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ILLUSTRATION OF THE IPA

Wenchang Min Chinese[†]

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Wenchang (文昌市) is situated in the northeast part of Hainan province (海南省), China. The city has a total population of about 570,000 local people.[1] The dialect (文昌话) spoken here is representative of Hainan Min dialect group of Chinese (ISO 639-3; code:nan).

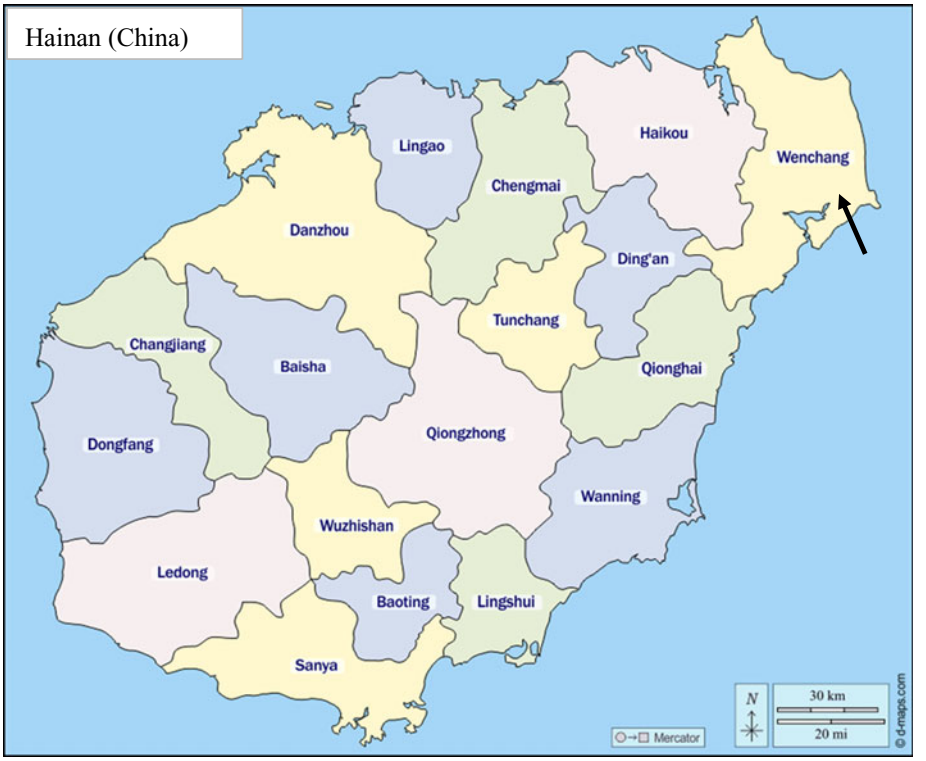


Figure 1. Map of Hainan Province, China and location of Wenchang in Hainan Province (d-maps.com n.d.).

[†]This article has been updated since its original publication. A notice detailing this can be found here: https://doi.org/10.1017/S0025100326101224

[1] Information comes from the following website: http://wenchang.hainan.gov.cn/wenchang/zjwc/zjwc.shtml#btqxqq

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The stop system in Wenchang Chinese is relatively unusual in Chinese dialects. In addition to commonly found voiceless and voiced plosive series, there exist implosives which form minimal pairs with voiceless plosives or voiced plosives in this dialect (Chao 1936; Hashimoto 1960; Liang 1986; Woon 1987; Liu 2006; Cun 2009; Xin 2013).

Two native speakers, one male and one female, were recorded. They were born and grew up in Wenchang until they pursued higher education in another city. At the time of recording, both of them are university students. The wordlist was compiled based on the descriptions in Liang (1986) and Woon (1987). The informants were then asked to read the wordlist for acoustic analysis. The recordings were made in a quiet room and a Tascam US-322 audio interface connected with a unidirectional Shure microphone and a laptop computer were used for recording. The acoustic analysis is based on the recordings of the male speaker, if not otherwise mentioned. Acoustic analyses are carried out using Praat (Boersma & Weenink 2021).

Consonants

There are 18 consonants in this dialect, the inventory of which is listed below and example words are given thereafter. Underlined tone marks, as in the first item, indicate checked tones.

	Bilabial	Dental	Alveolar	Velar	Glottal
Plosive	p b		t d	k g	
Affricate			ʦ dz		
Implosive	ɓ		ɗ		
Nasal	m		n	ŋ	
Fricative	ɸ		s		h ɦ
Lateral approximant			l		

Consonant	Sample word	Chinese character	Gloss
p	ap^{3}	盒	‘box’
b	be^{31}	马	‘horse’
ɓ	ɓe^{34}	病	‘disease’
m	ma^{33}	麻	‘numb’
ɸ	ɸui^{34}	非	‘very’
t	tu^{34}	书	‘book’
d	du^{31}	你	‘you’
ʦ	ʦe^{42}	坐	‘to sit’
dz	dze^{31}	野	‘arrogant’
ɗ	ɗu^{34}	猪	‘pig’

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n	nam^{33}	南	‘south’
s	san^{34}	餐	‘meal’
l	li^{31}	李	‘plum’
k	ki^{33}	棋	‘chess’
g	ge^{33}	牙	‘tooth’
ŋ	ŋe^{42}	硬	‘hard’
h	hou^{33}	投	‘to throw’
ɦ	ɦioŋ^{34}	凶	‘fierce’

Plosives and Implosives

There are eight stops /p b ɓ t d ɗ k g/ in this dialect, among which /b ɓ t d ɗ k g/ can occur in syllable-initial position and only /p t k/ can occur in syllable-final position and /p/ never appears in syllable-initial position. In terms of place of articulation, there are three places, namely bilabial, denti-alveolar and velar. Therefore, voiced bilabial plosive /b/ contrasts with bilabial implosive /ɓ/ whereas voiceless bilabial plosive /p/ does not exist in the initial position, voiceless denti-alveolar plosive /t/, voiced plosive /d/ and implosive /ɗ/ form a minimal set, voiceless velar plosive /k/ and voiced plosive /g/ contrast with each other with no corresponding velar implosive.

Figures 2 to 4 are histograms of the distribution of VOT values across three laryngeal categories occurring in syllable-initial position. Measurement of VOT values is made referring to both waveforms and wide-band spectrograms. VOT of the voiceless unaspirated plosives is measured as the interval between burst release to the voice onset of the following vowel. VOT of the voiced unaspirated plosives and voiced implosives is measured as the interval between the voicing onset to the release burst (Lisker & Abramson 1964; Abramson & Whalen 2017).

Both the voiced bilabial plosive /b/ and the implosive /ɓ/ (with few exceptions) have negative values with clear distinction between them and visual examination shows clearly that the voiced plosive /b/ tends to have a longer negative VOT. The average VOT value of the voiced bilabial plosive /b/ is −180 ms (SD=33.3, n=50) and that of the bilabial implosive /ɓ/ −37 ms (SD=15.6, n=76).

VOT values for the voiced alveolar plosive /d/ are negative, VOT values for the alveolar implosive /ɗ/ are characterized by dominant negative values and VOT values for the voiceless alveolar plosive /t/ are positive. With the exception of two tokens which have overlapped positive VOT between the alveolar implosive /ɗ/ and the voiceless alveolar plosive /t/, a distinctively pre-voiced onset for the alveolar implosive /ɗ/ and positive VOT for the voiceless alveolar plosive /t/ are evident. In this study, the average VOT of the voiced alveolar plosive /d/ is 192ms (SD=39.7, n=4),[2] that of the alveolar implosive /ɗ/ is −37ms (SD=19, n=89) whereas that of the voiceless alveolar plosive /t/ is 15 ms (SD=5, n=118).

It is clear that voiced and voiceless velar plosives show obvious distinction in VOT values, with the voiced velar plosive /g/ having negative VOT values and the voiceless velar plosive /k/ positive VOT values. The average VOT value of the voiced velar plosive /g/ is −150 ms (SD=25.2, n=22) and that of voiceless velar plosive /k/ 36 ms (SD=13.6, n=128).

[2] Voiced alveolar plosive /d/ is rare in this dialect, which is also reported in Woon (1987) and he hypothesizes that /d/ might have originated from a split of /l/ (Woon 1987: 10).

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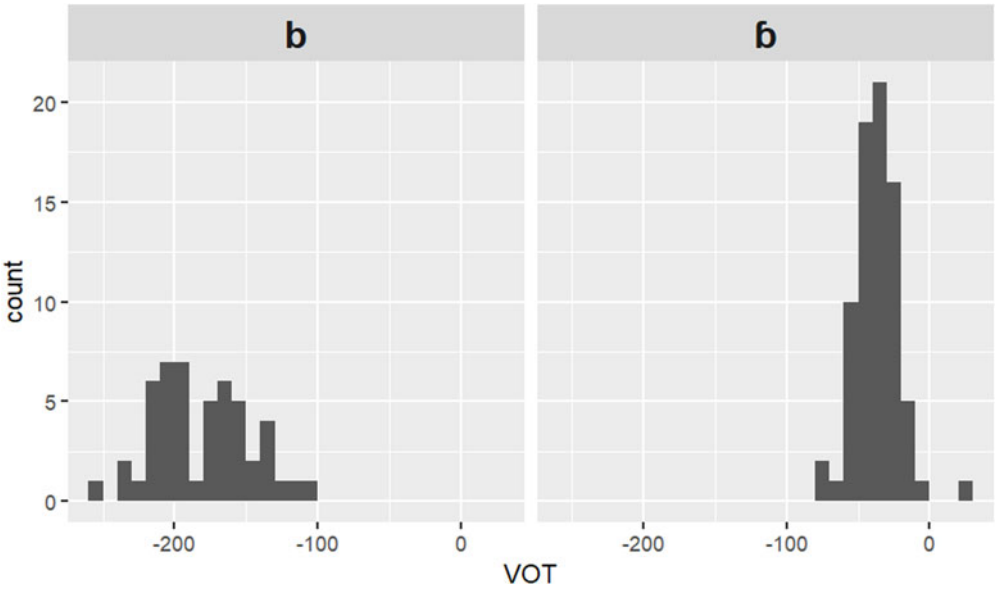


Figure 2. Histograms of distribution of VOT values (in ms.) of voiced bilabial plosive /b/ and bilabial implosive /ɓ/.

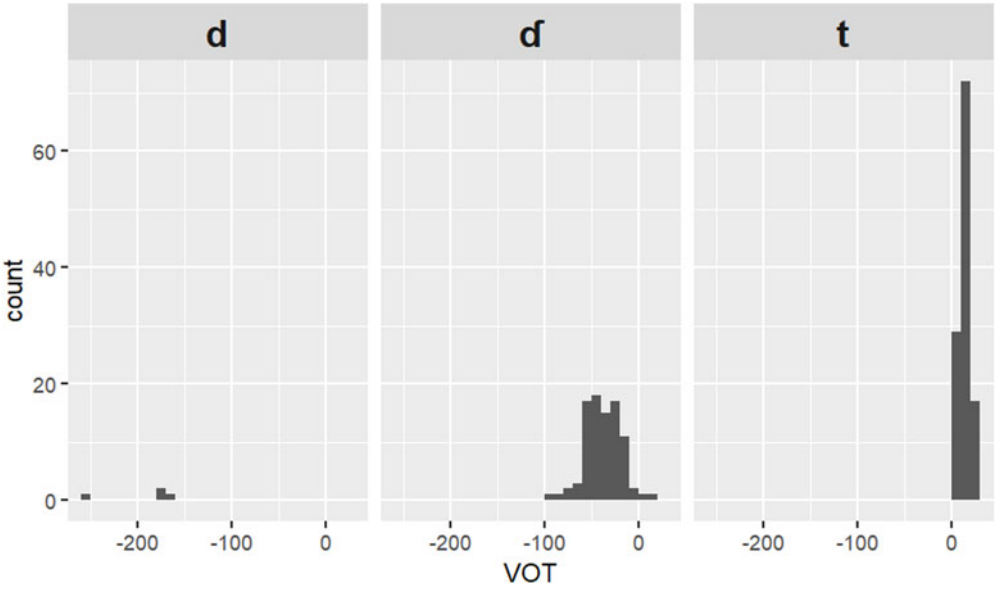


Figure 3. Histograms of distribution of VOT values (in ms.) of voiced alveolar plosive /d/, alveolar implosive /ɗ/ and voiceless unaspirated alveolar plosive /t/.

To sum up, voiceless unaspirated plosives show short lag VOT and both the voiced plosives and implosives (with four exceptions in total) have negative VOT. Generally speaking, implosives are characterized by shorter voicing lead VOTs than voiced plosives. The current finding of a VOT difference between voiced plosives and implosives is consistent with earlier research (Nihalani 1986, 2006; Naidoo 2012; Mori 2023).

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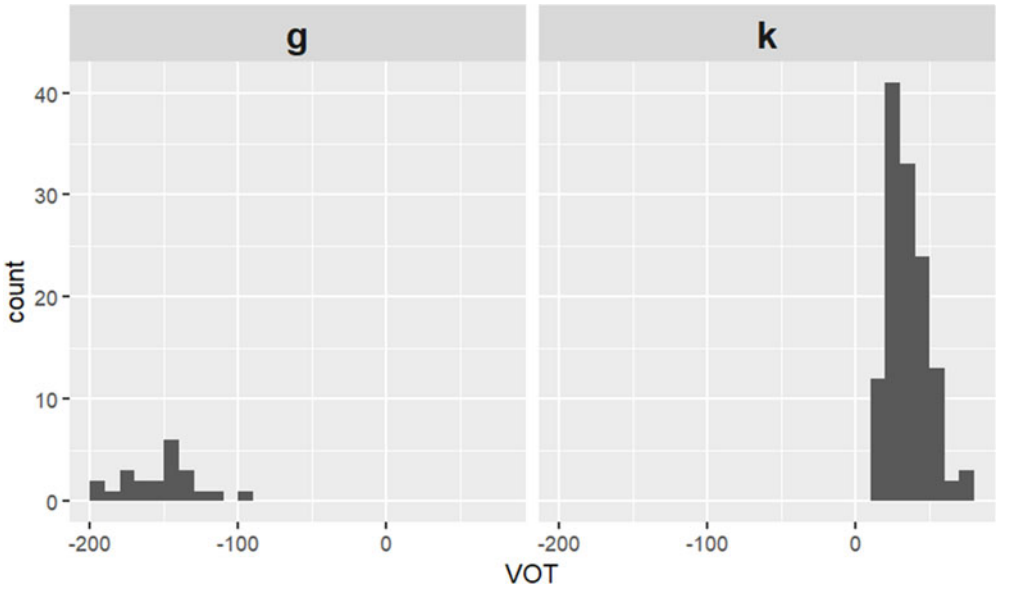


Figure 4. Histograms of distribution of VOT values (in ms.) of voiced velar plosive /g/ and voiceless velar plosive /k/.

In addition to a primary correlate of the voicing contrast, VOT values are also reported to correlate with place of articulation. For voiceless plosives, voiceless unaspirated plosives /t/ and /k/ have average VOT values of 15 ms and 36 ms respectively. This is in agreement with the general tendency observed in other languages and has been documented in many other languages: positive VOT values are longer as the place of articulation is further back (Lisker & Abramson 1964; Klatt 1975; Nearey & Rochet 1994; Cho & Ladefoged 1999; Öğüt et al. 2006; Bijankhan & Nourbakhsh 2009; Cho, Whalen & Docherty 2019; Genee & Li 2023). The correlation between the voicing contrast and VOT values does not hold true with respect to voiced plosives and implosives. For voiced plosives, /b d g/ have average VOT values of −180, −192, and −150 ms, respectively, where the ranges of VOT values overlap extensively. For implosives, the difference in VOT values between /ɓ ɗ/ is also negligible.

The realization of implosives can vary considerably across tokens, which is in accord with those reported in previous studies (Ladefoged 1968; Ladefoged & Maddieson 1996; Lindau 1984; Piñeros 2003; Nihalani 2006; Cun 2009). Figure 5 shows examples exhibiting the way an implosive may be realized in Wenchang dialect.

The token (5a) [ɓan^{33}] 'bottle' is characterized by increasing amplitude of vocal fold vibration during the closure, which is an acoustic feature typical of implosives (Catford 2010, originally published in 1939; Laver 1994; Chen 2000; Cun 2009; Ladefoged & Johnson 2014). Out of 165 implosive tokens, the number of tokens with characteristics similar to (5a) includes 143 monosyllabic words, accounting for 87% of the total.

Compared to the token (5a), the token (5b) [ɗo^{31}] 'to pour' has a much shorter voicing before the release of the closure, with about one or two glottal pulses in length before the release of implosive. There are only 18 tokens similar to (5b) with VOT values between −20ms and 0ms, significantly fewer than the first category. Implosives with short prevoicing are documented in previous studies (Ladefoged et al. 1976; Lojenga 1991; Demolin 1995; Mc Laughlin 2005; Cun 2009).

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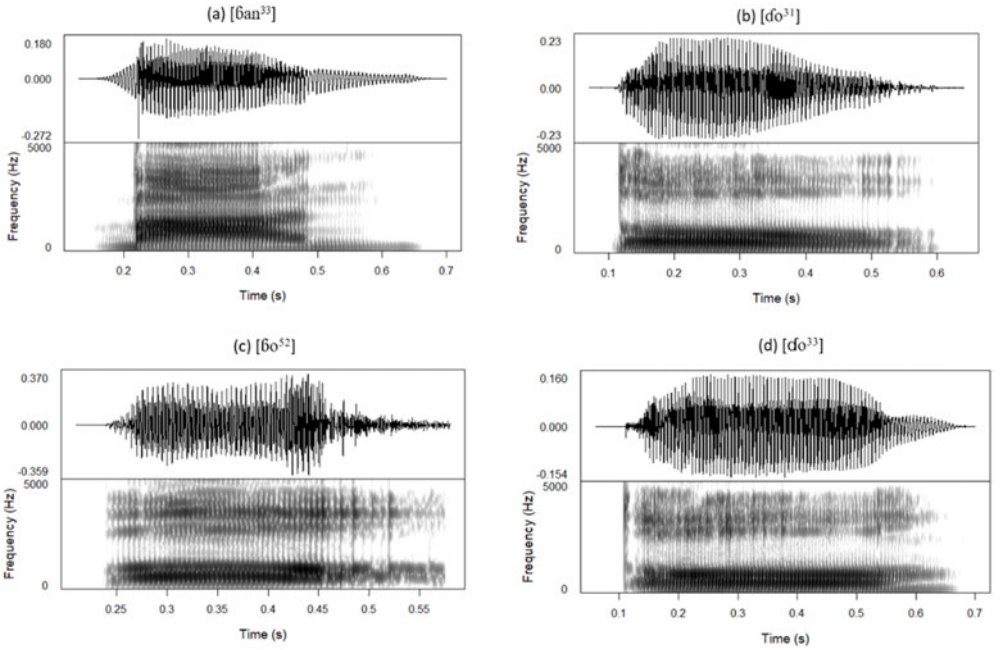


Figure 5. (a) [ɓan^{33}] 'bottle', (b) [ɗo^{31}] 'to pour', (c) [ɓo^{52}] 'disapprove', (d) [ɗo^{33}] 'long' – various realization forms of implosives in Wenchang dialect.

The token (5c) [ɓo^{52}] 'disapprove' shows a voiceless stop realization of an implosive where the voicing onset and oral release are almost synchronous. Among the current 165 implosive tokens, (5c) is the only token with a VOT of zero.

The production of token (5d) [ɗo^{33}] 'long' exhibits no pre-voicing before closure release, resulting in a voiceless production. A similar example where creakiness can also be observed after the release is reported in Cun (2009), and it can take up to 63ms for the vocal folds to get started. The voiceless variants of the implosives (similar to 5d) are also limited in quantity and amount to 3 tokens in total.

Plosives /p t k/ can occur in syllable-final position. In monosyllabic environments, these three voiceless consonants are not released in the coda position, but their effect on the preceding vowels is evident. Figure 6 shows /p t k/ at the end of the monosyllables [kiap^{3}] 'to clip', [tuat^{3}] 'extinct' and [liak^{3}] 'green'. These three words have the identical vowel—the low vowel /a/—preceding the syllable-final obstruents. Their formant trajectories show different transitional patterns. In the word [kiap^{3}] 'to clip', the second formant of the vowel falls slightly during the transition into the following bilabial consonant and ends around 1100 Hz. In the word [tuat^{3}] 'extinct', the F2 value of the low vowel ends around 1300 Hz. In the word [liak^{3}] 'green', F3 falls towards F2 and a velar pinch can be noticed. The formant frequencies at the coda position change, implying the articulatory gestures in the supralaryngeal cavity for the production of the post-vocalic plosives. Therefore, although syllable-final obstruents are not released, they differ in terms of their formant transitions.

Figure 7 compares the monosyllabic word [ɓak^{5}] 'north' read in isolation and in the intervocalic position of the bisyllabic compound word [ɓak^{5}uaŋ^{34}] 'the north wind' (extracted from two different positions of the passage 'the North Wind and the Sun').

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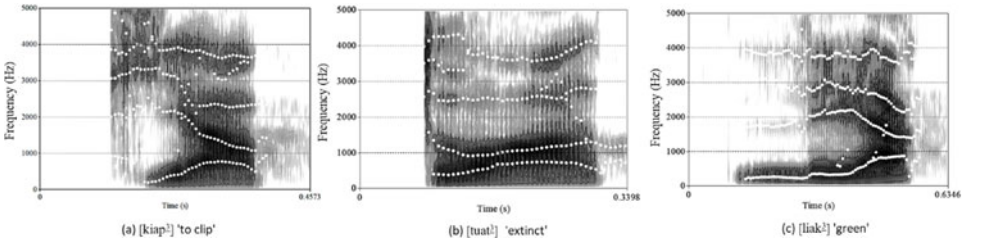


Figure 6. Formant transition patterns of /p t k/ at the syllable-final position in the example words: (a) [kiap˧] 'to clip', (b) [tuat˧] 'extinct', (c) [liak˧] 'green'.

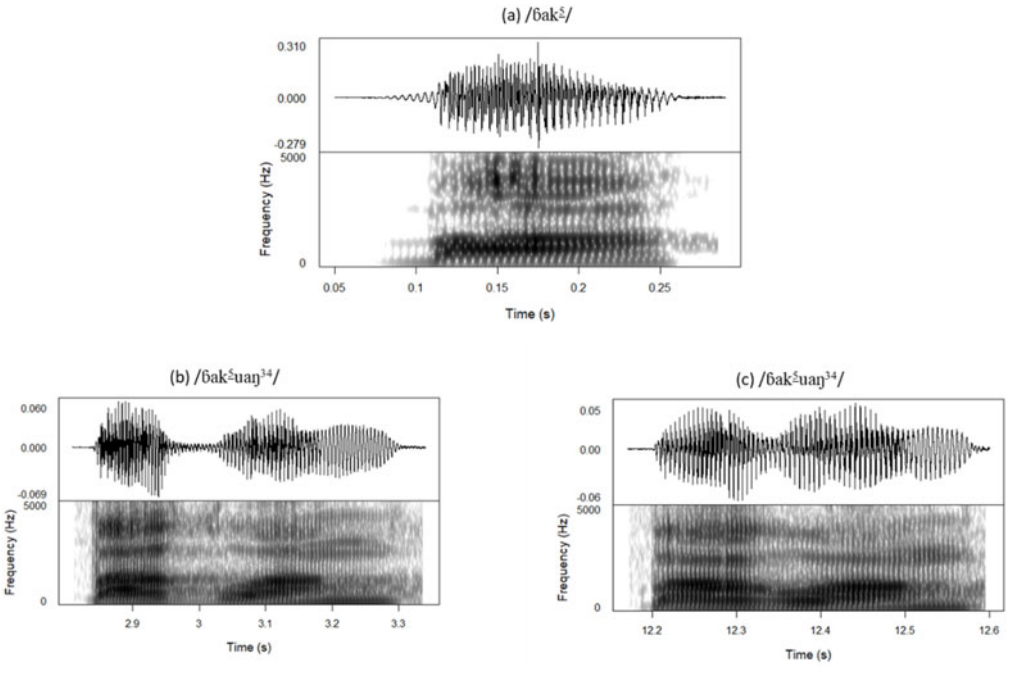


Figure 7. Syllable-final /k/ (a) in the monosyllabic word [ɓak˥] 'north', and (b) and (c) in the intervocalic position of the bisyllabic word [ɓak˥uaŋ˧˦] 'the North Wind' (extracted from the passage 'the North Wind and the Sun').

As is shown in the figure, when it is read in isolation, the voiceless velar plosive is not released whereas in the intervocalic position of the connected speech, it might or might not be audible. In (7b), the syllable-final /k/ is audible and appears as a voiced approximant whereas in (7c), it is inaudible.

Affricates

Affricates exhibit a two-way distinction in manner—voiceless /ts/ vs. voiced /dz/. The dento-alveolar affricates become palatalized [tɕ dʑ] when the following rhymes are unrounded high front vowel /i/ or rhymes beginning with /i/ such as /iu io ia iom ien ioŋ iaŋ iet iop iok iak/. Figure 8 shows sample FFT spectra of the affricates [ts dz tɕ dʑ] measured within the 500 to 10, 000 Hz frequency range in a 25-ms window centered around the midpoint of

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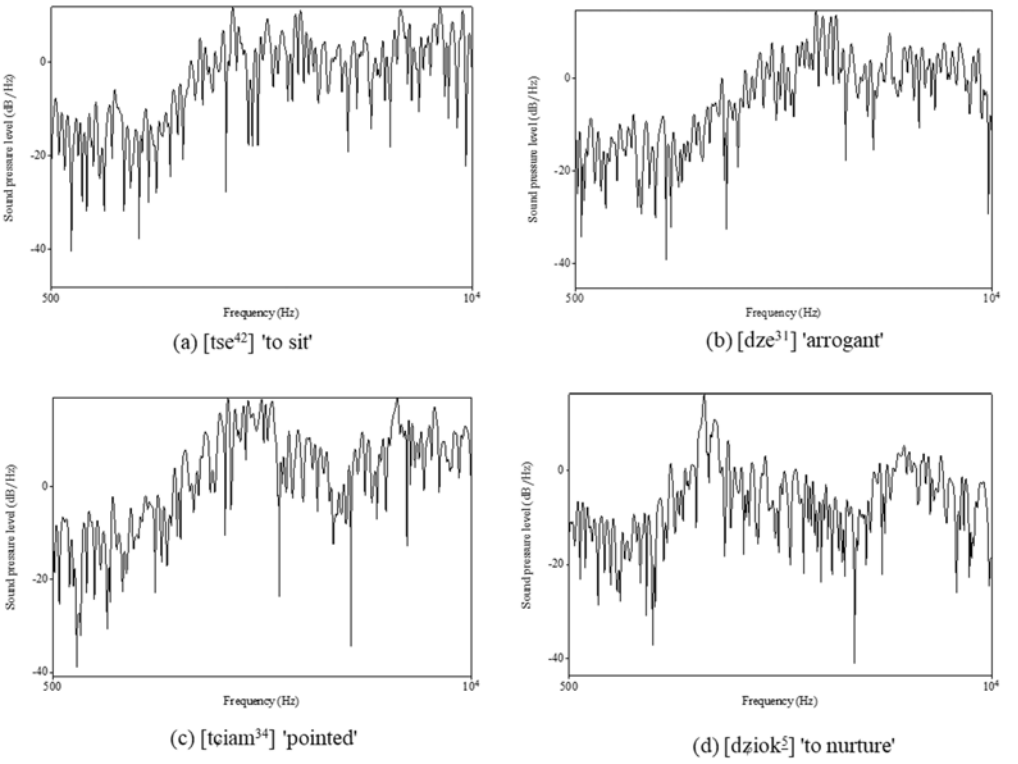


Figure 8. FFT spectra within the 500 to 10, 000 Hz frequency range in a 25-ms window centered around the midpoint of the affricate release phase of four sample words: (a) [tse^{42}] 'to sit', (b) [dze^{31}] 'arrogant', (c) [tɕiam^{34}] 'pointed' and (d) [dʑiok^{5}] 'to nurture'.

the affricate release phase (Forrest et al. 1988; Zsiga 1993; Jongman, Wayland & Wong 2000; Cho, Jun & Ladefoged 2002; Gordon, Barthmaier & Sands 2002). Figure 8 shows the spectra of denti-alveolar affricates and allophonic alveolar-palatal counterparts.

The voiced affricate shows more variation compared with its voiceless counterpart. Words (a) /dze^{31}/ 'grandpa', (b) /dʑiu^{34}/ 'again', (c) /dze^{21}/ 'liquid', (d) /dzuai^{31}/ 'sharp' and (e) /dzua^{42}/ 'hot' are examples of different realizations of the voiced affricate, as shown in Figure 9. The first type, which is illustrated in Figure 9a, is the typical pronunciation of a voiced affricate; that is, voicing starts before the release, which is followed by a period of fricative noise. In Figure 9b, no clear burst can be seen and Figure 9c is characterized by nasalization before the burst. Figures 9d and 9e illustrate a process of lenition where the realization form is a fricative instead of an affricate. In the token 9d it is realized as [z]; in the token 9e, voicing only appears one third of the way through the frication. The fricative realization of /dz/ is limited, amounting to 5 tokens (8.3% of 60 voiced affricate tokens) and in all other cases the realization of a plosive and a fricative is preserved in the present dataset.

Nasals

Nasals with three different places of articulation exist in this dialect and all are voiced. They are bilabial nasal /m/, alveolar nasal /n/ and velar nasal /ŋ/. All can occur in

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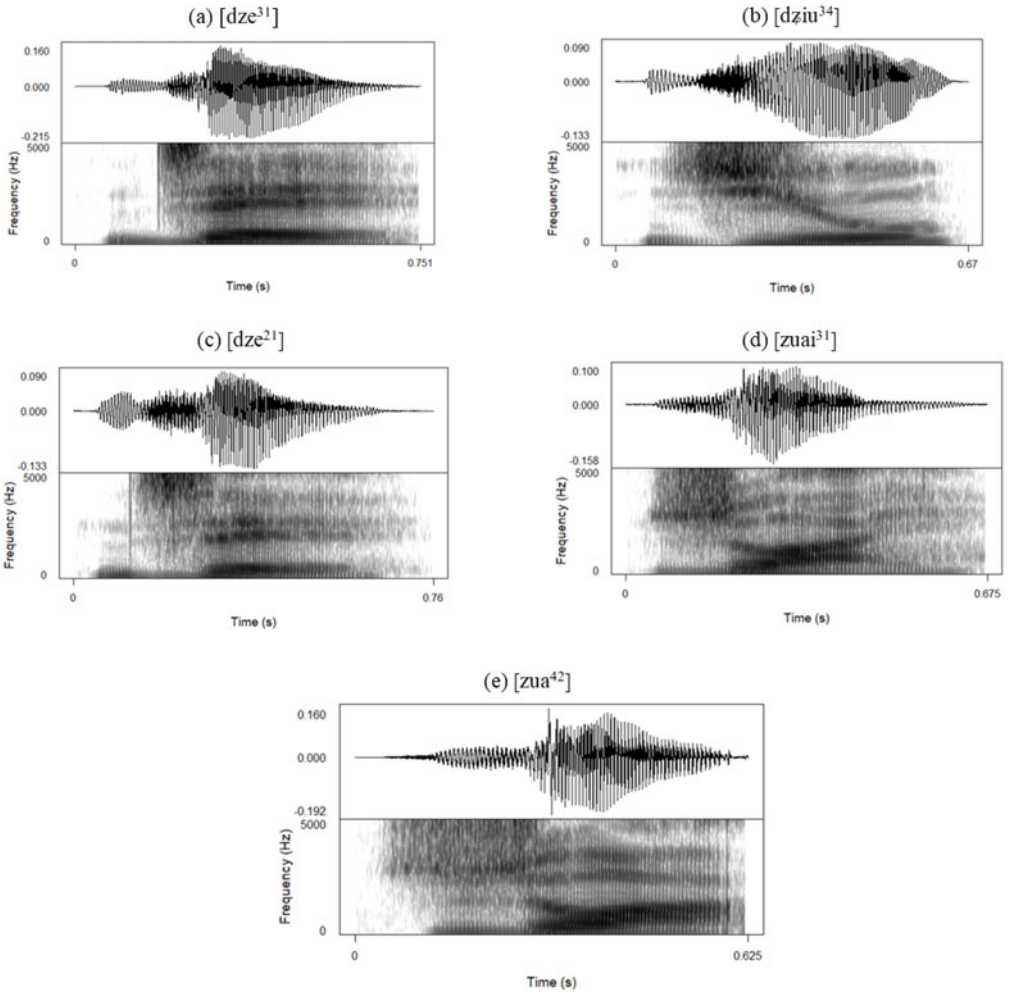


Figure 9. Waveforms and spectrograms of variability in the realization of the underlying affricate /dz/: (a) [dze^{31}] 'grandpa', (b) [dʑiu^{34}] 'again', (c) [dze^{21}] 'liquid', (d) [zuai^{31}] 'sharp' and (e) [zua^{42}] 'hot', ranging from an affricate to a devoiced fricative.

both syllable-initial and syllable-final position, with certain phonotactic restrictions. In syllable-final position, /m/ occurs after vowels /a o ia io/ and never co-occurs with syllable-initial homorganic bilabial consonants /ɓ b ɸ m/; /n/ occurs only after vowels /a u ie ua/; and /ŋ/ occurs after vowels /a e o ia io ua/ and does not co-occur with syllable-initial voiced velar plosive /g/.

Fricatives

There are three voiceless fricatives and one voiced fricative in this dialect: a bilabial fricative /ɸ/, a denti-alveolar fricative /s/, a voiceless glottal fricative /h/ and a voiced glottal fricative /ɦ/.

With respect to bilabial fricative /ɸ/, most, if not all, of the tokens in present study turn out to be voiceless aspirated bilabial plosive [p^{h}] instead of a bilabial fricative [ɸ], which

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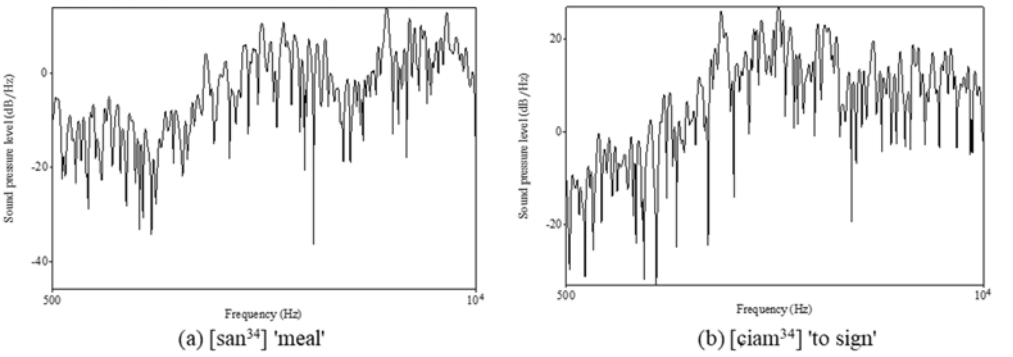


Figure 10. FFT spectra centered around the midpoint of the frication part of two sample words: (a) [san^{34}] 'meal' and (b) [ɕiam^{34}] 'to sign'.

may reflect a synchronic sound change in this dialect. The reason why bilabial fricative has disappeared or is disappearing from this dialect might be because it is a marked sound and rarely found in the world's languages (Ladefoged & Maddieson 1996). Controversy exists in the description of this sound. It has long been documented in the majority of previous impressionistic transcriptions as bilabial fricative /ɸ/ (Liang 1986; Woon 1987; Huang & Feng 1993; Zhang 2006). Xin (2013), however, points out that both [p^{h}] and [ɸ] exist in this dialect and they are in free variation. He further mentions that [ɸ] tends to appear before syllables that are not high-front 'Hongyin' (洪音) whereas [p^{h}] occurs before front 'Xiyin' (细音)[3] syllables. The source of this variation is yet to be determined. One reviewer also mentions the example word /ɸui^{34}/ 'very' is indeed pronounced with a bilabial fricative. Further research based on a larger scale is needed.

Fricative /s/ is realized as a palatalized variant [ɕ] when it occurs before a high front vowel /i/ or other rhymes /ia io iu iam iaŋ ien iom iat iop/ with the high front vowel as the first segment such as in /ɕiam^{34}/ 'to sign'. Figure 10 shows the spectra of denti-alveolar fricative and allophonic palatalized counterparts.

With respect to the glottal fricative /h/, previous studies differ in the symbols used to describe it. Liang (1986) and Xin (2013) describe it as a velar fricative /x/, whereas Hashimoto (1960) and Woon (1987) describe it as a glottal fricative /h/. Its phonetic realization may vary and exhibit coarticulatory variation as a result of different vowel environment. Figure 11 shows the spectra of /h/ followed by a back vowel and a front vowel.

The status of the voiced glottal fricative /ɦ/ is controversial and the controversy can be summarized as two points.

On one hand, earlier research (Hashimoto 1960; Liang 1986; Woon 1987) uses different symbols to transcribe it. It is transcribed as voiceless glottal fricative /h/ in Liang (1986), but voiced glottal fricative /ɦ/ in Hashimoto (1960) and Woon (1987). On the other hand, more recent research (e.g. Liu & Wang 2008) proposes treating it as allophonic variant of the null onset. Therefore, in this section whether or not the voiced glottal fricative exists in this dialect is discussed together with the zero onset as well as its variants.

[3] In traditional Chinese phonology, 'Hongyin' and 'Xiyin' are terms distinguishing different syllable finals. In modern phonetic terminology, 'Xiyin' refers to syllables with a high-front glide (/i/ or /y/) or syllables with nuclear vowels /i/ or /y/ and the rest are 'Hongyin'.

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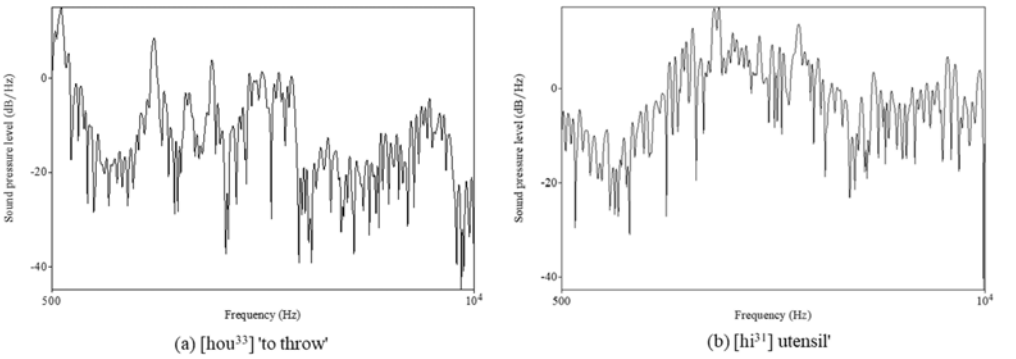


Figure 11. FFT spectra centered around the midpoint of the aspiration part of two sample words: (a) [hou^{33}] 'to throw' and (b) [hi^{31}] 'utensil'.

Figure 12 shows five pairs of words. It is obvious that typologically, the distribution of /ɦ/ in this dialect is different from Wu dialects such as Shanghai Chinese (Chen & Gussenhoven 2015) or Lili Wu Chinese (Shi & Chen 2022) where the appearance of /ɦ/ is tone-dependent or vowel-dependent. In this dialect, /ɦ/ can freely co-occur with vowels of different heights (e.g., high vowel /i/ in (1b) and /un/ in (4b), mid vowel /o/ in (2b) and /eŋ/ in (5b), and low vowel /au/ in (3b)) and across all tonal categories (e.g., falling in (1b) and (2b), level in (3b), and rising in (4b) and (5b)).

Words on the left side are transcribed as a zero onset by Liang (1986) and Woon (1987), but Woon (1987) further mentions that "words starting with a zero initial are always pronounced with a glottal stop". The present data, however, contradict Woon's statement, showing that the zero onset is not invariably realized as a glottal stop. The present findings show that it is realized as either a real null onset (e.g. 1a and 2a) or preglottalized onset [ʔ] (e.g. 3a, 4a and 5a). Another observation is that the allophonic realization of the zero onset is not conditioned by tones nor by the subsequent vowel context given that vowels in the example words vary in their vowel height (e.g. [i] vs. [au]) or backness (e.g. [i] vs. [un]) or tone category (e.g. falling vs. level). From the above analysis, we can draw the tentative conclusion that the zero onset can be realized either as a real null onset or with initial glottalization.

The examples appearing on the right in Figure 12 are transcribed with voiceless glottal fricative /h/ in Liang (1986), voiced glottal fricative /ɦ/ in Woon (1987) or an allophonic variant of the null onset in Liu & Wang (2008). Liu & Wang (2008) comment that because of weak energy, and short and almost imperceptible duration, all of these features suggest that voiced glottal fricative /ɦ/ is disappearing and merging with zero onset and may be treated as an allophonic variant of the null onset. Here, various acoustic evidence tends to support Woon's description. Aspiration can be noticed before the vowels, or the initial portion of the vowel witnesses lower intensity or longer duration than words with a zero initial, which all suggest the existence of the voiced glottal fricative. In addition, breathy phonation in /ɦ/ lowers the fundamental frequency (f0) of following vowels. As a result of a breathy voice effect, the right-hand words starting with /ɦ/ all start with a lower f0 than the left-hand words with the zero onset, and the original tonal contour does not surface until halfway into the syllable. A similar f0 lowering effect as a result of neighboring breathy sounds is well documented and is empirically supported from multiple languages (e.g. DiCanio 2012; Garellek et al. 2023; Gordon & Ladefoged 2001; Hombert, Ohala & Ewan 1979).

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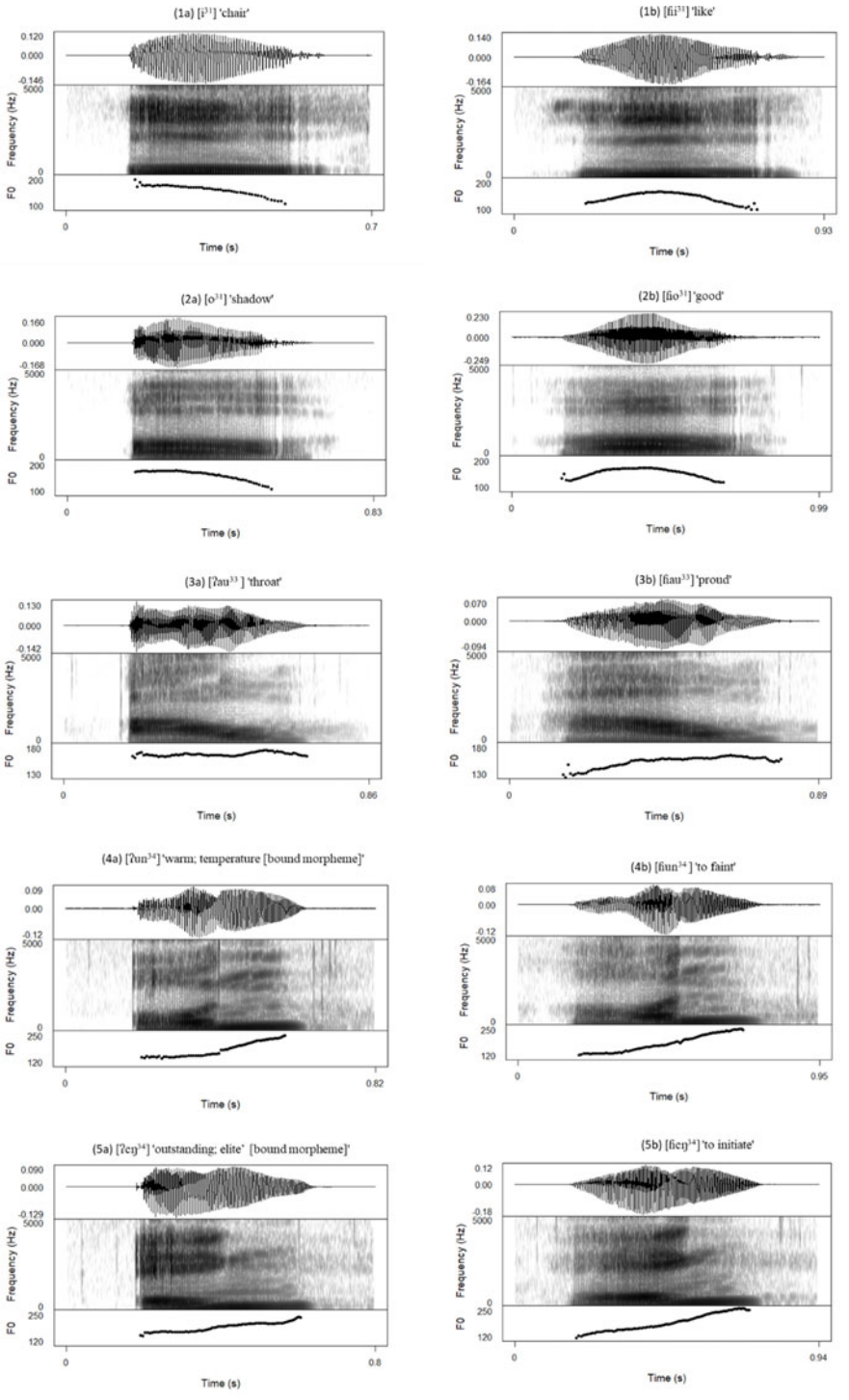


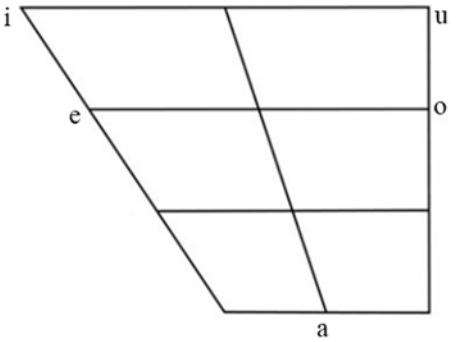
Figure 12. Comparison between /V/-initial syllables (left) and /ɦ/-initial syllables (right).

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Vowels

Monophthongs

The distribution of Wenchang monophthongs in open syllables in a traditional quadrilateral chart is shown below.



Monophthongs in (C)V structure

	Sample word	Chinese character	Gloss
i	i^{34}	医	'doctor'
e	be^{31}	马	'horse'
a[4]	ta^{34}	三	'three'
o	go^{33}	鹅	'goose'
u	gu^{33}	牛	'cattle'

Monophthongs in (C)VN structure

	Sample word	Chinese character	Gloss
am	nam^{33}	南	'south'
om	nom^{42}	软	'soft'
an	ɓan^{33}	瓶	'bottle'
un	sun^{34}	春	'spring'
eŋ	teŋ^{33}	承	'to admit'
aŋ	maŋ^{34}	梦	'dream'
oŋ	toŋ^{31}	总	'total'

[4] The symbol /a/ (a front vowel in the IPA) instead of IPA /ɐ/ is used here for typographical convenience.

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Monophthongs in (C)VT structure

	Sample word	Chinese character	Gloss
ap	ap^{3}	盒	'box'
op	hop^{5}	盖(紧)	'to cover closely'
at	sat^{3}	贼	'thief'
ut	kut^{3}	滑	'slippery'
ek	ɗek^{5}	德	'virtue'
ak	ɓak^{5}	北	'north'
ok	tok^{3}	俗	'secular'

Wenchang Chinese has 5 monophthongs /i e a o u/ in open syllable. Table 1 lists the mean frequency values of the first two formants as well as the number of tokens used for each monophthong. Figure 13 shows the mean frequency values for the monophthongs as well as vowel ellipses.

Table 1. Mean frequency values of the first two formants (in Hz), standard deviation in parenthesis, and the number of tokens of five monophthongs in open syllables.

Vowels	F1	F2	Number of tokens
a	853(30)	1281(46)	33
e	490(37)	2105(73)	48
i	284(35)	2228(85)	67
o	518(47)	845(60)	42
u	329(18)	678(52)	34

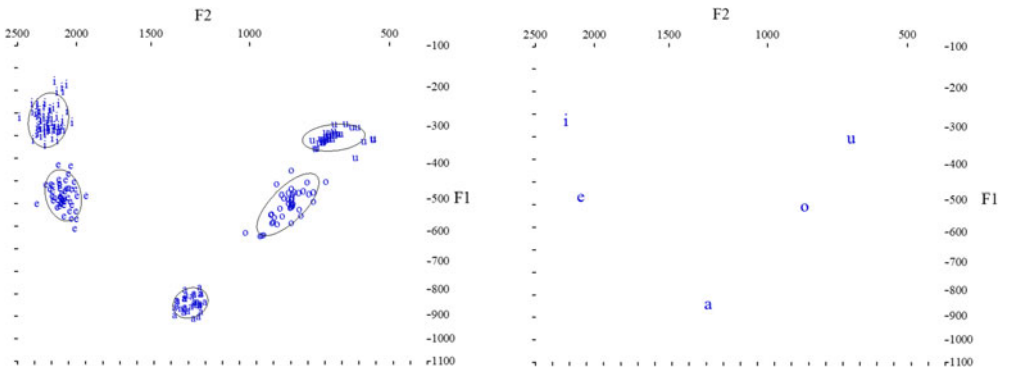


Figure 13. Vowel ellipses (left) and mean values (right) of F1 and F2 (in Hz) of monophthongs in open syllables. Ellipses represent 2 standard deviations (2 SD) from the mean.

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Two monophthongs /a ɔ/ can occur in syllables ending with bilabial nasal /m/ or bilabial plosive /p/, two monophthongs /a u/ occur in syllables ending with denti-alveolar nasal /n/ or plosive /t/ and three monophthongs /a e ɔ/ can occur in syllables ending with velar nasal /ŋ/ or velar plosive /k/.

Diphthongs

Diphthongs in (C)V syllables

	Sample word	Chinese character	Gloss
ai	tai^{31}	使	‘to use’
au	tau^{31}	跑	‘to run’
oi	oi^{33}	鞋	‘shoe’
ou	hou^{33}	投	‘to throw’
ia	tia^{31}	写	‘to write’
io	io^{33}	羊	‘sheep’
ua	kua^{34}	官	‘officer’
ue	ɓue^{33}	赔	‘to compensate’
ui	ui^{34}	危	‘danger’
iu	hiu^{33}	求	‘to beg’

Diphthongs in (C)VN syllables

	Sample word	Chinese character	Gloss
ien	tien^{33}	神	‘divinity’
iam	siam^{34}	签	‘to sign’
iaŋ	kiaŋ^{34}	江	‘river’
iom	iom^{34}	音	‘sound’
ioŋ	ɦioŋ^{34}	凶	‘fierce’
uan	uan^{31}	怨	‘to complain’
uaŋ	tuaŋ^{34}	庄	‘dealer’

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Diphthongs in (C)VT syllables

	Sample word	Chinese character	Gloss
iet	tiet^{3}	实	'solid'
iap	kiap^{3}	夹	'to clip'
iak	liak^{3}	绿	'green'
iop	siop^{5}	湿	'wet'
iok	dziok^{5}	育	'to nurture'
uat	tuat^{3}	绝	'extinct'
uak	ɗuak^{5}	啄	'to peck'

Ten diphthongs /ai au oi ou ia io ua ue ui iu/ can occur in open syllables. Figure 14 shows the formant distribution of each diphthong in open syllables represented by the start and end points of the arrow, the values of which are based on the mean values of F1 and F2 of the first and second element of the diphthongs. The starting and ending point of the diphthongs may fail to reach the target positions of the corresponding monophthongs, which conforms to previous findings of characteristics of diphthongs across different languages of the world (Gay 1968, 1970; Bladon 1985).

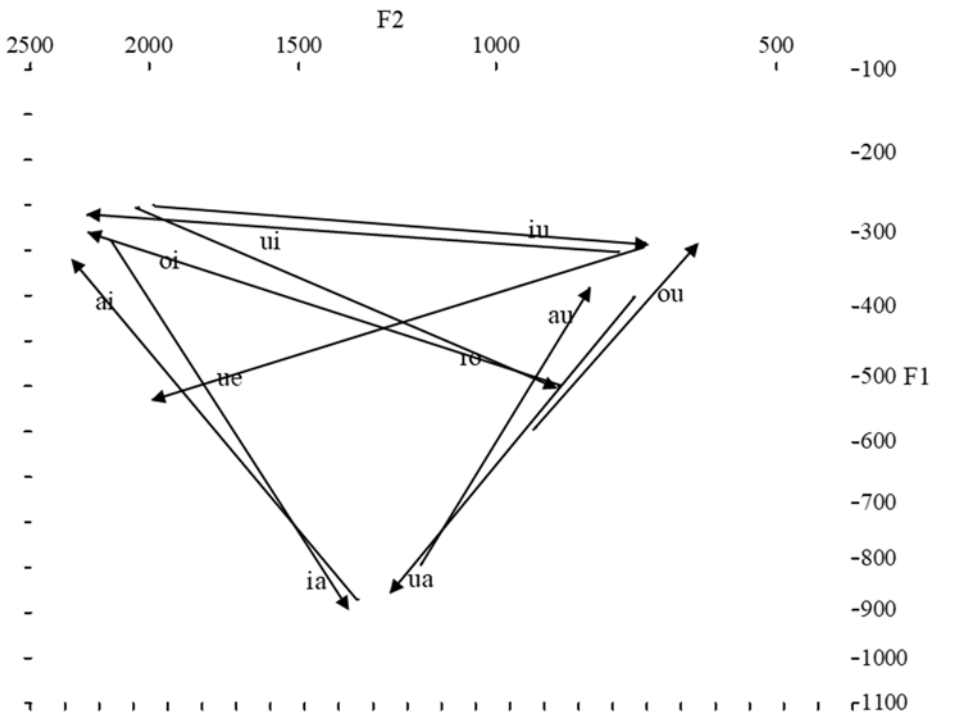


Figure 14. Mean F1 and F2 (in Hz) of the start and end points of diphthongs in open syllables.

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Four diphthongs /ie ia io ua/ can occur in syllables ending with a nasal or a plosive. Among them, /ia io/ can occur in syllables ending with bilabial nasal /m/ or bilabial plosive /p/, /ie ua/ occur in syllables ending with denti-alveolar nasal /n/ or plosive /t/, /ia io ua/ can occur in syllables ending with velar nasal /ŋ/ or velar plosive /k/. With respect to the transcriptions of diphthongs occurring in (C)VN and (C)VT syllables, no substantial difference from previous work is observed. For the diphthong /ie/, Woon (1987) transcribes it as /ian/ and /iat/, but further notes that the actual phonetic values approximate /ien/ and /iet/. The present study shows that average F1 and F2 values of the second element of /ien/ are 564Hz and 1835Hz in (C)VN structure and 560Hz and 1704Hz in (C)VT structure, which supports annotating them as /ien/ and /iet/.

Triphthongs

Triphthongs in (C)V syllables

	Sample word	Chinese character	Gloss
iau	ɗiau^{21}	吊	'to hang'
uai	kuai^{31}	怪	'weird'

There are two triphthongs /iau uai/ in Wenchang Chinese. As shown in Figure 15, their formant values do not necessarily reach the target values found for monophthongs.

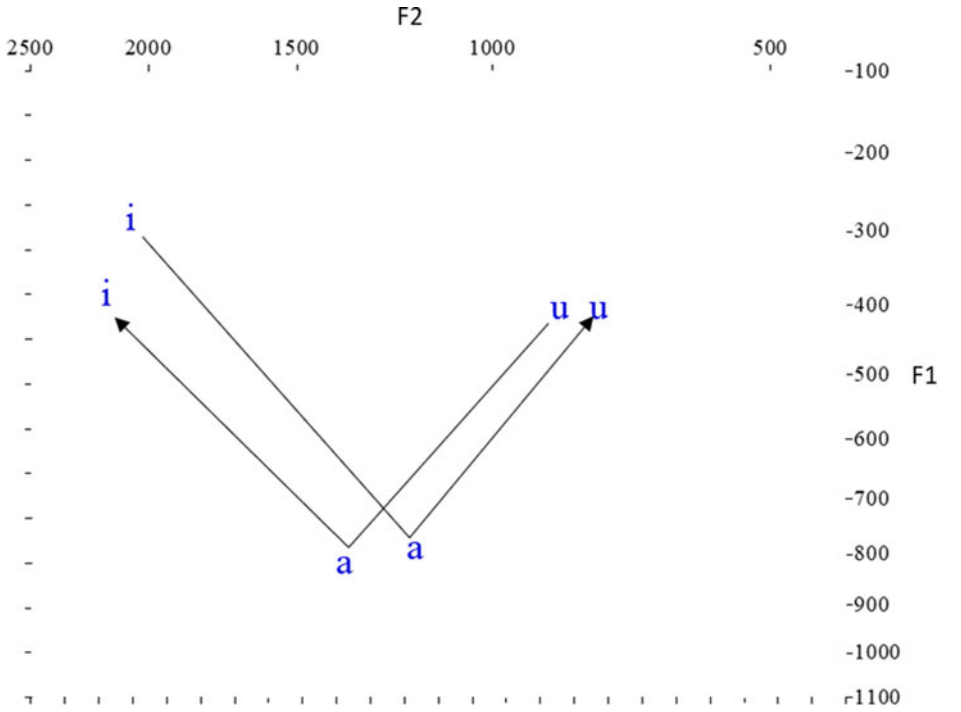


Figure 15. Mean F1 and F2 (in Hz) of the start, mid and end points of triphthongs in open syllables.

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Syllable structure

Syllables may take the form of (C)V(C), in which the syllable-initial consonant may be any consonant listed in the consonant chart except for /p/ and syllable-final consonants are restricted to /m n ŋ p t k/. Examples are given below:

V /i^{34}/ 医 'doctor' CV /be^{31}/ 马 'horse' VC /aŋ^{33}/ 红 'red' CVC /ɗek^{5}/ 德 'virtue'

No co-occurrence restriction is found between onsets and lexical tones. That is, onsets, no matter whether they are voiced, voiceless or implosives, can co-occur with any citation tones.

Syllable-initial bilabial consonants /ɓ b ɸ m/ never co-occur with syllable-final homorganic bilabial consonants /m p/. Syllable-initial voiced velar consonant /g/ occurs before a restricted set of vowels /u o e ou ua ue/ (Liang 1986).

Rhymes exhibit co-occurrence patterns with tones: short and checked tones T7(5̲) and T8(3̲) only occur with syllables ending with an obstruent and cannot co-occur with other rhyme types such as open syllables or syllables ending with a nasal.

Tone

	Tone Value	Sample word	Chinese character	Gloss
Tone 1	34	ti^{1}	诗	'poem'
Tone 2	33	ti^{2}	时	'time'
Tone 3	31	ti^{3}	死	'to die'
Tone 4	21	ti^{4}	四	'four'
Tone 5	42	ti^{5}	是	'yes'
Tone 6	52	ɗi^{6}	蒂	'the base of a flower'
Tone 7	5̲	tat^{7}	节	'joint'
Tone 8	3̲	ɗat^{8}	达	'to reach'

Previous studies of Wenchang dialect disagree with respect to the number of tone categories and the pitch level and pitch contour of each category, which can be seen in Table 2. Woon (1987) differs from all the other studies in that he shows that there are six tones, among which there are three short tones, T3(21̲), T5(42̲) and T6(51̲). The remaining studies agree with respect to the number of tones, but differ in the transcription of certain tones. T1 in Liang (1986) and Zhang (2006) is transcribed as a level tone 44, whereas in Huang & Feng (1993), Chen (2017) and Sun (2023), it is transcribed as a rising tone, 24 or 34. Another controversy lies in the tone value of T4, some transcribing it as 11 (Liang 1986; Woon 1987; Huang & Feng 1993; Zhang 2006) and Chen (2017) and Sun (2023) transcribing it as 25 or 15.

Raw data and normalized data of the f0 contours in this dialect are shown in Figure 16 and Figure 17. And normalized data are obtained following log z-score method proposed by Zhu (1994).

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Table 2. Previous descriptions of citation tones in Wenchang Chinese.

	T1	T2	T3	T4	T5	T6	T7	T8
Liang (1986)	44	22	21	11	42	53	55	33
Woon (1987)	44	33	21	11	42	51		
Huang & Feng (1993)	24	22	21	11	42	51	55	33
Zhang (2006)	44	22	21	11	42	53	5	3
Chen (2017)	34	22	31	25	41	52	45	33
Sun (2023)	24	22	21	15	331	452	45	33

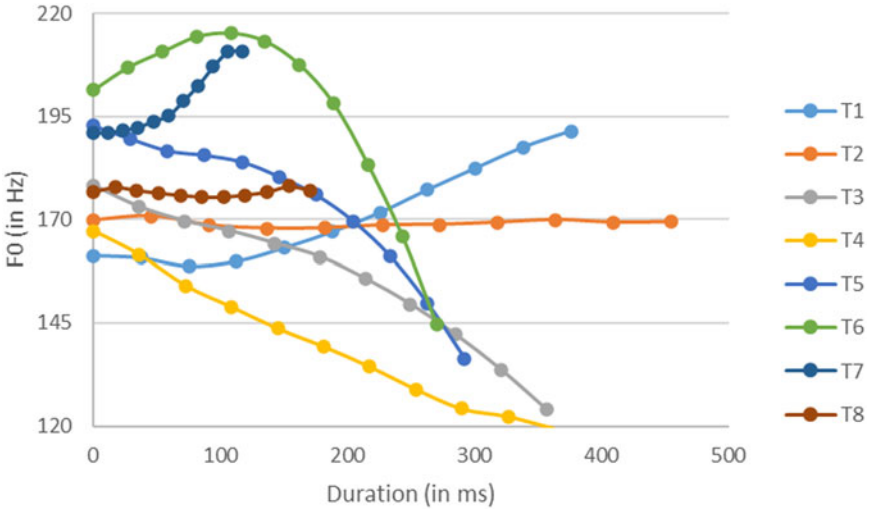


Figure 16. Raw f0 contours of citation tones of Wenchang dialect based on 12 tokens for each tone.

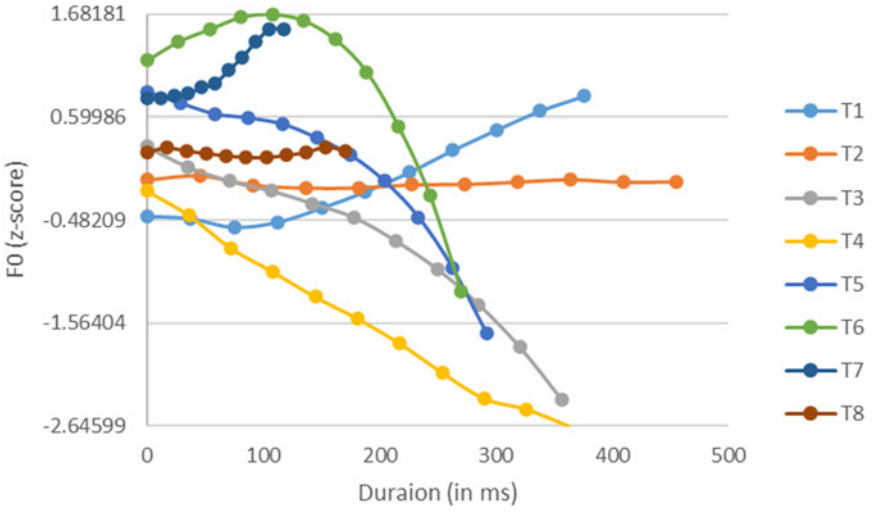


Figure 17. Normalized f0 contours of citation tones of Wenchang dialect using Log z-score normalization method based on 12 tokens for each tone.

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In sum, there are eight tones in this dialect and all citation tones are well differentiated from each other. The tone values are assigned based on a combination of perception and the f0 contours of each tone. T1 is a mid-to-high rising tone and transcribed as 34. T2 is a mid-level tone and transcribed here as 33. T3 and T4 are transcribed as 31 and 21, respectively, in that the onset of T3 is higher than T4 and different levels are used to differentiate them. T4 needs further study on a larger scale since there exist native speakers who pronounce this tone as a rising tone. T5 and T6 are two other falling tones with higher onset values, which we transcribe as 42 and 52. Instead of falling continuously from the very beginning to the end, T6 falls from 40% point of the syllable. Four falling tones, T3, T4, T5 and T6, can have creaky voice when they are read in isolation (see Figure 20 and accompanying text). T7 and T8 are much shorter than the other tones. T7 is a short high tone and is labelled as 5̲ and T8 a short mid tone which is assigned 3̲. T7 and T8 co-occur with syllables ending with a plosive whereas all the other tones co-occur with all the other syllable types.

Tone sandhi of reduplicated words

Research on tone sandhi of reduplicated words in Wenchang dialect remains limited, with only a single descriptive study by Woon (1987). Table 3 presents his descriptions of tone sandhi patterns on reduplicated syllables.

The present study re-examines the phenomenon using the test words shown in Table 4. Figures 18 and 19 show the corresponding f0 contours.

Table 3. Woon's descriptions of tone sandhi patterns of reduplicated syllables in Wenchang Chinese.

	Tonal context	Citation form	Sandhi pattern
Woon (1987)	T1+T1	44+44	55+44
	T2+T2	33+33	55+33
	T3+T3	2̲1̲+2̲1̲	55+2̲1̲
	T4+T4	11+11	55+11
	T5+T5	4̲2̲+4̲2̲	11+4̲2̲
	T6+T6	5̲1̲+5̲1̲	55+5̲1̲

Table 4. Reduplicated bisyllabic test words

	Sample reduplicated word	Chinese character	Gloss
Tone 1+Tone 1	seŋ^{34} seŋ^{34}	青青	'green'
Tone 2+Tone 2	toi^{33} toi^{33}	齐齐	'neat'
Tone 3+Tone 3	ɓien^{31} ɓien^{31}	扁扁	'flat'
Tone 4+Tone 4	kuai^{21} kuai^{21}	怪怪	'strange'
Tone 5+Tone 5	tse^{42} tse^{42}	静静	'quiet'
Tone 6+Tone 6	ɓe^{52} ɓe^{52}	破破	'shabby'
Tone 7+Tone 7	siop$^{5̲}$ siop$^{5̲}$	湿湿	'wet'
Tone 8+Tone 8	tiet$^{3̲}$ tiet$^{3̲}$	实实	'solid'

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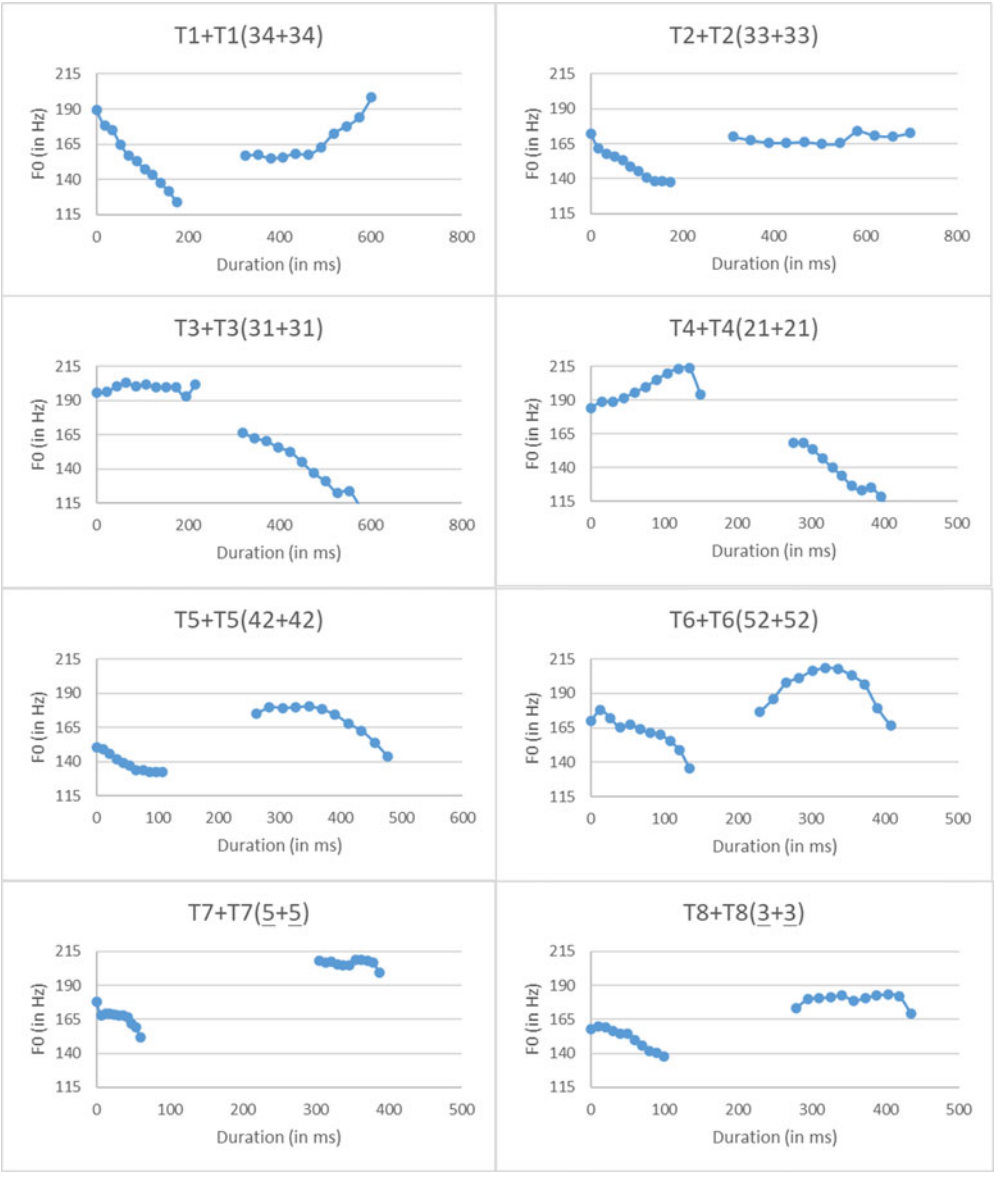


Figure 18. Raw f0 contours of reduplicated bisyllabic words.

Based on the f0 contours, we can see that the original tones on the second syllable are stable and those on the first syllable change. Tone sandhi patterns of reduplicated bisyllabic words in this dialect, therefore, belong to right-dominant patterns, similar to other Southern Min dialects such as Xiamen, Zhangzhou, Quanzhou, etc. as documented in Chen (2010).

The results of the present study differ to certain extent from Woon's descriptions. According to Woon (1987), T5 (tone value: 42) changes to a low-level sandhi tone 11 whereas all other tones occurring on the first syllable of a bisyllabic word may change to a high-level sandhi tone 55. In the preset study, T3 (tone value: 31) and T4 (tone value: 21) change to a high-level tone whereas all other tones change to a falling contour although the f0 onsets of the falling contour may differ.

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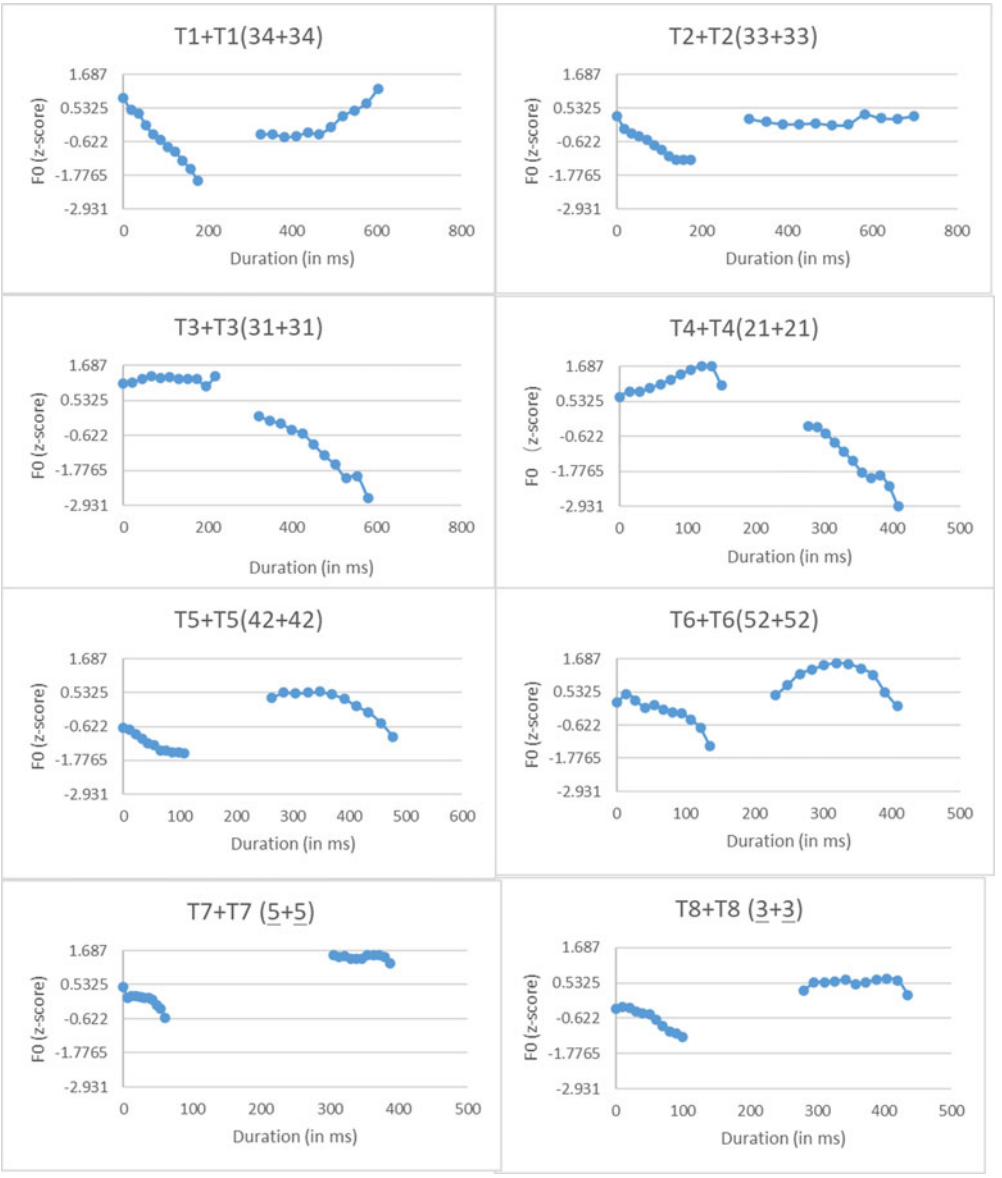


Figure 19. Normalized f0 contours of reduplicated bisyllabic words.

Table 5 compares tone sandhi patterns of reduplicated forms based on the present study with those of general bisyllabic compounds described by Huang & Feng (1993). To ensure a parallel comparison, only those items in the general compounds where both syllables share an identical citation tone are chosen.

Both similarities and differences can be found. The patterns are identical for two tones: T3 and T4 change to 55 and 55, respectively. For T1, T2, T5 and T8, the sandhi forms in both studies show falling tones; the slight difference lies in the starting or ending point. A more notable difference can be observed in the sandhi forms of tones T6 and T7, where the sandhi form of reduplicated words changes to a falling tone, while that of general compounds will retain the original tone.

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Table 5. A comparison of tone sandhi patterns: current findings on reduplicated syllables vs. Huang & Feng's description of general bisyllabic compounds (1993)

Tonal context	Current findings on reduplicated syllables		Huang & Feng's description of general bisyllabic compounds (1993)	
	Citation form	Sandhi pattern	Citation form	Sandhi pattern
T1+T1	34+34	41+34	24+24	42+24
T2+T2	33+33	32+33	22+22	21+22
T3+T3	31+31	55+31	21+21	55+21
T4+T4	21+21	55+21	11+11	55+11
T5+T5	42+42	32+42	42+42	21+42
T6+T6	52+52	42+52	51+51	unchanged
T7+T7	5+5	43+5	55+55	unchanged
T8+T8	3+3	32+3	33+33	21+33

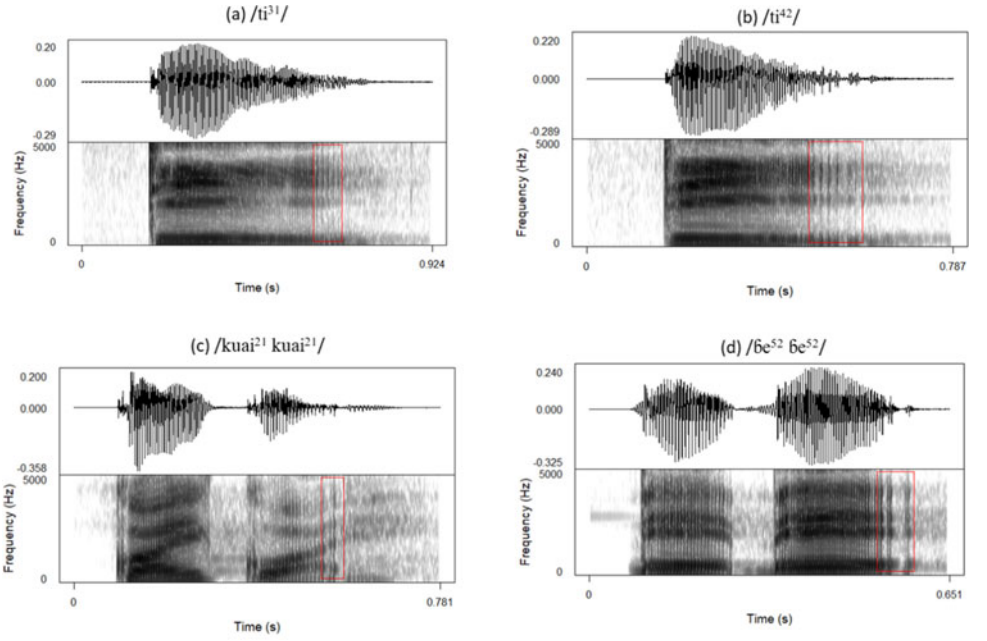


Figure 20. Examples of falling tones ending in creakiness: (a) /ti^{31}/ 'to die', (b) /ti^{42}/ 'yes', (c) /kuai^{21}kuai^{21}/ 'strange' and (d) /ɓe^{52} ɓe^{52}/ 'shabby'.

Future research is needed to explore whether these differences come from morphological conditioning (potentially creating special reduplication sandhi patterns similar to Mandarin reduplication), higher-level prosody factors or other factors.

Another phenomenon to note is the presence of creakiness at the end of different tones and falling tones in particular.

Figure 20 shows that in both monosyllabic context and bisyllabic contexts, falling tones may end in creakiness, regardless of their specific tonal categories. This observation is in

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accordance with Kuang (2017)'s finding in the study of Mandarin Chinese that creaky voice is not solely restricted to Tone 3 in Mandarin, but may instead correlate with any low f0 production, suggesting its emergence is likely governed by physiologically-driven mechanism with automatic and inherent nature.

Transcription of recorded passage 'the North Wind and the Sun'

The passage 'the North Wind and the Sun' is transcribed in four tiers: 1) Broad phonemic transcription; 2) Morpheme glosses; 3) English version; 4) Orthographic Characters.

Abbreviations used for the morpheme glosses: BA = light causative, CL = classifier, COP = copular, DEM = demonstrative pronoun, FOC = focus marker, GEN = genitive, MOD = modal verb, NEG = negative, PERF = perfective, RES = resultative complement marker, SG = singular.

ɓak^{5}	uaŋ^{34} kaŋ^{34} hai^{42} dziaŋ^{33}	|	tse^{34} lun^{42}	|	liaŋ^{42} keŋ^{31} hiaŋ^{21}	||	dzia^{21} ti^{33} |
North wind	and sun		quarrel		who more powerful		DEM time
the north wind and the sun		|	quarreled	|	who was more powerful.	||	At this moment, |
北风和太阳			争论		谁更厉害		这时

dziak^{3}	kai^{33} naŋ^{33}	|	kia^{33} kue^{21} lai^{33}	|	i^{34} siaŋ^{34} dziak^{3} tien^{34}	|	kau^{42} kua^{34}hau^{21}	||
one	CL person		walk pass come		3SG wear one CL		thick coat	
	one man	|	went past,	|	who was wearing	|	a thick coat.	||
	一个人		行过来		他穿一身		厚外袄	

ɓak^{5}	uaŋ^{34} kaŋ^{34} hai^{42}dziaŋ^{33}	|	tou^{34} ɗaŋ^{33}i^{21}	|	liaŋ^{42} tai^{33} hot^{5}lo^{42}	|
North wind	and sun		both agree		who first shed	
The north wind and the sun		|	both agreed	|	the one that shed	|
北风和太阳			都同意		谁先脱落	

lou^{34} naŋ^{33}	kai^{33} kua^{34}hau^{21}	|	liaŋ^{42} tsiu^{42} tui^{52} hiaŋ^{21}	||	ɓak^{5} uaŋ^{34}	|	hau^{33}tai^{33}	|
passerby GEN	coat		who FOC most powerful		North wind		first	
the passerby's coat		|	was the most powerful.	||	The north wind	|	first	|
路人的外袄			谁就最厉害		北风		头前	

ien^{31}mai^{21}	|	i^{34} kai^{33} ui^{34}lat^{3}	|	sot^{5}lat^{3} hau^{21}	||	ɗan^{42}ti^{42}	|	uaŋ^{34} na^{42} ɗua^{34}	|
display		3SG GEN power		hard blow		But		wind more stronger	
displayed	|	its power and	|	blew hard enough.	||	However,	|	When the wind blew stronger	|
显示		它的威力		出力吹		但是		风越大	

o^{52} mo^{52}	lou^{34}naŋ^{33}	|	ɓue^{31} i^{34}	kai^{33} kua^{34}hau^{21}	|	kue^{31} kai^{33} na^{42}kien^{31}	||	au^{42}lai^{33}	|
DEM CL	passerby		Ba 3SG GEN	coat		wrap RES more tight		In the end	
the passerby		|	wrapped the coat around him	|	tighter and tighter.	||	In the end,	|
那路人			把他的外袄			裹得越紧		后来	

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ɓak^{5} uaŋ^{34} bo^{33} ɓan^{33}ɸat^{5} |	na^{42} neŋ^{33} dzia^{21} tsiaŋ^{31} ||	tsiap^{5}lo^{31} |	hai^{42}dziaŋ^{33} |
north wind NEG choice	only can DEM situation	Then	sun	
the north wind had no other choice |	but to give up. ||	Then, |	the sun |	
北风没办法	只能这样	接下	太阳	

sut^{5} lai^{33} |	i^{34} tsio^{42} liau^{31} dziak^{3} hui^{42} |	o^{52} mo^{52} lou^{34}naŋ^{33} |
come	3SG shine PERF one moment	DEM CL passerby	
shone brightly |	and for a while |	the passerby |	
出来	它照了一会	那路人	

ɓien^{42} hut^{5}lo^{42} |	kua^{34}hau^{21} ||	tui^{42}au^{42} |	ɓak^{5} uaŋ^{34} |	bo^{33} ɗiet^{5} bo^{33} |
then take off	coat	At last	north wind	NEG MOD NEG
took off |	the coat. ||	At last, |	the north wind |	had to |
便脱落	外袄	最后	北风	不得不

teŋ^{33} tsien^{34} |	iaŋ^{33} ti^{42} |	hai^{42} dziaŋ^{33} |	keŋ^{31} hiaŋ^{21} ||
admit	still COP	sun	more powerful
admit |	that it was |	the sun |	that was more powerful. ||
承认	还是	太阳	更厉害

北风和太阳争论谁更厉害。这时一个人行过来，他穿一身厚外袄。北风和太阳都同意，谁先脱落路人的外袄，谁就最厉害。北风头前显示它的威力，出力吹。但是风越大，那路人把他的外袄裹得越紧。后来，北风没办法只能这样。接下太阳出来，它照了一会，那路人便脱落外袄。最后，北风不得不承认，还是太阳更厉害。

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