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Phonetic patterns of Koreans producing English vowels, /i, I, u, U/, in words and in sustained phonation

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To the Graduate Council:

I am submitting herewith a thesis written by Youngsun Kim entitled "Phonetic patterns of Koreans producing English vowels, /i, I, u, U/, in words and in sustained phonation." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech Pathology.

Carl W. Asp, Major Professor

We have read this thesis and recommend its acceptance:

Mary Erickson, Mark Hedrick, Sue Hume, Bernard Silverstein

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Carl Asp
Dr. Carl W. Asp, Major Professor

We read this thesis
and recommend its acceptance:

Mary L Erickson
Dr. Mary Erickson

Mark Hedrick
Dr. Mark Hedrick

Sue Hume
Dr. Sue Hume

Bernard Silverstein
Dr. Bernard Silverstein

Accepted for the Council:

CWMinkel
Associate Vice Chancellor and
Dean of The Graduate School

PHONETIC PATTERNS OF KOREANS PRODUCING ENGLISH VOWELS, / i, I, u, U /, IN WORDS AND IN SUSTAINED PHONATION

A Thesis Presented for the
Master of Arts Degree
The University of Tennessee, Knoxville

Youngsun Kim
May 1999

사랑하는 나의 아버지께 바칩니다.

in the memory of

my father,

Jinwon Kim

(1929 ~1984)

Acknowledgments

First of all, I would like to express my appreciation to Dr. Carl Asp. His insight and passion of speech sciences drove me to reach a good starting point as a young speech pathologist. I won't forget his saying, "Ideas are important, but how you share your ideas in scientific ways is more important."

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Abstract

Ten native-Korean male speakers and ten native-American-English male speakers produced the target vowels /i,I,u,U/ in both words and sustained phonation. These recorded speech samples were judged by a panel of three expert judges for vowel identification. They also were analyzed by the experimenter to determine the formant frequencies (F1 and F2) and the vowel duration. All measurements had a high degree of reliability.

Korean speakers produced the phonemic vowels, /i/ and /u/ with a high accuracy similar to that of native English speakers. Korean speakers produced the non-phonemic vowels, /I/ and /U/ with very low accuracy (high number of errors); these errors were not observed in the Americans. Korean errors for non-phonemic /I/ and /U/ were predictable errors, i.e., /i/ for /I/, and /u/ for /U/. In addition, Korean speakers had more errors for sustained vowel phonation than words.

The first formant (F1) was a better predictor for both the Koreans' phonemic and non-phonemic vowel identification. The second formant (F2) and vowel duration were inconsistent predictors of vowel identification. The Korean phonetic patterns provided information for ESL teaching strategies.

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Chapter I.

Introduction

How can a non-native person speak English like a native speaker? This is a common concern of people who want to speak English fluently. Speakers of English as a second language (ESL) want to obtain 100% intelligibility and to be free of a foreign accent. However, most ESL speakers are not fully intelligible and have a noticeable foreign accent. Both of these identify them as being different. Unfortunately, a foreign accent creates a stereotype and is perceived in a prejudicial way regardless of the content of the message. The ESL speakers may suffer emotionally from social discrimination (Gelfer, 1996). In addition, adult second language learners often experience emotional barriers such as anxiety, frustration, and alienation because of being so limited in a target language and yet so fluent and adequate in the native language (Price, 1991). In South Korea, all school age children are required to take English courses from the 3rd grade to 12th grade and most continue to study English as college students. Both spoken and written English proficiencies are used as criteria of employment by employers in South Korea.

How can ESL teachers help their students obtain 100% intelligibility and accent-free speech? According to the American Speech-Language-Hearing Association (ASHA), speech pathologists and teachers need to understand both the culture and the language forms to differentiate a dialect and difference pattern from a language or speech disorder (Battles, et al.,1982). Unfortunately, most second language teachers are insufficiently prepared for the unique role of teaching a second language. They want to meet the needs of second language learners, but they don't have the available information or the conceptual tools (Nostrand et. al., 1993).

The investigator used both Korean and American English phonetics to recognize that ESL teachers view Korean, Japanese and Chinese speakers as having the same vowel patterns. ESL teachers need to understand that Korean vowel patterns are different phonetic patterns from other Asian languages. Each language has a unique set of phonological differences, based on the phonemic and phonetic structures of their native language.

Standard Korean language (Seoul dialect) has 10 vowels, /a, e, i, o, u, y, ɛ, ʌ, ø,ɨ/. The English vowels /i/ and /u/ are phonemic in Korean, whereas the vowels /I/ and /U/ are not phonemic in the Korean language. Most Korean speakers consider /i/ and /I/ as being the same English phoneme. This is also true for the vowel sounds /u/ and /U/. In addition, Korean speakers use vowel duration phonemically in Korean; for example, /nun/ = 'snow' and /nu:n/ = 'eye'. Therefore, Korean speakers perceive the English /i/ and /I/ or /u/ and /U/ as having only different durations as with Korean vowel sounds.

The purpose of the current study was to identify the vowel patterns of Korean male speakers for the four English vowel sounds, /i/ and /I/ or /u/ and /U/ and compare their patterns to American adult male speakers. These vowels were selected because /i/ and /u/ are phonemic in the Korean language, whereas /I/ and /U/ are not phonemic. Vowel patterns were examined for both the perceptual and acoustic characteristics of these English vowels in terms of vowel identification, formant frequencies, and duration.

The experimental questions were as follows:

1. For the English vowels, /i, I, u, U/, is there a perceptual difference between Korean speakers and American speakers' productions in terms of percent correct

a. in /hVd/ words?

b. in sustained vowel phonation?

2. For the English vowels, /i, I, u, U/, is there an acoustic difference between Korean speakers and American speakers' productions for (a) the first formant frequency(F1), (b) the second formant frequency(F2), and (c) the vowel duration

a. in /hVd/ words?

b. in sustained vowel phonation?

3. For the English vowels, /i, I, u, U/, is there a relationship between perceptual percent correct and acoustic measurements of (a) the first formant frequency (F1), (b) the second formant frequency (F2), and (c) the vowel duration?

Chapter II.

Review of the Literature

1. Perceptual and Acoustic Description of Vowels

(1) Source - filter theory of vowel production

The vocal tract is an acoustic filter, the characteristics of which depend on the length and the shape of the vocal tract. When speakers produce different vowels, they are changing the filter characteristics of the vocal tract. The source-filter theory of vowel production (Fant, 1960) states that energy from the source (the vibrating vocal folds) is modified by resonance characteristics of the filter (the vocal tract). The basic principle of the theory of vowel production is that the filter function is independent of the source. Formant frequencies can change as a result of an articulatory change affecting the dimensions of the various parts of the vocal cavity system and thus the filter function. Formant frequencies provide information about the position of the speaker's articulatory organs.

Stevens and House (1961) summarized the source-filter theory of vowel production in the following equation :

$$P(f) = U(f)\ T(f)\ R(f)$$

Where P (F) is the Fourier spectrum of sound pressure measured at a distance from the lips during vowel production, R(f) is a factor that accounts for radiation from the lips, U (f) refers to the glottal volume velocity spectrum, and T (f) represents the transfer function which varies as configuration of the vocal tract changes. In general, U (f) and R (f) are independent of articulatory configuration, whereas T (f) is dependent upon the vocal tract shape, and varies from vowel to vowel.

Kent and Read (1992) noted that the perceptual and acoustic description of vowels is involved in vowel identification, formant frequency, spectrum, duration and fundamental frequency. The following sections will discuss: vowel identification, formant frequency and duration in vowel sounds.

(2) Vowel identification

In 1952, Peterson and Barney reported the acoustic measurements and the perception of vowels. They recorded two repetitions of ten vowels in /hVd/ context spoken by 33 men, 28 women, and 15 children. Acoustic measurements from narrow-band spectra consisted of formant frequencies, formant amplitudes, and fundamental frequencies. In addition, the /hVd/ speech samples were presented to 70 listeners for identification. The confusion matrix identified /i/ correctly with 99.9 % accuracy, /I/ with 92.9 % accuracy, /u/ with 99.2 % accuracy and /U/ with 96.5 % accuracy. The result of the measurement study showed a strong relationship between the intended vowel and the formant frequency (Hillenbrand, Getty, Clark & Wheeler, 1995). Hillenbrand et al. replicated Peterson and Barney's study with 45 men, 48 women, 46 children and 20 listeners. Their confusion matrix showed that /i/ was identified with 99.6 % accuracy, /I/ with 98.8 % accuracy, /u/ with 97.2 % accuracy and /U/ with 97.5 % accuracy.

Despite its prevalence in the literature, Peterson and Barney's database is recognized as having several limitations. For example, according to Ainsworth (1972), duration plays an important role in vowel perception. Also, Klatt (1976) showed that duration plays an important perceptual role in the identification of English vowel pairs that are similar in other respects, e.g. /i/ and /I/. In Peterson and Barney's database, however, vowel duration was not measured.

In a study examining on the role of fundamental frequency and formant frequencies in identifying speakers, LaRiviere (1975) noted that fundamental frequency, second formant frequency and third formant frequency are equally good predictors of confusion among speakers. These are entirely consistent with the speaker identification judgements for the voiced vowels. However, the fundamental frequency and formant frequencies are not the only acoustic cues which contribute to a speaker's identification.

(3) Vowel Formant frequency

The sound energy produced by the vocal folds is shaped by the resonances of the vocal tract. Vowel sounds have several resonances, ranging from low frequency to high frequency. When the vocal tract is reshaped by a change in the articulatory positions, the pattern of resonances changes. Thus, a particular combination of articulatory positions are associated with a vocal tract shape, which is in turn associated with a particular pattern of resonances. The resonances of the vocal tract are called formants. On the spectrogram, each formant appears as a dark band oriented horizontally on the page. Each vowel has a particular pattern of formant structure (Shriberg and Kent, 1995).

The formant frequency estimation is the position on the frequency scale of the peak of the spectrum envelope drawn to enclose the peak of harmonics. In the case of very low formant frequency or when two formant frequencies approximate each other, however, only one side of formant may be visible and the estimate has to be based on this information. In such case, the experimenter may go to a broad band spectrogram and determine the center of the formant band in the broad band spectrogram (Potter and Steinberg, 1950).

Rakerd and Verbrugge (1985) noted the rules for relating the formant frequency with articulatory position. The first formant frequency (F1) varies mostly with tongue height and the second formant frequency (F2) varies mostly with tongue advancement. In general, low vowels have a high Fl frequency and high vowels have a low F1 frequency. Back vowels have low F1 frequency and typically a small F2-F1 difference, whereas the front vowels have a relatively high F2 frequency and a large F2-F1 difference (see Table 1 and Figure 1).

(4) Vowel Duration

Although duration is neglected in the F1-F2 chart, it is always available as a cue in the physical signal of speech. Klatt (1976) concluded that in English, duration often serves as a primary perceptual cue in distinctions between (1) inherently long versus short vowels, (2) voiced versus voiceless fricatives, (3) phrase-final versus non-final syllables, (4) voiced versus voiceless postvocalic consonants, as indicated by changes in the duration of the preceding vowel in phrase-final positions, (5) stressed versus unstressed or reduced vowels and (6) presence or absence of emphasis. Duration is not sufficient in itself to identify any individual vowel. Duration, however, can help the listener to distinguish spectrally similar vowels, such as /i/ versus /I/, or to place vowels in large categories such as tense and lax. In the case of tenseness and laxness in English vowels, tense vowels have greater muscle activity and longer acoustic duration than lax vowels (Peterson and Lehiste, 1960).

An essential problem in the measurement of vowel duration is that of segmentation. Peterson and Lehiste (1960) described the major segmentation cues in the measurement of vowel duration as syllable nuclei. The beginning of a vowel after the initial voiceless fricative was determined by onset of voicing in the first formant. In the case of an initial /h/, formant movements were not adequate indications of the points of transition. The intensity curves, therefore, provided a valuable additional reference. Also, the beginning of final voiced plosives such as /d/ were determined by comparing narrow-band and broad band spectrograms, and then ascertaining at which moment in time the energy in higher harmonics was suddenly diminished because the cessation of voicing was not a proper cue for termination of the syllable nucleus. In

Table 1. Average Formant frequencies (in Hz) of 4 vowels spoken by male speaker (Peterson and Barney, 1952) and average vowel duration (in msec) in /hVd/ words (Peterson and Lehiste, 1960)

English Vowel	First Formant (F1) Frequency	Second Formant (F2) Frequency	Vowel Duration
i	270	2300	207
I	400	2000	161
U	440	1000	163
u	300	850	235

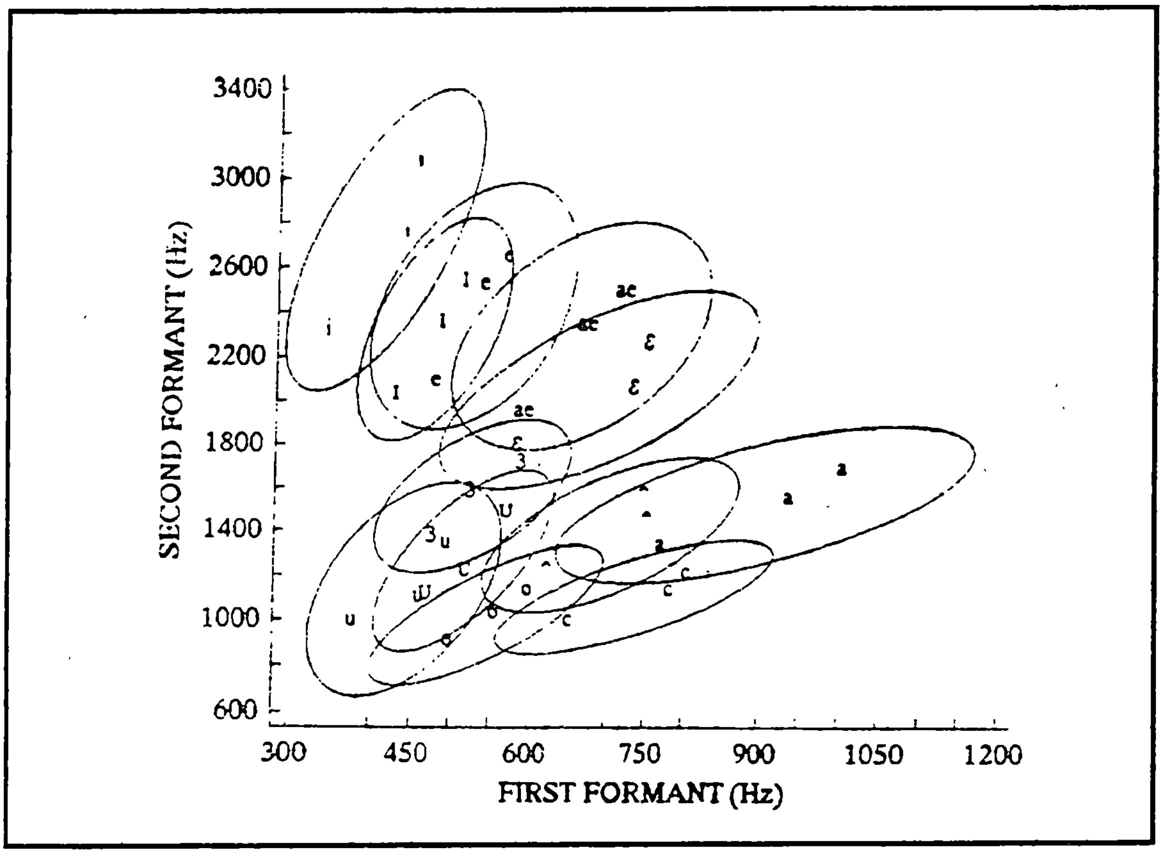

Figure 1. Average values of F1 and F2 frequencies for men, women, and child talkers for 12 vowels with ellipses fit to the data ("ae"=/æ/, "a"=/ ɑ /, " c "=/ ɔ /, " 3 "= / ɝ /) (Hillbrand et. al., 1995)

addition, Peterson and Lehiste (1960) computed vowel duration as a syllable nucleus in a CVC list (Table 1).

2. Speech learning in English as a second language

According to Flege (1992), when adults and older children learn the sound system of a second language (L2), inappropriate use of previously acquired structures in the native language (L1) generally prevents adult learners from being completely successful in mastering the sound system of an L2. In other words, they attempt to decompose L2 words into the phonemic units of L1 and produce the L2 words as if this sound consisted of phonetic elements from the L1.

Sapon (1952) suggested that an L2 learner's production errors arise because the ability to learn new forms of pronunciation diminishes with age. Difficulty in L2 pronunciation could arise from an inability to modify previous patterns of production or to develop new ones. Flege (1988) noted another difficulty for the L2 learner: the difficulty for L2 sounds that do have a counterpart in the L1 inventory, but that occur in an unfamiliar phonetic context or position. For example, Spanish learners appear to be less successful in producing English /s/ in word final than word initial position.

Flege (1992) found that the differences in production between native and nonnative speakers can be traced to an underlying perceptual difference. Perceptual similarity is a more important derminant of L1- for L2 substitution patterns than is articulatory similarity or difference. For example, English /t/ is perceptually more similar to the Hindi retroflex stops. Therefore, Hindi speakers are reported to use Hindi retroflex rather than dental stops in producing English /t/.

Flege and Bohn (1992) determined differences between native Spanish speakers learning English late versus early. Both the early and late learners closely resembled native English speakers in learning temporal contrasts. The speakers in each group produced durations as follows: /i/ was longer than /I/ and /u/ was longer than /U/. Also, the native English speakers and the early L2 learners produced English vowels with little spectral overlap. However, the late learners differed from the native English speakers in terms of intelligibility. In this study, three native English listeners identified vowels in /bVt/ words spoken by native English and Spanish subjects using one of seven keywords (/bVt/). Vowels spoken by the native speakers and the early learners were identified correctly almost without exception, but not vowels spoken by the late learners. For late inexperienced and experienced groups of L2 speakers, /i/ was perceived as /I/, and vice versa. Even though many of the L2 learners had lived in the U.S. for many years and used English daily, the overall intelligibility rates for English vowels were quite low in the absence of semantic context.

Flege (1992) reported that the correct identification rates for Korean subjects were quite low, especially for /æ/ . Korean is not analyzed as having /æ/ , but a perceptual study using a matrix of synthesized vowels indicated that nearly all steady-state, 40-msec vowels identified as /æ/ by native English speakers were consistently identified by Korean listeners in terms of Korean vowel category rather than being judged as falling outside the Korean vowel inventory. Thus /æ/ may not be treated as new by Korean learners of English.

Flege, Muno, and Fox (1992) instructed Spanish and English learners to judge the degree of dissimilarity of pairs of vowels. One finding of this study suggested that L2 learners with good pronunciation of English were better able to perceive sounds at a phonetic level than were L2 learners who pronounced English poorly. Furthermore, an L2 learner who pronounced English well judged pairs of English vowels to be more dissimilar than subjects who pronounced English poorly. This suggested an auditory basis for L2 speech learning ability, perhaps a difference in ability to store and access sensory information for unfamiliar L2 sounds.

Chapter III.

Method

1. Subjects

Ten native Korean male-speakers and ten native American-English male-speakers served as the subjects (see Table 2). The Koreans ranged in age from 25 to 41 years, had a mean age of 29.8 years, and were students at the University of Tennessee or at Pellessippi State Technical College in Knoxville. The Americans ranged in age from 23 to 45 years, had a mean age of 32.5 years, and were students or staff members of the Department of Audiology and Speech Pathology at the University of Tennessee, Knoxville. Eight American speakers were from the Southeast. The other two speakers were originally from West Virginia and Michigan.

The Koreans were from South Korea, had studied English for more than six years, had lived in the U.S. for a mean of two and one-half years, and had scored 500 or greater on the Test of English as a Foreign Language (TOEFL). The passing score indicated a minimum proficiency level for listening and reading the English language. However, the passing score did not indicated proficiency in speech intelligibility or freedom from a foreign accent.

All twenty subjects passed a pure-tone screening test at 25 dB HTL for frequencies 0.5, 1, and 2 kHz for both ears. This indicated all the subjects had normal-hearing tones.

2. Procedures

In 1952, Peterson and Barney reported perceptual vowel identification scores and accurate fundamental and formant frequencies of 10 English vowel sounds spoken in

Table 2. Subject information

Korean Speakers			American English Speakers		
Subject Number	Age (yrs)	Speaking English in U.S. (yrs)	Subject Number	Age (yrs)	Childhood Home States
1	25	4.9	1	23	East Tennessee
2	27	2.2	2	32	East Tennessee
3	28	2.5	3	40	North Carolina
4	25	1.1	4	28	North Carolina
5	27	0.1	5	30	Virginia
6	40	8	6	40	North Carolina
7	33	1.6	7	36	West Virginia
8	41	0.8	8	45	Michigan
9	26	1.5	9	23	East Tennessee
10	26	3.1	10	28	North Carolina
mean	29.8	2.5	mean	32.5	
Range	25 - 41	0.1 - 4.9	Range	23 - 45	

/hVd/ words. Over 40 years later, Hillenbrand et al. (1995) reported the importance of vowel duration and spectral changes in the acoustic characteristics of vowels. The current study used a design similar to the Peterson and Barney (1952) and the Hillenbrand et al. (1995) studies. However, a new condition of sustained vowel phonation was added.

(1) Stimuli, practice and recording session

For the current study, four vowels, /i/, /I/, /u/, and /U/ were spoken in /hVd/ words and in sustained phonation. The /hVd/ context provided the four words, i.e., heed, hid, who'd and hood. Each of 20 subjects spoke each words three times, e.g., " heed, heed, heed " and then spoke each vowel three times, e. g. " /i/, /i/, /i/ "(see, Appendix A).

For the practice session, each subject rehearsed the task to familiarize himself with the experimental procedures. The investigator determined whether each subject understood the tasks, and whether each subject's vowels were 'typical' of how they spoke the vowel sounds. Each subject spoke each item at the rate of one word or vowel per second while reading from the typed lists (see Appendix A). The investigator chose the second of three utterances for both the perceptual and the acoustic analyses.

For the Korean speakers, an audio tape recording, using an analogue audio recorder (Sony, model 2003), was made in a quiet room in the Korean Presbyterian Church in Knoxville. The electret microphone (Listen, model 100) was positioned within 3-inches from the speakers mouth, with the output fed directly to the tape recorder. A sound level meter (Realistic, model 33-2050) was used to measure the ambient noise level and to insure a + 20 dB S/N ratio for the tape recording. The same recording procedure was used for the American speakers in a quiet room of the

Department of Audiology and Speech Pathology. For the perceptual and acoustic analysis, the recorded speech samples were randomly ordered by the investigator.

(2) Vowel identification by an expert panel of three judges

A panel of three expert judges identified the vowels in one hundred and sixty speech samples (4 words x 20 subjects x 2 conditions) and 16 (10%) speech samples randomly chosen for estimating reliability. This resulted in the judgement of 176 speech samples. The expert panel consisted of three experienced speech pathologists who were clinical supervisors and who had ASHA Certification (CCC-SLP). Each judge independently transcribed the vowel that was perceived, using a vowel chart (see Appendix B for worksheet and raw data). Their task was forced choice, i.e., the panel had to select one of 12 English vowels for each sample. The four target vowels were included in the 12-vowel chart. The judges had no knowledge of the twenty subjects' background before making judgements, i.e., Korean vs American speakers.

(3)Vowel formant frequencies (F1 and F2) and duration

The vowel samples were low-pass filtered at 14,000 Hz and digitized using a 28,000 Hz sample rate. The formant frequency analysis used a 16 (14 + 2 shaping) coefficient Linear Predictive Coding (LPC) analysis at the mid-point of the vowel duration. For example, if the vowel was 200 msec in duration, the analysis was at the 100 msec point. If the peaks merged between F1 and F2, an additional coefficient was added to the LPC analysis in order to obtain a F1 and a F2 formant frequency. Vowel duration was measured using digital spectrograms computed by the Computerized Speech Lab (CSL) following criteria developed by Peterson and Lehiste (1960). The beginning and last regular periods of the vowel were measured by the investigator at the onset of voicing in the first formant and after the consonant /h/ ended. The last period of the vowel waveform was measured at the point that the energy in higher harmonics was suddenly diminished before /d/ was began. The duration of sustained vowel phonation was measured but not analyzed statistically because of subjects' individual differences regardless of group.

Chapter IV.

Result, Discussion and Conclusion

1. Results

(1) Measurement Reliability

To estimate reliability, ten percent of the Koreans and ten percent of the Americans' recording were randomly chosen for re-measurement of both the perceptual and the acoustic measurements. For the perceptual measurements (intra-judge reliability), the agreements within the 3-judge panel were 97 %, 97 % and 91 % for the first and the second judgement by each judge.

To estimate the reliability of the acoustic measurement, for /hVd/ words, Pearson product moment correlation coefficients for the re-measurement were computed . Correlation between the two measurements of first formant frequency (F1), the second format frequency (F2) and the vowel duration were 0.99, 0.99 and 0.98, respectively. For sustained phonation, the correlation coefficients of F1 and F2 were 0.99 and 0.99, respectively. Duration was not measured in the sustained phonation.

The above estimates of reliability showed a high measurement-remeasurement reliability for both the perceptual and the acoustic measurements (mean = 95 % and mean = 98 %, respectively). In summary, both the perceptual and acoustic measurements were repeatable.

(2) Perceptual analysis of English vowel sounds

For the Koreans speaking the English vowels /i, I, u, U/, the mean accuracy was 70 % in four / hVd / words and 59 % in four sustained vowel phonations, whereas the mean accuracy was 100 % and 97 %, respectively, for Americans speaking the same target vowels. The sustained phonation had 11 % less accuracy than /hVd/ words (mean= 59 % and mean = 70 %, respectively). The sustained vowels phonations were more difficult condition than /hVd/ words for the Koreans (see Tables 3 and 4, and Figure 2).

In /hVd/ words, the vowels, /i/ and /u/ of both the Koreans and the Americans had high mean accuracy (mean = 85 % and mean = 100 %, respectively). However, for the two vowels, /I/ and /U/, the Koreans had 45 % less mean accuracy than the Americans (mean = 55 % and mean = 100 %, respectively).

In sustained phonation, the vowels /i/ and /u/ of the Koreans and the Americans had high mean accuracy (mean = 97 % and mean = 100 %, respectively). However, for the two vowels, /I/ and /U/, the Koreans had 76 % less mean accuracy than the Americans (mean = 20 % and mean = 96 %, respectively).

Koreans target vowels, /I/ and /U/, were perceived mostly as the vowels, /i/ and /u/. The target and error vowels are similar in tongue height and tongue advancement. This different phonetic pattern may occur because the American English vowels, /I/ and /U/, are not phonemic in the Korean language.

(3) Acoustic analysis of English vowel sounds

An independent t-test was calculated to determined if there was a significant differences in the acoustic measurements between the Koreans and the Americans.

Vowel formant frequencies (F1 and F2) in /hVd/ words

The first format frequency (F1), which varies inversely with tongue height, was significantly lower for the Koreans than for the Americans for the vowels, /I/ and /U/ ($p = 0.01$ and $p < 0.01$, respectively). For Koreans, F1 mean differences between the adjacent /i/ and /I/, and the adjacent /u/ and /U/ were 11 Hz and 10 Hz, respectively.

Table 3. Vowel identified as percent (%) *correct* or percent *incorrect* in /hVd/ words (3a) and sustained phonation (3b) for ten Korean speakers

3a	/ hVd / Words: Identified Vowels:						
		i	I	U	u	o	ε
Target Vowels	i	**90**	10				
	I	30	**70**				
	U			**40**	57	3	
	u			17	**80**	3	

3b	Sustained Phonation: Identified Vowels						
		i	I	U	u	o	ε
Target Vowels	i	**97**	3				
	I	87	**13**				
	U			**27**	67	6	
	u				**97**	3	

Table 4. Vowel identified as percent (%) *correct* or percent *incorrect* in /hVd/ words (4a) and sustained phonation (4b) for ten American speakers

4a	/ hVd / Words: Identified Vowels						
		i	I	U	u	o	ɛ
Target Vowels	i	100					
	I		100				
	U			100			
	u				100		

4b	Sustained Phonation: Identified Vowels						
		i	I	U	u	ʌ / o	ɛ
Target Vowels	i	100					
	I		94				6
	U			97		ʌ: 3	
	u				97	o: 3	

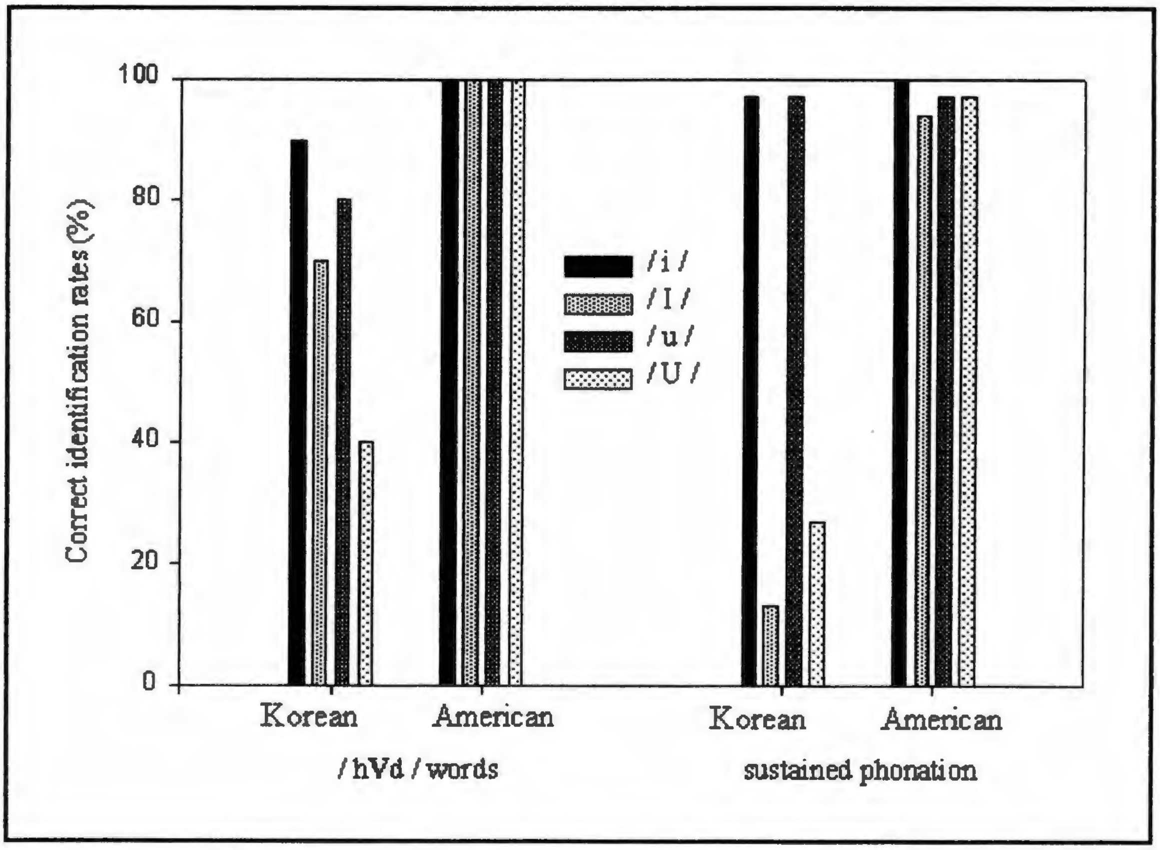

Figure 2. Vowel identification (percent correct) for *Korean and American speakers* in */ hVd / words and sustained phonation*

However, for Americans, the mean F1 differences were 122 Hz and 117 Hz, respectively. The Koreans' smaller F1 differences suggest similar tongue height positions for these adjacent vowels (See Table 5, and Figures 3 and 4). Thus, /i/ was substituted for /I/ and /u/ was substituted for /U/.

The second format frequency (F2), which varies with tongue advancement, showed a significant difference between Koreans and Americans for the vowels, /I/ and /U/, (p = 0.04 and p < 0.01, respectively). For the Koreans, the F2 mean differences of the adjacent /i/ and /I/, and the adjacent /u/ and /U/ were 70 Hz and 24 Hz, respectively, whereas it was 378 Hz and 81 Hz for the Americans. Koreans' smaller F2 differences suggested similar tongue advancement positions for these adjacent vowels, producing substitutions of /i/ for /I/ and /u/ for /U/.

In addition, the F2 for the Korean's /u/ was significantly lower than the Americans, even though both groups had a high mean accuracy (mean = 100 % and mean = 80 %, respectively). It suggested that F2 was not a major factor in correct vowel identification.

Vowel formant frequencies (F1 and F2) in sustained vowel phonation

The first format frequency (F1), which varies inversely with tongue height, were significantly lower for the Koreans than for the Americans of the vowels, /I/ and /U/ (p < 0.01 and p < 0.01, respectively). For Koreans, the mean F1 differences between the adjacent /i/ and /I/, and the adjacent /u/ and /U/ were 9 Hz and 3 Hz, respectively; however, for Americans, the differences were 114 Hz and 132 Hz, respectively. The smaller F1 differences for the Koreans suggested similar tongue height positions for these adjacent vowels (see Table 6, Figure 5 and 6), producing substitutions of /i/ for /I/ and /u/ for /U/.

Table 5. F1 (5a) and F2 (5b) frequencies in / hVd / words for ten Korean and ten American speakers

5a English Vowels	Mean of F1 Frequency (Hz)		Differences between Korean and American Speakers	Significant Level P value (<0.05)
	Korean Speakers (n=10)	American Speakers (n=10)		
/ i /	341	288	53	0.19
/ I /	330	410	80	**0.01**
/ U /	345	430	85	**< 0.01**
/ u /	355	313	42	0.07

5b English Vowels	Mean of F 2 Frequency (Hz)		Differences between Korean and American Speakers	Significant Level P value (<0.05)
	Korean Speakers (n=10)	American Speakers (n=10)		
/ i /	2200	2328	128	0.30
/ I /	2130	1950	180	**0.04**
/ U /	938	1409	471	**< 0.01**
/ u /	914	1328	414	**< 0.01**

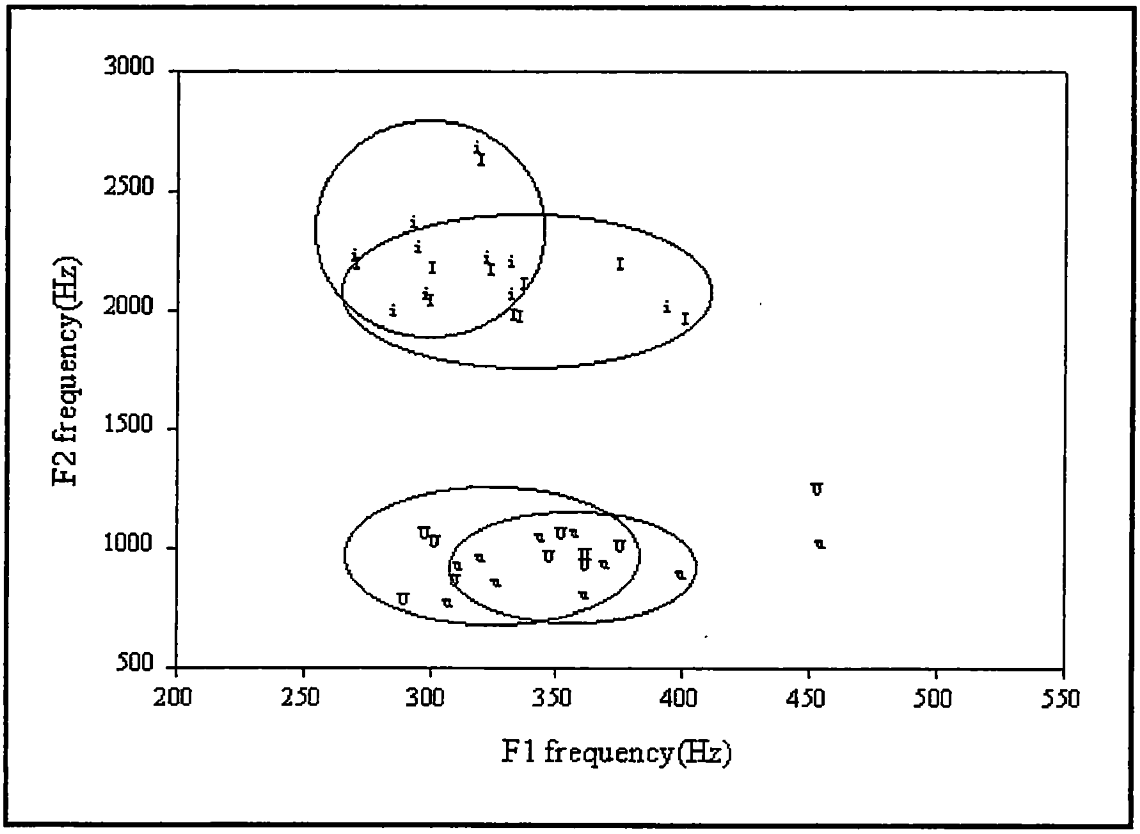

Figure 3. Individual values of F1 and F2 frequencies for *Korean speakers* in

/ hVd / words

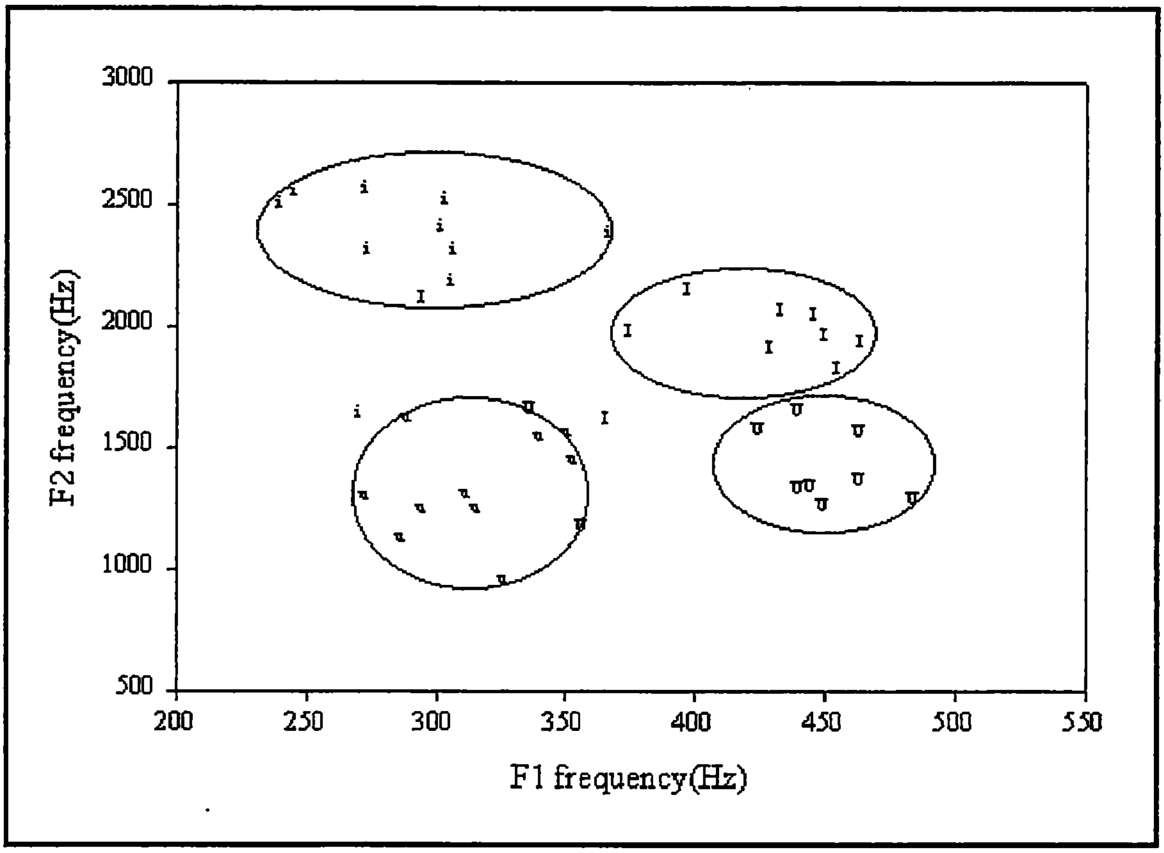

Figure 4. Individual values of F1 and F2 frequencies for *American English speakers* in */ hVd / words*

Table 6. F1 (6a) and F2 (6b) frequencies in sustained vowel phonation for ten Korean and ten American speakers

6a English Vowels	Mean of F 1 Frequency (Hz)		Differences between Korean and American Speakers	Significant Level P value (<0.05)
	Korean Speakers (n=10)	American Speaker (n=10)		
/ i /	295	309	14	0.61
/ I /	286	423	137	**< 0.01**
/ U /	314	439	125	**< 0.01**
/ u /	311	307	4	0.60

6b English Vowels	Mean of F 2 Frequency (Hz)		Differences between Korean and American Speakers	Significant Level P value (<0.05)
	Korean Speakers (n=10)	American Speakers (n=10)		
/ i /	2099	2311	212	0.22
/ I /	2197	2087	110	0.17
/ U /	856	1222	365	**< 0.01**
/ u /	846	1140	294	**< 0.01**

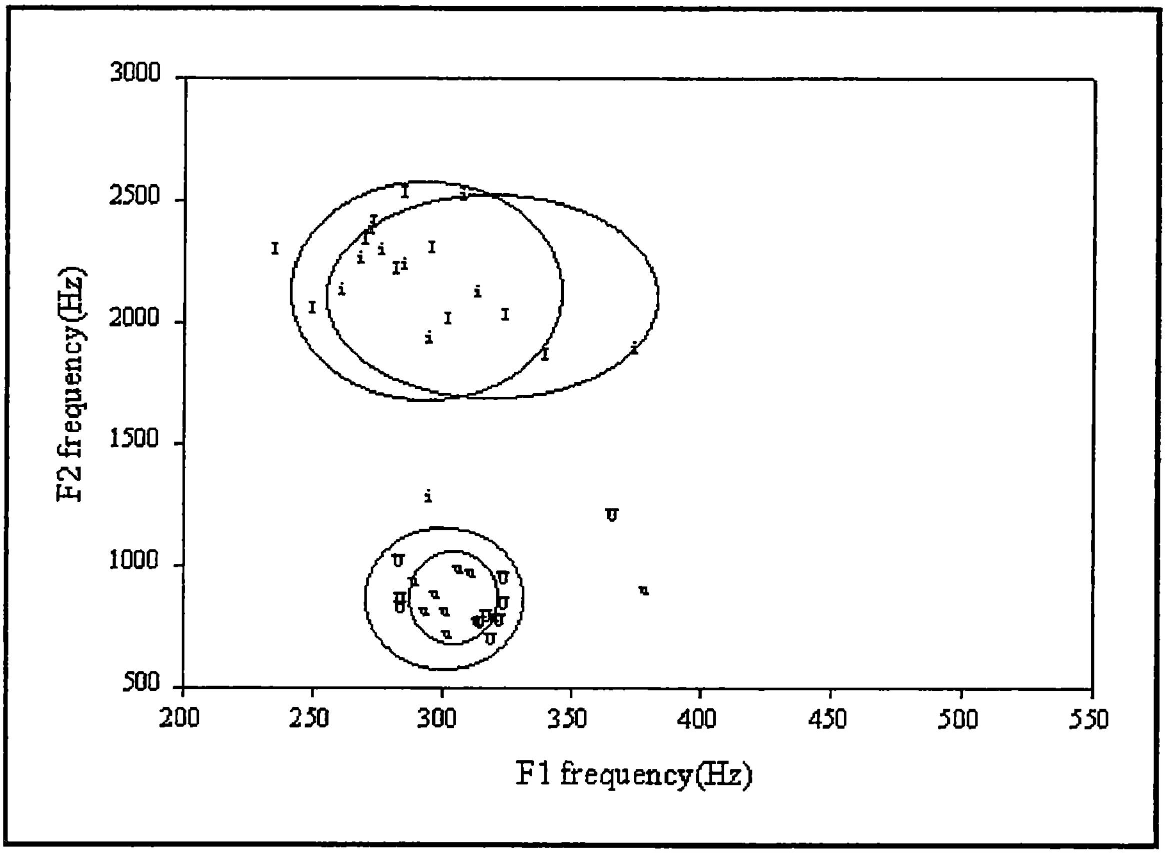

Figure 5. Individual values of F1 and F2 frequencies for *Korean speakers* in *the sustained vowel phonation*

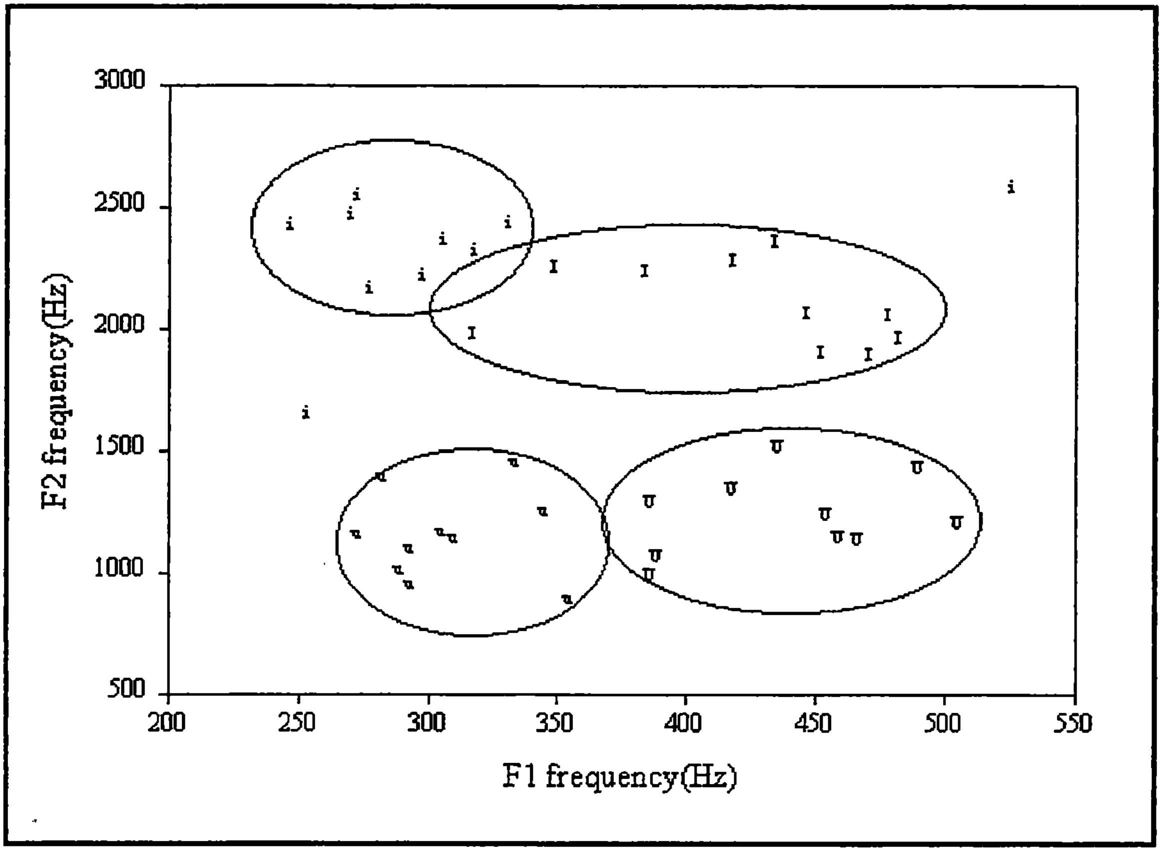

Figure 6. Individual values of F1 and F2 frequencies for *American English speakers* in *the sustained vowel phonation*

The second format frequency (F2), which varies mostly with tongue advancement, was significant lower for the Koreans than the Americans for the vowel, / U / (p < 0.01). Mean F2 differences of the adjacent /i/ and /I/, and the adjacent /u/ and /U/ were 98 Hz and 10 Hz respectively for Koreans, however, for Americans, the differences were 224 Hz and 82 Hz, respectively. The Koreans' smaller F2 differences suggested similar tongue advancement positions for these adjacent vowels, producing substitution of /i/ for /I/ and /u/ for /U/.

In addition, the Korean's F2 for /u/ was significantly lower than the Americans, even though both groups had high mean accuracy (mean = 97 % and mean = 97 %, respectively). The F2 for /I/ were not significantly different between the Koreans and Americans, even though Koreans had lower mean accuracy than the Americans (mean = 13 % and mean = 94 %, respectively). It suggests that F2 was not a major factor in the correct vowel identification.

For the sustained vowel phonation, Koreans had more overlap of the individual data points of F1-F2 plot than for the same vowels in /hVd/ words (see Figure 3 and 5). The Koreans had more difficulty in producing target vowels in sustained phonation.

Vowel duration in / hVd / words

For vowel durations (see Table 7, Figure 7 and 8), the Koreans', /I/ and /u/, in /hVd/ words were significantly shorter than Americans (p < 0.01 and p < 0.01, respectively). Koreans' standard deviation of vowel duration was larger than for the Americans.

The Koreans had similar mean duration for /i/ (263 msec) and /I/ (245 msec), and also for /u/ (235 msec) and /U/ (255 msec). Both the Koreans and Americans had longer durations for long vowels, /i/ and /u/ than for the short vowels, /I/ and /U/.

Table 7. Vowel duration in / hVd / words for ten Korean and ten American speakers

English Vowels	Mean of Vowel Duration (ms)		Differences between Korean and American Speakers	Significant Level P value (<0.05)
	Korean Speakers (n=10)	American Speakers (n=10)		
/ i /	263	329	66	0.05
/ I /	177	245	68	**< 0.01**
/ U /	214	255	41	0.12
/ u /	235	319	84	**< 0.01**

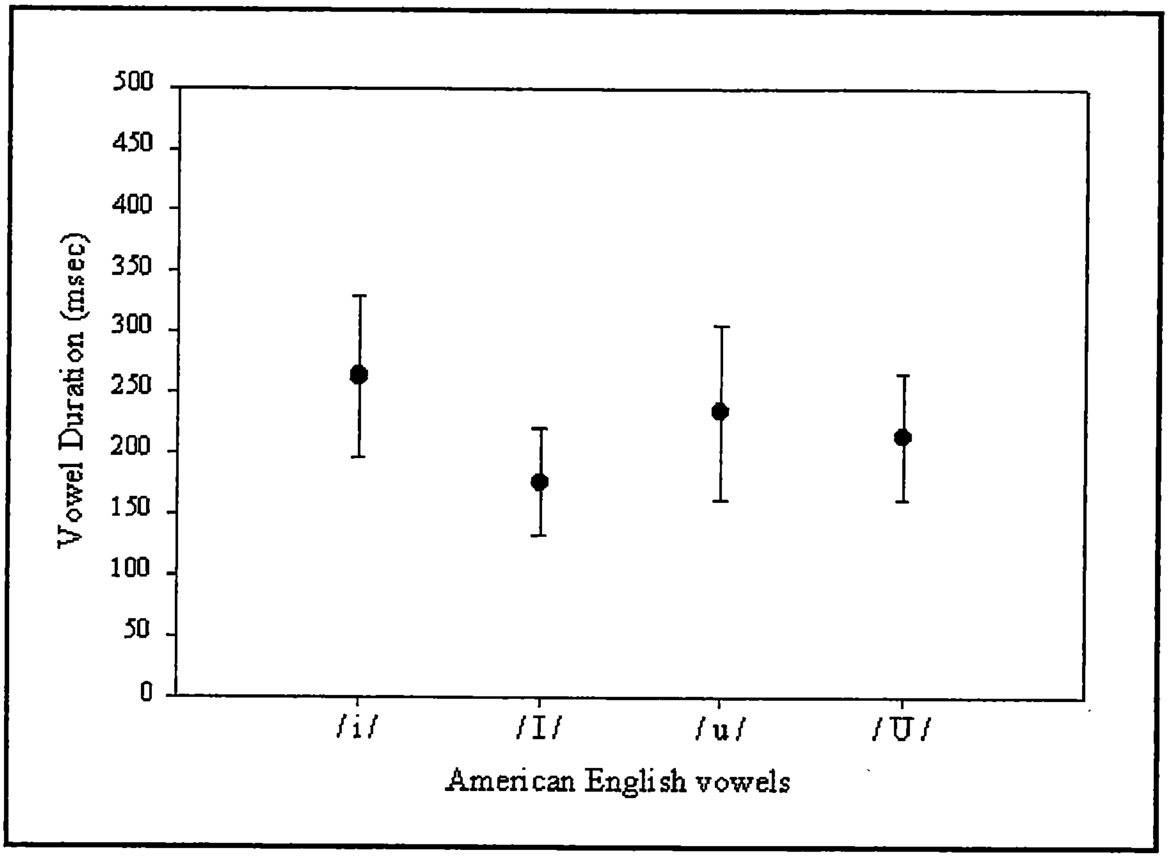

Figure 7. Mean values and Standard Deviation (SD) in Vowel Duration for *Korean speakers* in */ hVd / words*

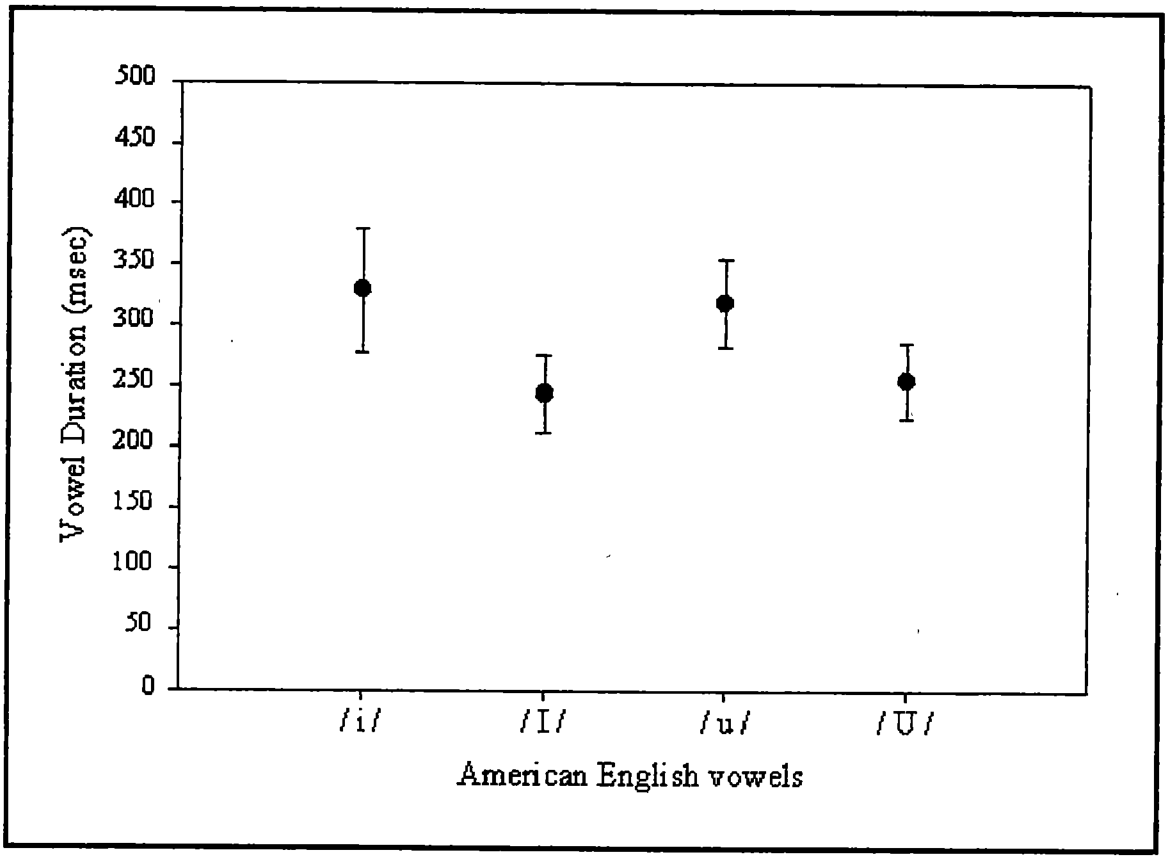

Figure 8. Mean values and Standard Deviation (SD) in Vowel Duration for *American English speakers* in / *hVd* / *words*

However, even though the Koreans' durations for all vowels were shorter than the Americans' duration. Koreans used relative duration in a similar way as did the Americans. Thus, vowel duration appeared not to be a phonemic cue in same cases.

2. Discussion

(1) Phonetic pattern of phonemic /i/ and /u/ for Koreans

For vowels spoken by the Koreans, the panel judged the target vowels,/i/ and /u/ as being correct in both words and sustained phonation. The high percent correct was similar to the Americans. The Koreans performed like Americans for these two vowels.

Since /i/ and /u/ are phonemic in the Korean language, the phonemic factor may be responsible for the high percent correct for the Koreans. It appears that the Koreans were able to perceive these two vowels clearly in English words and to use their Korean phonemic skills in producing them correctly. Apparently, the ESL teachers in Korea achieved a high level of success with these vowels.

The first formant (F1) agreed with the correct production of /i/ and /u/ for the Koreans and the Americans. F1 was similar for both groups in both words and sustained phonation. The F1 data suggested that the Koreans had tongue height positions that were similar to the Americans. For the second formant (F2) and for vowel duration, both measurements were inconsistent, i.e., they were good predictors for the vowel /i/, but not for the vowel /u/. It appeared that F2 and vowel durations were inconsistent for the non-native Koreans.

(2) Phonetic patterns of non-phonemic /I/ and /U/ for Koreans

For the Koreans, both target vowels, /I/ and /U/ had more errors than for the Americans. The high percentage of error by the Koreans may be due to /I/ and/U/

being non-phonemic in the Korean language. Non-phonemic vowels may be harder to perceive and produce correctly in English words. Apparently, the ESL teachers in Korea did not achieve a high level of success with these vowels. In addition, the time spent in the U.S. did not correct these vowel errors.

The Korean error patterns appear to be predictable. The vowel /i/ substituted for the vowel /I/, and the vowel /u/ substituted for the /U/. The same patterns occurred in both words and sustained phonation. It appeared that the phonemic structure of the /i/ and /u/ in the Korean language had a powerful influence in how Koreans perceive and produce the adjacent English vowels /I/ and /U/.

As before, F1 was a good predictor of the vowel identification in both words and sustained phonation. However, F2 was inconsistent; it was a good predictor only in words, and not in sustained phonation. Vowel duration was also inconsistent as a predictor in words.

LaRiviere (1975) indicated that formant frequencies and fundamental frequency are good predictors to identify speech sounds of native Americans speaking English phonemes. For the Korean speakers, the current study agreed with LaRiviere's results only for the F1; it did not agree for the F2 . The importance of F2 and vowel duration for foreign speakers may be different than for native speakers.

(3) Application of these results for ESL teachers

The phonetic vowel patterns for the Koreans are clear for the phonemic and the non-phonemic vowels in this study. For vowels that are not phonemic, /I/ and /U/, the Koreans have predictable error patterns. These non-phonemic vowels need a special teaching strategy to differentiate /I/ and /U/ from the adjacent vowels, /i/ and/u/. Since Korean speakers had more difficulty with sustained vowel phonation, this condition should be included both assessment and teaching strategy. Achieving a high percentage correct for non-phonemic vowels in a sustained phonation may stabilize and enhance the Koreans perceiving and producing these vowels in English words.

3. Conclusion

Based on the result of current study the following conclusion was drawn:

1. Korean speakers produce the phonemic vowels, /i/ and /u/ with high accuracy in English words as the American speakers in English words and sustained phonation.

2. Korean speakers produce the non-phonemic vowels, /I/ and /U/ with low accuracy; whereas the Americans had a high accuracy in English words and sustained phonation.

3. Korean errors for non-phonemic /I/ and /U/ are predictable errors. i.e., /i/ for /I/, and /u/ for /U/.

4. Korean speakers had more difficulty with sustained phonation than words.

5. The first formant (F1) is a better predictor for both phonemic and non-phonemic vowel identification.

6. The second formant (F2) and vowel duration were inconsistent predictors of vowel identification.

7. The Korean phonetic patterns provided information for ESL teaching strategy.

4. For further study

For Korean speakers, further studies should focus on both the perceptual and acoustic phonetic patterns of all English vowels and consonant sounds. The fundamental frequency and the third formant frequency should be added to F1, F2 and vowel duration. The perceptual and acoustic phonetic patterns of English speech could be used to develop and improve speech intelligibility and foreign accent reduction of Korean speakers.

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Appendices

Appendix A. Subject training and recording procedure: four spoken words and four sustained vowels

Thank you for joining my research. The current study focuses on the understanding the English vowel sounds spoken by Korean speakers. The result of this study may contribute to the improvement of English as a second language speech teaching. Your participation is voluntary and you may choose to discontinue at any time with no penalty to you. The information in this study will be kept confidential. The session is expected to take about 15 minutes.

Now, we will do a training session. First, you will speak 4 English words three times in an / hVd / context. You will pause after each word. To help you understand the target vowels, the following five example words are available. The target words have five different words with the same target vowel in the medial position.

Target Words	Example Words
Word # 1 heed	keep, need, please, mean, speed
Word # 2 hid	big, give, him, city, built
Word # 3 who'd	moon, soon, tomb, rule, whose
Word # 4 hood	put, could, good, push, took

Next, you will sustain 4 English vowel sounds three times in isolation.

Target Vowel	Example Word
Vowel # 1 ee	heed

Vowel # 2 i	hid
Vowel # 3 o	who’d
Vowel # 4 oo	hood

Let’s practice one word in / hVd / context and the same isolated vowel sound which is not used in my study.

‘had’ (pause), ‘had (pause), ‘had’.

‘a’ (pause), ‘a’ (pause), ‘a’

Now, we will do the recording session. You will speak four words and four isolated vowel sounds. Word number 1 to number 4 are four words in an / hVd / context. Vowel number 1 to number 4 are the four vowels spoken as isolated vowel sounds. Number 1 vowel sound is the same vowel as in Word number 1. This is also true for vowel number 2, 3 and 4. Make sure you speak the same isolated vowel as in the /hVd/ context. You will speak from word number 1 to 4, and then vowel number 1 to 4. Are there any questions?

Word number	Target Word	Vowel number	Target Vowel
1	heed (pause) heed (pause) heed	1	ee (pause) ee (pause) ee
2	hid (pause) hid (pause) hid	2	i (pause) i (pause) i
3	who’d (pause) who’d (pause) who’d	3	o (pause) o (pause) o
4	hood (pause) hood (pause) hood	4	oo (pause) oo (pause) oo

Are you satisfied that the vowels you spoke were typical of how you speak them? (Note: if not, you could discuss it with me)

Again, thank you for joining my research. If you have any questions concerning this study, contact Youngsun Kim (974-4775)

Appendix B. Worksheet and raw data for vowel identification

Thank you for your participating in my study. This study focuses on understanding the acoustic and perceptual characteristics of English vowel sounds spoken by native Korean male speakers. You will listen to 22 subjects' recorded samples. Each subject will speak 4 English words in / hVd/ words and 4 the sustained vowel phonation. You need to be an ASHA certified speech pathologist (CCC - SLP) with normal hearing Your participation is voluntary and it will take 40 minutes. Please transcribe each vowel sound by writing the phonetic symbol(see attached vowel chart). Don't write down distortion. You should transcribe a vowel sounds that is similar to the recorded vowel sound.

1. Subject number vs. Identification number

Subject Number	Identification Number	Subject Number	Identification Number
1	Korean # 1	12	Korean # 7
2	Korean # 2	13	American # 6
3	Korean # 3	14	American # 7
4	American # 1	15	American # 8
5	American # 2	16	Korean # 8
6	Korean # 4	17	Korean # 9
7	Korean # 5	18	Korean # 10
8	American # 3	19	American # 9
9	American # 4	20	American # 10
10	American # 5	21	Korean # 5
11	Korean # 6	22	American #5

2. Raw data for vowel identification

(1) The Judge # 1: Sue Hume, Ph.D., Clinical supervisor

Subject # 1
Sample #1: hid
2: hɪt
3: hud
4: hʊd
5: i
6: i >
7: u
8: u

Subject # 2
Sample # 1: hid
2: hɪt
3: hud
4: hud˚
5: i
6: ɪ
7: u
8: u

Subject # 3
Sample #1: hid
2: hit
3: hut
4: hud
5: i
6: i
7: u
8: u

Subject # 4
Sample # 1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: ɪ
7: u
8: ʊ

Subject # 5
Sample #1: hid^{ə}
2: hɪd
3: hud
4: hʊd
5: i
6: ɪ
7: u
8: ʊ

Subject # 6
Sample # 1: hit
2: hɪt
3: hut
4: hut
5: i
6: i
7: u
8: u

Subject # 7
Sample #1: hid
2: hit
3: hut
4: hud
5: i
6: i
7: u^{ə}
8: u

Subject # 8
Sample # 1: hid
2: hɪd
3: hud
4: hʊd
~~5~~ i
⑥ ɛ
7: u
⑧: ʌ

Subject # 9
Sample #1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: ɪ
7: u
8: ʊ̃

Subject # 10
Sample # 1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: ɪ
7: u
8: ʊ

Subject # 11
Sample #1: hid
2: hɪt
3: hud^{ʊ}
4: hut
5: i
6: i>
7: u
8: u>

Subject # 12
Sample # 1: hɪl
2: hɪt
3: hud
4: hu°d
5: i
6: i
7: u
8: u

Subject # 13
Sample #1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: i
7: u
8: ʊ

Subject # 14
Sample # 1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: ɪ:
7: u
8: ʊ

Subject # 15
Sample #1: hid
2: hɪd
3: hud^{ə}
4: hʊd^{ə}
5: i
6: ɪ
7: u
8: ʊ˜

Subject # 16
Sample # 1: hid^{ə}
2: hit
3: hud
4: hüd
5: i
6: i>
7: u
8: u>

Subject # 17
Sample #1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: i
7: u
8: u>

Subject # 18
Sample # 1: hid
2: hɪ̈t
3: hud
4: hut̥
5: i
6: i>
7: uː
8: u>

Subject # 19
Sample #1: hid
2: hɪd
3: hud
low volume 4: hʊd
5: i
6: ɪ
7: u
8: ʊ >

Subject # 20
Sample # 1: hid
2: hɪd
3: hud
4: hʊd
5: i
6: ɪ
7: u
8: ʊ

Subject # 21
Sample #1: hid
2: hid
3: hud
4: hud
5: i
6: i>
7: u
8: uᵊ

Subject # 22
Sample # 1: hid
2: hɪdᵊ
3: hud̊
4: hʊd
5: i
6: ɪ
7: u
8: ʊ

Name: ______________ Signature: S Hume Date: 7/23

(2) The Judge # 2: Debbie Suiter M.A., Clinical supervisor

Subject # 1
Sample #1: i
2: ɪ
3: u
4: ʊ
5: ɪ
6: i
7: u
8: u

Subject # 2
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: u

Subject # 3
Sample #1: i
2: ɪ
3: ʊ
4: u
5: i
6: ı
7: u
8: o

Subject # 4
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 5
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 6
Sample # 1: ɪ
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 7
Sample #1: i
2: ɪ
3: u
4: u
5: i
6: ɪ
7: u
8: u

Subject # 8
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 9
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 10
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 11
Sample #1: i
2: i
3: u
4: u
5: i
6: i
7: u
8: ʊ

Subject # 12
Sample # 1: i
2: i
3: u
4: u
5: i
6: i
7: u
8: u

Subject # 13
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 14
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 15
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 16
Sample # 1: i
2: ɪ
3: u
4: u
5: i
6: i
7: u
8: u

Subject # 17
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 18
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 19
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 20
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 21
Sample #1: ɪ
2: ɪ
3: u
4: u
5: i
6: i
7: ʊ
8: u

Subject # 22
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: ʊ
8: ʊ

Name: Debbie Suiter Signature: Debbie Suiter Date: 7/17/98

(3) The Judge # 3: Branda Beverly M.A., Clinical supervisor

Subject # 1
Sample #1: i
2: ɪ
3: ʊ
4: ʊ
5: i
6: i
7: u
8: o

Subject # 2
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 3
Sample #1: i
2: ɪ
3: ʊ
4: o
5: i
6: i
7: o
8: o

Subject # 4
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 5
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 6
Sample # 1: i
2: i
3: ʊ
4: ʊ
5: i
6: i
7: u
8: u

Subject # 7
Sample #1: i
2: i
3: u
4: u
5: i
6: i
7: u
8: u

Subject # 8
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
⑥: ɛ
7: u
8: ʊ

Subject # 9
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 10
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 11
Sample #1: i
2: i
3: ʊ
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 12
Sample # 1: ɪ
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 13
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
⑦: o
8: ʊ

Subject # 14
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 15
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 16
Sample # 1: i
2: i
3: ʊ
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 17
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: ʊ

Subject # 18
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: i
7: u
8: u

Subject # 19
Sample #1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 20
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Subject # 21
Sample #1: i
2: i
3: u
4: u
5: i
6: i
7: u
8: u

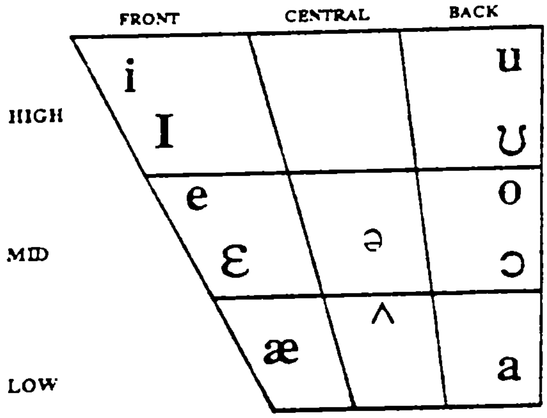
Subject # 22
Sample # 1: i
2: ɪ
3: u
4: ʊ
5: i
6: ɪ
7: u
8: ʊ

Name: Brenda
Beverly

Signature:

Date: 7/17/98

3. Vowels chart of English Vowels (Yavas, 1998)



Appendix C. Raw data of F1, F2 and vowel duration

1. First (F1) and second (F2) formant frequency of vowel / i /.

Subject Number	Korean speaker				American speaker			
	hVd words		sustained		hVd words		sustained	
	F1	F2	F1	F2	F1	F2	F1	F2
1	285	1984	295	1924	301	2937	330	2429
2	322	2213	276	2290	366	2372	317	2317
3	298	2056	261	2125	273	2304	277	2158
4	332	2196	272	2371	239	2492	246	2418
5	270	2214	268	2253	305	2177	297	2213
6	295	2255	285	2230	270	1631	253	1640
7	393	1999	374	1878	245	2542	272	2541
8	332	2058	313	2112	303	2511	270	2463
9	293	2359	295	1264	272	2551	525	2569
10	318	2667	308	2511	306	2303	305	2359

2. First (F1) and second (F2) formant frequency of vowel / I /.

Subject Number	Korean speaker				American speaker			
	hVd words		sustained		hVd words		sustained	
	F1	F2	F1	F2	F1	F2	F1	F2
1	335	1958	302	1998	449	1948	446	2055
2	337	2095	296	2298	445	2037	434	2346
3	300	2029	250	2042	374	1969	452	1887
4	375	2181	270	2334	394	2143	348	2243
5	271	2183	282	2211	454	1811	470	1881
6	324	2156	235	2284	365	1607	317	1969
7	401	1953	339	1859	294	2108	384	2224
8	333	1969	324	2018	463	1922	482	1951
9	301	2167	273	2402	428	1902	418	2268
10	320	2611	285	2521	432	2055	478	2047

3. First (F1) and second (F2) formant frequency of vowel / u /.

Subject Number	Korean speaker				American speaker			
	hVd words		sustained		hVd words		sustained	
	F1	F2	F1	F2	F1	F2	F1	F2
1	361	792	302	703	339	1534	333	1441
2	343	1033	311	955	352	1445	344	1241
3	357	1053	293	804	315	1238	288	1001
4	369	918	320	779	288	1613	282	1377
5	307	762	313	760	286	1120	309	1132
6	399	878	378	885	294	1239	354	879
7	454	1009	306	978	272	1292	272	1144
8	326	841	301	804	325	947	292	943
9	311	911	297	874	311	1302	292	1087
10	320	945	289	920	350	1551	304	1155

4. First (F1) and second (F2) formant frequency of vowel / U /.

Subject Number	Korean speaker				American speaker			
	hVd words		sustained		hVd words		sustained	
	F1	F2	F1	F2	F1	F2	F1	F2
1	347	948	319	682	463	1557	489	1412
2	352	1043	324	933	449	1253	454	1224
3	362	910	284	808	336	1647	417	1329
4	362	953	317	773	424	1559	435	1497
5	290	764	322	762	444	1331	466	1121
6	375	987	366	1187	356	1161	386	975
7	453	1236	283	1001	439	1637	386	975
8	310	845	315	749	484	1278	505	1194
9	302	1008	284	844	439	1317	459	1133
10	298	1045	324	832	463	1351	388	1052

5. Vowel Duration for vowels / i, I, u, U / in /hVd/ words

Subject Number	Korean speaker				American speaker			
	i	I	u	U	i	I	u	U
1	274	151	272	148	297	217	316	252
2	350	234	238	243	283	254	329	267
3	254	113	125	196	290	237	231	263
4	176	169	178	147	319	306	330	307
5	284	212	208	292	357	230	319	233
6	178	164	184	168	292	209	329	277
7	207	181	273	236	400	270	358	285
8	269	137	207	280	428	227	349	207
9	383	254	385	245	288	216	288	216
10	257	150	276	186	338	279	344	243

VITA

Youngsun Kim was born Yangyang, Kangwon-DO, South Korea. He received his B. A. in English Education at Kangwon National University, South Korea in February 22, 1993. After graduation, he finished his military service in the Korean Army.

He entered the graduate program of Speech-Language Pathology, the University of Tennessee, Knoxville, Fall 1996. During this program, he did his practicum in Hospital and private clinical settings in South Korea and worked as a Graduate Assistant. He graduated with M.A. in May, 1999. He will begin the Doctoral program in Summer, 1999.

His clinical interests include verbotonal method for the people with communication disorders, voice disorders, and pediatric and adult dysphagia. After finishing his study, he will go back to South Korea and work with children and adults.