The Characteristics of Vowel Identification Errors of University-level Korean Students of American English: HCA*

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Soon-hyun Hong. 2007. The Characteristics of Vowel Identification Errors of University-level Korean Students of American English: HCA. *Language and Linguistics* 39, 257-277. In an experiment on American English vowel identification ability by Korean listeners, a forced-choice test was administered to 20 Korean university students of English. The stimuli consisted of 324 syllables in which 9 vowels were presented in 18 onset consonant environments. The stimuli CV sequences were cut out of the pre-recorded speech words from an electronic dictionary, and then about 15% of the last part of the vowels was removed for use as stimuli, to avoid potential lexical and coda consonantal effects. After listening to the stimulus, the subjects were forced to click on one of 9 vowel icons on the screen of the computer. Then Hierarchical Cluster Analysis was conducted, demonstrating that the analysis can detect which specific vowel pairs (or triplets) are relatively more confused than the others within subjects. These results can be used as diagnostics to develop subject-customized English vowel listening practices.

Keywords: Vowel Identification, Vowel Perception, HCA, English Vowel Listening Diagnostics

1. Introduction

Korean learners of American English have difficulty perceiving English vowels and often identify them in terms of Korean phonemic categories.

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According to the literature, nonnative sounds tend to be perceived and produced according to the phonetic and phonological patterns of L1 categories (Best 1995, Flege 1988, 1995, Flege & Hillenbrand 1987).

Prior cross-language studies using identification (and discrimination) tasks to examine the performance of native language in perceiving L2 vowels are found on the native Japanese learners of English. It has been found that American English mid and low vowels are difficult for Japanese to distinguish and are "assimilated" to L1 vowel categories (Best 1995, Lambacher et al. 2000, Yamada 1995).

Psycholinguistic experiments using vowel identification tests are frequently found in the literature. Yamada et al. (in press) used both identification and categorical discrimination tests for native Japanese perception of 13 American English vowels, showing that confusions among the mid and low vowels were very common. Strange et al. (1998) studied the perceptual assimilation of 11 American English vowels by Japanese listeners. Listeners were forced to select the Japanese vowel category to which each American English vowel was most similar and to rate its category goodness on a 7-point scale. It was found that low and mid American English vowels were most often "assimilated" to low Japanese vowels.

The purpose of this paper is to show that an identification test can be extended to devise an L2 listening diagnostic tool, which may correctly evaluate the listening ability of L2 learners and can also check the degrees of English vowel "assimilation" to Korean vowel categories within subjects.

There are a lot of listening tests in the form of listening exams to evaluate the listening ability of L2 learners. Unfortunately, however, what they are testing is not exactly on how correctly L2 learners perceive English consonants and vowels. A high score in an English listening test would not necessarily correlate with the high perception accuracy of English vowels and consonants. If a subject knows more

English words, for example, s/he will have a better chance to understand English speech and hence may get a better chance of getting a higher listening score. Furthermore, a learner's L2 listening score does not specifically tell her/him which English vowels s/he has problems perceiving and which vowels s/he does not, and also which English vowels s/he confuses relatively more with which vowels.

Korean L2 learners' difficulties may result from the difference between the phonemic categories in Korean and English. For example, a learner might have no problem discriminating between English /i/ and /ɪ/, but serious problems discriminating between /u/ and /ʊ/ and between /ɛ/ and /æ/. Or a learner might have problems perceiving /æ/ after a group of preceding onset consonants, worse than after the other group of onset consonants. A new diagnostic measure should be developed to catch these within-subject L2 sound perception problems, and hence will be able to help better L2 listening by providing directions for customized listening practices.

This paper examines the perceptual abilities of Korean learners of English to distinguish among 9 English vowels /iy(i)/, /i(ɪ)/, /e(ɛ)/, /ae(æ)/, /a(ɑ)/, /V(ʌ)/, /o(ɔ)/, /u(ʊ)/ and /uw(u)/[1] after listening to a pre-recorded speech tokens spoken by a female native speakers of English.

The current project specifically points out the relative perceptual problems in identifying English vowels by Korean learners. The current project can detect, for example, whether a learner feels more difficulties identifying between English /iy/ and /i/ than between /uw/ and /u/. The literature does not mention, as far as the author knows, whether Korean learners have the same degree of difficulties in perception between these two pairs. As a result, the current project can evaluate whether

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1) In /iy(i)/, /i(ɪ)/, /e(ɛ)/, /ae(æ)/, /a(ɑ)/, /V(ʌ)/, /o(ɔ)/, /u(ʊ)/ and /uw(u)/, the symbols in the parentheses refer to IPA symbols. Due to incompatibility with statistics programs in IPA symbols, /iy, i, e, ae, a, V, o, u, uw/ will instead be used in this paper.

Korean learners of English with different levels of English ability show the same or different degree of identification difficulty across these pairs of English vowels. It will be shown that, the identification difficulty between English /uw/ and /u/ may not necessarily correlate with the identification difficulty between English /iy/ and /i/ within subjects. Subjects may have different patterns of vowel identification problems. To address these questions, the patterns will be represented as a "vowel confusability" hierarchy through Hierarchical Cluster Analysis (HCA). The resulting hierarchy will constitute a good diagnostic for L2 vowel perception ability of the subject. It is hoped that this study could offer L2 teachers and learners a detailed diagnostics for L2 vowel confusability, which in turn will constitute some detailed listening practice guidance.

2. Methods

2.1 Subjects

The listeners were 20 native Korean university students ranging in age from 20 to 25 years old. All of them were students of Department of English Language and Literature in a Korean university. All the listeners had 6 years of prior English instruction at the junior and senior high school levels, but the focus was on English grammar translation. And then they had another 3 years of major-level English instruction. None of the listeners had any reported history of speech or hearing problems.

2.2 Stimuli

A consonant-vowel matrix was made with the rows of 18 English consonants (/p, b, t, d, k, g, f, v, th(θ), dh(ð), s, z, sh(ʃ), ch(ʧ), dz (ʤ), h, l, r/) for the preceding onset consonant environments and with the columns of 9 primary-stressed vowels /iy, i, e, ae, a, o, u, uw, V/ for the target English vowels. /ŋ/ was excluded from the matrix since it does not appear in word-initial position in English. Nasals are also not considered since it is assumed that English nasals are easily identified by Korean learners and the number of the stimuli should be cut down as low as possible. For a longer list of stimuli in a perception test would cause listeners to easily lose their attention to the stimuli. Each cell was filled with a one- or two-syllable English word beginning with the target syllable. Some empty cells, due to English phonotactics or technical difficulty, were filled with neighboring consonants and/or vowel combinations (see 13 bold-faced words below) to make the cases as many as possible for a statistical analysis (9 cases for each consonant). The total number of the words is 162.

〈Table 1〉 CV matrix for stimuli

	iy	i	e	ae	a	o	u	uw	V
p	peak	pit	pest	pat	pop	pause	put	poop	puzzle
b	beast	bit	bet	bat	Bob	bawdy	bush	boot	bus
t	teeth	tick	test	task	top	taught	took	tooth	ton
d	deed	dick	desk	dad	dot	daughter	dubious	do	does
k	keep	kiss	kept	cat	cot	caught	could	coop	cut
g	geek	give	guest	gas	got	gawk	good	goof	gush
f	feast	fish	fetch	fat	father	fought	foot	food	fuss
v	veto	vista	vent	vat	vox pop	vault vaunted		voodoo	vulgar
th	thief **theme**	thick	theft	thank **thatch**		thaw			thud **thug**
dh	thee **these**	this	then **them**	that **than**	thy				thus
s	seat	sip	set	sat	sop	sought	soot	soothe	sup
z	zebra **zenith**	zinc **zip**	zest **zed**	zap				zoo **zoom**	
sh	sheath	ship	shed	shaggy	shock	shawl	shook	shoot	shut
ch	cheap	chip	chess	chat	chop	chalk		choose **chew**	chuck
dz	jeans	gist	jest	Japanese	job **java**	jaw		juice	judge
h	heed	hid	head	had	hod	hog	hood	hoot	hut
l	lead	lid	led	lad	lot	loss	look	lose	love
r	reed	rid	red	rat	rob	raw	rook	roost	rough

The spoken forms of these words were taken from the spoken word data in E4U CD-rom dictionary, spoken by a female English native speaker, and were resampled at a 48 kHz sampling rate. Each speech sample was verified through careful listening by the author. Then the target CV syllables were cut out from the sampled spoken words by referring to the wave and spectrogram windows in Wavesurfer, to avoid a potential lexical effect. Furthermore, to avoid a potential coda-consonantal effect and/or lexical effect, about 15% of the last portion of the vowel was removed through the author's careful listening and also through referring to its corresponding waveform and spectrogram. This procedure was included to make sure that the quality of the target vowel be as invariant as possible by the author's judgment. Such a trimming process does not affect the perception significantly under the assumption that the surface forms of auditory stimuli are retained in memory in the form of exemplars and can be retrieved upon request. The trimming process was motivated in Strange, Jenkins & Johnson (1983). They demonstrated that the vowels in spoken bVb syllables were modified to generate 7 modified syllable conditions in which different parts of the digitized waveform of the syllables in question were deleted and the temporal relationships of the remaining parts were manipulated. The identification results of vowels by untrained listeners showed that dynamic spectral information, contained in initial and final transitions taken together, was sufficient for accurate identification of vowels even when vowel nuclei were attenuated to silence. As for the stimuli in the current experiment, the initial and the proportionally variable center were retained.

2.3 Procedure

A brief introduction to each of the 9 vowels was given to the listeners before the identification test. A vowel perception testing computer program module was built, based on Alvin (Hillenbrand and Gayvert 2005), to make the 162 tokens randomized and repeated twice within a single block, totaling 324 stimuli. The testing program provided a computer screen showing 9 vowel icons with example words beginning with /h/ followed by target vowels (e.g. *heed*, *hid*, *head*, *had*, *hod*, *hawd*, *hood*, *who'd*, and *hud*) and also with IPA symbols for the target vowels. No problem was reported during the experiment since subjects were already familiar with the example words and IPA symbols.

Each subject heard the randomized stimuli presented via a PC over a headphone, and was forced to click on one of the 9 vowel icons for each stimulus s/he heard. In order to make the loudness consistent, the sound volume was fixed to a comfortable listening level by the author and listeners could not adjust the volume. After the click, there was a pause of 400ms before the next stimulus was presented. Without clicking, the next stimulus was not presented. When a listener made a wrong click, s/he could go back and make a readjustment click after listening to the previous stimulus again. Further s/he could listen to the stimuli repeatedly up to three times. The experiment for each listener took about less than 25 minutes.

3. Results

3.1 The structure of the resulting data

The following table shows the descriptive statistics of the resulting data:

〈Table 2〉 Mean accuracy rates across subjects

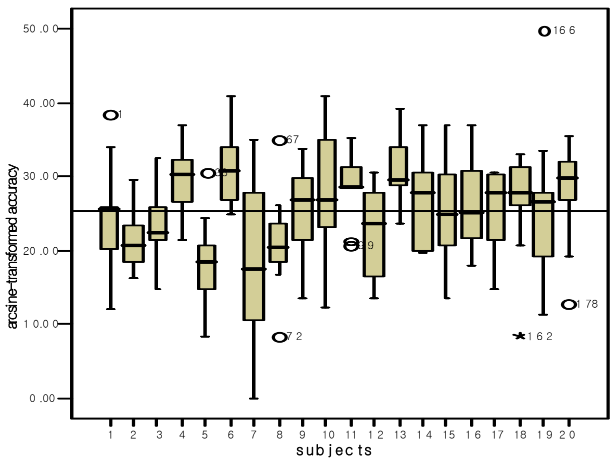
subject	mean	sd	N	subject	mean	sd	N
1	41.37	21.59	9	12	35.37	16.05	9
2	32.17	11.03	9	13	59.27	12.84	9
3	39.11	13.69	9	14	48.28	17.43	9
4	54.32	12.88	9	15	44.13	20.70	9

5	26.83	15.49	9	16	47.53	18.22	9
6	60.11	15.03	9	17	43.16	15.14	9
7	29.13	24.75	9	18	47.18	18.95	9
8	33.55	17.84	9	19	44.40	26.30	9
9	43.44	19.72	9	20	50.62	19.17	9
10	51.07	25.19	9	Grand mean	44.19	19.57	180
11	52.70	13.52	9				

The best and worst mean accuracy rates are 60.11% (subject 6) and 26.83% (subject 5), respectively. The grand mean of correct vowel identification responses of all subjects is 44.19% with s.d.=19.57.

The accuracy rates of each subject's vowel identification among the 9 vowels were arcsin-transformed to reduce a non-homogeneity problem and fed into one-way ANOVA to see if there is significant difference in accuracy across 20 subjects.

<Figure 1> Transformed vowel identification accuracy across subjects



In the box plot above, each box shows the variation of the arcsin-transformed vowel identification accuracy rates for each subject (grand mean=25.44, sd=7.73). Significant difference was found in accuracy rates across subjects: F(19, 160)=1.83 p<0.01 (Levene's Test: F=

1.127, p=0.33). This means that the vowel identification accuracy rates are different as a function of the subjects.

3.2 Problems of vowel identification rates in subjects 1 and 2

The vowel identification responses of subject 1 were reformulated for a confusion matrix for a hierarchical cluster analysis. The following are two-way asymmetric vowel confusion matrices for subjects 1 and 2, with the rows stimuli, the columns responses, and the number in each cell the number of identification responses, respectively:

〈Table 3〉 Subject 1: Two-way asymmetric vowel confusion matrix with frequencies

stim \ res	iy	i	e	ae	a	o	u	uw	V	# of stim.
iy	33	9	0	0	0	0	0	0	0	42
i	13	17	1	1	0	0	3	3	0	38
e	2	0	18	18	0	0	0	1	1	40
ae	0	0	26	13	0	0	0	0	1	40
a	0	0	0	0	15	12	2	1	4	34
o	0	0	0	0	5	23	1	1	4	34
u	0	0	0	0	1	2	7	10	4	24
uw	0	0	0	0	0	0	24	7	5	36
V	0	0	2	6	10	14	0	0	4	36

〈Table 4〉 Subject 2: Two-way asymmetric vowel confusion matrix with frequencies

stim \ res	iy	i	e	ae	a	o	u	uw	V	# of stim.
iy	16	24	2	0	0	0	0	0	0	42
i	21	13	0	0	0	1	1	2	0	38
e	0	3	10	18	7	2	0	0	0	40
ae	0	0	13	22	5	0	0	0	0	40
a	0	0	1	0	13	6	2	11	1	34
o	0	0	2	0	5	12	5	5	5	34
u	0	0	0	0	0	2	5	15	2	24
uw	0	0	0	0	0	1	22	11	2	36
V	0	0	5	1	3	10	4	6	7	36

The values in the matrices above are a reflection of the degree of contrast of a given set of stimuli. The greater the number, the greater is the similarity between vowels.

The vowel identification accuracy rates for each vowel in subject 1 and subject 2 are given below:

〈Table 5〉 Subjects 1 vs. 2: vowel identification accuracy rates for vowels

subjects	Vowel type	Accuracy(%)	# of correct responses	# of stim.
Sub 1	iy	78.6	33	42
	i	44.7	17	38
	e	45	18	40
	ae	32.5	13	40
	a	44.1	15	34
	o	67.6	23	34
	u	29.2	7	24
	uw	19.4	7	36
	V	11.1	4	36
	mean	42.3	137	324
Sub 2	iy	38.1	16	42
	i	34.2	13	48
	e	25	10	40
	ae	55	22	40
	a	38.2	13	34
	o	35.3	12	34
	u	20.8	5	24
	uw	30.6	11	36
	V	19.4	7	36
	mean	33.6	109	324

The identification accuracy rate for each vowel in subjects 1 and 2 says how accurately each subject identifies the target vowel. The grand accuracy means in subjects 1 and 2 are 42.3% and 33.6%, respectively, as shown in table 5. This suggests that subject 1 may be better in vowel identification than subject 2. The accuracy rates for /iy/ and /i/ in subject 1 are 78.6% and 44.7% while those in subject 2 are 38.1% and 34.2%, respectively. Therefore, it may be said that subject 1 is far better identifying /iy/ than subject 2. Accuracy rates for the other vowels can also be described the same way.

This analysis might be a good way to evaluate between-subjects' English perception abilities. However, it does not offer rather more important information: what kinds of English vowel identification errors, given a vowel, does a subject make relative to the other vowels? In table 3, for example, subject 1 correctly identified /iy/ 33 times out of 42 (78.6%) but incorrectly identified /iy/ as /i/ only 9 times (21.4%). In table 4, on the other hand, subject 2 correctly identified /iy/ only 16 times (38.1%) but incorrectly clicked on /i/ 24 times (57.1%). This means that subject 2 wrongly perceived /iy/ more frequently as /i/ whereas subject 1 has a relatively less serious problem for the identification of /iy/. Note that subject 2 wrongly perceived /i/ more frequently as /iy/ (21/38: 55.3%).

On the other hand, subject 1 has a more serious problem identifying /ae/, incorrectly identifying /ae/ as /e/ 26 times out of 40 (65%), as shown in table 3. However, subject 2 made less errors, incorrectly identifying /ae/ as /e/ 13 times out of 40 (32.5%), as in table 4. Subject 2 incorrectly identified /ae/ as /a/ 5 times out of 40 (12.5%) whereas subject 1 made no error at all. This information is very important since it may point out specifically what vowel confusability problems a subject suffers.

Another important aspect of vowel confusability errors is found with respect to stimulus /V/. Subject 1 confused /V/ frequently with both /o/ (14/36: 38.9%) and /a/ (10/36: 27.8%) but correctly identified /V/ only 4 times (11.1%). However, subject 2 confused frequently with /o/ (10/36: 27.8%) but correctly identified /o/ only 7 times (19.4%). These relative vowel confusability errors would have to be seriously considered and analyzed in detail to address what kind of perceptual vowel confusability problems s/he has.

However, this information in tables 3 and 4 is not enough to interpret more specifically which vowel(s) is(are) more confusable with which vowel(s) in each subject. In the next sub-section, the vowel confusion matrices of subjects 1 and 2, shown in tables 3 and 4, will be analyzed through Hierarchical Cluster Analysis (HCA) to tackle the relative vowel confusability problems suffered by the two subjects.

3.3 Introduction to HCA

In this subsection, a new analysis HCA is to be introduced for a easier interpretation of matrices. The following shows the matrix of distances among major US cities with each cell filled with mileage between two cities:

<Table 6> Distance matrix among major US cities

Distance	Bost.	NY	DC	Miami	Chi.	Sea.	SF	LA	Denv.
Boston	0	206	429	1504	963	2976	3095	2979	1949
NY	206	0	233	1308	802	2815	2934	2786	1771
DC	429	233	0	1075	671	2684	2799	2631	1616
Miami	1504	1308	1075	0	1329	3273	3053	2687	2037
Chicago	963	802	671	1329	0	2013	2142	2054	996
Seattle	2976	2815	2684	3273	2013	0	808	1131	1307
SF	3095	2934	2799	3053	2142	808	0	379	1235
LA	2979	2786	2631	2687	2054	1131	379	0	1059
Denver	1949	1771	1616	2037	996	1307	1235	1059	0

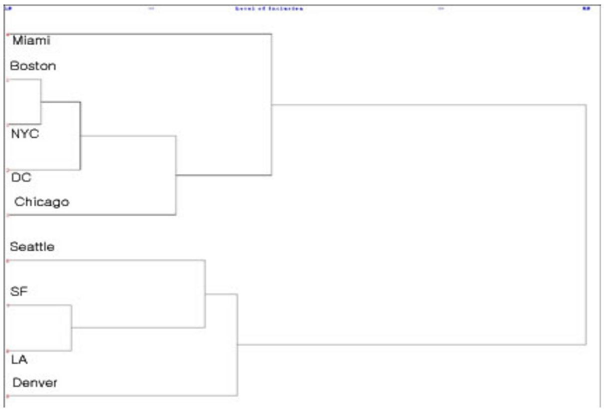
HCA can provide a visual representation of which cities are closer "perceptually" than the others in the form of hierarchy. For HCA, the following Euclidian Distances formula is used:

(1) Euclidian Distances(Anderberg 1973, Romesburg 1984):

$$\text{EUCLID}(x, y) = \sqrt{\sum_i (x_i - y_i)^2}$$

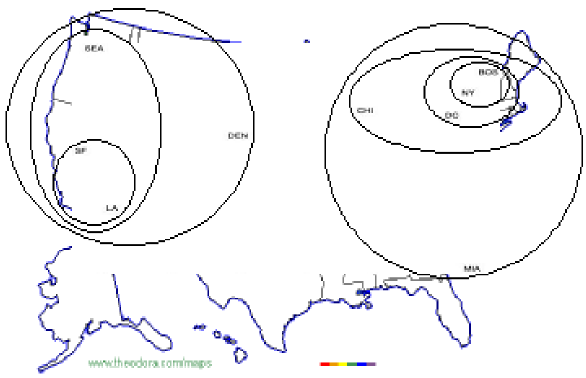
Then the distances were standardized with z-scores. The US city distance matrix was fed into HCA on the row cases for the following dendrogram:

〈Figure 2〉 Dendrogram for the distance matrix for US cities



The dendrogram shows that Boston and NYC are closest among cities and DC is located close to them. Note that the node formed leftward means that the two cities under the node are closer to each other than other cities. SF and LA are closer than the other cities. Seattle is represented close to SF and LA. And the remaining cities are represented to be close to the groups of cities already represented. This dendrogram is compared to the following schematic US map with the circles indicating the nodes in the dendrogram:

〈Figure 3〉 Schematic Map of major US cities

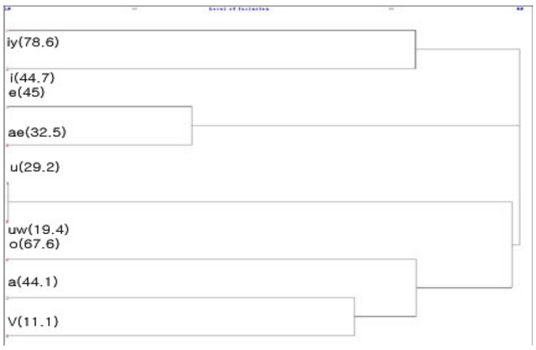


3.4 HCA application of vowel identification

HCA can be applied to vowel identification as in Lang and Ohala (1996) and Lambacher et al. (2000). Perceptually more similar vowels will be represented as a node at a lower scale value while perceptually more distant vowels at a higher scale value. A two-way symmetric vowel confusability matrix of subject 1 was formed from the two-way asymmetric vowel confusability matrices in tables 3 and 4, and fed into HCA.

The following shows the dendrogram for the relative vowel confusability by subject 1 across the stimuli vowels after HCA was conducted:

〈Figure 4〉 Dendrogram for subject 1

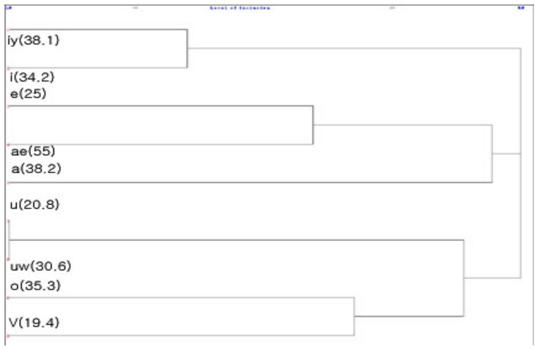


The vowels /u/ and /uw/ were most confusable with each other relative to all the other pairs of vowels as the node were formed the lowest(i.e. the left edge). This means that she perceived the two vowels to be almost identical. Note that number in the parenthesis next to each vowel refers to the correct identification rate. This subject further confused /ae/ with /e/ and /V/ with /a/. However, this subject had relatively less difficulty distinguishing between English /iy/ and /i/.

/e/ and /ae/ have been merged into the Korean vowel inventory and this subject, being attuned to Korean /e/, could not distinguish between English /e/ and /ae/. /V/ is not in the Korean vowel inventory and subject 1 took English /V/ mostly as /a/, and sometimes as /o/. Based on this result for subject 1, her English teacher could figure out her vowel confusability problems. This implies that a special listening practice customized for the subject (e.g. minimal pair practices for the problematic pairs) can be developed to help better his/her English vowel perception, which is a pending research question for further study.

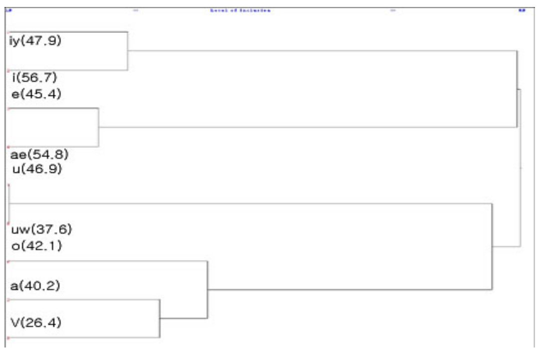
The following dendrogram is for subject 2:

〈Figure 5〉 Dendrogram for subject 2



Subject 2 had a more serious problem distinguishing between /u/ and /uw/. The pairs /iy/ vs. /i/ and /e/ and /ae/ were also seriously confused by this subject.

〈Figure 6〉 Dendrogram for all subjects



The dendrogram for the English vowel identification data for all 20 subjects showed that the most confusable pair by Korean L2 learners were /u/ vs. /uw/; /e/ vs. /ae/, /iy/ vs. /i/, and /a/ vs. /V/ were also easily confusable pairs. The distinctions in these pairs do not exist in the Korean vowel phonemic inventory, suggesting that Korean learners are attuned to the native vowels when listening to English vowels.

4. Discussions and conclusion

The goal of this study was to investigate how to measure the Korean L2 learners' vowel confusability.

As a first step, we statistically verified that vowel identification accuracy significantly varied across subjects. We further demonstrated, using HCA, specifically in what way university-level Korean students were confused among English vowels. The dendrogram (figure 6) for the overall Korean L2 learners clearly shows that the most serious vowel confusability problems were observed from the English pairs /e/ vs. /ae/ and /iy/ vs. /i/, and a triplet /a/ vs. /V/ vs. /o/. These pairs or triplets strongly suggest that Korean learners' native Korean vowel categories are transferred to English vowel identification.

The Korean L2 learners perceive American English sounds in terms of Korean phonemic categories. English /uw/ and /u/ are assimilated to native Korean /u/, English /e/ and /ae/ to native Korean /e/, English /a/ and /V/ are assimilated to native Korean /a/, and English /iy/ and /i/ to Korean /i/.

It was also found that the degrees of identification difficulties across vowel pairs or triplet vary within subjects. Subject 1 had more difficulties identifying between /a/ vs. /V/ than other pairs or triplets. However, subject 2 had more difficulties identifying between /o/ and /V/ and between /iy/ and /i/. Subject 1 showed perceptually more closeness between English /e/ and /ae/ than between /iy/ and /i/. Subject 2, however, showed more perceptual closeness between /iy/ and /i/ than /e/ and /ae/. This means that within-subject differences really exist and these subject-specific problems should be addressed by an individual-based customized vowel listening practices.

The following are the reference vowel identification data of a monolingual native American English male from Pennsylvania:

<Table 7> Confusion matrix with percentage identified in each cell for a native monolingual American English male from Pennsylvania.

AE	iy	i	e	ae	a	o	u	uw	V
iy	90.5	4.8	0	0	0	0	0	4.8	0
i	0	100	0	0	0	0	0	0	0
e	0	0	80	15	5	0	0	0	0
ae	0	0	5	87.5	7.5	0	0	0	0
a	0	0	2.9	2.9	91.2	2.9	0	0	0
o	0	0	5.9	5.9	23.5	64.7	0	0	0
u	4.2	4.2	0	0	0	0	88	0	4.2
uw	0	0	0	0	0	0	0	100	0
V	0	0	13.9	19.4	27.8	5.6	0	0	33

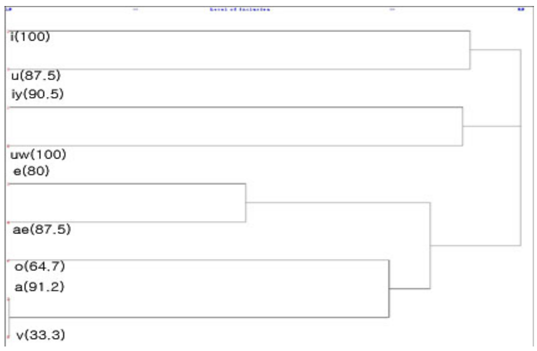
<Table 8> Correct identification rates for vowels for a native monolingual American English male

Vowel type	Accuracy(%)	# of correct responses	# of stim.
iy	90.5	38	42
i	100	38	38
e	80	32	40
ae	87.5	35	40
a	91.2	31	34
o	64.7	22	34
u	87.5	21	24
uw	100	36	36
V	33.3	12	36
mean	81.8	265	324

Table 8 shows that the mean of the correct vowel identification rates is 81.8%. He had a serious problem in identifying /V/ correctly (33.3%), identifying /V/ incorrectly as /a/ 27.8%, as /ae/ 19.4%, and as /e/

13.9%. He further identified /o/ correctly 64.7%. However, he identified /o/ wrongly as /a/ 23.5%. The subject was from Pennsylvania, USA, and the difficulty in the distinction between /V/ and /a/ might be due to American English dialectal variation, which will not be addressed in this paper. The following shows the resulting dendrogram, and the perceptual closeness between /a/ and /V/ is shown at the bottom:

〈Figure 7〉 Dendrogram for a native monolingual American English male from Pennsylvania



MacKain et al. (1981) found that Japanese learners of English with more English experience had significantly better performance on identification tests (and discrimination tests) than did less experienced Japanese subjects. According to Gottfried (1984), persistent perceptual difficulties with non-native vowel contrasts exist. American L2 learners with average 7 years of French study made significantly fewer errors on French vowels in CVC syllables than English monolinguals with no French experience. This suggests that language-specific phonetic perceptual patterns are modified by foreign language experience and that intensive conversational training in the L2 can facilitate perceptual learning. Bradlow et al. (1997) showed that minimal pair practices for 3 weeks significantly enhance L2 learners identification ability between /r/ and /l/. These reports suggest that the vowel minimal pair practices customized for the individual subject, based on the proposed vowel diagnostic using HCA, may help better his/her vowel listening. This is a pending question for further study.

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