An Acoustical Analysis of the Vowels, Diphthongs and Triphthongs in Hakka Chinese

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ABSTRACT

The study is a phonetic analysis of the vowels, diphthongs and triphthongs in Meixian Hakka. The formant measurements as well as the temporal organization are presented. Results show that (1) the relative distance between the mid vowels and the high vowels differ in male and female speech in Meixian Hakka; (2) diphthongs in Meixian Hakka may be separated into two categories according to the difference in formant structure relative to the monophthongal vowels and this was supported by the temporal structure of the diphthongs; and (3) the formant frequency data and the temporal organization provide a basis for the transcription of the Meixian Hakka vowel system.

Keywords: Acoustic phonetics; spectral patterns; temporal relationship; diphthongs; Hakka Chinese.

1. INTRODUCTION

Meixian Hakka is a dialect of the Hakka group of the Chinese language and it is the representative dialect of the Hakka group. Meixian Hakka is spoken in northeast Guangdong Province, China.

The Meixian Hakka sound system has been described in the past studies [2, 3, 6], however, no experimental data have been presented and little work on the phonetic analysis of Hakka vowels has been done.

It is generally agreed among the past studies that 5 monophthongal vowels [i, e, a, o, u], 11 diphthongs [ia, ie, io, iu, ua, uo, ui, ai, oi, au, eu] and 4 triphthongs [iai, iui, iau, uai] include in the vowel system of Meixian Hakka. In this study, the recordings of Meixian Hakka vowels, diphthongs and triphthongs were analyzed in a phonetic perspective. F_1, F_2 and F_3 onset and offset formant frequency measurements and the temporal organizations were presented. The phonetic characteristics of vowels, diphthongs and triphthongs in Meixian Hakka are uncovered and results of this study are compared with the past studies on other Chinese dialects as well as other languages.

2. METHOD

2.1. Test material and recording

In this study, the 5 vowels, 11 diphthongs, 4 triphthongs in Meixian Hakka were recorded for analysis. All vowels, diphthongs and triphthongs occur in (C)V syllables. Digital audio recordings were made of the native speakers of Meixian Hakka reading a randomized list of 20 meaningful monosyllabic words. Each test word was embedded in a carrier sentence, [ŋai11 tʰuk5 ____ pun35 m̩11 tʰaŋ44] “I read ____ for you (to) listen.”. Four readings of the word list were recorded. The speakers were instructed to read the word list at a normal rate of speech. The digital recordings took place in a quiet room.

2.2. Speakers

The speech data were provided by five male and five female speakers. They are native speakers of Meixian Hakka, who were in their sixties at the time of recording. They were born and grew up in the city of Meixian in Guangdong Province.

2.3. Analysis

Praat 4.3.19 speech analysis software was used for both spectral analysis and temporal measurement of the vowels, diphthongs and triphthongs. Speech data were captured at a sampling rate of 10,000 samples per second, which produce an upper frequency cut-off of 5,000 Hz. Formant trajectories were obtained for determining the steady states of the vowels, two elements of the diphthongs and three elements of the triphthongs. The frequencies of the first three formants were measured for each vowel at its steady state, close to the middle of the vowel if possible; each diphthong at the points of nearest approach to the steady states of the first and second elements; and each triphthong at the points of nearest approach to the steady states of the first, second and third elements. Measurements of the durations of the steady states and transitions were made with the aid of the formant trajectories, visual inspection of the waveforms, and auditory judgment of the investigator.

3. RESULTS 1: FORMANTS

3.1. Vowels

Figure 1 shows the mean values of F_1, F_2 and F_3 of 5 monophthongal vowels [i, e, a, o, u] in Meixian Hakka. Each IPA symbol on the left shows the first three formants of a vowel for the female speakers, whereas that on the right shows the first three formants of a vowel for the male speakers, respectively. Each mean value was obtained from 20 data points for a particular vowel (4 repetitions x 5 speakers). The acoustical data indicate that the formant patterns of [i], [e], [a], [o] and [u] for the male speakers are similar to those for the female speakers, respectively. The overall formant frequency values, particularly the F_1 and F_2 values, of the vowels for the male speakers are lower than those for the female speakers as expected. It is due to the differences in vocal tract dimensions and ratio of pharyngeal area to oral cavity area between male and female speakers [4].

Figure 1: Mean values of the first three formants (F_1, F_2, F_3) for the monophthongal vowels [i, e, a, o, u] in Meixian Hakka (left for male speakers and right for female speakers).

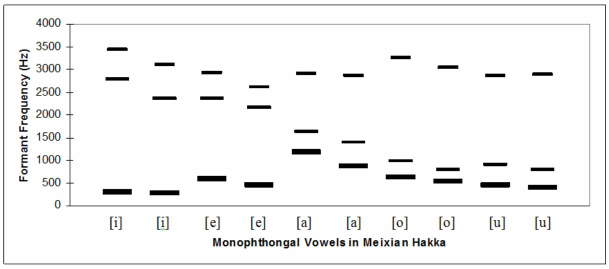
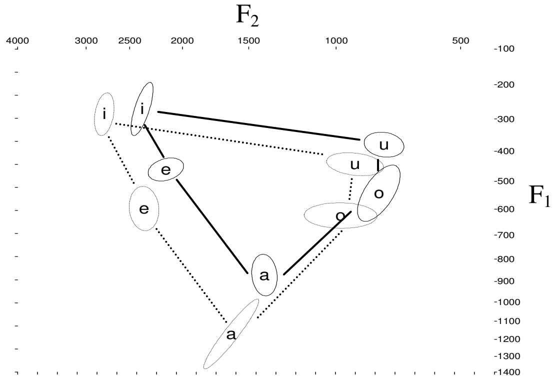


Figure 2 shows the positions of the vowel ellipses for the monophthngal vowels [i, e, a, o, u] in Meixian Hakka in the F1/F2 plane for 5 male and 5 female speakers. The relative positions of the vowel ellipses indicate that the vowel ellipses for the female speakers are located more to the left and lower area of the acoustical vowel space than those for the male speakers. It is resulted from higher formant frequency values of the resonant sounds produced by the female speakers. In addition, the acoustical vowel space for the female speakers is larger than that for the male speakers. Results show that the relative distance between the mid vowels [e, o] and the high vowels [i, u] is greater for female speakers than that for the male speakers. This difference between male and female speakers is found in the vowel system of Beijing Mandarin and Hong Kong Cantonese as presented by Zee [7, 8, 9]. As Hakka, Mandarin and Cantonese are major dialects of the Chinese language, it may suggest that this phenomenon occurs particularly in the Chinese dialects, which distinguish the dialects of the Chinese languages from other languages. In comparison, the difference in the relative distance between the mid and high vowels is greatest in Cantonese, followed by Mandarin, and then Hakka.

Figure 2: Vowel ellipses for [i, e, a, o, u] in Meixian Hakka in the F_1/F_2 plane. Solid ellipses indicate the acoustic data for male speakers and dotted ellipses indicate those for female speakers.



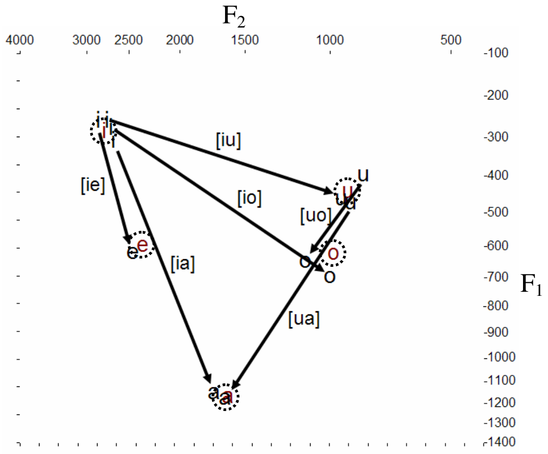
3.2. Diphthongs

In this section, the acoustical data of the 11 diphthongs in Meixian Hakka, which have been transcribed as [ia, ie, io, iu, ua, uo, ui, ai, oi, au, eu] were presented. The formant frequencies of the first two formants for the first and second elements of the diphthongs were compared among themselves and with the formant frequencies of their vowel targets in the monophthongal vowels.

Figures 3a-3b show the diphthong formants of the 11 diphthongs in Meixian Hakka in the F1/F2 plane for the 5 female speakers, with F_1 plotted on the ordinate and F_2 on the abscissa in Bark scales. The diphthong formants for the first and second elements are plotted against the formants of the 5 monophthongal vowels. Each of the two end points of an arrow shows the first and second elements of a diphthong. The dotted circles in Figures 3a-3b indicate the positions of the monophthongal vowels in the F1/F2 plane.

The acoustic data in Figure 3a indicate that the first and second elements of [ie, ia, io, iu, ua, uo] have F_1 and F_2 values that are equivalent to those of the monophthongal vowels said to be the target vowels of the diphthongs. The positions of the first and second elements of the diphthongs in the acoustical vowel space are close to the positions of the monophthongal vowels [i, e, a, o, u], respectively.

Figure 3a: Formant movements for the diphthongs [ie, ia, io, iu, ua, uo] and the 5 monophthongal vowels [i, e, a, o, u] in Meixian Hakka for 5 female speakers.



In contrast, the data in Figure 3b indicate that the first and second elements of the [eu, ui, oi, au] and the second element of [ai] do not achieve the formant frequency values of the corresponding monophthongal vowels. The first and second elements of [eu, ui, oi, au] and the second element of [ai] appear to be centralized, when considered in relation to the monophthongal vowels. Based on the spectral data, the diphthongs in Meixian Hakka may be separated into two categories. The first category consists of [ie, ia, io, iu, ua, uo], in which the F_1 and F_2 of the first and second elements for a diphthongs are equivalent to those of the monophthongal vowels. The second category consists of [eu, ui, oi, au, ai], in which centralization occurs and the two elements of the diphthong do not reach the formant frequencies of the target vowels. This phenomenon does not occur in the diphthongs of other Chinese dialects [7, 10] and it seems that it is a specific characteristic for the Hakka diphthongs. Among the vowels, [a] seems to be resistant to the effect of centralization.

Table 1 shows that, except the first element of [ai], [eu, ui, oi, au] have higher F_1 values for the first element of the diphthong than the monophthongal vowels [i, e, a, o, u]. It indicates that these diphthongs have more open articulatory positions at their beginning than the monophthongal vowels. On the other hand, F_2

Figure 3b: Formant movements for the diphthongs [eu, ui, oi, au, ai] and the 5 monophthongal vowels [i, e, a, o, u] in Meixian Hakka for 5 female speakers.

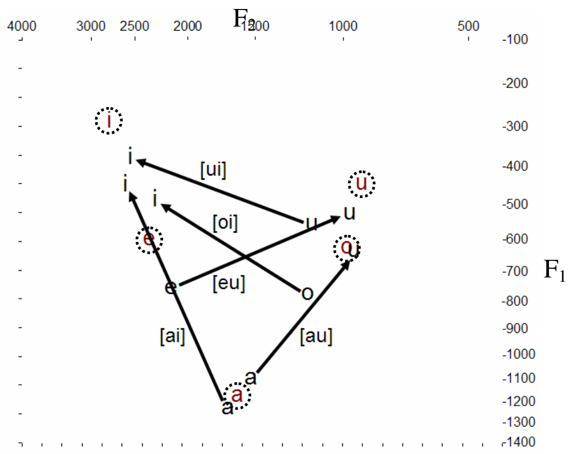


Table 1: Mean values of F_1 and F_2 (in Hz) and their standard deviations for the first and second elements of diphthongs [eu, ui, oi, au, ai] and their target vowels in Meixian Hakka for 5 female and 5 male speakers.

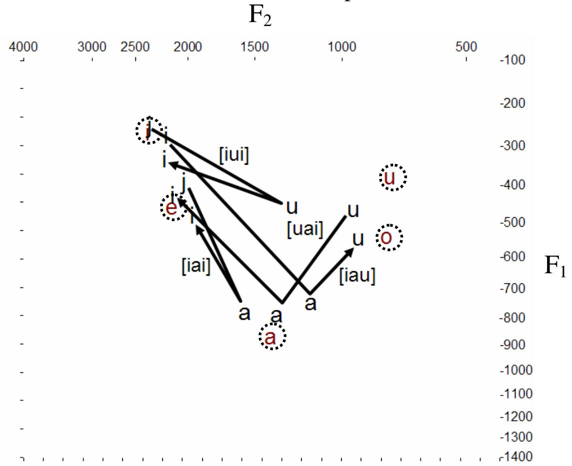
	Female speakers		Male speakers	
	F_1 (s.d.)	F_2 (s.d.)	F_1 (s.d.)	F_2 (s.d.)
[eu] (1st)	756 (35)	2144 (59)	629 (56)	1754 (74)
[e]	598 (40)	2355 (73)	460 (19)	2147 (79)
[eu] (2nd)	522 (82)	967 (91)	493 (33)	1054 (104)
[u]	443 (19)	912 (64)	379 (19)	786 (40)
[ui] (1st)	548 (31)	1138 (121)	457 (40)	1143 (86)
[u]	443 (19)	912 (64)	379 (19)	786 (40)
[ui] (2nd)	374 (25)	2550 (34)	365 (27)	2126 (142)
[i]	290 (31)	2775 (59)	268 (36)	2361 (64)
[oi] (1st)	781 (54)	1189 (143)	610 (24)	985 (37)
[o]	624 (24)	981 (86)	541 (52)	800 (56)
[oi] (2nd)	485 (50)	2306 (177)	465 (77)	1991 (131)
[i]	290 (31)	2775 (59)	268 (36)	2361 (64)
[au] (1st)	1099 (78)	1540 (92)	732 (61)	1181 (87)
[a]	1172 (97)	1621 (96)	872 (48)	1397 (40)
[au] (2nd)	631 (79)	948 (76)	502 (34)	853 (31)
[u]	443 (19)	912 (64)	379 (19)	786 (40)
[ai] (1st)	1209 (94)	1678 (67)	836 (39)	1414 (52)
[a]	1172 (97)	1621 (96)	872 (48)	1397 (40)
[ai] (2nd)	403 (88)	2632 (101)	420 (37)	2106 (199)
[i]	290 (31)	2775 (59)	268 (36)	2361 (64)

measurements indicate that [eu] and [au] ends with slightly more front articulatory positions than vowel [u], whereas [ui], [oi] and [ai] ends with slightly more retracted positions than [i]. Such acoustic outcomes are correlated with the activities of genioglossus and styloglossus as stated in the study of Collier [1].

3.3. Triphthongs

Figure 4 show the angled triphthong arrows indicating the formant movements for the triphthongs [iai, iui, uai, iau] in Meixian Hakka for male and female speakers. Results show that centralization occurs in all three elements of [iai] and [uai]. For the first and last elements of [iai] as well as the last element of [uai], they have the formant frequencies that are equivalent to those of monophthongal vowels [e] and it may be justified to transcribed them as [e]. Besides, centralization merely occurs in second and third elements of [iui] and [iau]. The formant frequencies of the first element for [iui] and [iau] are equivalent to those of monophthongal vowels [i].

Figure 4: Formant movements for the triphthongs [iai, iui, uai, iau] and the 5 monophthongal vowels [i, e, a, o, u] in Meixian Hakka for 5 male speakers.



4. RESULTS 2: TEMPORAL STRUCTURE

Figures 5a-5b show the temporal organization of the 11 diphthongs and 4 triphthongs in Meixian Hakka. As mentioned in the previous section, diphthongs in Meixian Hakka can be separated into two categories according to the difference in their formant patterns. As shown in Figure 5a, the temporal organization supports this classification. Regardless of [iu], diphthongs in the first category [ie, ia, io, ua, uo] tend to have relatively short

Figure 5a: Temporal organization of the 11 diphthongs [eu, au, ui, oi, ai, uo, ua, iu, io, ia, ie] in Meixian Hakka for a male speaker.

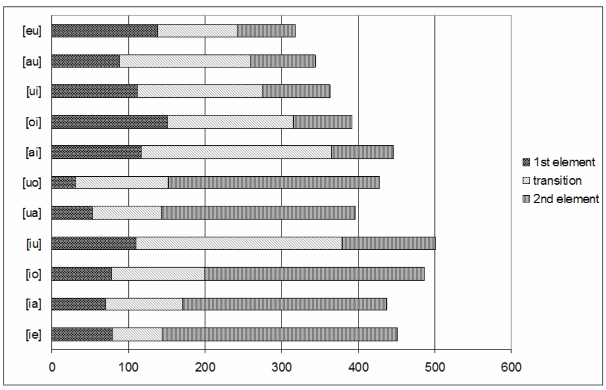
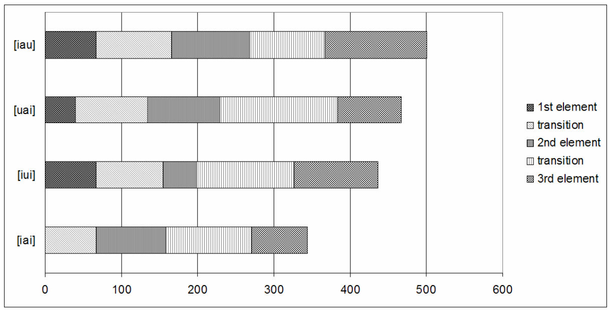


Figure 5b: Temporal organization of the 4 triphthongs [iau, uai, iui, iai] in Meixian Hakka for a male speaker.



steady states of the first elements, relatively short transitions and relatively long steady states of the second elements, in relation to those of the diphthongs in the second category [eu, ui, oi, au, ai]. For diphthongs in the second category [eu, ui, oi, au], the duration of the transition is longer than either the duration of onset or offset steady state.

5. CONCLUSION

The paper has presented the acoustic characteristics of the vowels, diphthongs and triphthongs in Meixian Hakka. The acoustical data presented in this study provide useful information for a better understanding of the various acoustic properties of the Hakka vowel system.

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