# AN ACOUSTIC ANALYSIS OF CENTRAL VOWELS IN MALAYSIAN HOKKIEN

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## ABSTRACT

This study describes and examines the acoustic properties of the central vowels [ɨ] and [ə̱] in Malaysian Hokkien (MH). The two central vowels are typologically special in that both of them are "full-fledged", phonemic vowels in an inventory. Therefore our main research question is to see if the two central vowels are subject to contextual influences, just like their counterparts in other languages (e.g. [2, 6, 8, 9]). Our principal finding is that no significant contextual variability is attested, indicating that central vowels may be resistant to coarticulatory effects, even though they are unreduced. While [8]'s results showed substantial contextual variations of the phonemic vowel [ɨ] in Korean, which casts doubt on a duration-based account [6, 9], our results instead suggest that central vowels may not necessarily be targetless [2].

**Keywords:** phonemic central vowels, targetless, duration, contextual variability, coarticulation

## 1. INTRODUCTION

Central vowels are often regarded as a "chameleon vowel" because their vowel quality may be contextually determined [2, 7, 9]. There are two competing views for the contextual variability in question. Browman and Goldstein [2] propose that it is because central vowels are lack of a target (or, the "targetlessness" view), while [6, 9] advocates a duration-based account, according to which contextual variability is attributed to undershoot in the wake of diminished duration. The two theories, however, may not be distinguishable with respect to reduced central vowels, because it is difficult to factor out phonetic length effects.

We believe that it will be particularly beneficial to study the acoustic properties of the two central vowels [ɨ] and [ə̱] in Malaysian Hokkien (hereafter MH) because they are phonemic vowels in their own right. On the one hand, our study offers an empirical assessment of the above two competing theories as to whether contextual variability will be attested among the "full-fledged" central vowels, whereby phonetic length effects are apparently not at issue. On the other hand, the present work also enriches our understanding of central vowels from a typological perspective because there are, to our knowledge, not so many languages having more than one phonemic central vowel.

## 2. METHOD

### 2.1. Participants

Four native speakers of MH (two males and two females) were recruited for this study. They are in their 70s to 80s in 2010. All of the participants were born and raised in Melaka (a.k.a. Malacca), Malaysia and speak the Eng Choon (or, Yongchun in Mandarin) variety of MH, a pan-Quanzhou accent of Southern Min Chinese, as the primary language. They were paid for their participation. No speech and hearing impairments were reported.

### 2.2. Stimuli

Like many other Chinese languages, the maximal MH syllable has four underlying elements CGVX, where, modulo the issues of phonemicization, C = {p, t, k, pʰ, tʰ, kʰ, b, g, s, ts, tsʰ, l, m, n, ŋ, ʔ}, G = {j, w}, X = {m, n, ŋ, p, t, k, ʔ} and the vowel phoneme inventory consists of the eight vowels, {i, e, a, ɔ, o, u, ɨ, ə̱}. Our recording materials are comprised of 109 monosyllabic CV words, where C is: (i) labial {p, pʰ, b}, (ii) coronal {t, tʰ, ts, tsʰ, s, l}, (iii) dorsal {k, kʰ, g}, or (iv) glottal {h, ʔ}. Note also that as a language-specific phonotactic rule in MH, labials do not co-occur with /ɨ/, e.g. *[pɨ].

### 2.3. Procedures

#### *2.3.1. Data collection*

Each target word was embedded in the carrier phrase in (1) below. The participants were asked to read each sentence twice from a computer screen.

| | | | | | | |
|---|---|---|---|---|---|---|
| (1) | *gua* | *tsʰau* | ___ | *tsʰau* | *sã* | *pai* |
| | I | transcribe | __ | transcribe | three | times |

'I transcribe ___ three times.'

The recording, with the help of a digital recorder (Edirol R09-HR) and a unidirectional microphone (Beyerdynamic M69NC), was made at a quiet hotel room in Melaka (whose background noise was about 40dB). The sampling rate was 44.1 kHz (16 bit). A total of 872 tokens (=109 words × 4 speakers × 2 repetition) were collected.

*2.3.2. Data analysis*

The acoustic analysis was done using Praat [1]. The segmentation was performed according to the beginning and endpoint of the second formant (F2). The values of the first three formants were extracted at the midpoint of a vowel with the help of a formant tracking script developed at the NTHU Phonetics Laboratory.

## 3. RESULTS

### 3.1. Acoustic properties of central vowels

*3.1.1. Formant values*

The mean formant frequencies for the eight phonemic vowels are given in Tables 1 and 2. As we can see, the vowels [ɨ] and [ə̠] are central vowels, judging from their F2 values (ranging from 1,500 Hz to 1,600 Hz for the male speakers). The mid central vowel [ə̠] is a (slightly) retracted schwa for the female speakers, which is located between [ɤ] and [ə] (i.e., normally ranging from 1,300 Hz to 1,600 Hz; see data from former studies in Table 3 for a cross-linguistic comparison).

**Table 1:** Mean formant values of the male speakers (in Hz; standard deviation in parentheses).

| | F1 | SD | F2 | SD | F3 | SD |
|---|---|---|---|---|---|---|
| i | 268 | 34 | 2170 | 164 | 2971 | 132 |
| e | 362 | 28 | 2006 | 148 | 2670 | 151 |
| ɨ | 313 | 21 | 1497 | 136 | 2368 | 150 |
| ə̠ | 414 | 57 | 1446 | 83 | 2445 | 280 |
| a | 766 | 77 | 1256 | 98 | 2776 | 262 |
| u | 316 | 32 | 747 | 89 | 2430 | 190 |
| o | 383 | 46 | 811 | 83 | 2634 | 311 |
| ɔ | 583 | 48 | 925 | 84 | 2878 | 347 |

**Table 2:** Mean formant values of the female speakers (in Hz; standard deviation in parentheses).

| | F1 | SD | F2 | SD | F3 | SD |
|---|---|---|---|---|---|---|
| i | 275 | 22 | 2719 | 121 | 3493 | 224 |
| e | 349 | 36 | 2608 | 144 | 3179 | 137 |
| ɨ | 329 | 33 | 1603 | 130 | 3030 | 149 |
| ə̠ | 443 | 68 | 1466 | 140 | 3114 | 96 |
| a | 1013 | 79 | 1478 | 136 | 2955 | 116 |
| | F1 | SD | F2 | SD | F3 | SD |
| u | 337 | 33 | 742 | 105 | 3082 | 138 |
| o | 365 | 43 | 772 | 88 | 3221 | 76 |
| ɔ | 578 | 82 | 929 | 78 | 3193 | 195 |

**Table 3:** A cross-linguistic comparison of formant values of *phonemic* central vowels (data from male speakers only; adapted from [8][a], [3][b] and [10][c]).

| | F1 | F2 | F3 |
|---|---|---|---|
| Korean [ɨ][a] | 321 | 1388 | |
| Korean [ɨ][b] | 390 | 1495 | 2405 |
| Taiwanese Mandarin [ɤ][b] | 481 | 1322 | 2584 |
| English [ɤ][b] | 460 | 1310 | |
| Welsh [ə][c] | 503 | 1522 | |

In Table 4, Euclidean distance was calculated in order to quantify the distances between central vowels and peripheral vowels (cf. [4, 9]). As we can see, for most speakers (i.e. F1, F2 and M2), [ɨ] and [ə̠] are closer to the back vowels ([u] and [o]), while the only exception is Speaker M1, whose [ɨ] and [ə] are more fronted. Remarkably, greater Euclidean distances were found between [e] and [ə̠] than those between [i] and [ɨ], thus confirming the above observation that [ə̠] is more retracted than [ɨ] in MH.

**Table 4:** Euclidean distances between central vowels and peripheral vowels in the same height.

| Speaker | Vowel categories | Euclidean distances | Proportion |
|---|---|---|---|
| F1 | [i]-[ɨ]-[u] | 1139:916 | 1.24:1 |
| | [e]-[ə̠]-[o] | 1116:810 | 1.38:1 |
| F2 | [i]-[ɨ]-[u] | 981:720 | 1.36:1 |
| | [e]-[ə̠]-[o] | 1058:513 | 2.06:1 |
| M1 | [i]-[ɨ]-[u] | 569:838 | 0.68:1 |
| | [e]-[ə̠]-[o] | 476:723 | 0.65:1 |
| M2 | [i]-[ɨ]-[u] | 850:752 | 1.13:1 |
| | [e]-[ə̠]-[o] | 723:630 | 1.15:1 |

*3.1.2. Duration*

As mentioned at the outset, the central vowels in MH are not reduced vowels. Regarding duration, we see from Table 5 that there are no satisitically significant differences between the two central vowels [ɨ] and [ə̠] (234ms and 236ms, respectively) and the other phonemic vowels (whose duration is between 224ms and 252ms). Consequently, we conclude that the two central vowels ([ɨ] and [ə̠]) are not reduced vowels, or, more precisely, they are not phonetically shorter in duration.

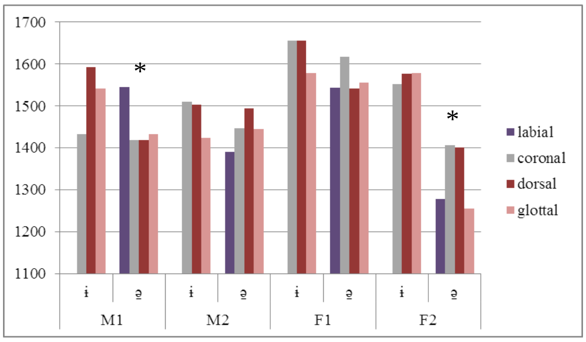
**Table 5:** An independent-sample t-test on durational differences between central vowels and other vowels.

| Vowel | i | e | ɨ | ə̠ | a | u | o | ɔ |
|---|---|---|---|---|---|---|---|---|
| Duration (in ms) | 224 | 233 | 234 | 236 | 252 | 234 | 239 | 226 |
| ɨ | 0.691 | 0.543 | -- | 0.459 | 0.959 | 0.964 | 0.700 | 0.912 |
| ə̠ | 0.733 | 0.849 | 0.459 | -- | 0.561 | 0.496 | 0.718 | 0.390 |

### 3.2. Contextual variations

In this study, we investigated the following four types of consonantal contexts: (i) labial (e.g., *pə̠* 'to fly'), (ii) coronal (e.g., *tɨ* 'pig'), (iii) dorsal (e.g., *kʰɨ* 'to go'), (iv) glottal (e.g., *ʔɔ* 'black'). A multivariate analysis of variance (MANOVA) with Four Consonant Place, Two Central Vowels and Four Speakers as between-subjects factors was conducted to see if place of articulation has an impact on F1 and F2 of the two central vowels. The results show that there were significant main effects of Vowel and Speaker on both F1 and F2 ($p$<0.001). It thus confirms that [ɨ] and [ə̠] have distinct vowel quality and there are inter-speaker variations in the production of the two central vowels. A significant Consonant Place effect can only be found on F1 ($p$=0.027) but not on F2 ($p$=0.221). From Figure 1, we can see that larger contextual variations on the second formants can be found only for [ə̠] produced by Speakers M1 and F2 (marked with a star in Figure 1 below), indicating that coarticulatory effects may not be consistent in this regard. Regarding the first formants, there is a significant difference between the labials and the other consonants. Alternatively, the schwa [ə̠] tend to be lower (or, compressed) when following a labial sound, which is a commonplace phenomenon.

**Figure 1:** A cross-speaker comparison of the coarticulatory effects on the second formants (where * = significant at the 0.05 level).




Tables 6&7 and Figures 2&3 illustrate the magnitude of contextual variations along the F2 dimension. The contextual variations are not very large (from 35 Hz to 136 Hz for the male speakers and from 37 Hz to 137 Hz for the female speakers). Contextual variations can be, *grosso modo*, observed in a decreasing fashion from this order: back vowels > central vowels > front vowels. Non-central vowels tend to be more retracted in F2 when following a labial. Back vowels tend to be more fronted in the context of a coronal onset (e.g. assimilation), however, Front vowels tend to be more fronted when following a dorsal (e.g. dissimilation). Notably, the barred-i [ɨ] is subject to dissimilatory coarticulation (more precisely, more fronted when following a dorsal, and further backed when following a coronal; but see [8]) .

**Table 6:** Magnitude of the coarticulatory effects on the second formants (male speakers).

| place | i | e | ɨ | ə̠ | a | u | o | ɔ |
|---|---|---|---|---|---|---|---|---|
| labial | 2147 | 1965 | -- | 1468 | 1209 | 699 | 742 | 868 |
| coronal | 2165 | 1986 | 1475 | 1433 | 1278 | 785 | 850 | 1003 |
| dorsal | 2167 | 2057 | 1548 | 1457 | 1255 | 755 | 818 | 876 |
| glottal | 2224 | 2040 | 1483 | 1439 | 1262 | 689 | 819 | 892 |
| **magnitude (=max-min)** | **78** | **93** | **73** | **35** | **69** | **97** | **108** | **136** |

**Table 7:** Magnitude of the coarticulatory effects on the second formants (female speakers).

| place | i | e | ɨ | ə̠ | a | u | o | ɔ |
|---|---|---|---|---|---|---|---|---|
| labial | 2719 | 2596 | -- | 1411 | 1449 | 701 | 723 | 871 |
| coronal | 2703 | 2581 | 1605 | 1512 | 1496 | 803 | 811 | 980 |
| dorsal | 2736 | 2627 | 1616 | 1472 | 1491 | 712 | 724 | 922 |
| glottal | 2740 | 2670 | 1578 | 1405 | 1413 | 666 | 790 | 862 |
| **magnitude (=max-min)** | **37** | **89** | **38** | **106** | **84** | **137** | **88** | **118** |

**Figure 2:** Contextual variations of the central vowels (male speakers).

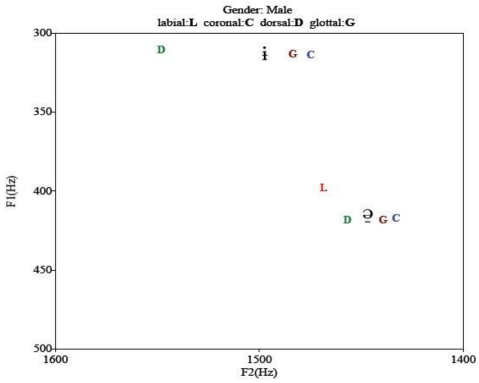
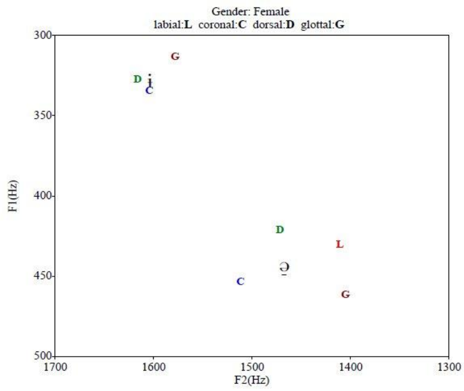



**Figure 3:** Contextual variations of the central vowels (female speakers).



In sum, we have shown that the central vowels [ɨ] and [ə̱] in MH are more resistant to contextual influences, if compared with the back vowels.

## 4. DISCUSSION AND CONCLUSION

In this work, our principal findings are: i) MH does have two full-fledged, phonemic central vowels, namely, [ɨ] and [ə̱], and ii) more importantly, the two central vowels are not subject to consonantal coarticulatory effects in the CV frame, indicating that central vowels may be inert to contextual influences. In other words, our results seem to suggest that central vowels may not be necessarily targetless [2], thus lending support to a duration-based account for contextual variability of central vowels (6, 9]).

Nevertheless, we believe that our results may be inconclusive for the issue in question. This is because it has been reported in [8]'s acoustic study that the Korean central vowel [ɨ], be it epenthetic or lexical/phonemic, exhibits substantial contextual variations as "a function of the place of articulation of a preceding consonant". Crucially, the phonemic barred-i [ɨ] in Korean is also a full-fledged vowel, whose phonetic length is not reduced, either. In other words, at least in Korean, contextual variability is attested, even though the central vowel is not reduced, or, is not significantly shorter in duration. It then appears that the Korean central vowel [ɨ], rightly so, is targetless. To this end, it is evident that conflicting patterns of coarticulation are found in similar contexts in different languages.

One possible explanation is that MH has two central vowels in its vowel inventory, whereas Korean has only one central vowel [ɨ].[1] It may well be the case that contextual variability is minimized in MH because of a more crowded vowel space, especially when [ɨ] and [ə̱] do not have a large difference along the F1 dimension (NB: for all speakers, the Euclidean distances between [ɨ]-[ə̱]-[a] are 143:470, or 0.3:1 in ratio; see also Tables 1 & 2). By contrast, in Korean, there is less pressure to realize the high central vowel [ɨ] in an accurate manner since there is only one central vowel in the Korean vowel inventory, endangering no potential contrasts [5]. So, more contextual variations are not unexpected if minimization of articulatory difficulties is active in the grammar [5].

In conclusion, our study does not seem to support either the targetlessness view [2], or the duration-based account [6, 9], as far as the contextual variability of the central vowels is concerned. Last but no least, it remains to be seen to what extent phonological contrasts play a role in coarticulatory effects.

## 5. ACKNOWLEDGEMENTS

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[1] Whether or not the vowels [ə] and [ʌ] are in allophonic variation is controversial in Korean phonology and may be subject to dialectical variations. We leave this issue open.