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Phonotactic Constraints on Zhangzhou Onsets

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Abstract

Zhangzhou Southern Min is theoretically assumed to have 7320 possible syllables but more than 70% of them are not attested in the empirical data, implying that substantial constraints have been governing the segmental sequencing and segmental-suprasegmental alignment. This study explores phonotactic constraints on syllable onsets. It addresses two important issues as to in what way syllable onsets are constrained, and what mechanisms have governed the alignment of Zhangzhou onsets with other syllables components and tones to generate syllables that are attestable. The exploration substantially stretches and advances our knowledge of phonological constraints in this Sinitic dialect, while contributing important linguistic data to the typology of phonotactics as an important language phenomenon in world's natural languages.

Keywords: phonotactics, onsets, tones, finals, mechanisms, Zhangzhou

1 Introduction

Sounds do not randomly combine with each other to form a functional syllable and/or a word in utterances. Instead, there are constraints posing restrictions on what sounds can be sequenced and how they can be sequenced to form a larger linguistic unit (e.g., Celata & Calderone, 2015; Zec, 1995; Kirby & Yu, 2007; Algeo, 1975; Pearce, 2007). For example, the segmental string *lbick is practically prohibited, because the onset cluster *lb violates the sonority sequencing principle that prefers a rising sonority from syllable edge to nucleus (Giegerich, 1992; Zec, 1995). However, in this case, the liquid sound [l] is more sonorous than the voiced obstruent [b]. Such restrictions on the speech sounds when they are aligned with others are generally known as phonotactics in the literature (e.g., Celata & Calderone, 2015; Algeo, 1975; Kirby & Yu, 2007; Zhang 2006; Pearce 2007). Phonotactics not only can determine syllable structure and inventory of any given language, but also can categorize the sequences of phonemes into linguistically permissible and impermissible. For example, consonant clusters are permissible at both onset and coda positions in English but are disallowable in Maori and Chinese. In Cantonese, there theoretically should have 5130 possible syllables (with tones), but only 36% can be attested in empirical data (Kirby & Yu, 2007).

In Zhangzhou Southern Min, a Sinitic dialect spoken in southern Fujian province of southeast China, an inventory of 15 onsets, 61 finals and 8 tones can be identified phonemically (Huang, 2019; 2021). Given such, there should have 7320 (=15*61*8) theoretically possible syllables that would be generated in the empirical data. However, based on the calculation result on Huang (2019)'s rhyme tables, only 2105 syllables are attested in the synchronic speech, implying about 5215 syllables, occupying as many as 71%, are blocked to occur and disable to constitute the permissible syllable inventory. This can be best demonstrated by sequencing constraints on those syllable onsets in this Sinitic dialect. Each onset is logically expected to produce 488 (=61*8) possible syllables; however, 127 syllables are obtained under the unaspirated labial stop /p/, while only 33 syllables under the voiced alveolar fricative /z/, by far fewer than the assumption of 488 syllables for each onset. The strong divergency between the theoretical assumption and the practically attested number implies substantial numbers of constraints having blocked the sequencing of Zhangzhou onsets with other syllable components in real-world utterances.

Driven by the intriguing phenomenon of phonotactics in human languages, this study specially concerns phonotactic constraints on Southern Min onsets. It aims to address why so many theoretically possible syllables are missing from the inventory of attestable syllables, and what mechanisms have been governing the sequencing of onsets with other syllable components and tones in Zhangzhou Southern Min. It incorporates four main sections comprising (a) introduction of Zhangzhou speech, syllable and tone; (b) discussion of the creativity of individual onsets in the production of attested syllable, (c) examination on co-occurrence constraints between onsets and tones, and (d) examination on co-occurrence constraints between onsets and finals. The exploration will substantially stretch and advance our knowledge of phonotactics in Southern Min, while contributing vital linguistics data to the typology of phonotactics as an important phenomenon in world's natural languages.

The material used in this study come from two sources. One is from the field data that the author collected in the urban districts of Longwen and Xiangcheng of Zhangzhou city in 2015. Another source is from the rhyme tables that Huang (2019) constructed to exhaustively tabulate sequencings of individual onsets across individual finals and tones. Upon these rhyme tables, this study is able to calculate the number of attested syllables as a function of syllable onsets, whereby exploring what have induced phonotactics in this dialect.

2 ZHANGZHOU AND SPEECH

2.1 Zhangzhou

Zhangzhou is a southern city of Fujian province in mainland China with a registered population of about 5.05 million in 2020 census. The colloquial language spoken by native people is Southern Min, known as Hokkien for its colloquial pronunciation for its homeland of Fujian province. The Zhangzhou speech is mutually intelligible with Southern Min varieties of Quanzhou, Xiamen and Taiwan; partially intelligible with Teochew and Leizhou Southern Min but is entirely unintelligible with other Chinese dialects (e.g., Mandarin, Hakka, Cantonese, Wu, and Gan).

Certain regional variation can be observed among its eleven administrative areas (Ma, 1994; Yang, 2008; Huang, 2018), particularly in its sound system. This study thus restricts the locality to the urban area of Longwen and Xiangcheng districts, which is conventionally considered to be historically-socially-culturally-linguistically-geographically representative of Zhangzhou (Ma 1994; ZZG 1999; Huang 2022).

2.2 Syllables

As a typical Southern Chinese dialect, the majority of morphemes in Zhangzhou is monosyllabic, such as *tʰĩ35 'sky'*, *tsʰŋ22 'bed'*, and *dɔ33 'road'*. However disyllabic and multisyllabic morphemes are also observable in the local vocabulary, such as*, dɐj32.tsi35 'litchi'*, *pi33.pɛ22 'loquat'*, and *ɓɐ̃35.diŋ33.tsi22 'potato'*. A template of C(G)V(X) can be generalized to characterise the internal structure of Zhangzhou syllables, in which onset (C) and nucleus (V) are obligatory while glide (G) and coda (X) are optional. The segmental system incorporates 15 onsets (/p, pʰ, ɓ, t, tʰ, ɗ, k, kʰ, ɠ, ts, tsʰ, s, z, ħ, ʔ/), 2 prevocalic glides (/j, w/), 13 nucleus (/i, e, ɛ, ɐ, ɔ, ɵ, u, ĩ, ɛ̃, ɐ̃, ɔ̃, m̩, ŋ̩/), and 8 (/j, w, m, n, ŋ, p, t, k /) codas. As seen, oral vowels, nasalised vowels and syllabic nasals can function as nuclei, while postvocalic glides, nasal consonants, and obstruent consonants can serve as codas. Six onset phonemes (/ɓ, ɗ, ɠ, z, ħ, ʔ/) are different from previous transcriptions (/b, l, g, dz, h, Ø/) (e.g., Dong, 1959; Lin, 1992; Ma, 1994; FJG, 1998; ZZG, 1999; Gao, 1999). The symbols posited in this study are strictly based on their auditory impression, acoustic manifestation and the consulting results with native speakers, aiming to respect their phonetic reality. Table 1 illustrates the onset inventory, with tonal pitch transcribed using Chao (1930)'s notation system.

Within the Sinitic convention, individual syllables are divided into two main parts of Initial (shēngmǔ 声母) and Final (yùnmǔ 韵母) (e.g., Duanmu 1999; Zhang 2006; Třísková 2011). The concept of final is created to refer to those syllable segments except onset, which typically includes a compulsory nucleus, along with an optional prevocalic glide and/or syllable coda. This Initial-Final model draws on the tradition of medieval Chinese philology (Třísková 2011) that can be traced back to ancient rhyming dictionaries, such as Qièyùn (A.D. 601). In Zhangzhou, 61 Finals can be constructed covering four major types of V, GV, VX, and GVX, as illustrated in Table 2. The two tables serve as the foundation to explore how the sequencing of Zhangzhou onsets and finals is constrained and what has triggered such phonotactics.

Table 1: Examples of Zhangzhou Onsets.

C	Examples		C	Examples	
/p/	pi33 'compare'	piŋ22 'friend'	/ɠ/	ɠi51 'language'	ɠiŋ22 'welcome'
/pʰ/	pʰi51'scab'	pʰiŋ22'comment'	/ts/	tsi51 'cook'	tsiŋ22 'feeling; emotion'
/ɓ/	ɓi51 'rice'	ɓiŋ22 'bright'	/tsʰ/	tsʰi51 'mouse'	tsʰiŋ22 'banyan tree'
/t/	ti51 'resist'	tiŋ22 'pavilion'	/s/	si51 'die'	siŋ22 'complete'
/tʰ/	tʰi51 'store'	tʰiŋ22 'suspend'	/z/	zi51 'fermented bean curd'	zin 22 'people'
/ɗ/	ɗi51 'you'	ɗiŋ22 'zero'	/ɦ/	ɦi51 'happy'	ɦiŋ22 'shape'
/k/	ki51 'point out'	kiŋ22 'lift up'	/ʔ/	ʔi51 'chair'	ʔiŋ22 'glory; honor'
/kʰ/	kʰi51 'tooth'	kʰiŋ22 'jade'			

Table 2: Examples of Zhangzhou Finals.

Final		Example	Final		Example
V	/ɐ/	kɐ41'teach'	VX	/ɐŋ/	kɐŋ41'descend'
	/e/	ke41'calculate; plan'		/iŋ/	kiŋ41'respect'
	/i/	ki41'remember'		/ɔŋ/	kɔŋ41'tribute'
	/u/	ku41'sentence'		/ɐw/	kɐw41'enough'
	/ɔ/	kɔ41'look after'		/ɐ̃w/	ɠɐ̃w33'root of lotus'
	/ɛ/	kɛ41'frame; shelf'		/ɐj/	kɐj41'boundary'
	/ɵ/	kɵ41'tell; sue'		/ɐ̃j/	kɐ̃j41'how about'
	/ɐ̃/	kɐ̃41'yeast'		/ɐp/	kɐp41'pigeon'
	/ĩ/	kĩ41'see; meet'		/ip/	kip41'anxious; urgent'
	/ɔ̃/	kɔ̃41'emit; pop up'		/ɔp/	kɔp41'catch with a cover'
	/ ɛ̃/	k ɛ̃41'quantifier for aircraft; machine'		/ɐt/	kɐt41'tie; knot'
	/m/	ʔm41'oh; all right'		/it/	kit41'orange'
	/ŋ/	kŋ41'steel'		/ut/	kut41'bone'
GV	/jɐ/	kjɐ41'post'		/ɐk/	kɐk41'horn; angle'
	/ju/	kju41'save; rescue'		/ik/	kik41'leather; transform'
	/jɔ/	ɦjɔ41'yes'	GVX	/ɔk/	kɔk41'country; nation'
	/jɵ/	kjɵ41'call; order'		/jɐw/	kjɐw41'seize; hand over'
	/jɐ̃/	kjɐ̃41'mirror; glass'		/jɐ̃w/	**ɠ**jɐ̃w41'stingy'
	/jɔ̃/	tsjɔ̃41'dipping sauce'		/wɐj/	kwɐj41'strange; to blame'
	/jũ/	ɗjũ51'turn; tweak'		/wɐ̃j/	ʔwɐ̃j51'sprain; wrench'
	/wɐ/	kwɐ41'hang'		/jɐm/	kjɐm41'sword'
	/we/	kwe41'pass through'		/jɐn/	kjɐn41'build; found'
	/wi/	kwi41'expensive'		/jɐŋ/	**kʰ**jɐŋ41'capable; competent'
	/wɐ̃/	kʰwɐ̃41'look; see'		/jɔŋ/	kjɔŋ41'arch'
	/wĩ/	kwĩ41'volume'		/wɐn/	kwɐn41'be used to'
VX	/ɐm/	kɐm41'supervise'		/jɐp/	kjɐp41'take by force'
	/im/	kim41'prohibit'		/jɐt/	kjɐt41'bear fruit; connect'
	/ɔm/	kɔm41'sloshy; muddy'		/jɐk/	kjɐk41'screechy'
	/ɐn/	kɐn41'separate'		/jɔk/	kjɔk41 'chrysanthemum'
	/in/	kin41'strength'		/wɐt/	kwɐt41 'determine'
	/un/	kun41'stick'			

2.3 Zhangzhou Tones

The urban area of Zhangzhou city has received a considerable number of impressionistically-auditory-based transcriptions (e.g., Dong, 1959; Lin, 1992; Ma 1994; FJG, 1998; ZZG, 1999; Gao, 1999; Yang, 2008) and some acoustic descriptions (Huang et al., 2016; Huang, 2018; 2020; 2022) on its monosyllabic citation tones. However, prior studies before Huang (2018)'s initiative are dominantly impressionistic and identify a seven-way tonal contrast with their pitch values not only differing among themselves, but from the phonetic reality. The eight-tonal system is posited based on two acoustically-statistically-justified assertions: (a) tones sharing a similar pitch contour can differ considerably in other parameters, such as duration, syllable type and phonation, and (b) tone having an identical realisation in citation can differ in other linguistic contexts (Huang2018; 2020).

This study adopts the proposal of eight-tone system, which is introduced in Table 3, along with their pitch and duration values, and corresponding names in terms of the Middle Chinese tonal category to make them diachronically traceable and synchronically comparable with other Sinitic dialects. The detailed discussion of the eight tones and their multidimensional properties can be referred to in Huang's (2018; 2020) work.

Table 3: Examples of Zhangzhou citation tones.

Tone		Pitc	Duration	Example 1
1	Yinping	[35]	extra-long	/tɐŋ35/ 'east'
2	Yangpin	[22]	extra-long	/tɐŋ22/ 'copper'
3	Shang	[51]	medium	/tɐŋ51/ 'to wait'
4	Yinqu	[41]	medium	/tɐŋ41/ 'frozen'
5	Yangqu	[33]	extra-long	/tɐŋ33/ 'heavy'
6	Yinru	[41]	short	/tɐp41/ 'answer'
7	Yangru	[22	long	/tsɐp221/ 'ten'
8	Yangru	[22]	extra-long	/tsi22/ 'tongue'

3 Creativity of Onsets

Logically, each onset in Zhangzhou Southern Min is theoretically able to combine with 61 finals and 8 tones to generate 488 (=61×8) possible syllables. However, the number of syllables that individual onsets can generate in real-world utterances is far less than the theoretical assumption. Table 4 shows the number of practically attestable syllables are obtained as a function of individual onsets. As seen, individual onsets present considerable variation in their creativity to generate syllables, with the number of attestable syllables ranging from 33 to 189, far less than the maximum number of 488 that each onset is logically able to generate.

Table 4. The number of permissible syllables obtained under different onsets.

Onset			Syllables
Labial	stop	p	127
		pʰ	99
		ɓ	124
Alveolar	stop	t	180
		tʰ	120
		ɗ	174
	affricate	ts	189
		tsʰ	142
	fricative	s	174
		z	33
Velar	stop	k	175
		kʰ	129
		ɠ	79
Pharyngeal	fricative	ħ	172
Glottal	stop	ʔ	188

As seen, only three onsets (/t/, /ts/ and /ʔ/) can generate 180 syllables and above, whereas three onsets (/pʰ/, /ɠ/ and /z/) are shown to produce syllables less than 100. The onset /z/ turns out to be the least productive, because only 33 syllables are able to begin with this onset, 455 less than what is theoretically assumed to be. The unaspirated onsets are preferred over their aspirated. For example, the unaspirated labial stop /p/ can generate 127 syllables while its aspirated counterpart /pʰ/ can only produce 99 syllables. Similarly, the unaspirated alveolar stop /t/ can generate 180 syllables, contrary to its aspirated counterpart /tʰ/ that can create 120 syllables. This reflects the phonotactic constraint of aspiration as a marked feature on the production of attested syllables.

Additionally, the alveolar occlusives are shown to be the most creative than onsets of other place of articulation. Specifically, the three alveolar stops (/t, tʰ, ɗ/) can generate 474 syllables in total, greater than their velar (/k, kʰ, ɠ/), labial (/p, pʰ, ɓ/), and glottal counterparts that separately generate 350, 383 and 188 syllables.

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4 Co-occurrence Restriction between Onsets and Tones

Significant constraints can be seen governing the co-occurrence between tones and onsets, which are induced by synchronic and diachronic factors. Table 5 presents the number of attested syllables that individual onsets can generate across individual tones, in which I, II, III, and IV correspond to the Middle Chinese (MC) tones of Ping, Shang, Qu, and Ru, while a and b represent the Yin and Yang registers, respectively.

Table 5. The number of attested syllables with respect to the onset-tone combination

	T1	T2	T3	T4	T5	T6	T7	T8
	[35]	[22]	[51]	[41]	[33]	[41]	[221]	[22]
	Ia	Ib	II	IIIa	IIIb	IVa	IVb	IVb
p	22	18	22	22	23	7	9	4
pʰ	20	16	14	23	11	7	3	5
ɓ	14	30	25	10	26	3	8	8
t	34	30	25	33	31	10	11	6
tʰ	26	20	17	24	16	9	3	5
ɗ	23	32	35	23	32	6	13	10
k	36	23	31	33	24	13	8	7
kʰ	32	17	22	26	9	11	6	6
ɠ	3	24	12	7	17	1	10	5
ts	36	27	31	34	28	12	11	10
tsʰ	35	15	25	30	14	11	5	7
s	37	24	29	34	22	13	8	7
z	2	9	6	1	6	1	6	2
h	33	28	25	29	28	12	9	8
ʔ	39	30	33	31	28	12	7	8

(1) Onsets occur least often in tones 6, 7 and 8. This reduction is understandable that results from the constraint of syllable coda type. The three tones are referred to as stopped/checked tones because their associated syllables are historically assumed to end in obstruent codas, where syllables in other tones end in sonorants. What needs a specific attention is that tone 8 is a newly posited tone. Its associated syllables are documented ending in a glottal stop; however, the glottal stop is discovered being deleted, leading related syllables to become open (Huang 2018). The special requitement on syllable coda type can substantially affect the combination of onsets and tones in the formation of attested syllables.

(2) For those onsets that are contrastive in aspiration, the aspirated onsets (/pʰ, tʰ, kʰ, tsʰ/) mostly have fewer attested syllables than their unaspirated voiceless counterparts (/p, t, k, ts/) across tones. This reflects aspiration as a marked feature that can constrain the productivity of onsets in the formation of attestable syllables.

(3) For those onsets that are contrastive in voicing, the voiced ones (/ɓ, ɗ, ɠ, z/) have fewer attested syllables than their voiceless counterparts of aspirated (/pʰ, tʰ, kʰ/) and/or unaspirated (/p, t, k, s/) in the Yin-registered tones but more in the Yang-registered tones. The changing number of attested syllables along with tonal registers can be seen as a consequence of diachronic constraint. Because syllables under Yang-registered tones are historically assumed to contain voiced onsets, while those under Yin-registered tones are aligned with voiceless onsets. This diachronic requirement on the voicing status of onsets can constrain the occurrence of voiceless onsets in Yang-registered tones, while limiting the voiced onsets to occur in the Yin tonal environments.

(4) The voiced alveolar fricative /z/ is the least productive across most tones, reflecting its most marked status. It cannot occur in any syllable whose nucleus features a nasality, so that syllables like *zṼ, *zN, *zGṼ, *zṼG, *zGṼG are all prohibited. The constraint on the nucleus type can affect its combination with tones, resulting in the fewest syllables that can be attested under this onset.However, this onset is allowed to occur in syllables ending in a nasal coda, such as zVN *(/zim51/ 'tolerate')*, and zGVN (*/zjɐn51/ 'infect'*).

5 Co-occurrence Restriction between Onsets and Finals

Significant constraints can also occur on the co-occurrence between onsets and finals. Table 6 shows the number of attested syllables with respect to the sequencing of onset-final type, while Table 7 shows the number with respect to the alignment between individual onsets and individual finals.

(1) Voiced onsets cannot occur before syllabic nasals. Specifically, syllables like *ɓN, *ɗN, *ɠN, and *zN are not allowed to exist. Instead, only voiceless onsets can precede a syllabic nasal to form syllables, such as pN, pʰN, tN, tʰN, kN, kʰN, and sN are all permissible. The main reason for this restriction can be ascribed to the synchronic factor of Obligatory Contour Principle (OCP) between voiced onset and nasality feature of nucleus. If a voiced onset occurs before a syllabic nasal, the OCP blocks their combination to form a CV syllable type. In contrast, the voiceless onsets do not violate such a principle, so that they can freely precede syllabic nasals, as generalized.

Table 6: The number of attested syllables with respect to onset-final type combinations

Final type	p	p^h	ɓ	t	t^h	ɗ	k	k^h	ɠ	ts	ts^h	s	z	ɦ	ʔ
V	29	26	29	32	24	32	32	25	16	35	29	32	7	27	27
Ṽ	8	6	18	10	6	14	12	4	6	13	7	8	0	11	11
N	2	2	0	5	4	1	3	2	0	2	4	4	0	5	8
VN	28	24	21	40	26	35	35	28	13	35	27	33	6	33	37
GV	10	9	8	17	12	17	18	16	8	24	16	22	4	22	24
GṼ	10	6	10	17	9	15	13	5	2	17	12	13	0	12	17
VG	10	6	6	10	10	9	9	6	3	10	8	6	0	8	8
ṼG	0	2	8	2	0	4	1	2	3	2	1	0	0	2	2
GVG	7	6	8	5	6	6	12	9	3	7	6	9	5	11	10
GṼG	0	0	1	0	0	2	0	0	4	0	0	2	0	1	2
GVN	7	2	4	21	11	20	19	15	10	21	16	24	4	19	23
VP	12	7	8	13	8	14	14	12	5	16	12	13	3	15	10
GVP	4	3	3	8	4	5	7	5	6	7	4	8	4	6	9

Table 7. The number of attested syllables with respect to onset-final combinations

Final Type		p	p^h	ɓ	t	t^h	ɗ	k	k^h	ɠ	ts	ts^h	s	z	ɦ	ʔ
V	ɐ	3	3	5	4	2	5	4	3	1	4	4	4	0	2	4
	e	2	3	5	5	5	6	4	4	2	6	4	4	0	5	5
	i	5	4	6	5	4	5	5	4	5	6	6	6	5	5	5
	u	3	4	3	5	1	4	4	4	2	5	4	5	2	5	3
	ɔ	5	5	4	5	4	4	4	4	2	4	3	3	0	4	4
	ɛ	6	2	2	2	3	2	6	3	2	4	5	4	0	3	1
	ɵ	5	5	4	6	5	6	5	3	2	6	3	6	0	3	5
Ṽ	ĩ	4	3	5	4	2	4	3	1	1	4	2	3	0	3	5
	ɐ̃	0	1	4	3	1	4	5	1	0	4	1	2	0	4	2
	ɛ̃	4	2	4	3	3	3	3	2	4	5	4	3	0	1	3
	ɔ̃	0	0	5	0	0	3	1	0	1	0	0	0	0	3	1
N	m	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5
	ŋ	2	2	0	5	4	1	3	2	0	2	4	4	0	3	3
VN	ɐm	0	0	0	5	3	5	4	4	1	4	4	3	0	5	5
	ɐn	4	3	3	5	4	4	3	3	4	4	4	3	0	5	4
	ɐŋ	5	5	4	5	4	5	4	2	1	3	3	2	0	4	3
	im	0	0	0	4	1	4	4	2	1	4	3	5	4	2	4
	in	5	4	3	5	1	3	5	4	3	5	2	4	2	3	5
	iŋ	5	3	3	5	5	4	5	5	1	5	5	5	0	4	4
	ɔm	0	0	0	1	1	1	0	0	0	0	0	3	0	0	2
	un	5	4	3	5	3	4	5	4	1	5	4	5	0	5	5
	ɔŋ	4	5	5	5	4	5	5	4	1	5	2	3	0	5	5
GV	jɐ	1	2	0	3	1	2	4	3	3	5	4	5	1	5	6
	ju	1	1	2	4	2	5	5	5	2	5	5	5	1	4	5
	jɵ	3	2	2	4	2	2	3	1	1	4	3	4	1	2	4
	jɔ	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	wi	3	2	1	4	4	5	4	4	0	4	2	5	0	5	5

	wɐ	2	2	3	2	3	3	2	3	2	6	2	3	1	5	4
GṼ	jɐ̃	3	3	2	3	2	2	5	0	1	5	4	3	0	5	4
	jũ	0	0	0	1	1	2	0	0	0	0	0	0	0	0	1
	jɔ̃	0	0	0	5	0	3	1	2	0	5	5	5	0	1	4
	wĩ	2	0	5	4	3	5	3	1	1	3	2	3	0	3	4
	wɐ̃	5	3	3	4	3	3	4	2	0	4	1	2	0	3	4
VG	ɐw	6	5	3	5	5	6	6	3	1	5	4	2	0	4	5
	ɐj	4	1	3	5	5	3	3	3	2	5	4	4	0	4	3
ṼG	ɐ̃w	0	0	3	0	0	2	0	1	3	0	0	0	0	1	1
	ɐ̃j	0	2	5	2	0	2	1	1	0	2	1	0	0	1	1
GVG	jɐw	2	2	3	4	4	4	5	5	1	5	3	5	3	4	5
	wɐj	0	0	0	0	0	0	3	1	0	0	0	0	0	2	1
	we	5	4	5	1	2	2	4	3	2	2	3	4	2	5	4
GṼG	jɐ̃w	0	0	1	0	0	2	0	0	4	0	0	0	0	0	0
	wɐ̃j	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2
GVN	jɐm	0	0	0	5	3	5	4	5	3	4	3	5	1	4	5
	jɐn	5	2	3	4	3	5	3	4	4	5	4	5	1	5	4
	jɐŋ	1	0	0	4	0	3	3	2	1	3	5	5	0	3	4
	jɔŋ	0	0	0	4	3	4	4	1	0	4	1	4	2	2	5
	wɐn	1	0	1	4	2	3	5	3	2	5	3	5	0	5	5
VP	ɐp	0	0	0	2	1	2	2	2	0	2	1	1	0	2	1
	ɐt	2	0	2	1	1	1	1	1	0	2	2	1	0	2	1
	ɐk	2	2	2	2	2	2	2	1	1	1	1	1	0	2	1
	ip	0	0	0	0	0	1	2	2	1	2	1	2	1	1	1
	it	2	1	1	2	0	1	1	1	1	2	1	2	1	1	2
	ik	2	1	1	2	1	1	2	1	1	2	2	2	1	2	2
	ut	2	1	1	2	2	2	2	2	0	2	1	2	0	2	1
	ɔp	0	0	0	0	0	2	0	0	0	1	1	1	0	1	0
	ɔk	2	2	1	2	1	2	2	2	1	2	2	1	0	2	1
GVP	jɐp	0	0	0	2	2	2	1	1	2	2	1	2	1	1	2
	jɐt	1	2	1	2	1	1	2	2	1	2	1	2	1	2	2
	jɐk	1	0	0	0	0	1	1	0	1	1	1	1	1	0	2
	jɔk	0	0	0	2	0	1	2	1	1	1	1	2	1	1	1
	wɐt	2	1	2	2	1	0	1	1	1	1	0	1	0	2	2

(2) The voiced obstruent onsets are able to occur before nasalised nuclei. As such, syllables like ɓṼ, ɗṼ, and ɠṼ are attestable in the data. This seems violating the OCP on the co-occurrence of nasality feature and voiced onset. The main reason for this generalization is that the voice obstruent onsets are seen undergoing a regressive assimilation to subsequent nasality feature and become nasal onsets ([m, n, ŋ]) at the surface (Huang & Hyslop 2022). It is thus proper to consider that syllables like ɓṼ, ɗṼ, and ɠṼ are permissible at the underlying level.

(3) The voiced fricative /z/ cannot occur before final type that has a nasalised vowel or a syllabic nasal. As such, syllables like *zṼ, *zN, *zGṼ, *zṼG, *zGṼG are all prohibited to occur. This also reflects the operation of the OCP between voiced onset and vocalic nasality, prohibiting the voiced fricative to occur before a nucleus that features nasality. In contrast, it is allowed to appear before final types such as V, VN, GV, GVG, GVN, VP, and GVP whose nucleus is [-nasal].

(4) Voiceless occlusives and affricates cannot occur before the GṼG final type. Specifically, syllables like *pGṼG, *pʰGṼG, *tGṼG, *tʰGṼG, *kGṼG, *kʰGṼG, *tsGṼG, and *tsʰGṼG are all prohibited and cannot be attested. In contrast, their voiced counterparts can occur before this final structure, such as ɓGṼG, ɗGṼG, and ɠGṼG are observable in the data. What worths a further mention is that these voiced obstruent onsets are essentially realized as their nasal counterparts at the surface level; and only a few tokens are found with the GṼG structure in the data (Huang, 2019).

(5) The labial obstruent onsets /p, pʰ, ɓ/ cannot occur in syllables containing a segment of [+labial] feature. Syllables like *Pm, *Pɐm; *Pim; *Pɔm; *Pjɐm; *Pɐp; *Pip; *Pɔp; *Pjɐp *Pjũ, *Pjɔ; *Pjɔ̃; *Pjɔŋ; and *Pjɔk are not attested, because of the shared labial feature between the onset and other syllable constituent of nucleus and/or coda. This labial restriction is also often reported in other Chinese dialects, such as in Wu (Zhang, 2006) and Cantonese (Kirby & Yu, 2007). However, few exceptions can also be seen as syllables Pju and Pjɵ are well-formed, such as /pjɵ35/ 'bid'; /ɓjɵ33/ 'temple', and /pʰju35/ 'fleet away'.

(6) The co-occurrence of labial nucleus and labial coda are not banned by this labial constraint. This is because the final types ɔm and ɔp are both well-formed and syllables like tɔm, tʰɔm, ɗɔm, sɔm, ʔɔm, ɗɔp, tsɔp, tsʰɔp, sɔp, and ɦɔp are all well tested, such as /sɔm35/ 'ginseng'; /ʔɔm35/ 'cover with hands'; /ɦɔp41/ 'catch with a cover or net'.

(7) The low back rounded vowel /ɔ/ is prohibited to occur before a coronal coda. As such, finals ɔn and ɔt are both ill-formed and syllables like *sɔn and *kɔt are not accepted. In contrast, this vowel can precede a labial or velar coda to form syllables like /sɔp221/ 'swob' and /kɔk41/ 'country'.

(8) The high back rounded oral vowel /u/ appears to be in a complementary distribution with its low counterpart /ɔ/ in the VX final type. It can only occur somewhere the /ɔ/ is prohibited and is banned to appear where the vowel /ɔ/ is allowable. As such, finals like *um *uŋ, *up, and *uk are disfavored, while finals like un and ut are accepted. For example, /kun35/ 'military' and /kut41/ 'bone' are practically used by the native speakers.

(9) The final /jɔ̃/ is more productive than its oral counterpart /jɔ/ to form syllables that can be attested empirically. Only one syllable/morpheme (/ɦjɔ41/ 'affirmative') contains the final jɔ. In contrast, its nasalized counterpart final /jɔ̃/

is able to combine 9 out 15 different onsets to form 31 attested syllables, such as tjɔ̃, ɗjɔ̃, kjɔ̃, kʰjɔ̃, tsjɔ̃, tsʰjɔ̃, sjɔ̃, ɦjɔ̃, and ʔjɔ̃. For example, /tjɔ̃41/ 'go up; rise'; /kjɔ̃35/ 'ginger'; /sjɔ̃35/ 'box, case'.

6 Discussion

As discussed, more than 71% of theoretically permissible syllables cannot be attested in the synchronic speech of Zhangzhou Southern Min, implying the segmental sequencing and segmental-suprasegmental alignment have been severely constrained in this dialect. This study conducted a comprehensive exploration into what phonotactic constraints have blocked the creativity of Zhangzhou onsets and restrict their combinability with other syllable components and tone, and how the phonotactics can be quantified. Explanations from both synchronic and diachronic perspectives have been given to interpret the mechanisms underlying such phonotactic constraints. This study substantially broadens our knowledge of phonotactics as a linguistic phenomenon in Sinitic languages with rich tonal contrasts. It also contributes well-attested data to generalise cross-linguistic tendency of phonotactics in world's natural languages, while shedding an important light on modeling and quantifying speakers' mental grammar of phonotactic restrictions using experimental methods.

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