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Frication as a Vowel Feature? – Evidence from the Rui’an Wu Chinese Dialect

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Abstract

Frication is not a common feature in characterizing vowels. However, Chinese dialects are known for having apical vowels. Additionally, there are fricative high vowels in a few dialects. This paper describes the phonetics and phonology of the vowels in the Rui’an Wu Chinese dialect, with an emphasis on vowel features distinguishing the high vowels. Rui’an has 12 monophthongs [i y ʉ e ø ɛ a ɿ ɔ o u ɯ]; and half of them [i y ʉ ɿ u ɯ] are high vowels. Formant data from 10 native speakers, 5 male and 5 female, were analyzed. And acoustic results reveal that [ɿ] is an apical vowel with significantly higher frication than other high vowels, whereas the difference in frication between [ʉ ɯ] and [y u] respectively is not confirmed. Rather, spectral difference plays a more important role in the distinction between labiodental high vowels [ʉ ɯ] and their plain rounded counterparts [y u].

Keywords: vowel, diphthong, fricative vowel, apical vowel, vowel feature, the Rui’an Wu dialect.

1. Introduction

Frication is not a common feature for the characterization of the vowels in the World’s languages ([1]). However, Chinese dialects are known for having apical vowels ([2]). And in a few dialects including Wu, Hui, Jin, Jianhuai Mandarin, Northwestern Mandarin, and other Mandarin dialect subfamilies, there are fricative vowels, that is, the vowels that are produced with audible frication ([3], [4], [5]). Fricative vowels are all high vowels, especially high front vowels, and frication adds complexity to vowel features characterizing high vowels ([6], [7], [8]). [9] proposed that fricative vowels are, in fact, at an intermediate stage for the apicalization of the high front vowels. Acquiring frication initiated sound change. Yet spectral difference plays a more important role in distinguishing fricative high front vowels from their plain counterparts in the Suzhou Wu dialect.

This paper describes the phonetics and phonology of the vowels in another Wu dialect, namely the Rui’an dialect, with an emphasis on fricative vowels. Rui’an belongs to the Oujiang group of the Wu dialects family from the south, while Suzhou belongs to the Taihu group from the north. And south and north Wu dialects are mutually unintelligible. The Rui’an dialect has 30 initial consonants, 30 finals, and 8 tones. There are 12 monophthongs [ɿ i y ʉ e ø ɛ a o ɔ u ɯ], 10 diphthongs [ai au ei əɯ əʉ ia iɛ iɔ yo uɔ], and 2 triphthongs [iau iəu] in open CV syllables; there are 3 monophthongs [a(ŋ) ə(ŋ) o(ŋ)], 2 diphthongs [ia(ŋ) io(ŋ)] in syllables with a nasal ending CVN; and there is a syllabic nasal [ŋ̍]. This paper focuses on monophthongs and diphthongs in open syllables.

The phonological status of the five high and mid-high vowels [y ʉ u ɯ o] are complex. [u o] are free variants after a bilabial consonant. [ɯ ʉ] occur after a bilabial stop, too. But /ʉ/ only occurs in an extremely limited number of lexical items such as [bʉ^{31}] “old woman”, [pʉ^{51}] “cloth”, etc. And in one particular item, [ɯ] and [ʉ] are free variants: [pɯ^{44}] = [pʉ^{44}] “wave”. Nevertheless, /y ʉ u ɯ o/ occur as five phonemes in elsewhere environment. The minimal pairs are as follows:

(1) [ku^{44}] (melon)≠ [kɯ^{44}] (elder brother) ≠ [ko^{44}] (home)
[o^{44}] (dirty) ≠ [ɯ^{44}] (dark) ≠ [ʉ^{44}] (prestige) ≠ [y^{44}] (waist) ≠ [u] (frog)
[ɦo^{22}] (summer) ≠ [ɦu^{22}] (paint) ≠ [ɦɯ^{22}] (infect) ≠ [ɦʉ^{22}] (taro) ≠ [ɦy^{22}] (yard)

Phonetically [ʉ] is a labiodental [y]. That is, [ʉ] is produced with a lingual articulation of [y] superimposed by a labiodental configuration. Similarly, /ɯ/ is realized as a fricative vowel with audible frication from the contact of lower lip against upper teeth, especially when it is onset-less or preceded by a velar stop. In other words, [ʉ ɯ] are both fricative vowels: [ʉ] is front and paired with [y]; [ɯ] is back and paired with [u].

It is a shared innovation for the Oujiang Wu group that the high back vowel is produced with frication. [10] reported that [u] in Wenzhou, the prestigious representative dialect of the Oujiang Wu group, is produced with audible frication, and it is proposed that /u/ could be alternatively transcribed as a syllabic consonant [v̩]. Rui’an occurs as a particular case in that the vowel inventory has distinction in frication for both front and back high vowels. This aims to provide a vowel phonology of Rui’an, on the basis of fine-grained acoustic phonetic details. And it is of theoretical interest to investigate how frication emerges as a vowel feature in a dialect with a complex vowel inventory.

2. Methodology

10 native speakers, 5 male and 5 female, provided audio speech. The ages range from 45 to 73 years old during the time of recording.

Meaningful monosyllabic words with target vowels and diphthongs were selected as the test words. Each target vowel or diphthong has three test words. The test words were randomized. Five repetitions were recorded for each speaker.

The audio recording was conducted in a quiet room during the second author’s fieldwork trip to Rui’an. Audio data were recorded through a laptop PC into a Terratec DMX Fire6USB sound card with a Shure SM86 microphone. The sampling rate is 22, 050 Hz.

The audio data were analyzed in Praat ([11]). The frequencies of the lowest three formants for each vowel and

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diphthong element were measured. LPC measurements were applied at the mid-point of a target vowel or diphthong element. The default settings of Praat were used. The time step was auto selected. The maximum number of formant is 5. The ceiling of formant searching range is 5000Hz for male speakers and 5500 for female speakers. The window length is 25 milliseconds, and Pre-emphasis is from 50 Hz. In addition to formants, Harmonicity, i.e. the Harmonics-to-Noise Ratio, were calculated for the high vowels of interest.

3. Results

3.1. Monophthongs

Figure 1 plots the 12 monophthongal vowels [ɿ i y ʉ e ø ɛ a o ɔ u ɯ] of Rui'an in an acoustic vowel plane by using the first formant (F1) as ordinate and second formant (F2) as abscissa with the origin of the axes to the top right. The axes are Bark-scaled ([12]), while the values along the coordinates are still labelled in Hertz. Each vowel ellipse illustrates the dispersion of 75 data points: 3 test words × 5 repetitions × 5 speakers.

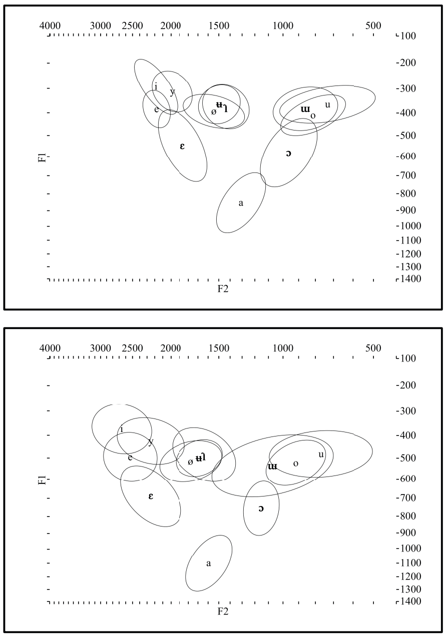

Figure 1: *2-sigma ellipses for the Rui'an monophthongs in male (upper) and female (lower) speakers.*

Rui'an vowels exhibit a triangular distribution in the acoustic F1/F2 vowel space. There are 4 levels of vowel height. The mid-low vowels [ɛ ɔ] contrast in backness but have a predictable lip rounding. That is, the back vowel [ɔ] is rounded, while the front vowel [ɛ] is unrounded. The mid-high vowels [e ø o] contrast both in backness, [e ø] vs. [o], and in lip rounding, [e] vs. [ø o]. The high vowels [i y ʉ ɿ ɯ u] demonstrate a three-way distinction of backness: [i y ʉ] are front; [ɿ] are central; [ɯ u] are back.

[ʉ] is a labiodental high front vowel, but its ellipse extensively overlap with the apical vowel [ɿ]. However, as shown in Table 1, one-way ANOVAs yielded significant difference in F2 and F3 for male speakers and in F1, F2, and F3 for female speakers.

The labiodental high back vowel [ɯ] is distributed left to its plain rounded counterpart [u] in the acoustic vowel plane, although their ellipses overlap to certain extent. As shown in Table 2, one-way ANOVAs yielded significant difference in F2 for male speakers and in F1, F2, and F3 for female speakers. That is, the statistical results confirm the difference in vowel backness (F2) between [u] and [ɯ].

Table 1: *One-way ANOVAs for the first three formants (in Hz) of* [ʉ ɿ] *in male and female speakers.*

		Male		Female	
		ʉ	ɿ	ʉ	ɿ
F1	Mean	351	360	478	464
	SD	30	35	31	45
	F-value	2.794		4.795	
	P-value	0.097		0.030	
F2	Mean	1486	1428	1682	1634
	SD	74	80	94	122
	F-value	20.818		6.971	
	P-value	<0.001		0.009	
F3	Mean	2469	2688	2705	3036
	SD	142	141	167	243
	F-value	88.541		93.376	
	P-value	<0.001		<0.001	

Table 2: *One-way ANOVAs for the first three formants (in Hz) of* [u ɯ] *in male and female speakers.*

		Male		Female	
		u	ɯ	u	ɯ
F1	Mean	353	364	469	517
	SD	28	33	32	60
	F-value	1.660		11.943	
	P-value	0.204		0.001	
F2	Mean	733	859	742	1062
	SD	113	76	95	197
	F-value	20.751		51.497	
	P-value	<0.001		<0.001	
F3	Mean	2621	2582	3205	3016
	SD	74	88	210	288
	F-value	2.773		6.789	
	P-value	0.102		0.012	

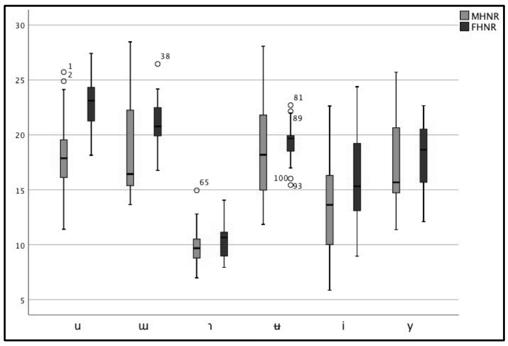

Figure 2: *Box-plot of mean HNRs for the high vowels* [i y ʉ ɿ ɯ u] *in male (MHNR) and female (FHNR) speakers.*

As mentioned earlier, the labiodental high front vowel [ʉ] and back vowel [ɯ] are actually fricated versions of their plain rounded counterparts [y] and [u] respectively. They are produced by a high front or back lingual articulation superimposed with a labiodental configuration, i.e. the contact of lower teeth against the upper teeth. The labiodental contact could result in audible frication, especially when the speaker reads minimal pairs with emphasis. In addition to [ʉ ɯ], there is an apical vowel [ɿ] in Rui'an. Apical vowel is not an established vowel category by International Phonetic Alphabet (IPA). Rather, apical vowels are treated as syllabic consonants. [1] classified apical vowels into fricative vowels. It is thus of theoretical interest to explore further if the six high vowels [i y ɿ ʉ u ɯ] in Rui'an contrast in frication, in addition to backness and lip rounding. Figure 2 is the box-plot of mean HNR for the six high vowels in male and female speakers. One-way ANOVAs with repeated measures yielded significant effects of vowel in both male speakers ($F(5,144) = 19.830$, $p < 0.001$) and female speakers ($F(5,144) = 65.543$, $p < 0.001$). And Tukey's Post Hoc tests confirmed significant differences between [ɿ] and the other high vowels ($p < 0.001$ for [y ʉ u ɯ] in male speakers and for [i y ʉ u ɯ] in female speakers; $p = 0.17$ for [i] in male speakers). However, there is no significant difference between [u] and [ɯ] ($p = 0.990$ in male speakers and $p = 0.324$ in female speakers), and [y] and [ʉ] ($p = 0.930$ in male speakers and $p = 0.732$ in female speakers).

In summary, frication does play a role in distinguishing the high vowels, especially in distinguishing the apical [ɿ] from the dorsal [ʉ], given that both of them occupy a high central position in the acoustic vowel plane. First, it is confirmed that the apical vowel [ɿ] has the lowest HNR, and it is produced with a significantly higher frication than other high vowels. Second, the fricative labiodental high vowels [ʉ ɯ] have high HNRs as other vowels do in both male and female speakers. This means frication is not attested in the distinction between [ʉ] and [y] or [ɯ] and [u] as predicted by visual observation. That's probably because that [y ʉ] and [u ɯ] already have apparent differences in formant-pattern. In other words, differences in formant-pattern overweigh differences in frication.

3.2. Diphthongs

Rui'an dialect has 10 diphthongs: 5 falling diphthongs [ai ei au əɯ əʉ] and 5 rising diphthongs [ia iɛ iɔ yo uɔ]. The production of diphthongs concerns with the dynamics between the onset and offset. This section compares formant-patterns of the onset and offset elements of diphthongs with their monophthongal counterparts in the acoustic F1/F2 vowel plane. Diphthong elements were denoted by their onset or offset counterparts in parentheses.

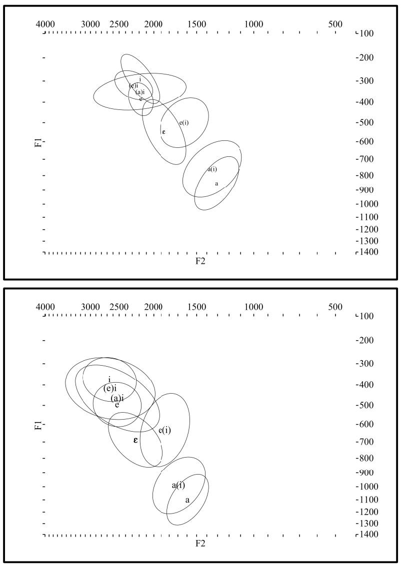

Figure 3: *2-sigma ellipses for the onset and offset elements of* [ai ei] *and corresponding monophthongs* [i e ɛ a] *in male (upper) and female (lower) speakers.*

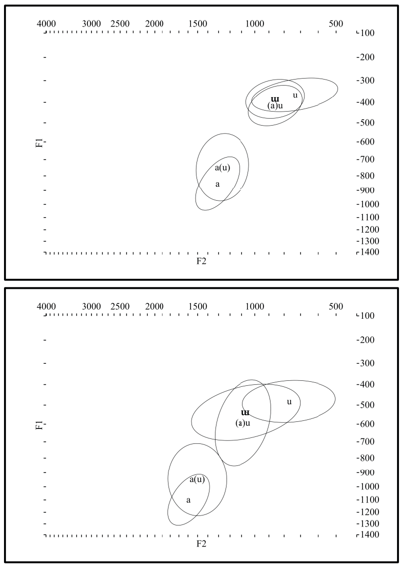

Figure 4: *2-sigma ellipses for the onset and offset elements of* [au] *and corresponding monophthongs* [a ɯ u] *in male (upper) and female (lower) speakers.*

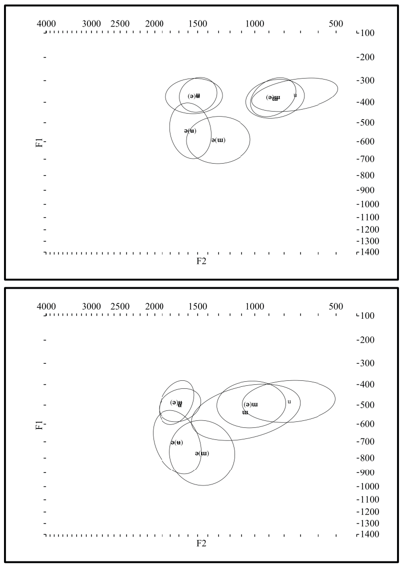

Figure 5: *2-sigma ellipses for the onset and offset elements of* [əɯ əʉ] *and corresponding monophthongs* [ɯ ʉ u] *in male (upper) and female (lower) speakers.*

Figures 3-5 show falling diphthongs [ai ei], [au], and [əɯ əʉ], respectively. First, the diphthong onset [a] in [ai au] exhibits a clear effect of anticipatory coarticulation so that the ellipses shift toward the offset targets in both male and female speakers. Second, the onset [e] in [ei] is much closer to [ɛ] than [e]. This dissimilatory effect is probably to ensure an enough spectral distance between the diphthong onset and offset, i.e. to facilitate lingual movement during diphthong production. Third, although there is no monophthong [ə] in Rui'an, it is observed that the onset [ə] in [əɯ əʉ] adjusted its position in the acoustic vowel plane according to its offset element [ɯ] or [ʉ]. Finally, offset elements in falling diphthongs, especially [ɯ ʉ] in [əɯ əʉ], generally share positions similar to their monophthongal counterparts in the acoustic vowel plane, although [u] in [au] and [i] in [ai ei] show certain degree of coarticulatory effect.

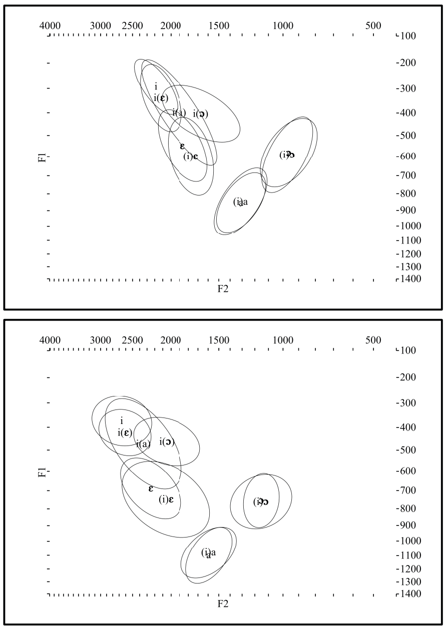

Figure 6: *2-sigma ellipses for the onset and offset elements of* [ia iɛ iɔ] *and corresponding monophthongs* [i e ɛ a] *in male (upper) and female (lower) speakers.*

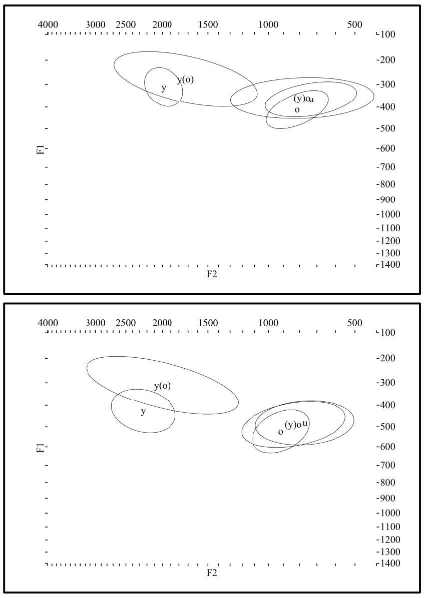

Figure 7: *2-sigma ellipses for the onset and offset elements of* [yo] *and corresponding monophthongs* [y o] *in male (upper) and female (lower) speakers.*

Figures 6-8 compare ellipses for diphthong elements in rising diphthongs [ia iɛ iɔ], [yo], and [uɔ] with their monophthongal counterparts, respectively. Better than in the production of falling diphthongs, both onset and offset elements in rising diphthongs have comparable distributions to their monophthongal counterparts in general, as ellipses for the diphthong onsets [i u] in [ia iɛ iɔ uɔ] and offsets [a ɛ o ɔ] in [ia iɛ iɔ yo uɔ] and the corresponding monophthongs extensively overlap with each other in both male and female speakers. The only exception is [y] in [yo], which exhibits a greater effect of coarticulation.

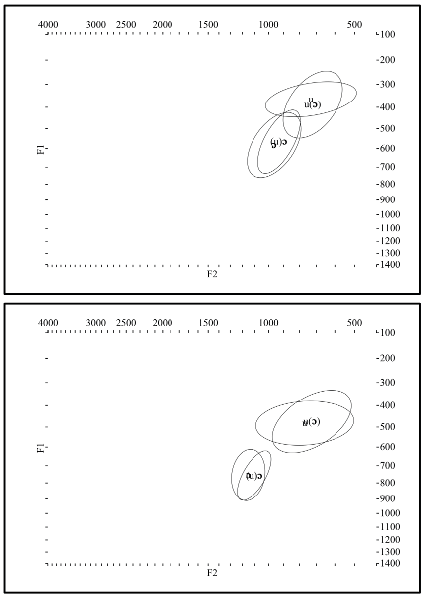

Figure 8: *2-sigma ellipses for the onset and offset elements of* [uɔ] *and corresponding monophthongs* [u ɔ] *in male (upper) and female (lower) speakers.*

In summary, both onset and offset elements in falling and rising diphthongs in Rui'an have comparable spectral targets as their monophthongal counterparts do, although diphthong elements are subject to certain coarticulatory effect. And rising diphthongs have a better control of spectral targets than falling diphthongs.

4. Discussion and Conclusion

Rui'an has a complex vowel inventory. The 12 monophthongs, including 1 apical vowel, distinguish in four levels of vowel height, and three levels of vowel backness. The HNR data confirm that frication plays a significant role in the characterization of high vowels, especially in distinguishing the apical vowel from its dorsal counterparts. However, the predicted difference in frication between labiodental high vowels [ʉ ɯ] and their plain rounded counterparts [y u] is not confirmed by the HNR data. To conclude, on one hand, frication serves as a vowel feature; but on the other hand, frication could be redundant and consequently disappear as soon as difference in formant-pattern is attested between vowels.

With a different direction of spectral dynamics, the 5 falling diphthongs and 5 rising diphthongs contrast in dynamic formant-patterns respectively. Among falling diphthongs, [ai ei] contrast in height in front vowel series, [au] and [əɯ əʉ] contrast in height in back vowel series, and [əɯ əʉ] contrast in peripherality. Among rising diphthongs, [ia iɛ] contrast in height, [ia iɛ] and [iɔ] contrast in peripherality, and [yo uɔ] have apparently different patterns of spectral dynamics.

5. Acknowledgements

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6. References

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