Labial Position and Acoustics of Korean and English High Vowels

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Abstract

This paper examines and contrasts the labial configuration and formant frequencies of Korean and English high vowels. Korean has three high vowels, /i, ɨ, u/, and English has four, /i, I, U, u/. The lip gestures and formant frequencies were compared within each language and across languages to determine whether the idea of maximal dispersion (Liljencrants and Lindblom (1972)) can account for the distribution of formant frequencies and also be extended to account for the labial configurations. Four male speakers of each language produced each vowel in four different contexts with five repetitions. The production of each word was videotaped and the sound was simultaneously recorded. The lip configurations were assessed using measurements similar to those in Linker(1982) and MANOVA was performed on the measurement data. The formant values were converted to the Bark scale to better represent the perceptual distance. The results of formant frequencies show that the mean F2 values of English back vowels, /u, U/, are significantly higher than that of Korean back vowel, /u/, while the F2 means of /i/'s in both languages are almost the same. The fact that Korean high vowels take more spaces in F2 is contradictory to the prediction of dispersion theory. The same tendency is shown in the result of the labial measurements. That is, Korean /u/ is produced with more rounded and more protruded lips than English /u/, while /i/'s in both languages are produced with the same degree of lip opening even though Korean /i/ used more spread lips. However, if we consider vowels in the same height (similar values of mean F1), we can find the maximal dispersion theory could explain the result since English has only two high vowels, /i, u/, and Korean has three.

Introduction

Studies of vowel spaces across languages have suggested to phoneticians that there are at least three possible principles to account for the distribution. They are Lindblom's *principle of maximal dispersion* (Liljiencrants & Lindblom, 1972), a more generally proposed principle of sufficient contrast (Lindblom, 1975, 1979, Maddieson, 1977), and Stevens's quantal theory (Stevens, 1972, 1989).

By the principle of maximal dispersion, Liljiencrants and Lindblom proposed that vowels tend to be distributed so as to be maximally far from one another in the available phonetic space. And the point vowels, /i/, /u/, /a/, tend to be pheripheral, maximizing the difference from center of vowel space.

The principle of sufficient contrast is actually a revised version of *the dispersion theory*, suggested by Lindblom (1975, 1979), Terbeek (1977) and Maddieson (1977). This theory says that vowels need not be maximally separated, but only separated far enough to contrast perceptually with each other. The

problem with this theory is that it is not clear what the "enough space" means. For this problem, Lindblom suggested that the degree of this contrast is invariant across languages and system size, but the phonetic values of vowel phonemes should exhibit more variation in small than in large systems.

The third theory of vowel systems, Stevens's(1972, 1989) *quantal theory* is completely independent of the first two. Stevens's model predicts fixed phonetic spaces for the point vowels, irrespective of the size of vowel systems. According to this theory, the relationship between articulatory and acoustic dimension is not linear, so that there are regions of the vocal tract where relatively great articulatory variations produce negligible changes in acoustic signal. Such an acoustically stable region is called a quantal region. Stevens proposed that the three point vowels are produced in such regions. Since point vowels do not require a great articulatory precision, most languages tend to use the same point vowels and they will occupy the same optimal positions in the acoustic space.

This paper studies the distribution of high vowels in two languages with different vowel systems. Korean has three phonologically high vowels, /i, ɨ, u/, and English has four, /i, ɪ, ʊ, u/. The distribution of high vowels in each language is examined acoustically and articulatorily and the observed distribution of measured values is evaluated against the predictions of the three principles mentioned above; *maximal dispersion*, *sufficient contrast*, and *quantal theory*. Most studies of dispersion or quantal theory have used only acoustic data (e.g., Formant values of vowels, voice onset time, tone spacing, etc.). However, in addition to an acoustic area, this paper tries to expand the application of the concept of dispersion or that of quantal area to an articulatory space of vowels. The distribution in the articulatory space is examined by measuring several aspects of labial position for each vowel. Since both languages have phonemically the same point vowels, /i/ and /u/, and each language has one or more vowels which the other language doesn't have, comparing the two languages' same or different vowels as well as their vowel systems as a whole allows us to differentiate the three theories as follows.

The *maximal dispersion theory* predicts that, in order to keep "the maximum contrast distance" between vowels, /i/ and /u/ in both languages would occupy extreme peripheral areas of the acoustic space and have extreme lip movements, while Korean /ɨ/ would occupy an intermediate position between English /I/ and /U/. Furthermore, to keep a maximal distance between vowels, vowels would not vary a lot.

The *sufficient contrast dispersion theory* predicts that the vowel space of Korean high vowels would take less space than English in the F2 dimension, which is believed to be an indicator of frontness versus backness. Also Korean vowels should have less extreme lip rounding for /u/ compared to English /u/, due to the fact that English has two round vowels, /u, ʊ/. In terms of variation, this theory would predict Korean vowels, in a smaller vowel system, would vary more than English ones.

Finally, *quantal theory* predicts that English and Korean /i/ and /u/, as quantal vowels, would take the same positions in acoustic space and use the same degree of labial movement. Also these vowels should vary a lot in labial positions but a little in acoustic space, since point vowels are supposedly very stable in the acoustic output compared with a wide range of articulation input. By contrast, the other non-point vowels would vary more in acoustic space and there should be only a corresponding variability in articulatory space.

To test these predictions, lip gestures and formant frequencies were compared within each language and across languages.

Method

Subjects

Four male speakers of each language participated in this experiment. The English subjects are in their early twenties (two OSU undergraduates and two OSU graduate students); the Korean subjects are in their late twenties (all OSU graduate students). The English speakers are all from a similar American Midwestern dialect area. The Three Korean speakers are from Seoul. One, originally from Kwangju (Chonnam province), had lived in Seoul for 8 years before coming to America. (These two dialects have no differences in vowel quality.)

Materials

Words with each target vowel in 4 different contexts - bilabial /b/ or /p/, alveolar /s/, velar /k/, glottal /h/ - were selected. For English words, coda consonants are not controlled, but they usually ended in /t/ and all of them are real words. Not all Korean words are real words, but the nonwords did not cause any problem for pronunciation. The test words are shown in Table I.

Table I. Korean and English test words

Korean			
ki -"energy"	pi - "rain"	si - "an hour (unit)"	hi - NM
kɨ -"that"	pɨ - NM	sɨ - NM	hɨ - NM
ku -"a circle"	pu -"richness"	su -"excellence"	hu -"after"

* NM= no meaning

English			
key	beat	seat	heat
kick	bit	sit	hit
cook	book	soot	hood
coo	boot	suit	who'd

Other words with other vowels were selected as foil data. There were 12 foil words for Korean and 16 foil words for English. (The foils are listed in an appendix.) The words were presented to the subjects on large cards (5 in. * 8 in.). 5 tokens of each word were pseudo-randomized so that the first and the last word in each card were from the foil words to avoid any list intonation effect. Each card contains seven words listed vertically.

Recording Procedures

Labial position was captured by video taping in a corner of a room: Each subject was sitting on a chair looking at the video camera, which was mounted on a tripod within 1 meter in front of the subject. A side view was caught by putting a mirror at a 45-degree angle to the right side of the subject's head. Behind and beside the subject's chair, there was calibration paper with horizontal and vertical gridlines 1 cm apart. These calibration grids were used to compare ratios of pictures between subjects and between tapings. One or more books were stacked behind subject's neck to prevent head nodding while reading. A subject's lips

were outlined in a dark color for easier measurement later. An adhesive black triangle tape was attached to the subject's earlobe to be used as a reference point for side view measurements. Subjects read each word in citation form by looking at a card which was held by the experimentor standing beside the video camera. Sound was recorded simultaneously for acoustic analysis. Figure 1 shows pictures (printed with a video printer) of one frame of the video film for a production of /u/, by a Korean speaker (above) and an English speaker (below).

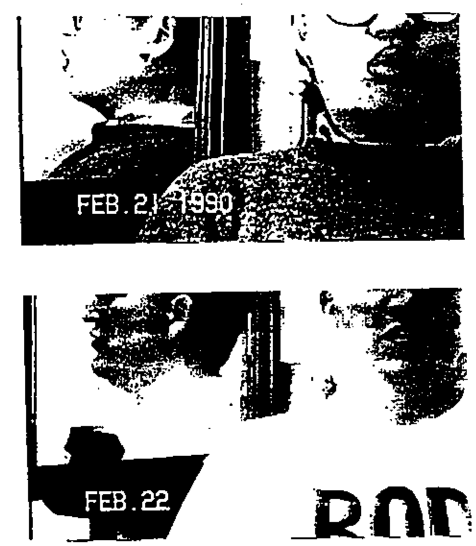

Figure 1. pictures of video film. (Hard copies of TV screen) The above one is a Korean subject and the below is an English subject saying [u].

Measurements

The tape was played on a VCR. A frame was chosen and paused when the lip movement reached a steady state, indicating the vowel reached its target position. Total eleven measurements of each lip shape were made on a TV monitor attached to the VCR. Four measurements were taken from the front view and seven measurements were taken from the side view. These are shown below :

From the front view

HOW : Horizontal outer width
HIW : Horizontal inner width
VCO : Vertical central opening
VSO : Vertical side opening

From the side view

VO : Vertical distance between upper and lower lips
CPP : Corner to protrusion plane

RTC : Reference to corner
CTU : Corner to upper lip
CTL : Corner to lower lip
VCU : Vertical distance from corner to upper lip
VCL : Vertical distance from corner to lower lip

Figure 2 defines these measurements. Most of these were adopted from measurements by W. Linker(1982). Among the side view lip measurements, Corner To Upper lip (=CTU) and Corner To Lower lip (=CTL) were defined as the distance from the corner of the lips to the outer most point on the upper and lower lips, respectively. For the Reference To Corner (=RTC) measure, the reference point was chosen as the point where the earlobe joins the cheek, since this place hardly moves when speaking. In addition to these eleven primary measurements, area of lip opening, a derived measure, was calculated based on the horizontal and vertical lip opening measurements using the following formula:

AREA = (VCO+VSO) * .25HIW + VSO * .25HIW.

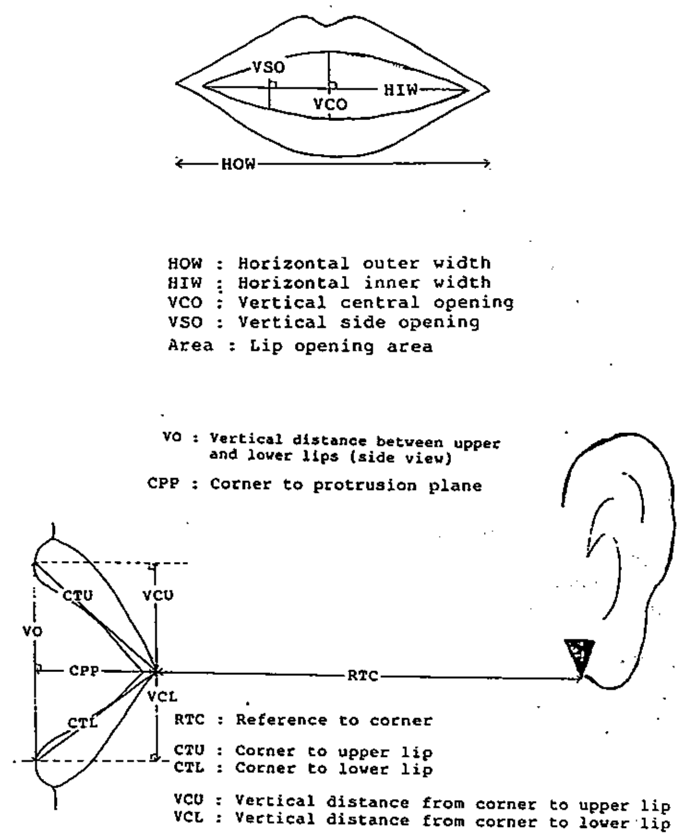

Figure 2. Eleven lip measurements, five from the front view and seven from the side view.

Also, since each subject's physical lip size is not the same, eight ratio values based on Horizontal Inner lip Width (HIW) measurement and four ratio values based on Vertical Central lip Opening (VCO) measurement were calculated as follows:

HIW/VCO,	HIW/RTC,	HIW/CTU,	HIW/CTL
HIW/VCU,	HIW/VCL,	HIW/VO,	HIW/CPP
VCO/RTC,	VCO/CTU,	VCO/CTL,	VCO/CPP

And two ratios of an upper lip opening relative to a lower lip opening:

CTU/CTL, VCU/VCL

were calculated. Thus, a total 25 measurements were collected from each vowel. Each measurement was made using a milimeter-scaled ruler. Whenever possible, a tenth of a milimeter unit was used. Since the side view was captured through a mirror set beside a subject's head, measurements from the side view were smaller than those from front view. To balance the side view with the front view measurements, each measurement of the side view was multiplied by the ratio of front to side view for each subject. These measurement data were analyzed using MANOVA & ANOVA to assess the effect of differences between languages, between vowels, and between contexts, and interactions among all these factors.

The sound was copied from the video tape to a cassette tape. The sound was digitized onto a PC and the formant values were measured using an LPC formant tracker with 14 coefficients, 200 window size and 100 window step. To obtain values that were closer to perceptual distances, formant measurements were converted from Hz to the Bark scale (Traunmuller, 1983).

Results and Discussion

Formant values

Figure 3 shows the formant values, F1 and F2, plotted in the Bark scale for each of the two languages. As the figure shows, English vowels are not maximally separated from one another. Also the vowel space for English is somewhat smaller in the F2 dimension than for Korean; this is mainly due to the low F2 of Korean /u/.

This result contradicts the predictions of all three theories discussed in the introduction. It is counter to the predictions of the Liljiencrants and Lindblom's maximal dispersion theory since the distance between two extreme vowels, /i/ and /u/, are not the same for the two languages. It is also counter to the predictions of Stevens's quantal theory since the same point vowel, /u/, occupies a different acoustic space in different languages. Also, the fact that English has a smaller range of F2 is counter to the predictions of Lindblom's Sufficient Contrast Theory, since English has phonemically more high vowels than Korean along the dimension of backness.

On the other hand, for the vowel /i/ the two languages are not significantly different in their mean values of F1 and F2 and their variation. This supports Stevens's quantal theory which discribes [i] as a quantal vowel, which should be relatively invariant across languages.

Figure 4 shows mean values for F1 and F2 for all of the vowels separately. The error bars show the standard deviation(SD)s.

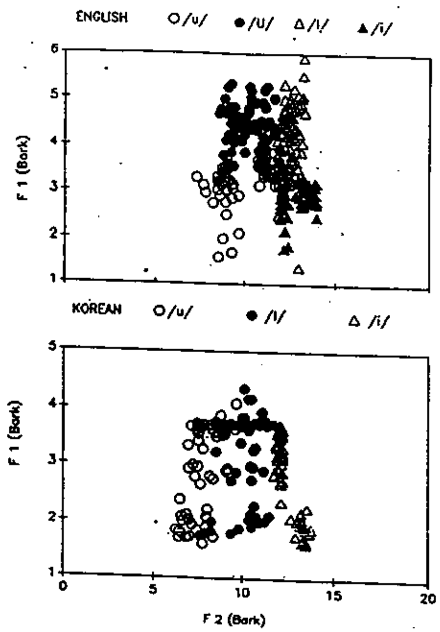

Figure 3. F1 and F2 of both languages in Barks

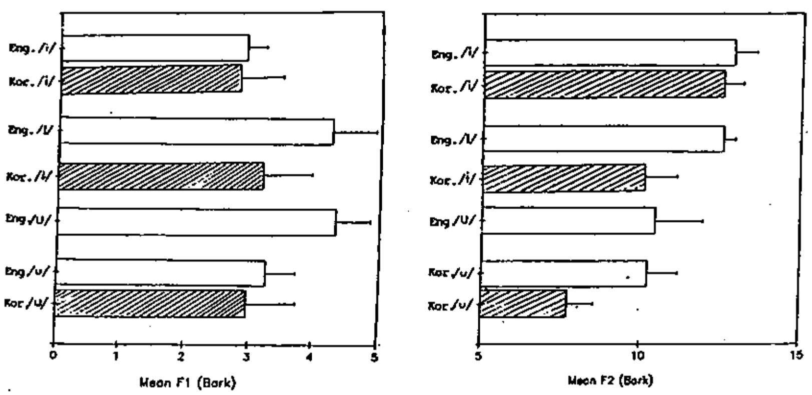

Figure 4. English/Korean means F1 & F2 in Barks

If the prediction of the sufficient contrast dispersion theory is right, Korean vowels should vary more than English vowels, because a smaller system is supposed to vary more. Since we are comparing all phonemically high vowels (meaning similar F1), we assume the variance would come from F2 dimension. For the vowel /i/, Korean does show more variance in F1 (=larger SD) than English, but a similar degree of variation in F2. For the vowel /u/, Korean also shows a larger SD in F1 but a smaller SD in F2 than English. Thus the fact that Korean /u/ varies less than English /u/ in F2 seems to be against the prediction of the sufficient contrast dispersion theory.

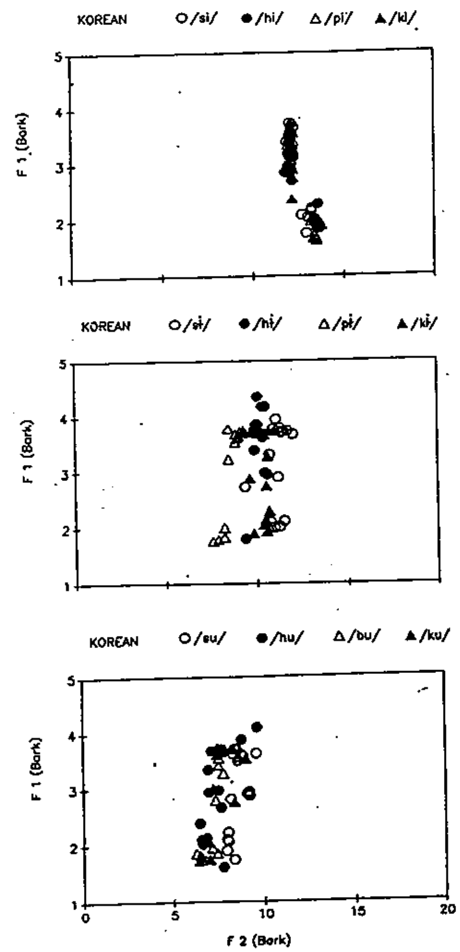

Figure 5. Context variations of each vowel in Korean

On the other hand, if we consider that English /ɪ/ and /ʊ/ are somewhat lower vowels(thus higher F1 values), we might reinterpret the result to be accounted for by the sufficient contrast theory. That is, English has phonetically only two very high vowels whereas Korean has three. Thus, English should vary more in F2. At the same time, this reinterpretation would also explain the larger variance of Korean in F1 dimension: Korean high vowels vary more than English /i/ or /u/ in F1 dimension since English has more vowels in this F1 dimension. Comparing only high tense vowels, we can say this result supports only the sufficient contrast theory, not the maximal dispersion or the quantal theory. Finally, the variations depending on contexts are shown in Figure 5 & 6.

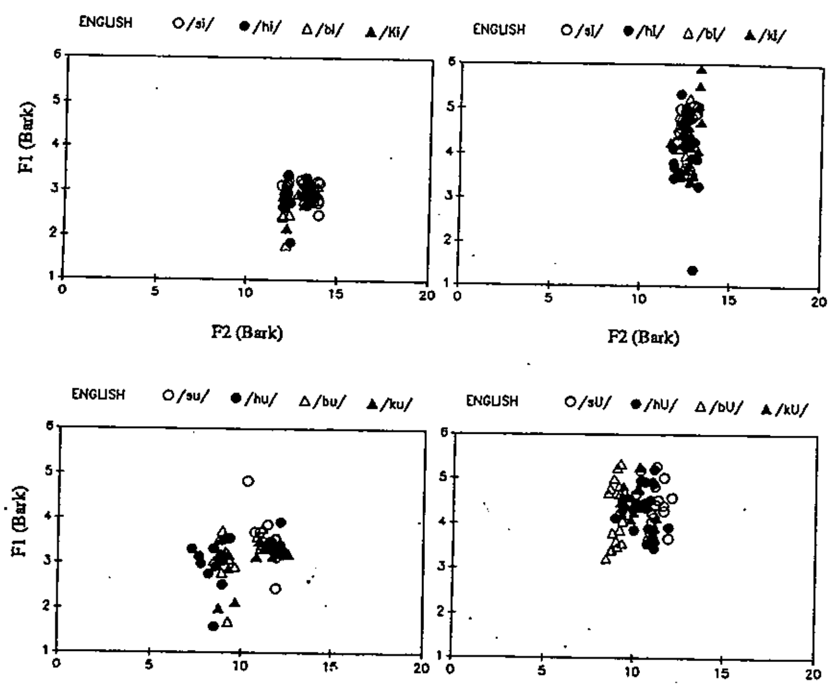

Figure 6. Context variations of each vowel in English

As seen in figure 5, Korean /i/ and /u/ do not vary much depending on contexts while /ɨ/ shows some variation: bilabials tend to have lower F2 and alveolars tend to have higher F2. In figure 6, English /i/ and /ɪ/ show little context variation but /u/ and /ʊ/ show some variation: alveolars tend to have higher F2 for both /u/ and /ʊ/ and bilabials tend to have lower F2 for /ʊ/ only. Thus, this context effect is only partially responsible for the larger variation of Enlgish /u/ than Korean /u/. That is, English /u/ varies more than Korean /u/ regardless of contexts. However, the reinterpreted sufficient dispersion theory cannot explain why front vowels vary very little in both languages.

Labial measurements

The ANOVAs show significant main effects of vowel and context in each language and a significant interactions of vowel*context and language*context. The measurement of RTC (Reference To Corner of mouth) was a good indicator distinguishing front vowels from back vowels in English. A few measurements were not good parameters for distinguishing vowels. They are HIW/VCL and CTU/CTL. VCU/VCL was also not a good parameter for some speakers. Most of the variations in the model of vowel, context, and vowel*context were best seen in five measurements: HIW, VCO, VSO, AREA, and VCO/RTC, in both languages. HIW/RTC also showed relevant variations, but in the Korean vowels only. Vowels in each language showed the same relationship in most measurements. For most lip measurements, a post hoc test of each language showed that English has three significantly different ($p < 0.01$) groups /i, ɪ/, /ʊ/ and /u/, while each of the three Korean vowels is significantly ($p < 0.01$) different from any other. Korean /ɨ/ usually has a measurement value intermediate between those of other two vowels, and English /ʊ/ usually has an intermediate value between /i, ɪ/ and /u/. Based on English grouping, we can tell the articulatory distribution, labial movements in general, of Englsih vowels is not accounted for either by the maximal dispersion theory or by the sufficient contrast theory. Figure 7 shows the relationships of vowels in English and Korean by lip measurements that showed significant effects of vowel.

English /i/ and /ɪ/ have very similar values for all measurements, while all the other vowels have significantly different values with one another. This corresponds to F2 related acoustic patterns described above. That is, English /i/ and /ɪ/ were overlapping more than any other vowel pairs in F2. Whereas all three Korean high vowels were well separated in F2.

However, the relationship between English vowels does not support the distinction between phonetically very high vowels and lower vowels we made before to reinterpret the sufficient contrast theory. Rather, the lower vowel /ʊ/ differs from other vowels in most measures instead of forming one group together with /u/. Next, variations in general and by contexts are considered to be compared with those of the acoustic results.

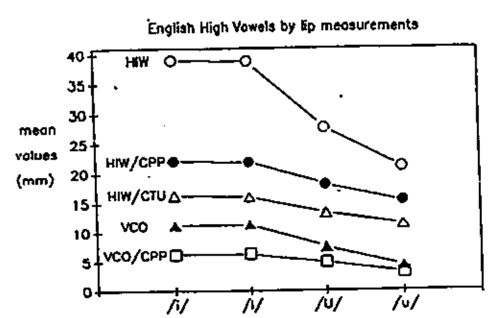

Figure 7. English and Korean high vowels by lip measurement values in means

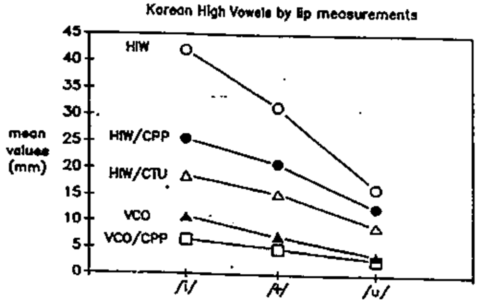

Figure 7. (Continue)

Variations

Variations in every measures for each vowel were considered. Table 2 shows means and SDs for /i/ and /u/ and Korean /ɨ/ (N=80 for each language). English /i/ varied a little more than Korean /i/, while both languages showed a similar degree of variation for every measures for /u/'s.

Table II

a. Mean and SD for each measures for /i/

Measurements	Korean		English	
	M	SD	M	SD
HOW	53.1	4.6	48.2	3.8
HIW	42.1	6.6	39.0	4.6
VCO	10.9	1.1	11.2	1.7
VSO	8.5	1.0	8.8	1.5
RTC	104.1	6.3	88.7	11.4
VO	24.3	3.2	21.0	2.6
CPP	16.8	2.2	18.2	3.5
AREA	29.4	5.9	28.2	6.2

b. Mean and SD for each measures for /u/ and Korean /ɨ/

Measure-ments	Korean /u/		English /u/		Korean /ɨ/	
	M	SD	M	SD	M	SD
HOW	48.5	3.6	43.1	4.8	52.6	4.6
HIW	16.4	6.0	21.0	2.2	31.4	8.0
VCO	3.7	1.2	4.3	1.4	7.3	1.8
VSO	2.7	0.9	3.1	1.1	5.7	1.3
RTC	113.3	4.9	95.6	12.4	106.1	6.0
VO	18.4	2.4	14.8	2.2	20.7	3.4
CPP	13.0	3.2	14.3	3.0	5.3	2.7
AREA	4.0	2.5	5.6	2.2	15.2	6.4

These results of articulatory variation does not always agree with that of the acoustic variation. First, the fact that F2 of English /u/ varied more than Korean /u/ corresponds to the larger variation of RTC in English, which is a measure of lip rounding and protrusion. On the other hand, the larger variance of CPP (a measure of protrusion) in Korean /u/ implies more variance in F2 dimension. Second, the larger variance of F1 in Korean /i/ and /u/ than English does not correspond to the similar variance of VCO, VSO or VO (measures of lip opening) in both languages.

In addition to these vowels, Korean /ɨ/, however, varied in general more than any other vowel. If we apply our reinterpreted sufficient contrast theory to this result, we can find the reinterpretation doesn't hold for the labial movements of each vowel since Korean, having phonetically more number of high vowels, varies articulatorily more than English. Therefore, we may need more evidence to claim that the sufficient contrast dispersion theory works for the distribution of vowels in phonetically same dimension. Or, variations in labial movements may not reflect the variations of acoustic values very well. We may need to examine tongue shapes in addition to labial positions.

Context effects

Significant main effects of context and significant vowel*context and language*context interactions were found. More measurements showed signifi cant context effects in English than in Korean; 16 (HIW, VCO, VSO, VCU, VO, AREA, HIW/VCO, HIW/RTC, HIW/CTU, HIW/CTL, HIW/VCU, HIW/VO, HIW/CPP, VCO/RTC, VCO/CTL, and VCO/CPP) out of 26 measures showed a context effect in English, while only 7 (HIW, AREA, HIW/RTC, HIW/CTU, HIW/CTL, HIW/VO, and HIW/CPP) did in Korean. A post hoc test of context showed the bilabial context to cause significantly smaller values than those of other contexts for most measures, and this matches the acoustic results described above.

Next, context effects on each vowel in each language were considered. The following table shows measures which show context effects for each vowel.

Here, all English vowels except /u/ have context effects for many measures. This is almost the opposite of the acoustic result described above, since by formant values English /i/ showed little variation by contexts, while /u/ showed some variation. On the other hand, the context effect for Korean is very similar to the acoustic result: only / /ɨ// varies a lot.

Table III.

Vowels	Measures showing context effects
English /i/	HIW, VCL, AREA, HIW/RTC, HIW/CTU, VCU/VCL, VCO/RTC, VCO/CTU, VCO
English /I/	HIW, VCO, VSO, VO, AREA, HIW/RTC, VCO/RTC, VCO/CTU, VCO/CTL, VCO/CPP
English /U/	HIW, VCO, VSO, AREA, HIW/VCO, HIW/CTU, HIW/VO, VCO/RTC
English /u/	HIW/CTU
Korean /i/	None
Korean / /ɨ//	HIW, VCO, VSO, AREA, HIW/RTC, HIW/CTU, HIW/CTL,HIW/VCU, HIW/VO, HIW/CPP, VCO/RTC
Korean /u/	None

Since some of 26 measures are highly correlated with one another, multi variate ANOVA was performed for context effects on each vowel. There was a significant ($p < .01$) main effect of context on all English vowels. Korean /i/ had a significant ($p < .01$) main effect of context while /u/ had a slightly significant ($p < .05$) context effect. So, there was a language by context interaction.

In summary, this context effects show a similar tendency with the variance effects described above in that English /i/ varies more and shows more context effects than Korean /i/, but both languages have a small variance and small context effects for /u/. These tendencies are again the opposite of the acoustic result in terms of variation and context effects. Maybe some other factors such as the tongue shape are involved to compensate for the labial movements to form the acoustic patterns.

Individual vowels

Phonemically same vowels in each language were compared. For a vowel /u/, English showed a significantly ($p < .01$) larger value than that of Korean for HIW, meaning English /u/ has horizontally more spread lips. English also showed a significantly ($p < .05$) larger value than that of Korean for VCO, meaning English /u/ is produced with vertically more open lips. Since AREA value is highly correlated with HIW and VCO values, English /u/ has, there fore, a significantly ($p < .01$) larger AREA value than that of Korean. Finally, English /u/ showed a significantly ($p < .01$) larger value of CPP and smaller value of RTC, HIW/VCL, and VCO/CTL, meaning English /u/ is less round ed and protruded than Korean /u/. This result agrees to the acoustic outputs, since English /u/ was higher than Korean /u/ in F2 values (= less rounded). The lip measurement values for /u/ in each language are in Table IV.

Table IV. Mean lip measurements for /u/ in millimeters.

Lang.	HIW	VCO*	AREA*	CPP*	RTC*	HIW/ VCL*	CTU	CTL	VCO/ CTL*
English	21.0	4.3	5.6	14.3	95.6	54.4	18.9	14.9	3.1
Korean	16.4	3.7	4.0	13.0	113.2	46.0	17.5	15.5	2.4

* : significantly different ($p < 0.01$)

For a vowel /i/, Korean showed a significantly larger HIW, RTC and HIW/VCO values and a smaller CPP value, meaning Korean /i/ is spreader than English. But both languages were not significantly different with each other in VCO or VSO measures for /i/, meaning both languages use similar amount of vertical lip opening. And this is supported by the acoustic result since /i/ in both languages were very similar in their F1 values (see figure 4).

For both /u/ and /i/ vowels, English showed a significantly large value of CTU than Korean while both languages were not significantly different by the value of CTL. This may mean that English speakers use more upper lips than Koreans do. However, this assumption could be too strong since these measures were not a significant indicator of vowels for some speakers as mentioned above. Mean lip measurements for /i/ in each language are in Table V.

Table V. Mean lip measurements (in millimeter) for /i/

Lang.	HIW*	RTC	CPP*	HIW/ VCO*	AREA	VCO	CTU*	CTL
English	38.9	88.7	18.2	35.5	28.2	11.2	24.1	9.3
Korean	42.1	104.1	16.8	39.1	29.4	10.9	22.9	20.2

*: significantly different ($p < 0.01$)

In sum, since the same point vowels in the two languages showed different articulatory patterns for most measures as in the acoustic result, the predic tions of maximal dispersion and quantal theory are not working at least in these languages.

Conclusion

We have examined the result of labial position and acoustic values in terms of three principles of vowel systems and have compared the acoustic result with that of articulatory result within and across languages. The salient foundings are as follows.

First, some acoustic results matched the patterns seen in the labial gesture measurements: /i/'s in both languages have very similar formant values and variance and their values for vertical lip opening and area of lip opening are not significantly different from each other. Also Korean /u/ showed more lip rounding or protruding than did English /u/, both acoustically and articulatorily.

Second, some other acoustic result did not match the articulatory result very well. English /i/ showed larger variation and context effects than Korean /i/ in labial positions but showed less variation in F1 and similar variation in F2. /u/ in both languages showed a similar variance in labial position but English /u/ showed more variation in F2 than Korean /u/. Korean /i/ showed the largest variance in labial measurements but not the larger variance in acoustic values.

Finally, contrary to the predictions of maximal dispersion theory and quantal theory, the two languages' pheripheral vowels or point vowels, /i/ and /u/, did not take the same extreme spaces. Rather, Korean with three high vowels takes up more of the F2 space than does English with four high vowels. This difference results from a lower F2 value in Korean /u/. At first glance this result seems to be contrary to the sufficient contrast theory of disper sion also. However, if we consider vowels with phonetically the same height, the sufficient contrast theory would explain the smaller F2 range in English compared to Korean, as well as the larger variation of English /u/ compared to that of Korean /i/ or /i/At the same time, however, this reinterpretation cannot explain the three groupings of English vowels, /i, I/, /U/ and /u/, nor why Korean /i/ varies more than English /i/ or /u/ in the labial configuration measurements. That is, the reinterpretation cannot explain the results of labial configuration. To explain the dismatch between acoustic results and labial position measure ment result, we need to measure some other factors such as tongue gestures.

*The original version of this paper was presented in the 119th meeting of the Acoustical Society of America, State College, Pennsylvania, 21-25 May 1990.

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Appendix

English foil data

fox	pen	sun	vase
ring	boat	nun	cab
fog	bell	day	love
team	pay	girl	mud

Korean foil data

tʃʰɔ 'a wife'		tʃəl	'a temple'	sən	'a line'
he	'a sun'	tal	'a moon'	ton	'money'
pe	'a pear'	mos	'a pin'	san	'a mountain'
ke	'a dog'	tʃang	'a market'	non	'a field'

An articulatory study of the features ATR in Akan and emphasis in Arabic

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Abstract

Akan contrasts two sets of vowels, one in which the tongue root is advanced and the larynx lowered ([+ATR]), and another in which the tongue root is retracted ([-ATR]) (Lindau, 1979). Arabic contrasts two sets of consonants, one in which the pharynx is constricted ([+emphasis]) and another in which it is not ([-emphasis]). Lindau suggests that the two phenomena can be combined as various settings along a single phonetic dimension of pharynx width, with [+ATR] as maximally expanded and [+emphasis] as maximally constricted, and that this dimension can be reduced to the binary phonological feature [±expanded], since no language contrasts more than two settings. This paper tests this hypothesis. Measurements of pharyngeal diameter were taken from X-ray tracings from productions by two Arabic speakers and three Akan speakers, and a multivariate analysis of variance was performed. Although emphasis is primarily a consonant feature in Arabic, it is legitimate to compare vowels in this cross-linguistic study, because as noted by Card (1983), [+emphasis] spreads to vowels and consonants within the same word. The results showed significant interaction between the more and less expanded feature values and the two languages, implying that emphasis in Arabic is controlled by a different mechanism from that used for [±ATR] in Akan.

Introduction

This paper compares two features in which pharyngeal width has been implicated -- [±ATR] in Akan and [±emphasis] in Arabic. Akan has a type of vowel harmony where two sets of vowels contrast; one in which the tongue root is advanced and the larynx is lowered, and as a result the pharynx is wide ([+ATR]), and another in which the tongue root is retracted and as a result the pharynx is narrow ([-ATR]) (Lindau, 1979). The vowels of Akan are as follows:

set 1			set 2	
i	u		ɪ	ʊ
e	o		ɛ	ɔ
		a		

The low vowel /a/ is neutral with respect to the vowel harmony. The tongue root mechanism involved with [ATR] is usually combined with vertical displacement of the larynx and sometimes with movements of the back pharyngeal wall and is also independent of the mechanism for controlling tongue height (Lindau, 1978).