FORMANT ANALYSIS OF THE VOWELS IN TAIZHOU CHINESE

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ABSTRACT

This study presents the formant frequencies of the vowels which are symbolized in the previous studies as [i ɿ u ɯ o y ɑ ɛ ɔ ɚ ɛ̃ ɔ̃] in CV, [æ ʊ ɑ ə ɔ] in CV[ʔ], and [ɑ i ə ɔ] in CV[ŋ] syllables in Taizhou Chinese. Praat was used to perform LPC analysis of the Taizhou vowels elicited from two male and two female native speakers. The analysed vowel formant data show that (i) in CV syllables, [i] is close to [ɿ]; [u ɯ o] are like [ɯ ɨ u], respectively; [ɛ] should be [ei] or [ɛi], whereas [ɛ̃] is [ɛ]; (ii) in CV[ʔ] syllables, [æ ʊ ɑ] are likely to be [ɛ u a]; and (iii) in CV[ŋ] syllables, [ɑ] is [a]. The formant data give support to the phonetic description of the Taizhou vowels.

Keywords: Vowel formant frequencies, acoustic analysis, Taizhou vowels.

1. INTRODUCTION

Taizhou is one of the main cities in Jiangsu Province, located at the north bank of Yangtze River. The dialect spoken in Taizhou is classified as a member in the Mandarin dialect group according to [2]. Taizhou dialect is also considered as the representative of the dialects distributed in the boundary region between Lower Yangtze Mandarin and the Northern Wu dialects [6]. As suggested in [4] and [1], there are similarities between Taizhou dialect and the Wu dialects, in particular in vowel system.

Table 1: Vowel inventory of Taizhou Chinese described in the previous studies.

Studies	CV	CV[ʔ]	CV[ŋ]
Gu [1]	[i ɿ u y ɑ ɛ ɔ ər ɛ̃ ɔ̃]	[æ ʊ ɑ ə ɔ]	[ɑ i ə ɔ]
Lu [4]	[i ɿ u y a e ɔ ə ɯ ɛ̃ ɔ̃]	[ɛ ʊ a ə ɔ]	[a i ə o]
NJU [5]	[i ɿ u y a ɛ ɔ ər ɛ̃ ɔ̃]	[æ ʊ a ə ɔ]	[a i ə o]
Zhang [7]	[ɿ u o y a e ɔ ɚ ɛ̃ ɔ̃]	[æ o ɑ ə ɔ]	[ɑ i ə o]

According to the previous studies [1, 4, 5, 7], the vowels in Taizhou Chinese occur in three syllable types, CV, CV[ʔ], and CV[ŋ]. As presented in Table 1, the description of the vowel inventory of Taizhou Chinese varies in different studies. The differences in the vowel inventory of Taizhou Chinese described in the four previous studies are summarized as follows. In CV syllables, (*i*) there is a vowel [i] included in [1, 4, 5] but not in [7]; (*ii*) a vowel [o] is included in [7] but not the other three studies; (*iii*) a vowel [ɯ] is included in [4], which is treated as a diphthong [ɤɯ] in the other three studies; and (*iv*) there are variations in the representation of the vowels [a]/[ɑ], [e]/[ɛ], and [ə]/[ər]/[ɚ] among the studies. As for in CV[ʔ] and CV[ŋ] syllables, the variations lie in the representation of the vowels [æ]/[ɛ], [ʊ]/[o], [a]/[ɑ], and [ɔ]/[o].

In the present study, the Taizhou vowels are tentatively symbolized as [i ɿ u o y ɑ ɛ ɔ ɚ ɯ ɛ̃ ɔ̃] in CV syllables, [æ ʊ ɑ ə ɔ] in CV[ʔ], and [ɑ i ə ɔ] in CV[ŋ] syllables. The study investigates all the 21 Taizhou vowels by performing formant analysis, in view of the lack of formant frequency data in the previous studies in substantiation of the IPA transcription of the vowels in Taizhou Chinese. It intends to enhance the phonetic description of Taizhou vowels based on the vowel formant data.

2. METHOD

2.1. Speakers

Speech samples were collected from two male and two female native Taizhou speakers with no history of hearing or speech difficulties. All the speakers were in middle age of 50 to 60 years old, who were born and grew up in the city of Taizhou, using Taizhou Chinese as the primary medium of communication at home and work, though they also spoke Putonghua with the non-Taizhou Chinese speakers.

2.2. Test materials

The test materials used for the study are the 21 meaningful monosyllabic words presented in Table 2, including 12 vowels in CV syllables, 4 vowels in CV[ʔ] syllables, and 5 vowels in CV[ŋ] syllables. Note that there are some test words in which the syllable has no initial consonant. All the selected test words are associated with a high tone, [44], [45], or [4]. The exception is a single test word [ɔŋ^{21}], as no words that contain the rime [ɔŋ] with a high tone occur in Taizhou Chinese. The test words were randomized on a reading list for eliciting five repetitions of each word from the speakers.

Table 2: Test monosyllabic words containing the 21 Taizhou vowels in CV, CV[ʔ], and CV[ŋ] syllables.

Vowels in CV				Vowels in CV[ʔ]			
i	[i^{44}]	ɛ	[ɛ^{44}]	æ	[æʔ^{4}]	ə	[təʔ^{4}]
ɿ	[sɿ^{44}]	ɔ	[ɔ^{44}]	ʊ	[pʊʔ^{4}]	ɔ	[ɔʔ^{4}]
u	[tu^{44}]	ɚ	[ɚ^{45}]	ɑ	[pɑʔ^{4}]		
o	[u^{44}]	ɯ	[tɯ^{44}]	Vowels in CV[ŋ]			
y	[y^{44}]	ɛ̃	[ɛ̃^{44}]	ɑŋ	[ɑŋ^{45}]	əŋ	[təŋ^{44}]
ɑ	[pɑ^{44}]	ʊ̃	[tʊ̃^{44}]	iŋ	[iŋ^{44}]	ɔŋ	[ɔŋ^{21}]

2.3. Data collection and analysis

The speakers took part in an audio recording in a quiet room individually. They were asked to utter the test words at a normal rate of speech. Speech data were collected by using a digital recorder with a microphone. The speech analysis software, Praat, was used to perform LPC analysis of the first three formant frequencies (F1, F2, F3) of the vowels in the test words. The formant frequencies were measured at the temporal mid-point of the steady-state section of vowel formant trajectories, by making reference to the spectrograms of the speech signals.

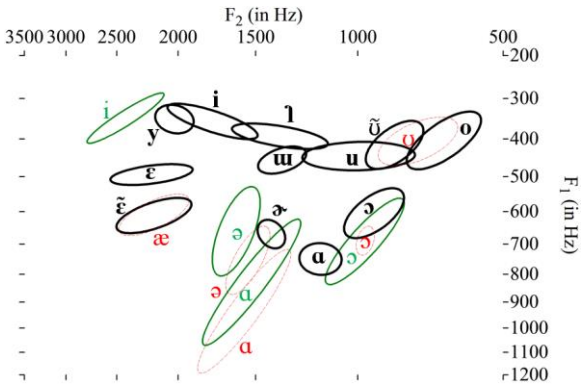
3. RESULTS

Fig. 1 and Fig. 2 show the vowel ellipses on the F1/F2 plane for the 21 Taizhou vowels in three syllable types, CV (thick solid line), CV[ʔ] (red dashed line), and CV[ŋ] (green solid line), produced by the male and female speakers in this study. The ellipses were drawn based on the mean values and standard deviations of the F1 and F2 of 10 tokens (5 repetitions x 2 speakers) of each vowel from the speakers of the same gender.

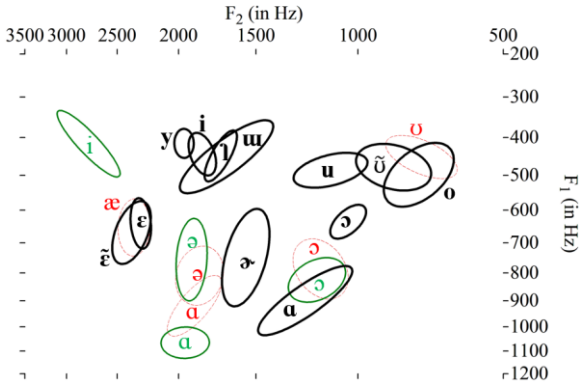
A comparison of the two figures shows that the male vowel ellipses tend to be positioned more leftward and upward on the F1/F2 plane (Fig. 1) than the female vowel ellipses (Fig. 2), due to the smaller formant values for the male vowels than the female ones. There are some other differences observed between the male and female vowel ellipses, including (*i*) no overlap between [ɛ] and [ɛ̃] nor between [ɯ] and [ɿ] in CV syllables for the male speakers, but for the female speakers; (*ii*) no overlap between [ɔ] in CV and [ɔ] in CV[ʔ] syllables nor between [ɚ] in CV and [ə] in CV[ʔ] syllables for the female speakers, but for the male speakers; and (*iii*) a more downward position for [ɑ] in CV and CV[ŋ] syllables than in CV[ʔ] syllables for the female speakers, but the reverse for the male speakers. In spite of the mentioned gender differences, there are a number of similarities between the male and female vowels that represent the uniqueness of the Taizhou vowels. The details are presented as follows.

Figures 1-2: Vowel ellipses on the F1/F2 plane for the 21 Taizhou vowels in CV (thick solid line), CV[ʔ] (red dashed line), and CV[ŋ] (green solid line) syllables produced by male and female speakers.

(1) Male vowel ellipses



(2) Female vowel ellipses



3.1. [i] in CV and CVN syllables

For both the male and female speakers, the vowel [i] in CV syllables is centralized on the F1/F2 plane, positioned in between the vowels [y] and [ɿ] in CV syllables. Perceptually, [i] in CV syllables is significantly different from [i] in CV[ŋ] syllables. This is supported by the formant data of [i] in the two syllable types presented in Table 3. As can be seen, the F2 is significantly smaller for [i] in CV syllables (1762 Hz for male; 1833 Hz for female) than [i] in CV[ŋ] syllables (2428 Hz for male; 2776 Hz for female), resulting in the centralization on the F1/F2 plane for [i] in CV syllables. The formant data indicate that in Taizhou, [i] in CV syllables is more likely to be a high central vowel, rather than a high front vowel [i] as in CV[ŋ] syllables. It should be added that in CV syllables, the F1 and F2 of [i] for the female speakers and the F1 of [i] for the male speakers are very close to those of [ɿ] as presented in Table 3. It was also told by the speakers, based on their intuition, the tip of tongue is raised and close to the alveolar ridge during the articulation of both [ɿ] and [i] in CV syllables. Thus, it is probable that the

vowel [i] in CV syllables of Taizhou Chinese is actually [ɿ]. Nonetheless, articulatory data needs to be collected to support the claim.

Table 3: Formant values (in Hz) for [i] in CV and CV[ŋ] syllables and [ɿ] in CV syllables.

Vowel	Male			Female		
	F1	F2	F3	F1	F2	F3
[i] in CV	356	1762	2984	443	1833	3295
[i] in CV[ŋ]	348	2428	3211	416	2776	3065
[ɿ] in CV	393	1369	2798	448	1712	2831

3.2. [u ɯ o] in CV syllables

As shown in Fig. 1 and Fig. 2, the vowel ellipses for [u], [ɯ], and [o] in CV syllables are positioned distinctly on the F1/F2 plane, in spite of a minimal overlap at the boundaries of the three male vowel ellipses. A comparison of the formant values for the three vowels presented in Table 4 shows a large difference in F2, where the F2 is smaller for [o] and larger for [u] than [ɯ]. In view of the small values of F1 and F2 for [o] and its vowel ellipse positioned at the high back corner on the F1/F2 plane, [o] is probably a high back vowel [u].

Table 4: Formant values (in Hz) for [o u ɯ] in CV syllables.

Vowel	Male			Female		
	F1	F2	F3	F1	F2	F3
[o] in CV	404	682	2697	449	768	2329
[u] in CV	444	1000	2562	486	1121	2809
[ɯ] in CV	455	1354	2566	450	1679	3050

As for the vowel described as [u] in the previous studies, it is more centralized on the F1/F2 plane than the vowel [o]. Based on the observation during the recordings, there was no apparent lip protrusion made for [u] as is made for [o]. The lack of lip rounding results in a larger F2 for [u] than the rounded [o] as presented in Table 4, which suggests [u] presumably an unrounded high vowel [ɯ].

There is a vowel [ɯ] in Taizhou Chinese described in [4], which is considered as a diphthong in [1, 5, 7]. Based on the formant data in the present study, the formant trajectories of the vowel are without large change throughout (*See* Fig. 3). The formant values taken at the time points of 20% and 80% of the vowel [ɯ] for the male and female speakers presented in Table 5 show a striking similarity in F1 and F2 between the two time points. The data indicate [ɯ] is a monophthong, rather than a diphthong. Because of a significant large F2 for [ɯ] and its centralized position on the F1/F2 plane, [ɯ] is assumed to be a high central vowel [ɨ].

Figure 3: Superimposed formant trajectories on the spectrograms of [ɯ] in [tɯ^{44}] for a male (the left panel) and a female (the right panel) speaker.

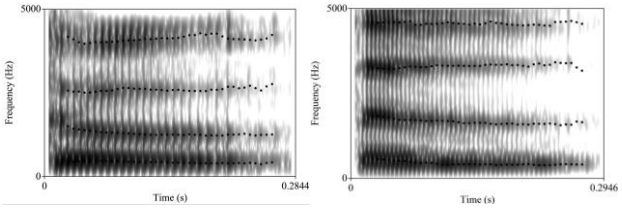


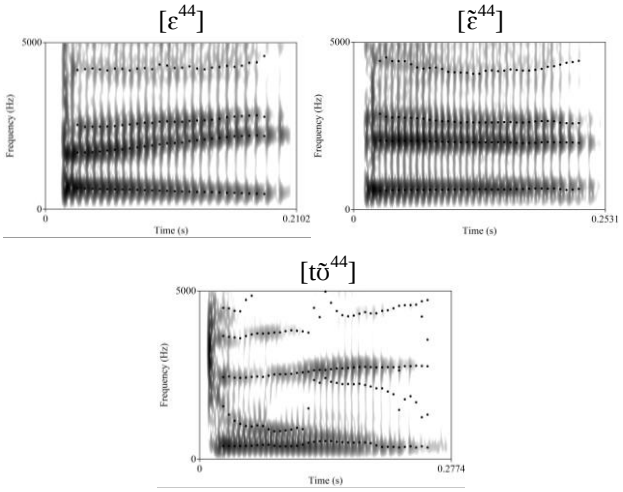
Table 5: Formant values (in Hz) for [ɯ] in CV syllables at the 20% and 80% time points.

Time point	Male			Female		
	F1	F2	F3	F1	F2	F3
20%	476	1393	2533	437	1690	2981
80%	496	1342	2578	441	1637	3043

3.3. [ɛ ɛ̃ ɔ̃] in CV syllables

In CV syllables, there are two nasalized vowels described as [ɛ̃] and [ɔ̃] in the previous studies, and the former has an oral counterpart [ɛ]. Based on the formant data in the present study, no nasalization is made for [ɛ̃] as is made for [ɔ̃]. A comparison of the spectrograms of [ɛ], [ɛ̃], and [ɔ̃] in CV syllables (Fig. 4) shows that [ɛ̃], similar to [ɛ], lacks the nasal or anti-formants as in the case of [ɔ̃]. The formant data suggest that [ɛ̃] is an oral vowel.

Figure 4: Spectrograms of [ɛ] in [ɛ^{44}] 愛, [ɛ̃] in [ɛ̃^{44}] 案, and [ɔ̃] in [tɔ̃^{44}] 鍛 for a male speaker.



As for the oral vowel [ɛ], the spectrogram presented in Fig. 4 shows that it is not a monophthong as described in the previous studies. For the four Taizhou speakers in this study, the formants of [ɛ] gradually change throughout the sound, with a decrease in F1 and an increase in F2. The formant values taken at the time points of 20% and 80% of the vowel [ɛ] for the male and female speakers presented in Table 6 show a significant

difference in F2 between the two time points. This is not true for its counterpart [ɛ̃]. The formant data of [ɛ] indicate that it is a diphthong, likely to be [ei] or [ɛi].

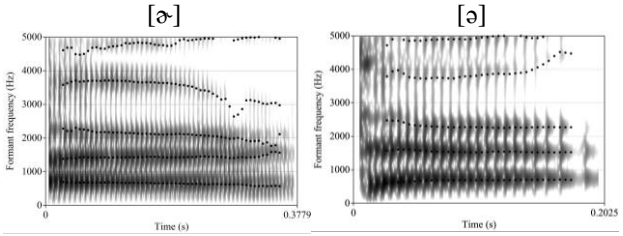
Table 6: Formant values (in Hz) for [ɛ] and [ɛ̃] in CV syllables at the 20% and 80% time points.

Vowel	Time point	Male			Female		
		F1	F2	F3	F1	F2	F3
[ɛ] in CV	20%	522	2139	2816	646	2278	3110
	80%	487	2296	2880	566	2381	3150
[ɛ̃] in CV	20%	597	2173	2881	642	2402	3182
	80%	637	2171	2871	715	2374	3205

3.4. [ɚ] in CV

Similar to the case of [ɛ] in CV syllables, the vowel [ɚ] in CV syllables has the dynamic changing formant pattern, with a progressive decrease in F1 and an increase in F2 throughout the vowel as shown in Fig. 5. Compared with the formant trajectories of [ə] in CV[ʔ] syllables, F3 is significantly small during [ɚ] in CV syllables, which indicates the rhoticity of the vowel. The small F3 appears at the very beginning and throughout the vowel, suggesting [ɚ] is a monophthong, rather than a sequence of [ər].

Figure 5: Superimposed formant trajectories on the spectrograms of [ɚ] in [ɚ^{45}] 兒 and [ə] in [təʔ^{4}] 德 for a male speaker.



3.5. [æ] and [ʊ] in CV[ʔ] syllables

The vowels [æ] and [ʊ] in CV[ʔ] syllables have the formant patterns similar to those for the vowels [ɛ̃] and [o] in CV syllables, respectively. As shown in Fig. 1 and Fig. 2, the vowel ellipses for the paired [æ]-[ɛ̃] and the paired [ʊ]-[o] overlap to a large extent, in particular for the male speakers. The formant data of the two paired vowels for the male and female speakers presented in Table 7 denote the similarities in the F1 and F2 between the paired vowels in each case. As presented earlier, the formant data on the vowels [ɛ̃] and [o] in CV syllables suggest that they are [ɛ] and [u], respectively. Thus, the vowels [æ] and [ʊ] in CV[ʔ] syllables are also [ɛ] and [u], respectively.

Table 7: Formant values (in Hz) for [æ] and [ʊ] in CV[ʔ] syllables and [ɛ̃] and [o] in CV syllables.

Vowel	Male			Female		
	F1	F2	F3	F1	F2	F3
[æ] in CV[ʔ]	610	2190	2881	653	2354	3071
[ɛ̃] in CV	611	2191	2877	668	2376	3128
[ʊ] in CV[ʔ]	407	771	2558	451	759	3024
[o] in CV	404	683	2697	499	769	2330

3.6. [ɑ] and [ɔ] in CV, CV[ʔ], and CV[ŋ] syllables

In Taizhou, the vowels [ɑ] and [ɔ] occur in all CV, CV[ʔ], and CV[ŋ] syllables. As shown in Fig. 1 and Fig. 2, the vowel ellipses for [ɑ] and [ɔ] are positioned more to the bottom and the front of the F1/F2 plane when the vowels occur in the closed syllables of CV[ʔ] and CV[ŋ] than in the open CV syllables. For the male speakers, the vowel ellipses for [ɔ] in the open and closed syllables overlap to a large extent (Fig. 1), whereas the female vowel ellipses for [ɔ] in the open and closed syllables are slightly separate (Fig. 2). As for the vowel [ɑ], there is a significant difference in position of the vowel ellipse between the open and closed syllables for either the male or female speakers. The formant values for [ɑ] in the three syllable types presented in Table 8 show that F2 is significantly larger for [ɑ] in CV[ʔ] and CV[ŋ] syllables than in CV syllables. The data suggest that the vowel is [ɑ] in CV syllables, but a front [a] in CV[ʔ] and CV[ŋ] syllables.

Table 8: Formant values (in Hz) for [ɑ] in CV, CV[ʔ], and CV[ŋ] syllables.

Vowel	Male			Female		
	F1	F2	F3	F1	F2	F3
[ɑ] in CV	748	1165	2824	900	1242	2599
[ɑ] in CV[ʔ]	907	1532	2495	968	1861	2537
[ɑ] in CV[ŋ]	832	1526	2625	1064	1954	2683

4. CONCLUSION

The vowel formant data presented in this paper differ from the previous description of the vowels in Taizhou Chinese. The formant data in the present study suggest that the Taizhou vowel inventory presumably includes [y ɿ i ɯ u ɛ ɔ ɚ ɑ ɔ̃] in CV syllables, [u ɛ ɔ ə a] in CV[ʔ] syllables, and [i u ɔ ə a] in CV[ŋ] syllables. In the future time, data from more speakers will be collected to give further support to the description of the Taizhou vowels presented in this paper.

7. REFERENCES

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