

Right-Dominant Tones in Zhangzhou: On and Through Phonetic Surface

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Abstract

This study conducts a systematic acoustic exploration into the phonetic nature of rightmost tones in a right-dominant tone sandhi system based on empirical data from 21 native speakers of Zhangzhou Southern Min, which presents eight tonal contrasts at the underlying level. The results reveal that, (a) the F0 contour shape realisation of rightmost tones in Zhangzhou appears not to be categorically affected by their preceding tones. (b) Seven out of eight rightmost tones have two statistically significantly different variants in their F0 onset realisation, indicating their regressive sensitivity to the offset phonetics of preceding tones. (c) The forms of rightmost tones are not straightforward related to their counterparts in citation. Instead, two versions of the F0 system can be identified, with the unmarked forms resembling their citation values and the marked forms occurring as a consequence of the phonetic impact of their preceding tones and the F0-declining effect of utterance-final position. (d) The phonetic variation of rightmost tones reflects the across-linguistic tendency of tonal articulation in connected speech but contradicts the default principle for identifying the right dominance of tone sandhi in Sinitic languages.

Keywords: Right-dominant tones, Zhangzhou

1 Introduction

The realisations of tones can be alternated when they come into contact with one other in connected speech. The process of contextually triggered tonal alternation is referred to as tone sandhi in the linguistic literature (Benedict, 1948; Pike, 1948; Leiste, 1976; Gandour, 1978; Ballard, 1988; Chen, 2002; Zhang, 2007; Ratliff, 2015). Amongst those languages where tone sandhi is prevalent, they

vary considerably in the way that tones change, what has motivated tones to change, and under what domain tones are supposed to change, resulting in a dynamic and diverse profile of tone sandhi as a language phenomenon particularly. This can be straightforwardly illustrated by the classification of the tone sandhi system in Sinitic languages, which is conventionally categorised into either right-dominant or left-dominant, depending on the position where syllables are supposed to retain the forms of their corresponding citation tones and keep the range of tonal contrasts. For example, Shanghainese and many Wu dialects are often reported to exhibit a left-dominant sandhi system, in which the initial syllables preserve their citation forms and syntagmatically extend the realisations rightwards over the entire sandhi domain (Ballard, 1998; Chen, 2000; Duanmu, 2005; Zhang, 2007). In contrast, other Sinitic languages like Southern Wu and most Min are classified as having a right-dominant sandhi system because the final (rightmost) syllables are assumed to remain the tonal contrasts and values of citation forms, while those of non-final tones are replaced by their corresponding sandhi forms (Wright, 1983; Shih, 1986; Ballard, 1988; Chen, 2000; Zhang, 2007; Rose, 2016).

Thus, the preservation of citation forms has been regarded as a default principle to classify the dominance of a tone sandhi system. However, are the citation forms intactly preserved without any change? Are the forms not affected by the surrounding contexts, even at the phonetic level? Does not the continuous motion of vocal apparatus in connected speech production cause any effect on the realisation of tones at the dominant/prominent position? These have been open questions to be addressed because there is still a lack of systematic investigations to clarify such concerns in the literature. It is thus still far from the satisfaction that an insightful picture can be provided to shape and deepen our understanding in this regard.

Driven by these intriguing questions, this study is designed to explore to what extent the citation forms are preserved for those tones at the rightmost position of multisyllabic constructions. It is built upon a relatively large scale of empirical data from 21 native speakers of Zhangzhou Southern Min that presents a typical right-dominant tone sandhi with eight tonal contrasts at the underlying level. Acoustic normalisations on tonal F0 and duration are applied to abstract away variable indexical content from invariable linguistic content in speech signals, while the statistical technique of pairwise t-test is conducted to examine whether the F0 realisation of rightmost tones is affected by their preceding tones; if so, to what extent they are affected, and what conditions the variation?

Incorporating field linguistics, phonetics, phonology, and statistical testing gives this study a strong foundation of generalisable samples, objective instruments, and scientific patterns while helping this study achieve a higher level of generalisation and explanation. It directly fills in the research gap in the tonal study of this dialect. It also sheds important light on those Asian languages that exhibit tone sandhi as an important phenomenon in their sound systems.

2 Zhangzhou and Speech

Zhangzhou 漳州, romanised differently as Chiang Chiu or Changchow, is a prefecture-level city situated in the Southern Fujian province of Mainland China, with the latitude and longitude coordinates at 24.5130° N, 117.6471° E. It faces the Taiwan Strait to its east; borders the Fujian cities of Xiamen, Quanzhou, and Longyan on its east, northwest, and west, respectively, while its southwest region borders the Chaozhou city of Guangzhou province. Zhangzhou covers an area of approximately 12,600 square kilometres, with a registered population of about 5.6 million in the 2020 census. The language spoken by native people is predominantly Southern Min (known as Hokkien), which is mutually intelligible with Southern Min varieties of Quanzhou, Xiamen and Taiwan; it has a certain degree of mutual intelligibility with Teochew and Leizhou Southern Min but is unintelligible with other Chinese dialects (e.g., Mandarin, Hakka, Cantonese, Wu, Xiang, and Gan). Mandarin, as the official language of China, is commonly used on public occasions. Hakka dialect is also found but only spoken by a relatively small population living in western mountainous areas, like Hua'an, Nanjing, Pinghe, and Zhao'an counties which border a

major Hakka-speaking city of Longyan (FCCEC, 1998; Guo, 2014).

As a consequence of long-standing maritime trade, the speech of Zhangzhou, along with other Southern Min dialects (e.g., Xiamen and Quanzhou), has been spread to many regions in Asia since the early 12th century and historically served as a lingua franca among Chinese communities, such as Singapore, Malaysia, and Indonesia (Ma, 1994). Therefore, the locality must be clarified when conducting a rigorous linguistic study of Zhangzhou's speech. The research area being concerned in this study is Longwen and Xiangcheng, the inner districts of Zhangzhou city in Fujian province. Restricting research area in specific urban regions help in minimising the effects of regional variations while specifying the research aim to examine how tonal realisations in the citation and dominant contexts are related from a scientific and statistical point of view.

3 Research Material and Design

3.1 Stimulus

The data being addressed were obtained by the author in 2015 in the urban districts of Xiangcheng and Longwen of Zhangzhou city from 21 native speakers (9 males and 12 females). They were selected based on a set of criteria that included age, intellectual curiosity, physical condition, birthplace, language environment, occupation, education, and competence in another language (s), with an average age of 56.5 for males and 50 for females. The corpus incorporated about 588 disyllabic phrases for investigating tone sandhi behaviour across 64 (=8 tones * 8 tones) disyllabic tonal combinations and about 160 monosyllabic morphemes for the citation tone investigation. Tokens were chosen across syllable types and contained comparable numbers of onsets with different manners and places of articulation and vowels of varying height and backness to maximally balance the intrinsic perturbation effects on tonal F0 from tautosyllabic segments. They were recorded from individual speakers in an acoustically absorbent room of Zhangzhou Hotel via a professional cardioid condenser microphone at a sampling frequency of 44100 Hz.

3.2 Acoustic Processing

The obtained field data were acoustically processed in Praat, with the tonally relevant

duration identified as incorporating all elements except syllable onsets. The durational onset was set at the glottal pulse, where the amplitude of air pressure fluctuation began to increase; the periodicity of speech wave vibration appeared regular, and the formant patterns in the spectrogram were stable and identifiable. The offset was set at the point where periodicity and formant patterns ceased to be visible. Figure 1 illustrates how tonally relevant duration was identified in this study. Based on the labelled duration, F0 and duration values were extracted using a script at 10 equidistant sampling points.

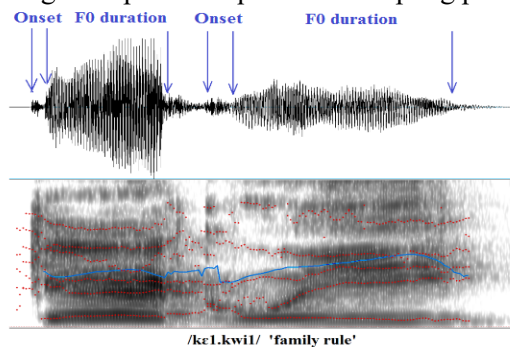


Figure 1: Praat labelled disyllabic example /kɛ1.kwi1/ 'family rule' (WYF, male).

Because acoustic signals are easily affected by extralinguistic information, such as speakers' sociocultural background, pragmatic intent, vocal tract anatomy, and physiology (Anderson, 1978; Ladefoged, 1999; Harrington, 2010; Rose, 1987, 2016), processes of normalisation were applied to abstract away the variable indexical context from the invariable linguistic content in this study. These included the z-score approach for F0 normalisation as in formula (1) and the absolute approach for duration normalisation as in (2) (Huang et al., 2016; Huang 2018; 2020).

$$Z_i = (X_i - m) / s \quad (1)$$

$$D_{\text{norm}} = (D / D_{\text{mean}}) * 100 \quad (2)$$

In (1), m and s , separately, stand for the raw mean F0 value and the standard deviation estimated from all sampling F0 values for all tokens of all tones in a specific context from a given speaker. X_i is an observed F0 value at a given sampling point, while Z_i is its corresponding normalised value derived as the distance from the mean F0 value, corresponding to the speakers' neutral pitch. In (2), D_{mean} represents the mean raw duration estimated from the average duration of all tokens in all tones from individual speakers. D is the duration observed for a given tone, while D_{norm} is its corresponding normalised value expressed as

a percentage of the average duration of all tones from the speaker being considered.

3.3 Statistical Testing

This study applied the statistical technique of pairwise t-test by effect sizes to determine (a) whether the F0 realisations of tones at the right-dominant position are statistically significantly affected by their preceding tones. (b) If yes, to what extent are they affected, and what conditions the variations? The application of this testing requested all possible pairwise comparisons of the values derived from acoustic quantification and normalisation. For example, each tone would have 28 ($8 * 7 / 2$) paired normalised F0 differences at the 10% sampling point to be tested and examined whether its onset realisation was significantly affected by the offset of preceding tones. The Bonferroni correction was performed to control for the Type I Error and achieve significance (Levshina, 2015; Huang 2018). The corrected alpha was calculated by dividing the critical P value by the number of comparisons being considered. The testing result was visualised using the hierarchical clustering algorithm, and the threshold at one was consistently selected to determine the distance for significance.

4 Zhangzhou Citation Tones

Numerous works have documented Zhangzhou citation tones. However, the majority of studies are impressionistic and describe a seven-way tonal contrast (Dong, 1959; Lin, 1992; Ma, 1994; FJG, 1998; ZJG, 1999; Gao, 1999; Zhou, 2006; Chen, 2007; Yang, 2008; Guo, 2014; Huang et al., 2016). Huang (2018; 2020)'s studies were principally acoustic and advocated an eight-tonal system based on the assertion that, (a) relying on one single context of citation, and a single parameter of F0/pitch is not sufficient to figure out the totality of tonal contrasts, because tonal neutralisation occurs across linguistic contexts, including the citation position; and tones that have similar F0 contour can differ significantly in other parameter.

As an extension to explore the nature of Zhangzhou tones in synchronic speech, this study adopts the eight-tone proposal. The pitch system of the eight tones in the citation is summarised in Table 1 with examples of (semi-) minimal pairs and their corresponding Middle Chinese (MC) tonal categories, making them diachronically traceable

and synchronically comparable with other Sinitic dialects. Figure 2 visualises the F0 pattern of the eight citation tones in Zhangzhou derived from quantifying 21 speakers’ monosyllabic utterances.

Tone	Pitch/F0	Example	
1	Yinping	mid rising [35]	/kɔ/ ‘mushroom’
2	Yangping	mid-low level [22]	/kɔ/ ‘glue’
3	Shang	high falling [51]	/kɔ/ ‘drum’
4	Yinqu	mid-high falling [41]	/kɔ/ ‘look after’
5	Yangqu	mid level [33]	/hɔ/ ‘rain’
6	Yinru	stopped mid-high falling [41]	/kɔk/ ‘country’
7	Yangru	stopped mid-low level [221]	/tɔk/ ‘poison’
8	Yangru	mid-low level [22]	/kɔ/ ‘snore’

Table 1. Pitch system of Zhangzhou citation tones.

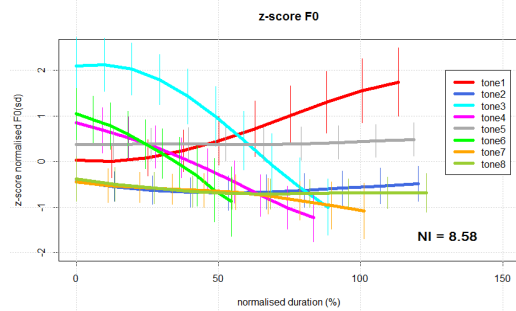


Figure 2: F0 pattern of Zhangzhou citation tones.

As indicated, Zhangzhou citation tones vary considerably in pitch/F0. Three contour shapes—rising (tone 1), level (tones 2, 5, and 8), and falling (tones 3, 4, 6, and 7)—and four contour heights—mid-low (tones 2, 7, and 8), mid (tones 1, and 5), mid-high (tones 4, and 6), and high (tone 3)—can be identified in the F0 inventory. Tones 4 and 6 appear to have a similar mid-high falling contour [41] in the citation context, but the duration of tone 6 is shorter. Tones 2 and 8 share a similar low-level contour [22] in the citation. Still, they are observed behaving differently in the sandhi (non-rightmost) environment, with tone 2 being realised as a mid-level [33] and tone 8 as a mid-falling [32] (Huang 2018; 2020). In other words, tones with a similar F0/pitch contour can differ considerably in other phonetic parameters and linguistic contexts. The description serves as a reference to investigate to what extent the citation forms are preserved in the rightmost position of disyllabic constructions and to what extent the realisations of rightmost tones are affected by their preceding tones.

5 Right Dominance of Zhangzhou Tone Sandhi

Zhangzhou presents a typical right-dominant tone sandhi system. This can be justified from three major aspects. The first significant aspect is that the realisations of those non-rightmost tones are changed to forms entirely different from their citation forms at both phonological and phonetic levels. This can be seen from Table 2 about the pitch realisation of eight individual tones before tone 2, patterned in X+2 where X refers to tone number. For example, the pitch of tone 3 is changed to a mid-rising [25] from a high-falling contour [51] in the citation. In addition, neutralisation processes occur in this non-rightmost context: tones 1 and 2 are neutralised to a mid-level [33]; while tones 5, 7 and 8 neutralise their pitches to a mid-falling [32] before tone 2. These two characteristics in the non-rightmost position can be demonstrated by the acoustic pattern in Figure 3, which is derived from normalising 21 speakers’ disyllabic utterances.

X+2	Non-right	Citation	Example
1+2	[33]	[35]	/ts ^h ɛ̃1.tɛ2/ ‘raw tea’
2+2	[33]	[22]	/ʔɛŋ2.tɛ2/ ‘black tea’
3+2	[25]	[51]	/tsɛ3.tɛ2/ ‘morning tea’
4+2	[63]	[41]	/swɛ̃4.tɛ2/ ‘unpacked tea’
5+2	[32]	[33]	/ʔjɔŋ5.tɛ2/ ‘have tea’
6+2	[65]	[41]	/sip6.tɛ2/ ‘moisten tea’
7+2	[32]	[221]	/sik7.tɛ2/ ‘colorful tea’
8+2	[32]	[22]	/pɛ8.tɛ2/ ‘Bai tea’

Table 2. Examples of X+2 sandhi pattern.

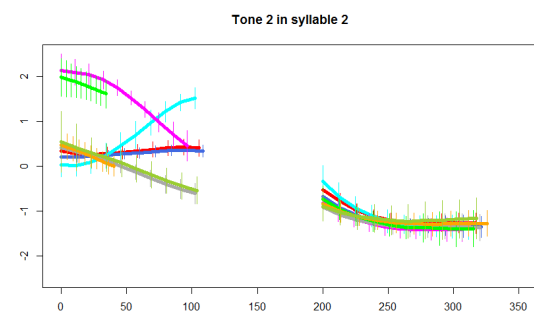


Figure 3: F0 contours of X+2 pattern in Zhangzhou.

This third significant aspect is that the pitch contours of the rightmost tones are observed to be categorically similar to their corresponding citation forms. This can be seen from Table 3 about the pitches of eight individual tones after tone 2. For example, tone 5 is realised as a mid-level [33] in

the 2+5 pattern as in the citation. However, the realisations are not always straightforwardly the same because the contour onsets of rightmost tones are observed as being phonetically sensitive to surrounding contexts and present variations. For example, tones 2 and 8 are realised as [211] in the rightmost position but as [22] in the citation. Such a slight phonetic difference can be ascribed to be affected by the effect of final-position declination. The two characteristics of rightmost tones (contour shape preservation and contour onset variation) can be demonstrated in Figure 4, which plots the normalised F0 contours of the 2+X pattern.

2+X	Right	Citation	Example
2+1	[34]	[35]	/tɛ2.hwɛ1/ ‘camellia’
2+2	[211]	[22]	/tɛ2.dɛw2/ ‘tea house’
2+3	[52]	[51]	/tɛ2.6i3/ ‘dried tea’
2+4	[41]	[41]	/tɛ2.tjɛm4/ ‘tea store’
2+5	[33]	[33]	/tɛ2.ts ^h ju5/ ‘tea tree’
2+6	[41]	[41]	/tɛ2.sik6/ ‘tea colour’
2+7	[211]	[221]	/tɛ2.sit7/ ‘tea dessert’
2+8	[211]	[22]	/tɛ2.hjɔ8/ ‘tea leaf’

Table 3. Examples of 2+X sandhi pattern.

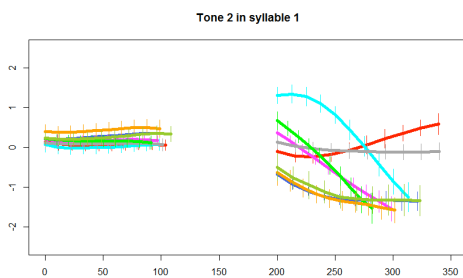


Figure 4: F0 contours of 2+X pattern in Zhangzhou.

As seen, the contour shape preservation of citation forms in the rightmost context justifies the existence of a right dominant tone sandhi system in Zhangzhou. However, the observed contour onset variations conflict with the general assumption that the rightmost tones are straightforwardly related to the citation tones, with the citation-tone pitch values preserved and unchanged. It thus appears to be a crucial issue to investigate to what extent the citation forms are preserved, and to what extent the rightmost tones are affected by surrounding phonetics, and how such effects can be justified and generalised using scientific methods and modern linguistic theories. These are about to be discussed in the next section in the hope of superseding our understanding of the right dominance in tonal languages.

6 Phonetics of Rightmost Tones

This section discusses the acoustic property of individual rightmost tones as a function of their preceding tones in disyllabic phrases of Zhangzhou speech. Figure 5 plots the acoustic patterns and the clustering results of pairwise t-tests derived from empirical data from 21 native speakers, representing the central tendency of Zhangzhou speech as an independent variety.

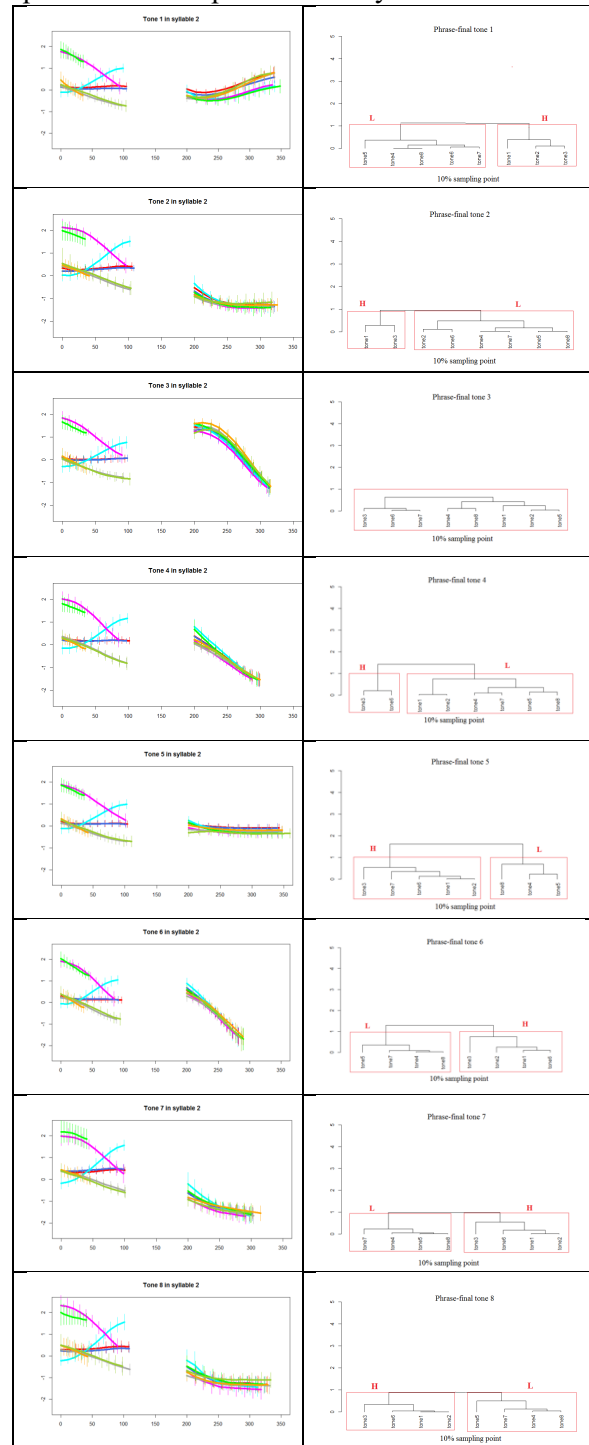


Figure 5: F0 patterns of Zhangzhou rightmost tones from 21 native speakers.

Tone 1-Yinping: all normalised F0 contours of rightmost tone 1 are rising as a function of eight preceding tones but have variation at the onset that can be justified by the pairwise t-test comparison by effect sizes. As shown on the right panel of Figure 5, the normalised F0 values representing different X+1 patterns are clustered into two groups at the 10% sampling point, with the value significantly higher after tones 1, 2, and 3 than it is after other tones. The common feature of tones 1, 2 and 3 at the non-right position is [-falling]. Thus, it can be generalised that if a preceding tone has the feature of [-falling], the onset value of tone 1 is statistically significantly higher.

Tone 2-Yangping: all normalised F0 contours of tone 2 are falling with a low-level plateau during the second half across different combinations. The pairwise t-tests reveal statistically significant but marginal differences in the F0 onset, with the values higher after tone 3 than after any other tones at the 10% sampling point. The conditioning factor appears to be contour-relevant because the phrase-initial tone 3 presents a rising trend. Thus, it can be generalised that if the preceding tone has a [-falling; -level] feature, the onset value of tone 2 turns out to be statistically significantly higher.

Tone 3-Shang: the F0 contours of rightmost tone 3 consistently show a high-falling tendency across X+3 patterns. Statistically, the pairwise t-test comparisons reveal no significant difference among the normalised F0 values of this tone at the 10% sampling point. This can be seen in Figure 5. The eight tonal combinations are clustered into one single net. Thus, the F0 realisation of this rightmost tone 3 is unaffected by its preceding tones. This may be ascribed to its high onset value, which is high enough that made it not easy to be affected.

Tone 4-Yinju: the F0 contours of this tone are consistently falling across different combinations but with slight differences in the onset values. The statistical testing result reveals that its F0 values are significantly higher after tones 3 and 6 than after other tones. This can be seen from the figure that tones 3 and 6 are clustered together at the 10% sampling point. Thus, the F0 onset realisation of the phrase-final tone 4 is also sensitive to the F0 offset of preceding tones. If the preceding tone possesses a feature of [+high offset] (shared by tones 3 and 6), its onset is supposed to be statistically significantly higher.

Tone 5-Yangqu: this tone consistently presents a level contour around the midpoint across all tonal

combinations. The pairwise t-testing result reveals that its onset values are significantly affected by the offset of preceding tones; as shown in Figure 5, the eight terminal nodes are clustered into two groups at the 10% sampling point. The values tested are significantly lower after tones 4, 5, and 8, which share a falling trend with a low offset. Thus, the conditioning factor for its onset variation can be generalised as [falling; low offset]. If the preceding tone has a downward contour [+falling] with an offset lower than the midpoint [+low offset], the onset of this tone 5 is supposed to be statistically significantly lower, and vice versa.

Tone 6-Yinru: all normalised F0 contours of this tone are falling as a function of the non-rightmost tones but with variation in the onset height. As shown in the figure, the terminal nodes on the right panel have been clustered into two groups at the 10% sampling point, with the values being significantly higher after tones 1, 2, 3, and 6 have an offset at or above the midpoint. Thus, similar to the variation in tone 5, if preceded by a tone that has a [+high offset] at or above the midpoint, the onset of this tone is supposed to be statistically significantly higher, and vice versa.

Tone 7-Yangru: the F0 contours of this tone all present a falling tendency with a low-level plateau across X+7 patterns but also have considerable variation in onset values. As visualised in Figure 5, the eight tones on the right panel, signifying the eight combinations that the tone is assigned with, are clustered into two groups at the 10% sampling point, with the values after tones 1, 2, 3, and 6 being significantly higher than the values in another group. Therefore, the F0 onset realisations of tone 7 are also sensitive to preceding tones. The conditioning factor can also be generalised as [low offset] and [falling]. If the preceding tone has a non-falling contour with an offset at or above the midpoint, featured as [-low offset] and [-falling], the onset of this tone 7 should be statistically significantly higher, and vice versa.

Tone 8-Yangru (New tone): similar to tones 2 and 7, the normalised F0 contours of this tone are all falling in the first half but tend to be level in the second across X+8 combinations, as seen in Figure 5. The onset realisation is also regressively sensitive to the phonetics of preceding tones, with the values significantly higher after tones 1, 2, 3, and 6 than after other tones at the 10% sampling point; however, the effect appears to be marginal. Similarly, the conditioning environment for the

onset variations of tone 8 can also be generalised as [low offset] and [falling]. If the preceding tone is featured of [-low offset] and [-falling], the onset of this tone is supposed to be statistically significantly higher, and vice versa.

7 Onset Variations of Rightmost Tones

As described above, the contour shapes of rightmost tones are generally not affected by preceding tones because regardless of whether preceded by a rising, falling or levelling contour, each rightmost tone is seen having its contour shape consistently the same. However, the contour height of most rightmost tones is phonetically sensitive to the contour offset of preceding tones, causing them to have dynamic variations in F0 onset values that are tested to be statistically significantly different. This section summarises how the F0 onsets of rightmost tones are affected by the non-right ones and how their forms are related to corresponding citation values.

(1) The F0 realisation of right-most tones does not always resemble their citation forms, although they are very similar in contour shape. This can be seen in Table 4, which showcases the F0 values of the eight rightmost tones across 64 tonal combinations. The top row shows the eight tones concerned with their corresponding citation F0 values for comparison. In contrast, the leftmost column shows the non-rightmost tones with their sandhi F0 values to examine how they affect their following tones. The divergence between the rightmost forms and citation forms can be ascribed to two significant factors. One is their phonetic sensitivity to the F0 offset of preceding tones, causing them to have dynamic and diverse outputs at the surface level, as discussed above. The other factor may be ascribed to the pitch/F0 declination effect in the utterance-final position (Lieberman, 1967; Pierrehumbert, 1987; Maeda, 1976; Cohen et al., 1982; Ladd, 1984; Yuan & Liberman, 2010; Rose, 2014). They appear to have a lower F0 height than their citation forms. For example, tones 2, 7, and 8 are realised as either [211] or [311] in the phrase-final context, with a low-level plateau about one degree lower than that in citation [22]. Apart from the F0-declining effect, the F0 range of the rightmost tones appears lower than that of the non-rightmost tones. This can be seen from the F0 contour distributions in Figure 5, in which the normalised F0 range is between -0.84 and 2.33 for the non-rightmost tones but between -1.7 and 1.64

for the rightmost tones. Such a lowering F0 range may also be considered a declining effect of the utterance-final position.

Tone	T1 [31]	T2 [22]	T3 [51]	T4 [41]	T5 [33]	T6 [41]	T7 [221]	T8 [22]
T1[33]	35	211	52	41	33	41	211	211
T2[33]	35	211	52	41	33	41	211	211
T3[25]	34	311	52	51	33	51	311	311
T4[63]	34	211	52	41	33	41	211	211
T5[32]	35	211	52	41	33	41	211	211
T6[65]	34	311	52	51	33	51	311	311
T7[32]	35	211	52	41	33	41	211	211
T8[32]	35	211	52	41	33	41	211	211

Table 4. F0 inventory of rightmost tones across 64 tonal combinations.

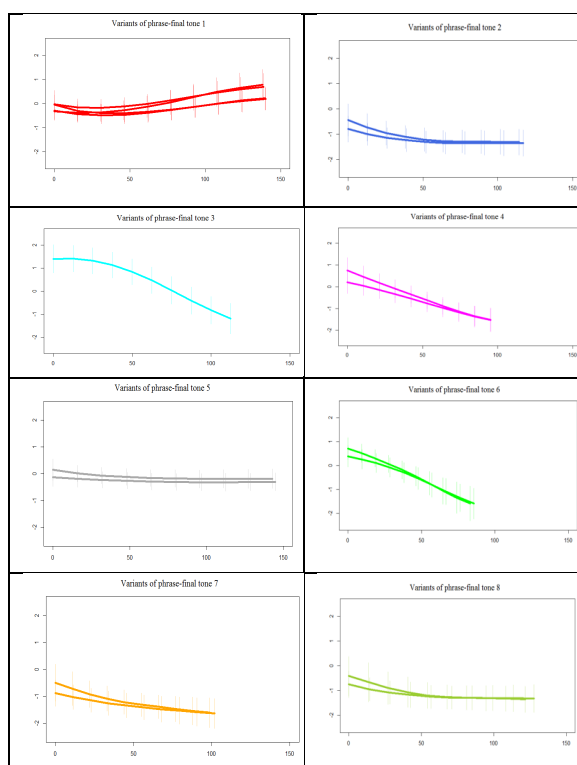


Figure 6: F0 system of Zhangzhou rightmost tones in disyllabic tonal combinations from 21 native speakers.

(2) The F0 contour shapes of rightmost tones tend not to be categorically affected by the tones that precede them. Regardless of whether the preceding tone has a rising, level, or falling F0 contour, the individual rightmost tones present a consistent tendency in their contour shape across different combinations. In other words, the change of contour shape of their preceding tones does not cause any categorical change in their contour realisation. For example, as plotted in Figure 5, tone 1 consistently presents a rising contour, while tone 3 shows a falling contour in any tonal combination. In addition, the contour shape of individual rightmost tones remains categorically

the same as their corresponding citation form. For example, tone 1 presents a rising contour in both the phrase-final (rightmost) position and the citation. This property to a great degree justifies the right-dominancy of the tone sandhi system in this dialect because no paradigmatic substitution occurs for the tones in this position, though they are connected with other tones within the same constructions.

(3) The rightmost tones do not always have an identical F0 realisation as a function of their preceding tones. All tones except tone 3 have two statistically significantly different variants in their onset height because of their phonetic sensitivity to the F0 offset of the tones that precede them. This can be seen in Figure 6, which plots all F0 variants that can be identified based on the acoustic quantification and pairwise t-testing results. In general, the F0 contours tend to have a statistically significantly higher onset after tones ending in a [-low offset] and [-falling] but have a lower onset if the preceding tone is characteristic of [+falling] and [+low offset]. The two different versions of onset realisation, although predictable, raise a theoretical issue as to which onset form, the raised F0 or the lowered F0, should be considered as the unmarked form for the underlying representation and which one should be treated as the derived form that occurs in a marked context.

8 Discussion

As discussed, most rightmost tones have two statistically significantly different F0 onsets. Incorporating the auditory observation, acoustic distribution, position-induced depressing effect, and the correlation with citation form, it is appropriate to consider the lowered F0 onset as the unmarked form while the raised one as the marked form whose occurrence is motivated by the F0 offset of preceding tone. Thus, a linguistically phonetic F0 system of the rightmost tones can be derived and represented using numerical notation, with 5 indicating the highest F0 level and 1 the lowest, as summarised in Table 5, along with the citation values for comparison purposes.

Tone	Rightmost		Citation
	Unmark	Marked	
1	[34]	[35]	[35]
2	[211]	[311]	[22]
3	[52]	[52]	[51]
4	[41]	[51]	[41]
5	[33]	[43]	[33]
6	[41]	[51]	[41]
7	[211]	[311]	[221]
8	[211]	[311]	[22]

Table 5. A linguistically phonetic F0 system of Zhangzhou's rightmost tones in disyllabic construction.

The unmarked forms of the rightmost tones generally resemble their corresponding citation forms. Tones 2, 7, and 8 have a lower levelling trend that can reasonably be considered a consequence of the pitch/F0 declining effect of utterance-final position. The marked forms of most tones have one degree higher than their unmarked and citation forms, which is predicted to occur as regressive assimilation to preceding tones that are featured [-low offset] and [-falling].

The phonetic sensitivity, on the one hand, reflects the across-linguistic phenomenon of tonal coarticulation, particularly concerning the carryover effect (i.e., the influence of the preceding tones on phrase-final tones) (e.g., Scholz & Chen 2014; Xu 1994; Zhang & Liu 2011). Such a dynamic tonal behaviour is not arbitrary. Still, it reflects a continuous motion of the vocal apparatus of human beings in speech production, which can cause considerable overlapping in articulatory gestures while giving rise to diverse outputs that can be perceived and generalised in real-world data. However, on the other hand, this linguistic finding of Zhangzhou right-most tones contradicts and challenges the default principle for the identification of the right-dominance of tone sandhi in Sinitic languages, which considers that the right-dominant tones are straightforwardly related to their corresponding citation tones, with the citation values preserved and unchanged (e.g., Wright 1983; Shih 1986; Ballard 1988; Chen 2000; Zhang 2007). As discussed above, a set of marked forms are statistically justified as utterly different from the citation forms. Thus, tones behave far more dynamically than expected, but the behaviours are generally predictable following an intrinsic set of grammar that can be generalized and justified using scientific patterns.

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