Lip rounding in Amoy and Mandarin high vowels: maximum dispersion, or adequate separation.

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Abstract

There are two hypotheses about the relationship between phonological contrasts and phonetic feature scales. Some phoneticians propose that values are chosen so that contrasting phonemes are maximally separated, e.g., Lilijencrants and Lindblom, 1972, while others claim that they need only to be adequately separated, e.g., Maddieson, 1977. This paper tests the competing hypotheses by comparing lip position in Mandarin [i], [y], [u] with that of Amoy [i] and [u]. According to adequate separation, the lip spreadness/roundness of Mandarin will be more extreme than that of Amoy, since there are three high vowels in Mandarin but only two in Amoy. According to the maximum dispersion hypothesis, the degree of roundness should be the same in both languages. Amoy and Mandarin data were collected from three bilingual speakers. The results support the *Adequate Separation Theory*. This paper also tests Wood's (1986) claim that in a language with two high rounded vowels, /u/ and /y/, /u/ is more rounded than /y/. The result shows that this claim is not necessarily true.

Introduction

There are two competing theories for predicting the positions of phonological entities within phonetic space. According to Liljencrants and Lindblom's (1972) *Maximal Dispersion Theory*, phonological entities are maximally separated. Thus in a language with two high vowel phonemes, /i/ and /u/, maximal dispersion predicts that the vowels will spread maximally apart to occupy opposite corners of the vowel space. If there is a third high vowel, say /y/, the first two vowel will still be maximally separated, occupying the same peripheral positions as shown in (1):

(1)	2 vowel system:	i		u
	3 vowel system:	i	y	u

Adequate Separation Theory (Maddieson, 1977), by contrast, predicts that there should be some fixed interval between adjacent vowels, as phonological entities are "as separated as they need to be", therefore /i/ and /u/ in a two-vowel system can be closer together than in a three-vowel system as shown in (2):

(2)	2 vowel system:		i	u
	3 vowel system:	i	y	u

In this study, lip rounding of high vowels is used to test both theories. The degree of lip rounding influences F2; the more rounded a vowel is, the lower the

F2, and the more spread the lips are, the higher the F2. Thus, the degree of lip rounding can be used as a crude measure of the spacing of vowels in the F2 dimension of the vowel space. Acoustic measurement of F2 will be carried out in follow up study to compare with the articulatory data here. In addition to testing the two hypotheses, Wood's (1986) claim about the degree of lip rounding of /u/ and /y/ in a language is also tested. In his study, Wood claims that in a language with two high rounded vowels, the back rounded vowel will be more rounded than front rounded vowel. Thus Mandarin /u/ would be more rounded than Mandarin /y/.

Experiment

Mandarin is a language with three high vowels /i/, /y/, and /u/. Amoy is a language with two high vowels /i/ and /u/. The study used three subjects, JRG, CK (male), and CYT (female), all bilingual speakers of both languages. (Bilingual speakers were used to control for speaker variability in lip size while testing for inter-language differences.) The corpus is given in Table I. The Mandarin words are all in fourth tone which is a falling tone. The Amoy words are all in second tone, which is also a high falling tone. Tokens from each language are repeated five times. For each repetition, the tokens are randomized to avoid context effect.

Table I. Corpus

Amoy		Mandarin	
/i/	'chair'	/i/	'easy'
/li/	'you'	/li/	'stand'
		/y/	'jade'
		/ly/	'discipline'
/u/	'small island'	/u/	'object'
/lu/	'female'	/lu/	'road'

Method

A video recording of a speaker's face was made simultaneously with the audio recording. Subjects were asked to sit with their heads against a wall covered with a paper marked with 1 cm squares. This background grid was for detecting camera distortion, and for scaling the measurements from the TV into a constant proportion for the three subjects. A mirror was placed at a 45 degree angle at the right side of the subject to capture the side view, as shown in Figure 1. There are four reference points drawn on the subjects' faces; one on the nose, one on the center of the chin, one on the right side of the jaw, and one beneath the right ear.

Measurements from the frontal view are made of the following distances as shown in Figure 2. Measurements preceded by triple asterisks are statistically significant ($p < 0.05$):

- ***Width between outer corners (measurement BC)
- ***Width between inner corners (IJ)
- Distance from nose reference to lip line (perpendicular from A to BC)
- ***Vertical compression -- distance from vermillion border of upper lip to inter--lip line (perpendicular from D to BC)
- Vertical compression -- distance from inner edge of upper lip to inter--lip line (perpendicular from E to BC)

***Vertical compression -- distance from inner edge of lower lip to inter--lip line (perpendicular from F to BC)
***Vertical compression -- distance from vermillion border of lower lip to inter--lip line (perpendicular from G to BC)
Vertical compression -- distance from front jaw reference to inter--lip line (perpendicular from H to BC)
***Distance from vermillion border of upper lip to right outer corner (DC)
***Distance from inner border of upper lip to right outer corner (EC)
***Distance from inner border of lower lip to right outer corner (FC)
***Distance from vermillion border of lower lip to right outer corner (GC)
***Distance from front jaw reference to right outer corner (HC)
***Distance from vermillion border of upper lip to left outer corner (DB)
***Distance from inner border of upper lip to left outer corner (EB)
***Distance from inner border of lower lip to left outer corner (FB)
***Distance from vermillion border of lower lip to left outer corner (GB)
***Distance from front jaw reference to left outer corner (HB)
***Distance from vermillion border of upper lip to right inner corner (DJ)
***Distance from inner border of upper lip to right inner corner (EJ)
***Distance from inner border of lower lip to right inner corner (FJ)
***Distance from vermillion border of lower lip to right inner corner (GJ)
***Distance from front jaw reference to right inner corner (HJ)
***Distance from vermillion border of upper lip to left inner corner (DI)
***Distance from inner border of upper lip to left inner corner (EI)
***Distance from inner border of lower lip to left inner corner (FI)
***Distance from vermillion border of lower lip to left inner corner (GI)
***Distance from front jaw reference to left inner corner (HI)

Figure 1. Setting of the experiment: subjects with marks on the face, sits in front of grid papers with a 45 degree mirror showing the side view.

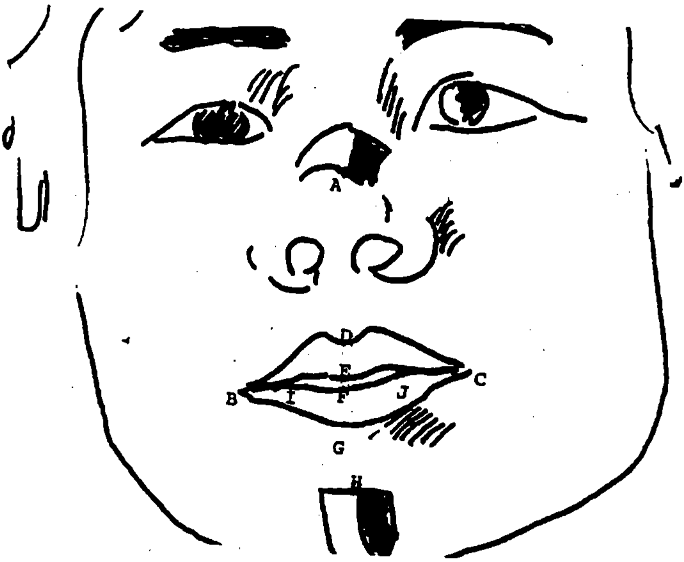

Figure 2. 10 points for the measurement in the front view.

Following are measurements from the sagittal view as shown in Figure 3.:
For lip compression, following measurements were taken:

***Distance between vermillion border of upper lip to vermillion border of lower lip

For lip protrusion, following measurements were taken.

Distance from the reference under the ear to the vermillion border of upper lip (12)
***Distance from reference under the ear to the outer corner of lip (13)
Distance from reference under the ear to the vermillion border of lower lip (14)
***Distance from reference under the ear to inner corner of lip (17)
***Distance from inner corner of lip to the inter--lip line (perpendicular from 3 to 24)
Distance from outer corner of lip to the inter--lip line (perpendicular from 7 to 24)
Distance from reference under ear to the inter--lip line (perpendicular from 1 to 24)

Other measurements taken were:

Jaw position --- distance from reference under the ear to the side jaw reference

Vertical position of jaw -- distance from nose reference to lateral jaw reference (65)
Vertical position of jaw -- distance from 5 to horizontal line passing through nose reference (perpendicular from 5 to horizontal line 6x -> 56x)
Vertical position of lower lip -- distance from nose reference to vermillion border of lower lip (64)
Vertical position of lower lip -- distance from vermillion border of lower lip to horizontal line passing through nose reference (perpendicular from 4 to horizontal line 6x -> 46x)

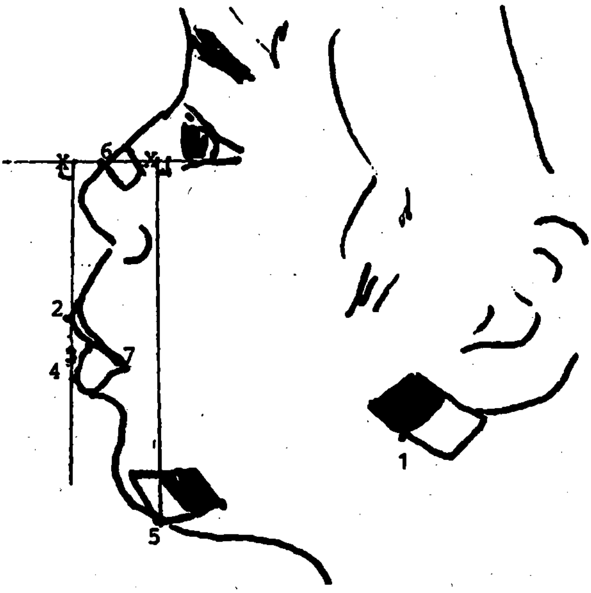

Figure 3. 7 points and a reference line for the measurement in the side view.

Data Analysis

A two-way ANOVA (language * vowel) was done on each measurement separately. Only those measurements which showed a significant ($p<0.01$) or nearly significant ($p<0.05$) language by vowel interaction is discussed in detail below. They are BC, IJ, DBC, FBC, GBC, DC, EC, FC, GC, DB, EB, FB, GB, HB, DJ, EJ, FJ, GJ, HJ, DI, EI, FI, GI, HI, 13, 17, 24, and 324.

A MANOVA was done for each subject to determine whether the measures are correlated with difference in lip configuration for the corresponding vowels in two languages. A Contrast test was also done to test the difference between the corresponding vowels in two languages.

Results and Discussion:

Even though for one out of three subjects the difference between corresponding vowels in two languages is not significant, generally the trend for all three subjects is that Mandarin /i/ to be more spread than Amoy /i/ and Mandarin /u/ is more rounded than Amoy /u/. In other words the *Adequate Separation Theory* is supported to be more correct in this experiment. Sidney Wood (1986) claimed that in a language with two high rounded vowel, /u/ is more rounded than /y/. Thus, Mandarin /u/ should be more rounded than /y/. By comparing all the measurements, it was found that this is not necessarily true. Again Mandarin IJ (width between inner corners of lips) is used here to represent the degree of roundness of different vowels and this is shown in Figure 4. In this figure, measurement IJ is chosen to represent the degree of lip roundness for different vowels for each subject.

CYT (female)

MANOVA shows that she uses different lip positions for the "same" vowel in the two languages. The language*vowel effect approaches significance (F[4,87] =1.4704, P=0.0131). The Contrast test shows that CYT's Mandarin /i/ and /u/ are different from the corresponding //i/ and /u/ in Amoy. By averaging and comparing all the measurements for the two corresponding /i/'s, Mandarin /i/ is more spread than Amoy /i/ (F[1,29] =1.9767, P=0.103). Mandarin /u/ is more rounded than Amoy /u/ (F[1,29] =1.9937 P=0.0096).

CK (male)

MANOVA shows that he also uses different lip positions for each vowel in different languages. The language*vowel effect is significant (F[4, 116]=1.7198, P=0.0001). Contrast test shows that, for CK, the difference between vowel /i/'s in the two languages is not significant, whereas that between vowel /u/'s in the two languages approaches significance.

Mandarin /i/ is similar to Amoy /i/ (F[1, 29] =3.7840, P=0.1208). However, by adding and comparing all the measurements, Amoy /i/ is less spread than Mandarin /i/. As for /u/, Mandarin /u/ is more rounded than Amoy /u/ (F[1, 29] = 1.8373, P=0.0190).

JRG (male)

MANOVA shows that he seems to use the same vowel in both languages. There is no significant language* vowel effect (F [4, 145]=1.455, P=0.1575). Contrast test shows that the difference between /i/'s in both languages is not significant, while, that between /u/'s is significant at a 0.05 level. Mandarin /i/ is similar to Amoy /i/ (F[1, 29]=0.9922, P=0.4923). Mandarin /u/ is less rounded than Amoy /u/ (F [1, 29]=1.6983, P=0.0364).

The comparison between Mandarin and Amoy in terms of lip roundness is described for each of three subjects.

In Sum, even though for one out of three subjects the difference between corresponding vowels in two languages is not significant, generally the trend for all three subjects is that Mandarin /i/ is more spread than Amoy /i/ and Mandarin /u/ is more rounded than Amoy /u/. In other words, the *adequate separation theory* is supported to be more correct in this experiment.

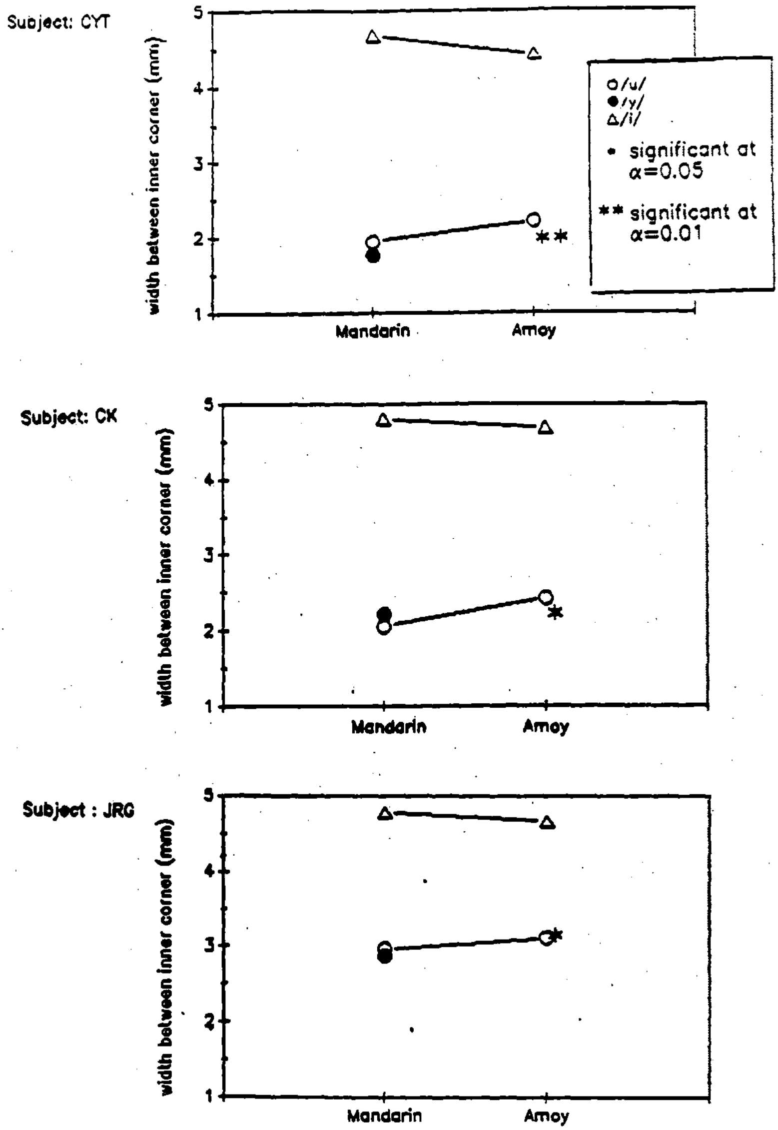

Figure 4. Measurement IJ for three vowels, /u,y,i/, plotted for Mandarin and Amoy for three subjects. Here * indicates significant at $\alpha = 0.05$ and ** at $\alpha = 0.01$.

Next, Sidney Wood's (1986) claim that, in a language with two high rounded vowel, /u/ is more rounded than /y/ is tested using Mandarin data. By comparing all the measurements for /u/ and /y/ in Mandarin, it was found that Wood's (1986) claim is not necessarily true. As the result shown in Table II, two subjects out of the three show the same tendency which contradicts with Wood's claim. For CYT and JRG the /y/ is more rounded, thus disagrees with Wood's prediction. CK is the only one which agrees with Wood's theory.

Table II. Degree of lip rounding of /u/ and /y/ in Mandarin measured from width between inner corner of lip opening (IJ).

Subject	Vowel	Means
CYT	/u/	1.94871795 cm
	/y/	1.76923077 cm
CK	/u/	2.06172840 cm
	/y/	2.22222222 cm
JRG	/u/	2.96969697 cm
	/y/	2.88636364 cm

Conclusion:

In representing the relationship between phonological contrasts and phonetic feature scales, *Adequate Separation Theory* seems to explain the present data better than the *Maximum Dispersion Theory*. In order to test whether there is an adequate fixed interval to distinguish between vowels, further acoustic analysis of F2 and F3 needs to be done. From this study we could conclude that phonological entities are not maximally separated. Furthermore, it was also found that Wood's theory may not necessarily be true. The degree of rounding of /u/ and /y/ seems to be a speaker dependent characteristic. We may need more data using more subjects.

Since all of the three bilingual speakers behave differently from each other, the history of language acquisition for each subject needs to be taken into account. Further study is necessary to investigate how the two languages interfere with each other.

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Bibliography

Liljencrants, J. & Lindblom, B. 1972. "Numerical simulation of vowel quality systems: the role of perceptual contrast", *Language* 48: 840--862.

Lindblom B. & Sunberg, J. 1971. "Acoustical consequences of lip, tongue, jaw and larynx movement", *JASA* 50: 1166-1179.
Maddieson, I. 1977. "Tone loans: a question concerning tone spacing and a method of answering it", *UCLA Working Paper in Phonetics* 36: 49-69.
Wood, S. 1986. "The acoustical significance of tongue, lip, and larynx maneuvers in rounded palatal vowels", *JASA* 80 (2): 391-401.