ms. It can be said that the effect of residence experience for approximately one year does not affect the pre-consonantal vowel duration. The ratio between voiced and voiceless vowel duration, another measurement, also supports this argument. Ratios calculated for voiced: voiceless vowel duration of each group show the proportion in detail: native speakers = 1: 0.70; KUS with residence = 1: 0.86; KUS without residence = 1: 0.85; KES students = 1: 0.95. We can't find the meaningful difference between KUS with residence and KUS without residence. Interestingly, Korean elementary school students can't produce distinctive durational difference on voiced and voiceless segment in word final stop sounds.

The second features are average duration, the mean difference, and the ratio difference for the stop closure. It has been investigated in several recent research studies. Arslan and Hansen (1997) report that the closure duration prior to the release of a stop consonant at the end of a word is longer for non-native speakers than for English native speakers. It implies that the effect of background language affects the duration of the stop closure.

In this study, it appears that the effect of residence experience in America may not influence on this parameter duration. The closure duration for English native speakers is the shortest at 79 ms and three Korean groups have longer durations as follows: 151 ms for KUS with residence experience, 126 ms for KUS without residence experience, 111 ms for KES students. It seems that the meaningful statistical difference between two Korean university student groups may not be found. The mean difference of the stop closure duration for KUS with residence experience is the longest of all groups at 86 ms, compared to English native speakers at 45 ms, KUS without residence experience at 37 ms, and KES students at 43 ms. However, the ratio between voiced and voiceless closure duration implies that the effect of residence experience for university students affects this parameter. Ratios calculated for voiced: voiceless closure duration of each group show the proportion in detail: native speakers = 1: 1.77; KUS with residence = 1: 1.78; KUS without residence = 1: 1.34; KES students = 1: 1.46. The ratio difference between voiced and voiceless duration for two groups - native speakers and KUS with residence experience - clearly supports that the effect of residence experience in America has some influence on L2 production pattern in the stop closure.

The third temporal features considered here are average value and the degree of the release burst. It is generally known that this parameter is greatly influenced by background language. English optionally has the release-burst in word final position. Byrd (1993) searching the

TIMIT database reports that almost 60% of English stops were *audibly* released in word final position. On the contrary, Korean has no released stops. It is certain that Koreans are unfamiliar with the English released stops in the prepausal position so that they insert the default vowel in case of adopting English loan words. Korean also differs from English in that English has both voiced and voiceless stops in the final position, while in Korean the three-way contrast of lenis, fortis, and aspirated stops neutralizes and yields only voiceless stops. It is safe to say that the more L2 speakers are familiar with the target language - English, the more the degree of their release is similar to English native speakers'.

In this laboratory study, the degree of the release burst is different depending on the groups: English native speakers release 98%, KUS with residence experience 84% (voiceless 87.5%, voiced 80.5%), KUS without residence experience 80% (voiceless 81.3%, voiced 78.7%), and KES students 49.6% (voiceless 45.8%, voiced 53.5%). In this case, we can not find the significant rate of difference between the two Korean university students' groups. The mean difference of the release burst for English native speakers is the longest of all the groups at 22 ms, compared to KUS with residence experience at 16 ms, KUS without residence experience at 19 ms, and KES students at 2 ms. Ratios calculated for voiced: voiceless duration of the release burst for each group show the proportion in detail: native speakers = 1.45: 1; KUS with residence = 1.30: 1; KUS without residence = 1.36: 1; KES students = 1.09: 1. It can be said that the effect of residence experience for approximately one year does not affect the release burst duration.

In a short conclusion, the effect of residence experience for a year selectively influences on the temporal features in the word-final stop production. Though we may argue that it affects ratio difference between voiced and voiceless duration for the stop closure, we can't find the evidence that it includes "the pre-consonantal vowel which regarded the most significant signal in voicing distinction" (Raphael, 1972; Kang, 2005b). That is, we can't support the hypothesis that all of the temporal features in L2 production can be changed under the condition of one-year American residence.

2.3.2 Frequency characteristics

By following the source-filter theory (Fant, 1960), the output energy is a product of the source energy and the resonator or filter, in which the source energy is measured as the fundamental frequency and the characteristics of the resonator or filter are measured as the formant frequencies. Naturally, the frequency characteristics represent the speech structure.

Frequency characteristics vary among themselves depending on linguistic stress, speaker emotion, gender, age, and background language. However, when these factors are controlled, reliable values in the frequency characteristics can be obtained (Kent & Read, 2002). Fundamental and formant frequencies are measured from the point of 100 ms where the glottal

peak in the periodic portion of the voiced speech begins. It seems that the frequency characteristics are quite steady on this point, considering that the pre-consonantal duration extends almost from 150 to 200 ms.

A. Fundamental frequency

The range of the fundamental frequency (cumulative percentage 10% to 90%) is various: native speakers (80~120 Hz), KUS with residence experience in America (100~135 Hz), KUS without residence experience in America (120~150 Hz), and KES students (190~270 Hz). Generally, the effect of background language influences on the fundamental frequency. Yang (1996) reports that the mean value of the fundamental frequency for American English male is 130 Hz, while Korean male has the mean value of 169 Hz. It implies that if Korean English learners develop English production well, they are close to native speakers' pattern.

In this part, we can say that the effect of the residence experience affects the fundamental frequency. $f_0$ range from 100 to 135 Hz for KUS with residence experience in America is roughly similar with the pattern of English native speakers ranged from 80 to 120 Hz. It is clear that they are different from their counterpart ranged from 120 to 150 Hz. The mean value of 118 Hz for KUS with residence experience in America is roughly similar with that of 101 Hz for English native speakers, compared to 131 Hz for KUS without residence experience in America and also to 226 Hz for KES students. The results are graphed in <Figure 1>.

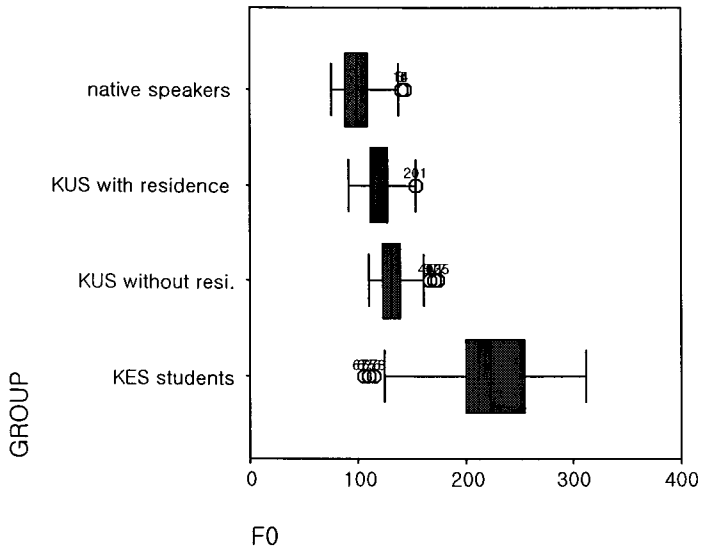


Figure 1. The box plot of word-final stop fundamental frequency (Hz). Null hypothesis represents the case where the average of the fundamental frequency is equal across four groups [$F(3, 767) = 1226.8$, $p < .001$]. *KUS* stands for *Korean university students* and *KES* for *Korean elementary school students.*

B. Formant frequency

The frequencies of the first two formants, F1 and F2, are known to be related with dimensions of vowel articulation. The frequency of F1 is inversely related to tongue height, and the frequency of F2 is related to tongue advanced. By considering articulatory-acoustic correspondence, it is safe that the relationship between F1 and F2 implies speech characteristics of each group.

The mean value of the first and the second formant frequency suggests that the articulatory structure of KUS with residence experience in America has a roughly similar pattern with that of English native speakers. The mean value for KUS with residence experience in America is 662 Hz (voiceless 673 and voiced 650 Hz) of F1 and 1737 Hz (voiceless 1725 and voiced 1750 Hz) of F2, while English native speakers have the mean value of 715 Hz (voiceless 740 and voiced 690 Hz) of F1 and 1727 Hz (voiceless 1706 and voiced 1750 Hz) of F2. Considering that the mean value for KUS without residence experience in America is 618 Hz (voiceless 624 and voiced 613 Hz) of F1 and 1800 Hz (voiceless 1778 and voiced 1820 Hz) of F2 and KES students have the mean value of 755 Hz (voiceless 756 and voiced 753 Hz) of F1 and 2147 Hz (voiceless 2112 and voiced 2183 Hz) of F2, we can support the evidence that the effect of residence experience in America influences on formant frequency. The results are graphed in <Figure 2>.

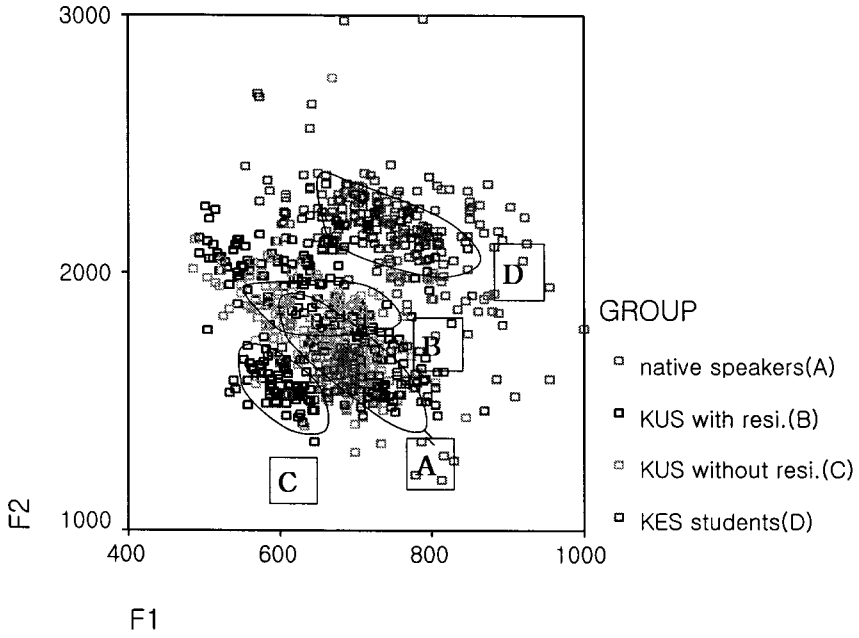


Figure 2. The scatter plot of F1 and F2 in word-final stops (Hz). Null hypothesis represents the case where the average of F1[$F(3, 767) = 147.4$, $p < .001$] and F2[$F(3, 767) = 153.1$, $p < .001$] is equal across four groups. A: *native speakers (native speakers of English).* B: *KUS with resi. (Korean university students with residence experience in America).* C: *KUS without resi. (Korean university students without residence experience in America).* D: *KES students (Korean elementary school students without residence experience in America).*

KUS with residence experience in America for a year has a similar formant frequency range pattern with English native speakers. The range of the first formant and the second formant frequency values (cumulative percentage 10% to 90%) is as follows: native speaker (A) (F1: 640 ~790 Hz, F2: 1500~2200), KUS with residence experience in Ameirca (B) (F1: 570~730 Hz, F2: 1520~1970 Hz), KUS without residence experience in America (C) (F1: 540~700 Hz, F2: 1525~2050 Hz), and KES students (D) (655~860 Hz, F2: 1880~2350 Hz).

In this scatter plot, the range of F1 and F2 for Korean university students with residence experience closely overlaps with that for English native speakers. By following the result from the frequency characteristics, we can say that the effect of residence experience affects the formant structure.

## 3. Perception

### 3.1 Stimuli

A highly educated native speaker of American English was recruited to make stimuli. He was a 27-year-old male who was born and raised in Illinois. He had no history of speech disorders and problems in pronunciation. Minimal pairs of English plosives were selected across places of articulation (bilabial, alveolar, and velar) in the final position. He was asked to read the words embedded in the frame sentence randomly ordered three times. Recording was conducted in a sound-proof broadcasting booth at the University of Incheon. Sounds were recorded with a Shure SM10A microphone on a TASCAM DA-P1 DAT recorder. Recorded sounds were digitalized at a sampling rate of 44,100 Hz and a quantization rate of 16 bits.

The selected words with a typical pronunciation of Standard American English composed stimuli for perception tests. Those words were segmented at a zero-crossing point nearest to the boundary between unit intervals by referring to the waveform and spectrogram of the words on Praat 4.3.19. As a result, a sequence of the preceding vowel and the closure in word-final non-release, and the preceding vowel, the closure and the release-burst in word-final release was obtained. Durations of the unit intervals in milliseconds are provided in <Table 3>.

Table 3. Duration of the cue intervals (ms)

| Position | Word | Preceding Vowel | Closure | Release burst |
|---|---|---|---|---|
| Word-final | dap | 220 | 149 | 40 |
| | dab | 378 | 72 | 72 |
| | dat | 209 | 194 | 55 |
| | dad | 371 | 36 | 50 |
| | dack | 200 | 176 | 20 |
| | dag | 398 | 61 | 77 |

Each unit segment was encoded as voiced or voiceless. Then I produced a sequence of 2 digit signals (the preceding vowel and the closure duration in non-release condition) or 3 digit signals (the preceding vowel, the closure duration and release duration in release condition) by repeated permutation, where each interval functions as a binary digit of 0 and 1.

### 3.2 Procedure

The ExperimentMFC program on Praat was used for the perception tests. Each stimulus was randomly ordered and repeated three times. The perception tests were conducted in a quiet office. Subjects who already took part in the production experiment took the perception test after a week. They were asked to click the mouse on one of the two words presented on the screen wearing a headset. It took around 30 minutes for each subject to complete the series of tasks. The subjects' responses were statistically analyzed with SPSS 10.0.

Responses were analyzed in terms of "Identification Correctness Test" and "Cue Influence Test". These were proved as useful measure standards by previous studies. The identification correctness was defined as the percentage of the correct responses when the original signal was given as stimuli (e.g., Hillenbrand et al. 1984; Crowther & Mann, 1992; Abramson & Tingsabadh, 1999; Lisker, 1999; Redford & Diehl, 1999; MacKay et al., 2001; Park & Kang, 2005; Kang 2005a, b, 2006a, b). For example, responses are considered as correct if the subjects' response is voiceless when a sequence unit of voiceless preceding vowel, voiceless closure, and voiceless release duration is presented in release environment. The response correctness tests how difficult it is to identify the orignal segments correctly.

The resistance of cues to environmental masking is adopted as the measure tool for cue influence in this study. Originally the idea of "Cue Influence Test" adopts from concept of "signal or phoneme robustness" in phonology. Burnham (1986) viewed robustness as acoustic salience and also contrasts that were widely distributed across the world's languages and were acoustically less similar. In a recent study, Wright (2004) suggested that robustness was "a robustly encoded phonological contrast" to survive signal degradation or interference in reception. "Cue influence test" transforms the degree of acoustic salience and resistance to neighbor environments into mathematical measurement. This mathematical measurement was recently carried out in studies of Kang (2005a, b, 2006a, b), Kang and Park (2005), and Park and Kang (2005).

In order to quantify the abstract notion of robustness to the target cue influence, its resistance to the masking of the neighborhood cues is digitalized as digit (0 as voiceless and 1 as voiced) and measured. This target-cue influence is measured as the percentage of non-masked cue when a stimulus is given where only one signal in a particular interval is different from the signals in other intervals (background signals). For example, in order to measure the influence of the voiced pre-consonantal vowel cue in final release environment, the signal 100 (the sequence of voiced preceding vowel, voiceless closure, and voiceless release) is

given to subjects. If she/he chooses 1 (voiced sound), the cue of the preceding vowel gets the influence count, because the cue of the preceding vowel leads the voiced response not masked by adjacent voiceless closure and voiceless release.

### 3.3 Results and Discussion

#### 3.3.1 Consonant Identification Test

The first perceptual experiment was to examine the subjects' accuracy for consonant identification in word final position depending on the presence or absence of the release-burst. English native speakers identified the pure stop voicing signals more clearly than Korean subjects in both conditions of release and non-release. As shown in <Table 4>, Koreans made more errors perceptually in non-released stops than in released stops except for Korean university students who had studied in America.

Table 4. Result of Consonant Identification Test (%)

| | final release | | | final non-release | | |
|---|---|---|---|---|---|---|
| | voiceless | voiced | mean | voiceless | voiced | mean |
| Native speakers | 100 | 99 | 99.5 | 97 | 100 | 98.5 |
| KUS with residence experience | 87 | 100 | 93.5 | 98 | 98 | 98.0 |
| KUS without residence experience | 95 | 95 | 95.0 | 78 | 89 | 83.5 |
| KES students | 92 | 85 | 88.5 | 74 | 80 | 77.0 |

Note: *KUS* stands for *Korean university students* and *KES* for *Korean elementary school students.*

In the final release environment, we cannot find the difference between KUS with residence experience who achieved 93.5% accuracy and KUS without residence experience who achieved 95% accuracy. Even Korean elementary school students identify the phonemes 88.5% correctly. We can say that the cue of the release burst improves the identification rate for non-native English speakers.

In final non-release environment where the release burst cue is removed, KUS with residence experience with 98% accuracy show a similar pattern to English native speakers who achieved 98.5% accuracy. Their rate is quite higher compared to KUS without residence experience who are achieved only 83.5% accuracy. It is safe that the effect of residence experience in America affects the segment identification in the final non-release environment.

#### 3.3.2 Cue Influence Test

The second experiment was to analyze perceptual pattern for subjects of each group through cue influence experiment. <Table 5> shows the perceptual pattern of each group through the cue influence experiment.

Table 5. Result of Cue Influence Test (%)

| | word final release | | | word final non-release | |
|---|---|---|---|---|---|
| | pre-con. vowel | closure | release burst | pre-con. vowel | closure |
| Native speakers | 40.0 | 30.5 | 29.5 | 62.7 | 37.3 |
| KUS with residence experience | 42.6 | 28.9 | 28.4 | 60.5 | 39.5 |
| KUS without residence experience | 36.5 | 33.3 | 30.0 | 57.0 | 43.0 |
| KES students | 38.7 | 32.5 | 28.7 | 59.5 | 40.5 |

Note: *KUS* stands for *Korean university students* and *KES* for *Korean elementary school students.*

In the release environment, a factor (4 groups) * dependent list (response) one-way ANOVA was undertaken to determine if the effect on the groups was comparable. It yielded a significant main effect on the groups [$F(3, 1982) = 4.1$. $p < .01$]. Also T-test for two groups of Korean university students showed that the effect of residence experience was moderately significant [$t = 1.9$, $df = 809$, $p < .05$].

Native speakers of English depend 40% on the pre-consonantal vowel, 30.5% on the closure, and 29.5% on the release burst as the cue influence percentage, KUS with residence experience depend 42.6% on the preceding vowel, 28.9% on the closure, and 28.4% on the release burst. KUS without residence experience depend 36.5% on the preceding vowel, 33.3% on the closure, and 30% on the release burst, and KES students depend 38.7% on the preceding vowel, 32.5% on the closure, and 28.7% on the release burst. In this environment, cue-dependency of KUS with residence experience shows the similar pattern with that of English native speakers. It means that these two groups already decide the voicing in the preconsonantal vowel.

In non-release environment, a factor (4 groups) * dependent list (response) one-way ANOVA was undertaken to determine if the effect on the groups was comparable. It yielded a non-significant effect [$F(3, 1029) = 0.8$. $p > .05$]. Native speakers of English depend 62.7% on the preceding vowel and 37.3% on the closure as the cue influence percentage, KUS with residence experience in America depend 60.5% on the preceding vowel and 39.5% on the closure. KUS without residence experience in America depend 57% on the preceding vowel and 43% on the closure, and KES students depend 59.5% on the preceding vowel and 40.5% on the closure. It is true that the degree of pre-consonantal vowel dependency for English native speakers and KUS with residence experience is higher than that for KUS without residence experience and the KES group.

In a short conclusion, the effect of residence experience in America for a year affects the perceptual procedure which decides what cue leads the L2 system. KUS with residence experience in America depends more on pre-consonantal vowel in deciding the voicing

perceptually than KUS without residence experience in America.

## 4. Conclusion

On the whole, the residence experience in America for Korean university students influences on L2 production as well as perception. They show roughly similar patterns with English native speakers. In the particular production and perception analysis, however, we can find somewhat different asymmetry results.

The asymmetry in production exists between temporal and frequency features. The effect of residence experience for a year affects the frequency features, not the temporal features in the word final stop production. The production of Korean university students who had studied in America shows similar durational patterns of each cue with that of Korean university students who hadn't studied. On the contrary, the fundamental frequency and the range of F1 and F2 of Korean university students who had studied in America closely overlap with those of English native speakers. It is safe to say, based on this result, that the effect of residence experience for a year affects the formant structure.

This asymmetry result can be found in perception, too. We cannot find the difference between Korean university students with residence experience in America and those without experience in identification test in the word-final release environment. In the final non-release environment where the release burst cue is removed, however, Korean university students with residence experience in America who achieved 98% of identification accuracy show a similar pattern with English native speakers who achieved 98.6% of identification accuracy, compared with Korean university students without residence experience in America who achieved 83.5% accuracy. It is true that the effect of residence experience affects the segment identification in the final non-release environment. In the cue influence test, both groups of English native speakers and Korean university students with residence experience in America depend 5% to 7% more on the pre-consonantal vowel in deciding the final stop voicing than both groups of Korean university students without residence experience in America and Korean elementary school students in both environments. On the contrary, both groups of Korean university students without residence experience in America and Korean elementary school students put from 5% to 7% more emphasis on stop closure duration.

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Received: January 30, 2007
Accepted: March 15, 2007

▲ Seok-Han Kang
Language Institute, University of Incheon,
#177 Dohwa Dong, Nam Gu,
Incheon 402-749, South Korea.
Tel: +82-32-770-8006, 018-693-1545
E-mail: kangseok@yonsei.ac.kr