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Distribution of the Mandarin vowels in typological perspective*

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Lee, Ok Joo and Yan Xiong. 2021. Distribution of the Mandarin vowels in typological perspective. *Linguistic Research* 38(2): 329-363. The present study is designed to examine the distribution of the Mandarin vowels from a typological perspective. Despite little research on this topic, earlier literature has reported that Mandarin is an exceptional language which contains a larger number of uncommon marked vowels (e.g., Crothers 1978). The purpose of the present study is twofold. The primary aim is to achieve a better understanding of the typological features of the Mandarin vowel system by analyzing the frequency distribution of the Mandarin vowels and the relation between markedness and distribution. Another goal is to examine the vowel distribution differences between two types of language data, namely, lexicon and natural speech. Results of quantitative analyses reveal that with the most unmarked peripheral vowels /a/, /i/, and /u/ being the most frequently occurring ones, the overall vowel distribution patterns in Mandarin lexicon conform to the cross-linguistic tendencies of vowel distribution and markedness. While the tendency of most vowels favoring Tone 4 is found, the relative percentage of Tone 1 and Tone 3 occurrences appears to be higher in the low vowels than the high and mid vowels in lexicon. However, different distribution patterns emerge when comparing lexicon and natural speech, in that the mid vowels (i.e., /ə/, /ɤ/, /o/) and apical vowel (i.e., /ʅ/) appear at significantly higher frequencies in natural speech. The differences can be explained by the fact that these vowels occur in some high frequency words (e.g., 'de', 'wǒ', 'shì'). Findings of this study suggest that different claims in previous studies of phonological typology are in part attributed to the nature of the language data examined (e.g., phonemic inventory, lexicon, natural speech). **(Seoul National University)**

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1. Introduction

Phonological typology is certainly one way to understand the enormous variation of sounds in human languages and the possible limits on the variation. It examines the

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sound inventories, the sequencing of sounds, and their occurrence in different structural positions (Maddieson 2011: 534). It therefore helps us to understand sound universals, namely, universal tendencies of sound patterns across languages as well as absolute universals that hypothetically exist in all human languages. Much discussion on sound universals is constructed from examinations of the dominancy of some sounds over others. Although languages vary immensely in their sound inventory, there are cross-linguistic tendencies that some sounds occur in more languages than others (Croft 2003: 118-119). Some universals seem to have no exception: all languages have consonants and vowels, and they are structured into larger units such as syllables and words (Velupillai 2012: 69).

Recent studies of sound universals assume that unmarked sounds are more natural, normal, and widespread and that the degree of markedness of sound is negatively related to the occurring frequency. Markedness relations also define implicational hierarchies among sounds: sound X is more marked than sound Y if the presence of X implies the presences of Y but not vice versa (see Greenberg 1966: 17, 1976; Gamkrelidze 1978: 19-20; Maddieson 1984 for a detailed discussion of typological markedness of language sounds). For instance, we expect that if a language has marked vowels, it also has unmarked vowels corresponding to those marked ones.

Despite little discussion of typology on Chinese phonology, some intriguing peculiarity of the vowel system of Mandarin (i.e., a standard variety of Chinese) has been noted in earlier literature (e.g., Crothers 1978; Duanmu 2009, see Section 2). The Mandarin vowel inventory has been reported to be rather marginal, such that it shows a disproportional distribution between unmarked vowels and marked vowels. That is, a relatively large number of uncommon marked vowels appear in the system, some of which have no corresponding unmarked ones. Furthermore, some marked vowels occur at higher frequencies in the corpus of commonly used characters (i.e., morphemes). However, earlier examinations of the vowel inventory of Mandarin bear at least two major limitations: first, phonemicization of the Mandarin vowels varies to a large extent (e.g., 5 vowels in Duanmu 2007, Lin 2007, 6 vowels in Yang and Oh 2020, 7 vowels in Shi 2002, Zhang 2002, and 9 vowels in Lin and Wang 2013). Therefore, different typological characteristics are likely to be claimed depending on how many and which vowels are included as phonemes in the inventory. Second, since a majority of research focuses on the phonemic inventory, it gives little information on how vowels are distributed in lexicon or natural spoken language.

The present study is designed to investigate the typological characteristics of the Mandarin vowels through quantitative analyses of vowel distribution patterns. The purpose of this study is twofold. The primary goal is to understand the frequency distribution of the Mandarin vowels and its relation to markedness. It also aims to examine the vowel distribution differences between two types of language data, namely, lexicon and natural speech. To achieve the research goals, two types of corpus are analyzed: a lexicon corpus of 109,223 character tokens and a natural spoken language corpus of 61,041 character tokens. The numbers of syllables with tone contrasts are 1,226 and 976 in lexicon and natural speech, respectively. Since vowels can occur in three positions of syllable (i.e., pre-nuclear, nuclear, and post-nuclear positions) in Mandarin, the vowel distribution is examined with regard to the position where the vowel occurs. Considering that only the nuclear vowel is obligatory, the analysis of this study centers the distribution patterns of the nuclear vowels, including the so-called hidden vowels which are not transcribed in the pinyin transcription (see Section 3 for a detailed discussion of data and methodology). Given the paucity of phonological typology research on Chinese, findings of this study will shed light on sound similarities and differences between Mandarin and other varieties of Chinese as well as those between Chinese and other languages.

This paper is organized as follows. Section 2 gives a brief overview of the Mandarin phonology with the following introduction of language universals relevant to the Mandarin vowels. Section 3 discusses the datasets and analysis methods employed for the study. Section 4 presents the results, and the conclusions and the typological implications of the results are discussed in Section 5.

2. Background

2.1 Mandarin sound inventory

The sound inventory of Chinese has three primary components: consonants, vowels, and lexical tones. While a syllable, which generally corresponds to a morpheme, is composed of these three components, the inventory for each component differs greatly across the varieties of Chinese. It is generally agreed that Mandarin has twenty two consonants, as shown in Table 1. In the table, the pinyin letters and the IPA transcription in the square bracket are given, and the cells for aspirated sounds are shaded. Most consonants can occur in syllable initial position, but /ŋ/ can only appear in the coda. Among the consonants, the three palatals occur only when one of the pre-nuclear glides /j/, /ɥ/ or nuclear vowels /i/, /y/ follows. Due to this constraint, some phonologists treat the palatals as phonetic variants of other consonants such as the dentals (e.g., Duanmu 2007; Lin 2007).

Table 1. Consonant inventory of Mandarin

	labial		labio-dental	dental		post-alveolar		palatal		velar	
stop	b[p]	p[pʰ]		d[t]	t[tʰ]					g[k]	k[kʰ]
fricative			f[f]	s[s]		sh[ʂ]		x[ɕ]		h[x]	
affricate				z[ts]	c[tsʰ]	zh[tʂ]	ch[tʂʰ]	j[tɕ]	q[tɕʰ]		
nasal	m[m]			n[n]						ng[ŋ]	
approximant						r[r]					
lateral				l[l]							

Leaving aside interjections, Mandarin is often said to have six vowels, namely, four high vowels, one mid vowel, and one low vowel. The vowel inventory is shown in Table 2. As presented in the table, there is no one-to-one correspondence between the pinyin letters and the sounds transcribed in IPA. For instance, ‘i’ in pinyin represents [i], [ɿ], or [ʅ], while the high back rounded vowel [u] is written as ‘u’ or ‘o’ in pinyin depending on where it occurs in syllable.

Table 2. Vowel inventory of Mandarin

	front		central	back	
	unrounded	rounded	unrounded	unrounded	rounded
high	i[i]	ü[y]	i[ɿ, ʅ]		u/o[u]
mid	e/o[e, ə, ɤ, o]				
low	a[a, ɑ, ɛ]				

However, the phonemic classification of the Mandarin vowels can differ primarily for two reasons. The first reason relates to the high central unrounded, which unlike other vowels, involves the tongue tip in articulation. It has two phonetic variants, [ɿ] and [ʅ], that are limited in distribution: [ɿ] occurs only after the dental fricative and affricates in nuclear position with no following coda, and [ʅ] occurs only after the post-alveolar consonants (i.e., retroflex) in nuclear position with no following coda. While they have been traditionally treated as 'apical vowels',[1] some phonologists treat them as syllabic approximants or syllabic consonants, i.e., the voiced extension of the preceding fricatives (Lee and Zee 2003; Lin 2007: 72; Lee-Kim 2014; Chao 1968: 24; Duanmu 2007: 36-37). The second complication concerns how to treat allophonic variations. For instance, the mid vowel has four phonetic variants [e], [ə], [ɤ], and [o], which are all in complimentary distribution. The low vowel also has three allophonic variants [a], [ɑ], and [ɛ]. The phonemicization of the mid and low vowels largely varies in literature.

For a thorough examination of the vowel properties and distribution patterns, the present study regards [ɿ] and [ʅ] as two high central vowels and treats the allophonic variations in Table 2 as different vowels to analyze them separately. A detailed distinction among vowels can shed light on the relation between articulatory or acoustic qualities of vowels and their distribution patterns. For instance, if we posit only one mid vowel for phonemic economy (e.g., Duanmu 2007), then it would be difficult to examine the distribution of the variants of the mid vowel and its relation with vowel properties. When necessary, some of the vowels will be combined for further analysis. Table 3 presents the twelve vowel inventory for this study that contains five high vowels, five mid vowels, and two low vowels.

Table 3. Mandarin vowels for present study

	front		central	back	
	unrounded	rounded	unrounded	unrounded	rounded
high	i[i]	ü[y]	i[ɿ], i[ʅ]		u/o[u]
mid	a[ɛ], e[e]		e[ə]	e[ɤ]	o/u[o]
low	a[a]			a[ɑ]	

Mandarin has four tones, which are often labeled as Tone 1 to Tone 4 for ease of reference. The pitch value is based on Chao's five-number scale, in which '5' indicates the highest pitch and '1' indicates the lowest pitch (Chao 1930, 1968: 26). The iconic tone mark is placed on the nuclear vowel in the pinyin transcription. Table 4 presents a well-known set of words with identical segments and differing tones.

1 The term 'apical vowel' and the symbols [ɿ, ʅ], which have been widely adopted in the field of Chinese phonology, are from Karlgren's *Etudes sur la phonologie chinoise* (Chinese translation 中国音韵学研究 by Chao, Luo, and Li 1948: 197-199).

Table 4. Tone inventory of Mandarin

tone number	pitch pattern	pitch value	example
1	high level	55	mā [ma]$_{55}$ 'mother' 妈
2	rising	35	má [ma]$_{35}$ 'hemp' 麻
3	falling-rising	214	mǎ [ma]$_{214}$ 'horse' 马
4	high falling	51	mà [ma]$_{51}$ 'scold' 骂

Among the four tones, Tone 3 has a few phonetic variants. While it can be realized as '214' in phrase final position, it becomes shortened as '21' in non-final position when followed by Tone 1, 2, or 4. When followed by another Tone 3, it becomes Tone 2.[2]

2.2 Sound universals and Mandarin vowels

Despite the immense diversity of languages sounds, there are asymmetries in that some sounds occur more frequently than others. For instance, among over fifty plosives, [p], [t] and [k] are extremely common across languages, while the voiced uvular plosive [G] is relatively rare (Crothers 1978). Likewise, oral vowels are more common than nasal vowels across languages (Ferguson 1966: 58). Imposing the notion of markedness to the asymmetrical distribution of sounds, the sounds more widely distributed than others are defined to be relatively unmarked, while the marked sounds are designated to be restricted in distribution.[3] Therefore, we can say that [p], [t] and [k] are relatively unmarked plosives, and that nasal vowels are marked vowel types.

As for a typology established by the content of vowel inventories, several universals have been discovered. First, the most common set of phonemic vowel qualities is /i, e, a, o, u/, and most languages with more than five basic vowels include these qualities (Maddieson 2011: 542). Second, when considering height, backness, and lip-rounding to be the three dimensions to distinguish vowel qualities, height is the primary distinctive feature even in very small inventories. Even when a language has only two phonologically contrastive vowels, the differences will always be in the vowel height

2 The Tone 2 derived from Tone 3 is not phonetically identical to the original Tone 2, in that the derived Tone 2 has a slightly lower pitch. However, native speakers do not perceive the differences between the original Tone 2 and the derived Tone 2 (Wang and Li 1967; Zee 1980a; Peng 2000).

3 The notion of markedness was pioneered by the Prague School of Linguistics in the theories of Trubetzkoy (1939) and Jakobson (1941). According to this earliest notion, one member of the sounds distinguished by only one feature has a wider distribution in contrast to the other member within a given language and across languages. The less widely distributed member is more marked than the other.

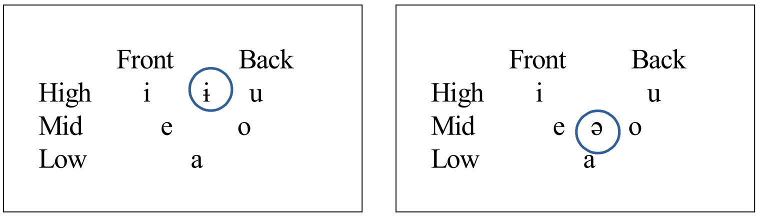
dimension rather than in the backness or lip-rounding dimension (Ladefoged and Maddieson 1996: 286). Third, there is a strong tendency that vowel systems are peripherally symmetrical and that if asymmetrical, they have more front vowels than back vowels. The term ‘peripherally symmetrical’ means that the vowels located at the outer borders of the so-called vowel space tend to occur in the same heights in both the front and the back (Schwartz et al. 1997). Fourth, while high and mid vowels tend to have front and back counterparts, low vowel tends to have no backness contrast. This often makes the vowel system prefer an odd number of peripheral vowels, as in /i, e, ɛ, a, ɔ, o, u/ (Schwartz et al. 1997: 243). Last, markedness of roundness interacts with other vowel qualities. That is, roundness is marked in front vowels and unmarked in back vowels. Therefore, front vowels are usually unrounded, whereas back vowels are usually rounded. The most common vowel system in human languages has five peripheral vowels as in Figure 1.

	Front				Back
High	i				u
Mid		e		o	
Low			a		

Figure 1. Five vowel system

Basic peripheral vowels, which are acoustically farther apart from one another in the vowel space, are considered to be unmarked (Kingston 2007: 409). They include the front unrounded, back rounded, and low vowels. On the other hand, marked interior vowels include those articulated in a central position as well as front rounded, back unrounded, and non-low central vowels (Crothers 1978: 100).[4] As the number of vowels increases, interior vowels are added to the vowel inventory. For instance, a very common six vowel system tends to contain five peripheral vowels and one interior vowel, i.e., either /ɨ/ as in Figure 2a or /ə/ as in Figure 2b (Spencer 1996: 118-120).

4 Peripheral vowels are defined acoustically, in that low peripheral vowels have higher F1 values while high vowels have either the lowest or the highest F2 and F3 values. In contrast, these acoustic properties do not vary significantly when the tongue body is central or when the lips are rounded in front vowels or unrounded in back ones (Kingston 2007: 409).



(a) (b)

Figure 2. Six vowel system

In spite of little typological research on the sounds of Mandarin, it has been reported that the Mandarin vowel system runs counter to universals. According to Crothers (1978), Mandarin shows an exceptional distribution of the unmarked peripheral vowels and marked interior vowels, as shown in Figure 3. In the figure, the vowels outside the circle are peripheral and those inside the circle are interior.

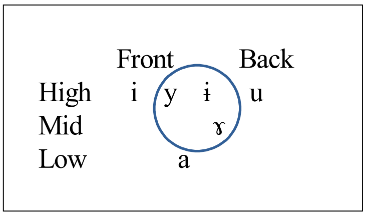


Figure 3. Mandarin vowel system (Crothers 1978)

More specifically, Crothers (1978: 93-152) argues that the Mandarin vowel system is incompatible with vowel universals at least in five aspects: (a) with low vowels excluded, the number of interior vowels cannot exceed the number of front and back vowels. However, Mandarin only has two peripheral vowels /i/ and /u/, but has three interior vowels /y/, /ɨ/, and /ɤ/. (b) A non-low back unrounded vowel of a given height generally implies a back rounded vowel of the same height. However, Mandarin has /ɤ/ but does not have /o/. (c) A back unrounded vowel of a given height implies a front unrounded vowel of the same height. But Mandarin has /ɤ/ but does not have /e/ or /ɛ/. (d) A height contrast in the interior vowels is not common, but /y/ and /ɤ/ differ in height. (e) Interior vowels generally have the same degree of backness (i.e., front rounded or back unrounded). However, /y/, /ɨ/, and /ɤ/ all differ in backness.

In addition, Mandarin does not seem to conform to the cross-linguistic correlation between vowel properties and occurring frequency. For instance, typological observations find that mid vowels are more common than high vowels, which in turn are more common than low vowels (i.e., 'mid > high > low'). Among high vowels, front vowels are more frequent than back vowels (i.e., 'high front > high back') (Maddieson 1984: 123-135). However, Duanmu (2009: 92) finds no significant distributional difference among /i/, /u/, and /a/ in Mandarin. Furthermore, although markedness increases in the order of '/a/ « /i/ « /u/' (Crothers 1978: 100), the occurring frequency among the three vowels in Mandarin does not differ much: /i/ (14.27%) > /a/ (13.78%) > /u/ (13.40%). Duanmu's analysis of the most commonly used 2,500 characters rather finds a higher frequency of the cross-linguistically uncommon apical vowel /ʅ/, with 'shi' being the most common syllable in Mandarin.

3. Research questions and methodology

The present study raises questions of whether and how the Mandarin vowel system is typologically distinguished from those of other languages. Considering that results of the phoneme-based analysis in early literature vary depending on how sounds are phonemicized and do not reveal how frequently sounds occur in a language,[5] this study analyzes the distribution characteristics of the Mandarin vowels in lexicon and further compares them to the distribution patterns in natural speech. Section 3.1 first lists the specific research questions for the study, and Sections 3.2 and 3.3 explain two types of data and the data analysis method, respectively.

3.1 Research questions

The specific research questions that the present study aims to provide answers to are as follows:

1) What is the relation between the vowel distribution and markedness in Mandarin? Do the vowel distribution patterns of Mandarin indeed run counter to sound universals?

2) How are the Mandarin vowels distributed in lexicon and natural speech? Are there any differences between the distribution patterns in lexicon and those in natural speech? If yes, what are the factors that cause such differences?

5 For example, the UPSID lists 393 languages that have /i/ and 392 languages that have /a/. But /a/ tends to be the most frequent vowel in most languages (Ladefoged 2005: 175).

3) Are there any distributional relations between vowels and tones in Mandarin?

3.2 Data

In order to understand the vowel distribution patterns in Mandarin, two types of corpus are analyzed, namely, a lexicon corpus of 109,223 character tokens and a natural spoken language corpus of 61,041 character tokens. The corpus used to analyze the vowel frequency patterns in lexicon is Mandarin Syllable Frequency Counts for Chinese Characters (Tsai 2000), which was constructed from Libtabe's Lexicon (version 0.1.3). In total, 13,045 characters were extracted after manually correcting the mislabeled pronunciations and excluding one repeated character and the characters of which pronunciations are not provided in Modern Chinese Dictionary (现代汉语词典 7th edition, Chinese Academy of Social Sciences Institute of Linguistics 中国社会科学院语言研究所词典编辑室 2016).[6] The vowel frequencies of 13,045 characters were analyzed in the present study.

To examine the relative use frequencies of the vowels in natural speech, a corpus of conversations was built by transcribing the TV talk show programs Face-to-Face (面对面), Highlighters (高光者), and Kefan's Listening (可凡倾听). These talk shows were chosen since the interviewer and interviewee in each show had unscripted spontaneous conversations in standard Mandarin. The shows were produced from 2013 through 2018, and the interviewers were in their 30's or 40's and the interviewees were from nineteen to sixty four in age when the shows were on air. Thirteen talk show episodes were transcribed in Chinese characters by the authors. After excluding exclamations (e.g., 哎呀, 唉, 啊, 哦) and syllables only with nasal (e.g., 嗯) as well as a few English words, a total of 61,041 character tokens were included in the corpus. Table 5 gives information on each show episode.

6 Mandarin Syllable Frequency Counts for Chinese Characters contains 28 characters labelled with incorrect pronunciations, 1 repeated character, and 13 characters of which pronunciations are not provided in Modern Chinese Dictionary.

Table 5. TV talk shows transcribed for Mandarin natural speech corpus

	interviewer	interviewee	main topic	episode time	number of character tokens
1	董倩(F)	哈文(F)	producing TV show Spring Festival	11:22	2,385
2	董倩(F)	刘洋(F)	aviation experience and training	14:47	3,408
3	王宁(F)	蒋欣(F)	life as an actress	18:23	3,149
4	董倩(F)	廖智(F)	dancing as an earthquake survivor who lost her legs	41:19	7,254
5	王宁(F)	董卿(F)	working as a TV program producer and host	22:05	3,920
6	董倩(F)	王威(F)	cancer survival	41:55	7,182
7	董倩(F)	张艺谋(M)	film directing	22:28	3,335
8	王宁(F)	梁枫(M)	import exhibition	20:42	2,766
9	董倩(F)	李彦宏(M)	internet, AI, Baidu	19:48	4,392
10	董倩(F)	姚明(M)	sports	13:05	2,960
11	古兵(M)	唐帅(M)	working as a lawyer for the deaf	25:08	4,835
12	曹可凡(M)	胡歌(M)	car accident and filming experience	22:58	4,568
13	何润锋(M)	王源(M)	music composition and study	48:53	10,887
			total character tokens:		61,041

Both lexicon and natural speech contain a large number of repeated characters. After repetitions were excluded, 13,045 characters and 1,882 characters were extracted in lexicon and natural speech, respectively. The numbers of syllables with tone contrasts are 1,226 and 976, and those with no tone contrasts are 404 and 378 in lexicon and natural speech, respectively. These are summarized in Table 6.

Table 6. Numbers of characters and syllables in Mandarin lexicon and natural speech

	lexicon	natural speech
total number of character tokens	109,223	61,041
number of characters after excluding repetitions	13,045	1,882
number of syllables with tone contrast included	1,226	976
number of syllables with tone contrast excluded	404	378

In order to achieve separate pictures of the overall distribution patterns in the language and the actual use frequencies in everyday speech, the repetitions were eliminated from the lexicon corpus while the repetitions were included in the natural speech corpus. In other words, the absolute frequency is analyzed in lexicon, while the frequency weighed by the actual use is examined in natural speech. Therefore, the vowels of 13,045 characters in lexicon and those of 61,041 characters in natural speech were analyzed.

3.3 Analysis

As introduced in Section 2.1, the twelve vowels were analyzed in the present study: /i/, /y/, /ɿ/, /ʅ/, /u/, /ɛ/, /e/, /ə/, /ɤ/, /o/, /a/, /ɑ/. Several considerations were made for the vowel analyses. First, when Mandarin Syllable Frequency Counts for Chinese Characters provides two or more pronunciations for a character in lexicon, the first pronunciation, which is the most frequent pronunciation, was chosen. In the case of natural speech, the pronunciation corresponding to the contextually given meaning was selected when a character has more than one pronunciation (e.g., [lə] for particle 了, [ljɑu] for 'to understand' 了(解)). When a character has a non-standard alternative pronunciation, the standard pronunciation provided in Modern Chinese Dictionary was chosen (e.g., [xwɑ] (not [xwar]) for 'flower' 花, [ʂei] (not [ʂwei]) for 'who' 谁).

Second, vowels can occur in three positions of syllable, i.e., pre-nuclear, nuclear, and post-nuclear positions. Since only the nuclear vowel is obligatory in Mandarin, the vowel analysis centers the vowel distribution patterns in nuclear position. While the pre-nuclear and post-nuclear components are optional, the issue of whether the pre-nuclear components should be treated as consonants or vowels is still controversial. Following the Chinese phonology tradition, this study included the pre-nuclear components in the vowel analysis. However, they were transcribed as the approximant symbols, /j/, /w/, and /ɥ/, so as to be distinguished from the vowels in nuclear and post-nuclear positions. The post-nuclear components were transcribed using the vowel symbols, /i/ and /u/, since they are generally treated as vowels.

Third, there are some nuclear vowels that are omitted in the pinyin transcription (i.e., /e/ in '-ui', /ə/ in '-un' and '-ing', and /o/ in '-iu'). These 'hidden' vowels were also transcribed and included in the nuclear vowel analysis.

Last, tone sandhi (i.e., T3 change and tone changes of 'yi (一)' and 'bu (不)') applies to a small number of syllables in natural speech. The original lexical tones (not the changed tones) were transcribed when analyzing the relation between vowels and tones.

Table 7 shows the correspondence between the IPA transcription of the twelve vowels and the pinyin letters. The conversion from the pinyin system to the IPA transcription for all Mandarin syllables examined in this study is provided in *Appendix*.

Table 7. Mandarin vowels in IPA and pinyin

	vowel	pinyin
high	/i/	‘i’, ‘yi’
	/y/	‘ü’, ‘yu’, ‘u’ (after ‘j’, ‘q’, ‘x’)
	/u/	‘u’, ‘wu’, ‘o’ (in syllable final position; before ‘ng’)
	/ɿ/	‘i’ (after ‘z’, ‘c’, ‘s’)
	/ʅ/	‘i’ (after ‘zh’, ‘ch’, ‘sh’, ‘r’)
mid	/e/	‘e’ (after ‘i’, ‘y’ in syllable final position; before ‘i’) hidden nucleus in ‘–ui’
	/ɛ/	‘a’ (between ‘y/i’ and ‘n’)
	/ə/	‘e’ (before ‘n’, ‘ng’, ‘r’) hidden nucleus in ‘–un’, ‘-ing’
	/ɤ/	‘e’ (in syllable final position in CV syllable)
	/o/	‘o’ (after ‘u’ in syllable final position; before ‘u’) hidden nucleus in ‘–iu’
low	/a/	‘a’
	/ɑ/	‘a’ (before ‘ng’, ‘u’)

4. Results

The analysis results of the vowel distribution patterns and markedness with reference to syllable position (i.e., pre-nuclear, nuclear, and post-nuclear positions) and vowel height are presented in Section 4.1. The distributional relation between vowels and lexical tones is analyzed in Section 4.2, and the distributional differences between lexicon and natural speech are discussed in Section 4.3. In each section, we first present the results from lexicon and proceed to compare them to the results from natural speech.

4.1 Vowels and markedness

4.1.1 Overall vowel frequency distribution

One of the twelve Mandarin vowels in Table 3 occurs in nuclear position. However, one of /i/, /y/, and /u/ appears in pre-nuclear position, which are transcribed as the approximants /j/, /w/, and /ɥ/ in this study. In post-nuclear position, either /i/ or /u/ can occur. We present the distribution patterns of the nuclear vowels, followed by those of the pre-nuclear and post-nuclear vowels.

Nuclear vowels

Figure 4 shows the frequency distribution of the twelve nuclear vowels in Mandarin lexicon. The vowels are arranged in the order of frequency in the figure.

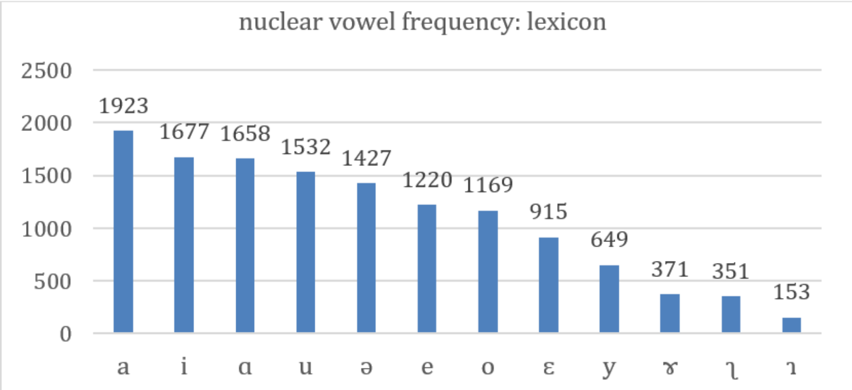


Figure 4. Nuclear vowel frequency of Mandarin lexicon

Figure 4 reveals that with /a/ being the most frequently occurring vowel, /a/, /i/, /ɑ/, and /u/ are the top four frequent vowels. The next four frequent vowels are the mid vowels /ə/, /e/, /o/, and /ɛ/, and the least frequent vowels include the high vowels /y/, /ʅ /, /ɿ/, and the mid vowel /ɤ/. Note that the four most frequent vowels consist of unmarked basic vowels, whereas the least frequent vowels are marked vowels. This result shows that the peripheral vowels occur at significantly higher frequencies than the interior vowels in Mandarin lexicon. If we make no backness distinction in low vowel and use /a/ to refer to the low vowel as most studies of phonological typology do, the most frequently occurring nuclear vowels in Mandarin are the unmarked peripheral vowels /a/, /i/, and /u/. This conforms to the relational universals between markedness and distribution: unmarked vowels show a wider distribution.

The exception to the relation between frequency and markedness seems to be the mid central vowel /ə/: although it is an interior vowel, it has a relatively high occurring frequency. But recall from Figure 2b that /ə/ is the common internal vowel that constructs a six vowel system with five peripheral vowels. Although /ə/ occurs more frequently than

/e/ and /o/, which are also common peripheral vowels, the presence of /ə/ along with /e/ and /o/ in Mandarin is in line with a typical vowel system.

Now let us look at the overlaid nuclear vowel frequency patterns of lexicon and natural speech in Figure 5. In the figure, the left y-axis corresponds to natural speech, and the right y-axis corresponds to lexicon. And the solid line and the dotted line correspond to lexicon and natural speech, respectively.

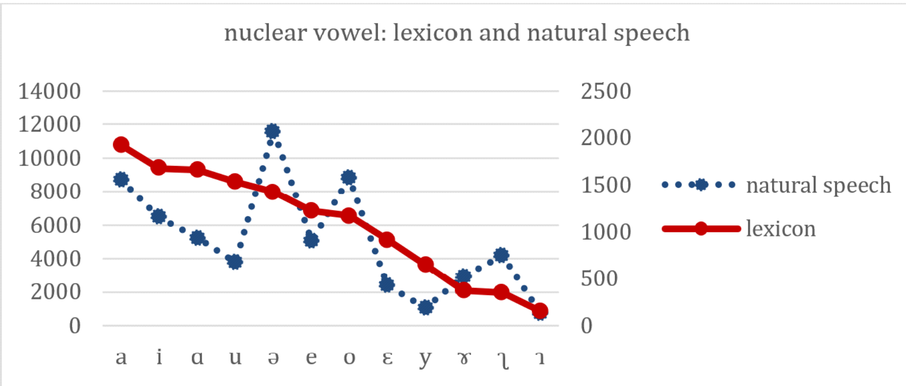


Figure 5. Nuclear vowel frequency of Mandarin lexicon and natural speech

As shown in Figure 5, the frequency patterns in lexicon and natural speech show both similarities and differences. While we can see a similar relative frequency among the basic unmarked vowels /a/, /i/, /ɑ/, and /u/, an intriguing discrepancy is also found: in natural speech, the vowel of the highest frequency is /ə/, and the frequencies of /o/ and /ʅ/ are notably high. The higher frequencies of /ə/, /o/, and /ʅ/ in natural speech should be related to the relative word frequencies of natural speech. The distributional differences between lexicon and natural speech presented in this section will be discussed in greater detail in Section 4.3.

Pre-nuclear and Post-nuclear vowels

The frequency of the pre-nuclear vowels is in the order of '/j/ > /w/ > /ɥ/', as shown in Figure 6. Note that the marked /ɥ/ occurs at a significantly lower frequency. This corresponds to the frequency order of the nuclear vowels '/i/ > /u/ > /y/'. In Figures 6 and 7, the left y-axis corresponds to natural speech while the right y-axis corresponds to lexicon, and the solid line and the dotted line correspond to lexicon and natural speech, respectively.

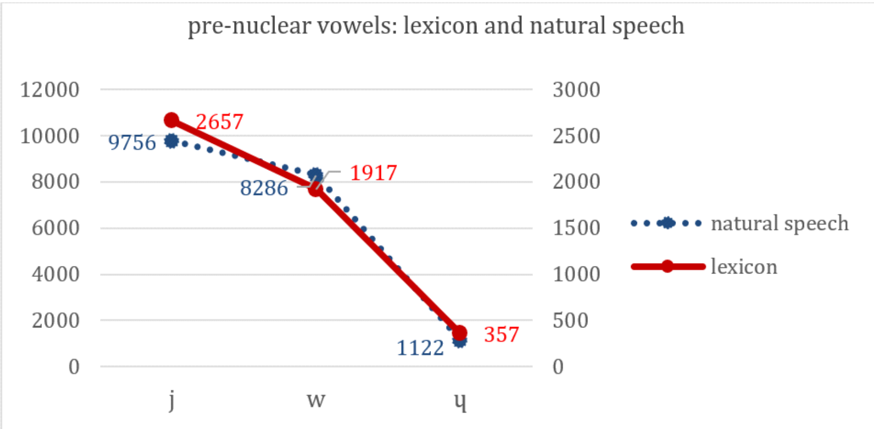


Figure 6. Pre-nuclear vowel frequency of Mandarin lexicon and natural speech

The post-nuclear vowels, on the other hand, show a reverse frequency order. As shown in Figure 7, /u/ occurs more frequently than /i/.

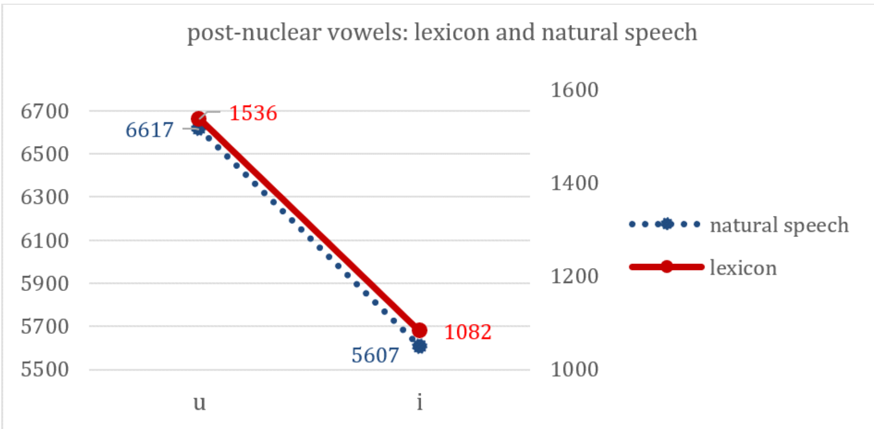


Figure 7. Post-nuclear vowel frequency of Mandarin lexicon and natural speech

While the relative frequency of /u/ and /i/ in post-nuclear position is different from that in pre-nuclear position, it should be noted that the overall occurring frequencies of the post-nuclear vowels are considerably low. This may be due to the fact that not only /u/ and /i/ but also the nasal consonants /n/ and /ŋ/ can occur in post-nuclear position in Mandarin. Also note that lexicon and natural speech show strikingly similar frequency patterns of both the pre-nuclear and post-nuclear vowels.

4.1.2 Unmarked vowel frequency distribution

Among the most unmarked vowels /a/, /i/, and /u/, markedness increases in the order of '/a/ « /i/ « /u/' (Crothers 1978: 100; Maddieson 1984: 123-135). However, Duanmu (2009: 92) finds no significant distributional difference among /a/, /i/, and /u/ in Mandarin (see Section 2.2). We analyzed the frequency distribution patterns of the most unmarked vowels /a/, /ɑ/, /i/, and /u/ in nuclear position as shown in Figures 8 and 9. Figure 8 shows the frequency analysis of /a/, /ɑ/, /i/, and /u/, while Figure 9 presents the frequency analysis of /a/, /i/, and /u/, in which /a/ represents the low vowel with no backness distinction. In Figures 8 to 10, the left y-axis and the right y-axis correspond to natural speech and lexicon, respectively. And the solid line and the dotted line represent lexicon and natural speech, respectively.

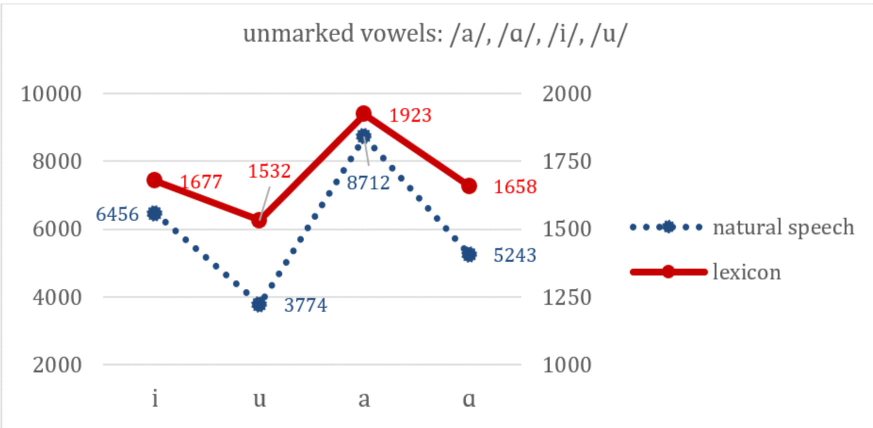


Figure 8. Frequency distribution of unmarked vowels in nuclear position (/a/ and /ɑ/ distinguished)

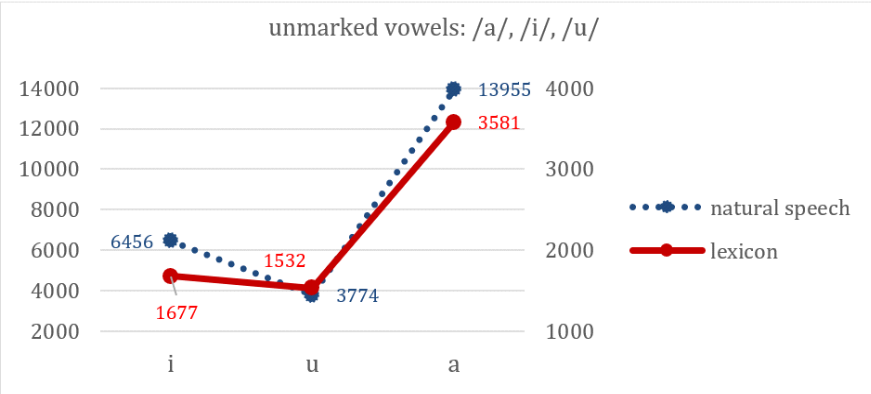


Figure 9. Frequency distribution of unmarked vowels in nuclear position (/a/ and /ɑ/ not distinguished)

Figure 8 presents the frequency order '/a/ > /i/ > /ɑ/ > /u/'. The highest frequency of the low vowel becomes very clear when the low vowels /a/ and /ɑ/ are combined, as in Figure 9. The frequency order of /a/, /i/, and /u/ is '/a/ > /i/ > /u/', with the low vowel being far more frequent than the high and back vowels. The patterns found in both lexicon and natural speech conform to the relational universals between markedness and distribution among the basic peripheral vowels.

However, somewhat different patterns emerge in Figure 10 when we analyze the vowels that appear in all three syllable positions (i.e., pre-nuclear, nuclear, and post-nuclear positions). In the figure, /a/ represents the low vowel with no backness distinction.

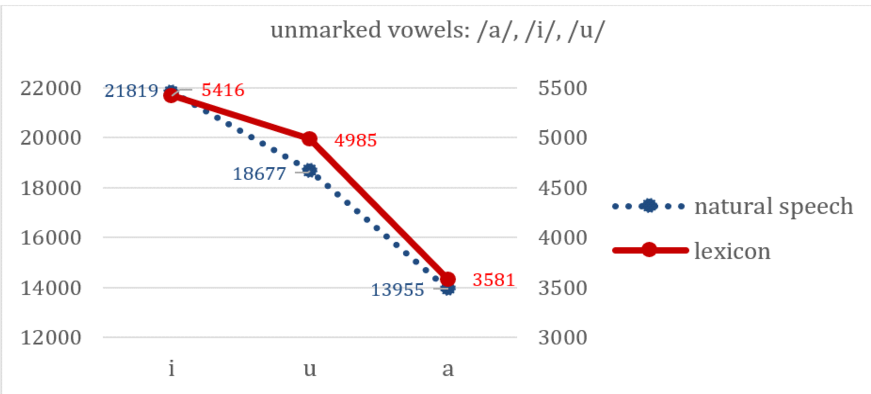


Figure 10. Frequency distribution of unmarked vowels in pre-nuclear, nuclear, and post-nuclear positions

Figure 10 shows that while /i/ has a higher frequency than /u/, the low vowel /a/ occurs at the lowest frequency in both lexicon and natural speech. This is due to the phonological constraint that, unlike /i/ and /u/, /a/ can appear neither in pre-nuclear position nor in post-nuclear position. The results presented in Figure 10 imply that we see different frequency patterns according to which syllable positions are analyzed. That is, depending on whether we examine the nuclear vowels or the vowels appearing in all possible positions, different results are yielded. It is also important to point out that the unmarked basic vowels show very similar frequency patterns in lexicon and natural speech in Figure 6 through Figure 10.

4.1.3 Vowel height and frequency distribution

Primary contrasts of vowel are made in the height dimension, and the frequency relation with height is known to be ‘mid > high > low’ (Maddieson 1984; Ladefoged and Maddieson 1996; see Section 2.2). In order to understand the relation between vowel height and frequency distribution in Mandarin, let us look at the occurring frequencies of the high, mid, and low vowels in nuclear position in lexicon in Figure 11 and those in natural speech in Figure 12. Since the question of whether the so-called apical vowels /ɿ/ and /ʅ/ are vowels or not can be controversial, the high vowels including the apical vowels and those not including the apical vowels are analyzed separately. In the figures, the solid line represents the analysis including the apical vowels, and the dotted line represents that excluding the apical vowels.

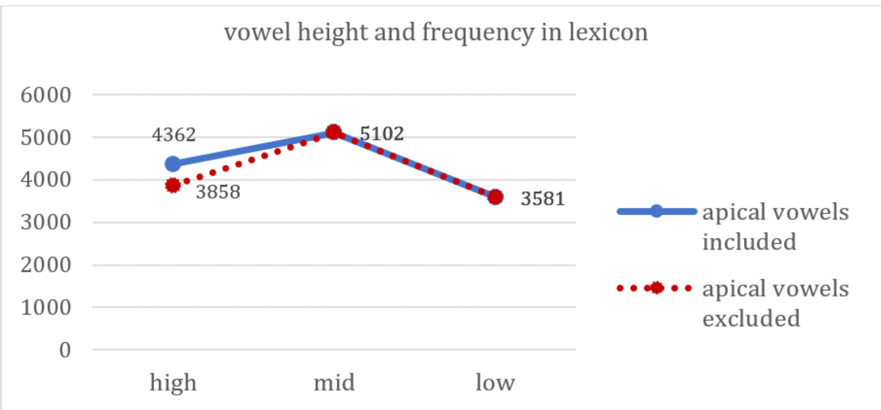


Figure 11. Vowel height and frequency in Mandarin lexicon

Figure 11 shows that although the low vowels /a/ and /ɑ/ are the two of the most frequently occurring vowels in Mandarin lexicon, the mid vowels are distributed at a higher frequency than the high and low vowels. A similar frequency pattern is found when excluding the apical vowels /ɿ/ and /ʅ/. These patterns conform to the cross-linguistic distribution tendency of ‘mid > high > low’ vowels.

A higher frequency of the mid vowels is more evident in natural speech. As shown in Figure 12, the frequency of the mid vowels is significantly higher than the high and low vowels. Recall that notable higher frequencies are observed among the mid vowels earlier in Figure 5. In particular, the vowel /ə/ is the most frequently occurring vowel in natural speech. Another point to make is a larger frequency difference between the high vowels with the apical vowels and those without the apical vowels. This is due to the relatively high occurring frequency of /ʅ/ presented also in Figure 5.

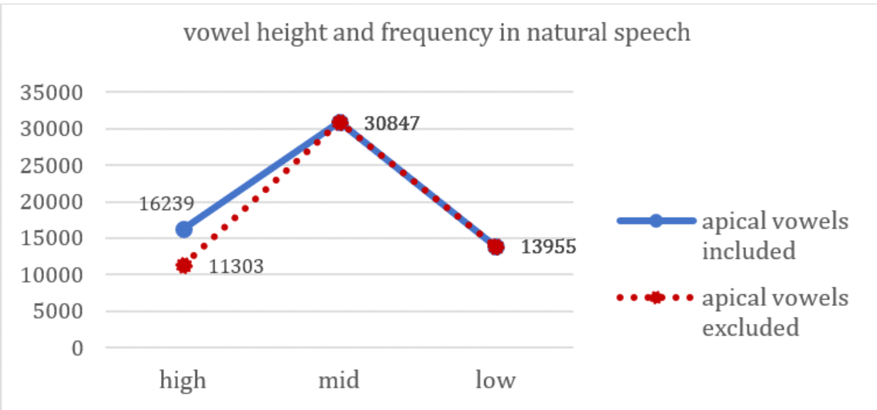


Figure 12. Vowel height and frequency in Mandarin natural speech

The distributional distinction between lexicon and natural speech raises the question of what may make the mid vowels (i.e., most notably schwa /ə/) and the apical vowel /ʅ/ occur at remarkably higher frequencies in natural speech. This question will be further explored in Section 4.3. Now, we turn to the question of whether the vowel occurrence has any relation with lexical tones in Mandarin.

4.2 Distributional relation between vowels and tones

The distributional relation between vowels and lexical tones is probably one of the least researched topics in phonological typology. One of the questions pertaining to the relation between vowels and tones is whether some vowel properties tend to prefer certain tone types. To tackle this question, the vowel frequency distribution is examined in relation to four lexical tones (i.e., T1, T2, T3, and T4) and neutral tone (i.e., toneless T0). First, we can look at the overall frequency distribution of four lexical tones and neutral tone in lexicon presented in Figure 13. As shown in the figure, T4 is the most frequently occurring tone type, and the frequency order is ‘T4 > T2 > T1 > T3’ from highest to lowest. This result is compatible with Duanmu (2009: 95), who finds that 33.5% of 2,500 common characters is T4 whereas 17.8% of those is T3.

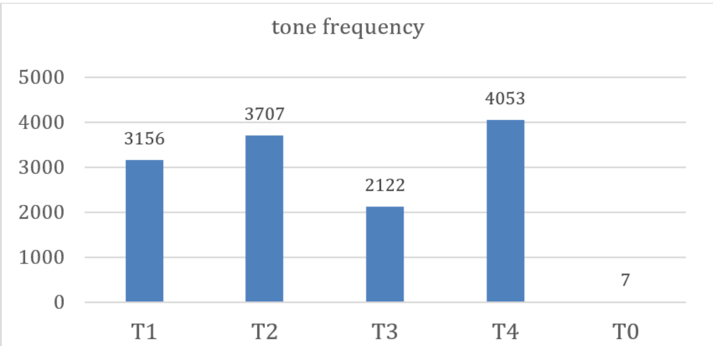


Figure 13. Tone frequency in Mandarin lexicon

An examination of the tone distribution in each vowel reveals that T3 and T4 tend to occur at the lowest frequency and at the highest frequency, respectively, in lexicon. As shown in Figure 14, this tendency is found across the vowels with the exception of /ɑ/, /ə/, /u/, and /ʅ/.

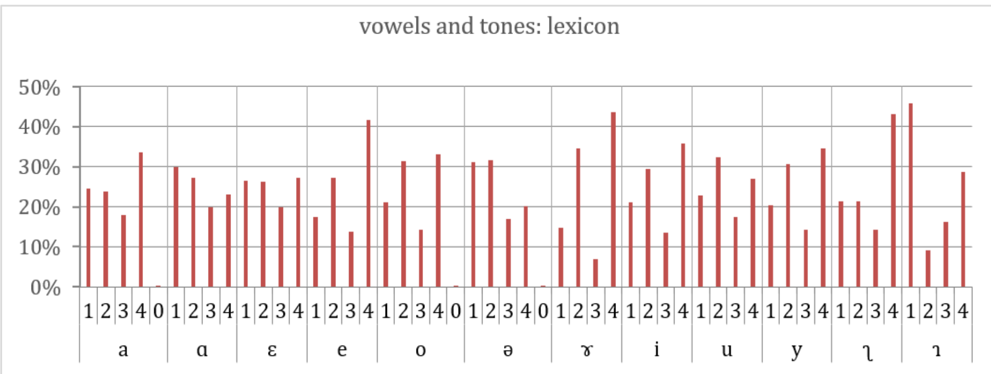


Figure 14. Tone frequency in each vowel in Mandarin lexicon

While T4 seems to be favored in most vowels, Figure 15 shows another interesting tendency: although the high and mid vowels are distributed in a similar fashion across the four tones, the low vowels show relatively high occurrences of Tone 1 and Tone 3 in comparison to the high and mid vowels. In the figure, the percentage of tones with regard to vowel height is analyzed. The correlation between vowels and tones could be intriguing, while a thorough examination of tone typology in relation to vowel qualities remains beyond the scope of the present study.

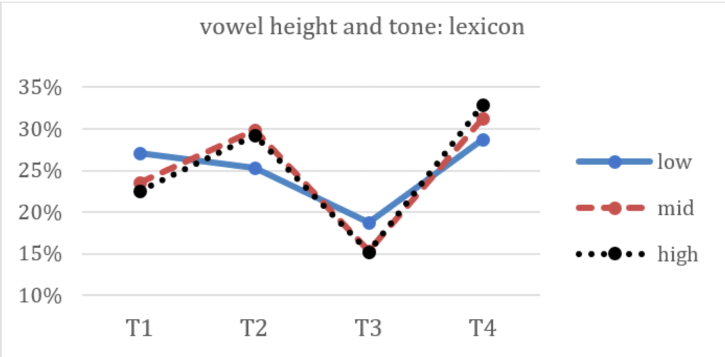


Figure 15. Vowel height and tone in Mandarin lexicon

The T4 dominance is more salient in natural speech, as shown in Figure 16. In the figure, the dotted bar corresponds to natural speech, whereas lexicon is represented by the solid bar for a comparative purpose. We can see that along with a significantly higher frequency of T4, T0 (i.e., neutral tone) appears at a higher frequency in natural speech.

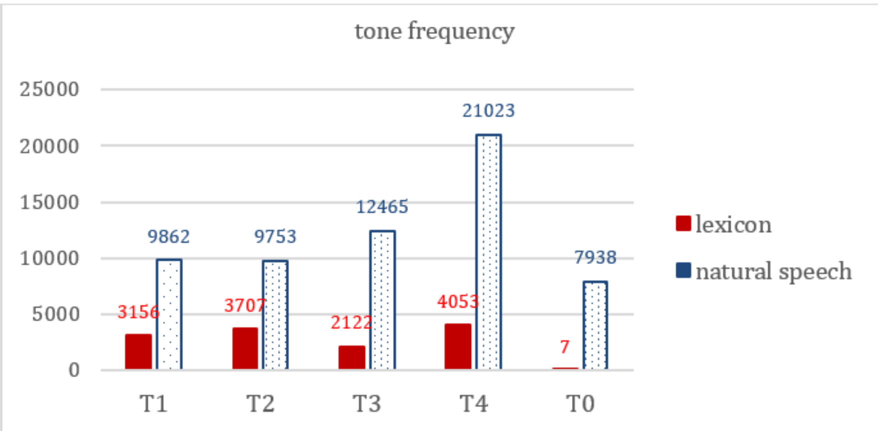


Figure 16. Tone frequency in Mandarin natural speech

An examination of the tone frequency distribution in each vowel shows the remarkably high frequencies of T4 and T0 in natural speech. As shown in Figure 17, the higher frequency of T4 is observed across the vowels with the exception of /o/, /ə/, and /i/. Considering that schwa /ə/ often occurs in T0 syllables in Mandarin (e.g., ‘le’ 了, ‘de’ 的), the high frequency of T0 is certainly correlated with the frequent occurrence of schwa in natural speech.

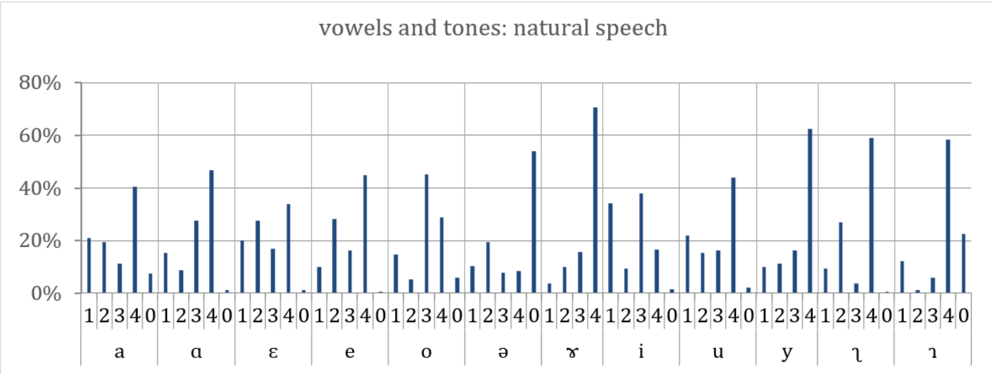


Figure 17. Tone frequency in each vowel in Mandarin natural speech

Figure 18 presents that as in lexicon, T4 occurs at the highest frequency in vowels of all heights in natural speech. However, the higher percentage of Tone 1 and Tone 3 occurrences in the low vowels found in lexicon is not observed in natural speech. While the high and low vowels show similar tone distributions, T0 appears at a higher frequency in the mid vowels. This is because T0 is often realized in syllables with schwa /ə/.

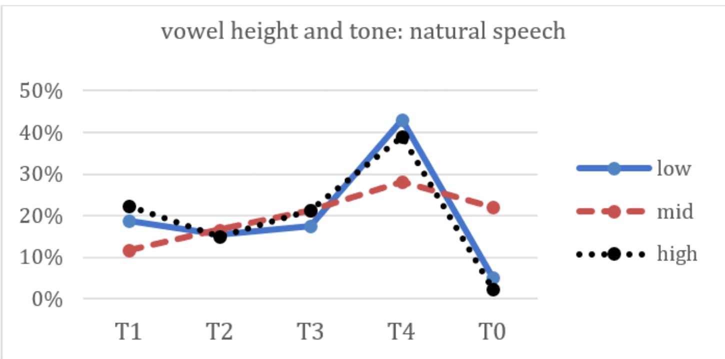


Figure 18. Vowel height and tone in Mandarin natural speech

4.3 Distributional differences between lexicon and natural speech

As presented in Sections 4.1 and 4.2, while the overall vowel distribution patterns in lexicon conform to the universal tendencies of vowel distribution and markedness (e.g., Crothers 1978; Maddieson 1984; Maddieson and Ladefoged 1996), an interesting difference between lexicon and natural speech is also found, in that some marked internal vowels occur at a significantly higher frequency in natural speech. In particular, the frequencies of the mid vowels /ə/, /ɤ/, and /o/ as well as the apical vowel /ʅ/ are notably high. This distribution discrepancy between lexicon and natural speech is due to the skewed syllable distribution in natural speech shown in Figure 19. Among 976 syllable types (including tone contrasts), which are the pronunciations of 61,041 characters, 201 syllable types appear only once or twice. In contrast, the most frequently used syllable type, namely ‘de’ [tə] with T0, occurs 3,295 times, and this takes up 5.4% of the total 61,041 syllable tokens.

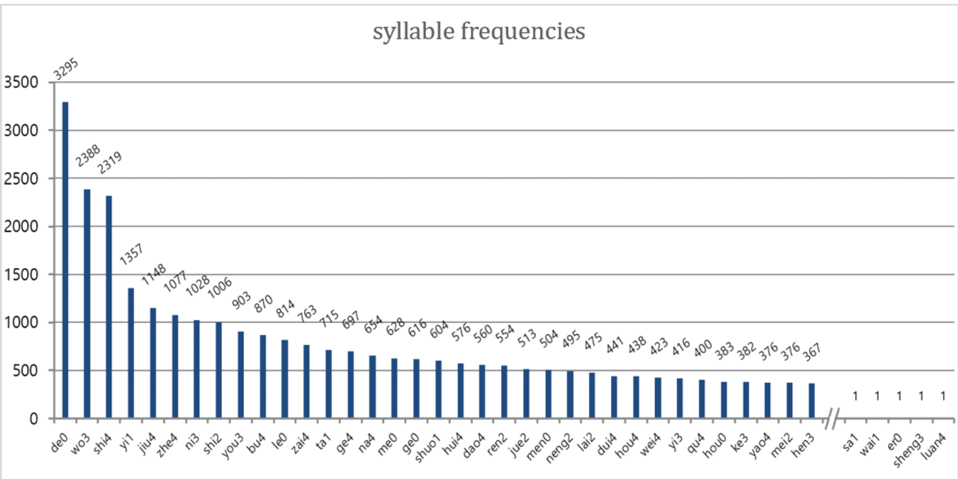


Figure 19. Syllable frequency in Mandarin natural speech

The syllable distribution patterns shown in Figure 19 are related to the relative word frequencies of natural speech. Table 8 shows the ten most frequently occurring syllable types in the pinyin transcription. The nuclear vowels that the syllables contain are also given. And the occurring frequency and cumulative percentage for each syllable are presented.

Table 8. Ten most frequent syllable types in Mandarin natural speech

frequency rank	syllable	nuclear vowel	occurring frequency	cumulative percentage
1	de	ə	3,295	5.40%
2	wǒ	o	2,388	9.31%
3	shì	ʅ	2,319	13.11%
4	yī	i	1,357	15.33%
5	jiù	('hidden') o	1,148	17.21%
6	zhè	ɤ	1,077	18.98%
7	nǐ	i	1,028	20.66%
8	shí	ʅ	1,006	22.31%
9	yǒu	o	903	23.79%
10	bù	u	870	25.21%

As shown in the table, the ten most frequent syllable types take up more than 25% of the total 61,041 syllable tokens. Note that /ə/ is the nuclear vowel of the most frequently occurring syllable 'de' and that /o/ appears in three syllables 'wǒ', 'jiù', and 'yǒu' (i.e., #2, #5, and #9 syllables). Another mid vowel /ɤ/ appears in 'zhè' (i.e., #6 syllable). Also note that the apical vowel following a retroflex consonant /ʅ/ occurs in two syllables 'shì' and 'shí' (i.e., #3 and #8 syllables). Therefore, the higher frequencies of /ə/, /ɤ/, /o/, and /ʅ/ in natural speech can be attributed to the fact that those vowels are included in the frequently occurring function words, pronouns, and verbs. This is shown in Table 9.

Table 9. Twenty most frequent characters in Mandarin natural speech

frequency rank	character	syllable	nuclear vowel
1	的	de (dí, dì)	ə (i)
2	我	wǒ	o
3	是	shì	ʅ
4	一	yī	i
5	个	ge (gè)	ə (ɤ)
6	就	jiù	('hidden') o
7	这	zhè	ɤ
8	你	nǐ	i
9	有	yǒu	o
10	了	le (liǎo)	ə (ɑ)
11	不	bù	u
12	在	zài	a
13	那	nà	a

14	么	me	ə
15	说	shuō	o
16	时	shí	ʅ
17	会	huì	(‘hidden’) e
18	得	de (dé, děi)	ə (ɤ, e)
19	人	rén	ə
20	们	men	ə

5. Discussion and conclusion

This study analyzed the distribution of the twelve vowels of Mandarin in two types of corpus: lexicon and natural speech. Results of the study show that with the most unmarked peripheral vowels /a/, /i/, and /u/ being the most frequently occurring vowels, the overall vowel distribution patterns in *lexicon* conform to the universal tendencies of vowel distribution and markedness (e.g., Crothers 1978; Maddieson 1984; Maddieson and Ladefoged 1996). The relation between vowel height and frequency distribution that has been claimed to exist across languages, namely, ‘mid > high > low’ is also found. The distributional differences between lexicon and natural speech can be attributed to the high frequency words that contain such marked internal vowels as /ə/, /ɤ/, and /ʅ/ as well as /o/ in natural speech.

A closer examination further reveals that the frequency distribution among the most unmarked vowels in *nuclear* position in both lexicon and natural speech is ‘/a/ > /i/ > /u/’, which also indicates that the distribution of the basic peripheral vowels in Mandarin is in line with sound universals. However, when the basic vowels in all three syllable positions (i.e., nuclear, pre-nuclear, and post-nuclear positions) are taken into account, the frequency order turns out to be ‘/i/ > /u/ > /a/’. This shows that depending on which syllable positions we count the occurring frequencies from, different vowel frequency patterns may emerge. When we consider that the most stable phonetic qualities and phonological status of vowels are realized in nuclear position, this study suggests that the vowel distribution of Mandarin should be based on the examination of nuclear vowels. We then find no convincing reason that the Mandarin vowel system should be considered exceptional in terms of sound universals (cf., Crothers 1978; Duanmu 2009).

In relation to the notably higher occurrence frequency of schwa in natural speech, the status of schwa in Mandarin needs a few additional comments. Possibly due to its acoustic distance from the peripheral vowels and the less effort required for articulation, schwa is the most preferred interior vowel in primary vowel systems and does not interact with other sounds in the system (cf., Schwartz et al. 1997). Therefore, the high frequency of schwa does not necessarily make the Mandarin vowel system much different from those of other languages. It should also be noted that tonal neutralization (i.e., deletion or significant reduction of lexical tone) is widely witnessed in unstressed syllables (e.g., second syllable of a disyllabic word) in Mandarin. Since the syllables of neutral tone in this study do not include those of tonal neutralization, we presume that the actual occurring frequency of schwa associated with unstressed syllables in spoken Mandarin must be considerably higher than that reported in the present study. It is also possible that the increasingly higher occurrence of schwa in Mandarin may represent its significance in mental lexicon, while this issue remains beyond the scope of this study.

Results of this study also suggest that there may be some possible distributional correlation between vowels and lexical tones in Mandarin. That is, although the tendency of most vowels favoring Tone 4 is found, Tone 1 and Tone 3 appear to occur at relatively high frequencies in the low vowels in lexicon. Tone 1 is a high level tone, while Tone 3 is often realized as a low level tone in non-final position of phrase or sentence although its citation form is transcribed as ‘214’ in Chao’s five-number scale. Then it is possible to conjecture that the level tones may be favored in the low vowels in Mandarin lexicon. While the relation between consonants and tones has been observed in a number of earlier studies (e.g., Zee 1980b; Hombert 1978; Chen 2000; Yip 2002; Xu and Xu 2003; Francis et al. 2006), the question of whether and how vowels may be related with tones is still far less clear. Although the association between low tones and low vowels has been reported in some Chinese dialects, studies on this matter often offer conflicting answers (Cao 2009; Cao and Wang 2009; Zhang and Xing 2011). Future research should be directed to the question of how vowel qualities interact with tone register and contour in Chinese.

The present study further demonstrates the importance of the analysis methods and the nature of language employed in studies of sound typology. While a large number of studies are based on phonemic inventories of languages, the phonemes posited for any given language can largely differ from one study to another. The phonemicization normally reflects various theoretical views on what sounds are, how they are arranged, and how they are constructed into larger units such as syllables. With high variability of phonemicization in mind, the present study does not adopt any theoretical point of view. Instead, it posits the twelve vowel inventory where some vowels can be treated as allophones of a phoneme in certain theories of phonology. The purpose is to achieve a clear picture of the typological features of the Mandarin vowels. It is surely possible for further studies to combine some of the vowels of this study into one sound for more abstract phonemic analyses.

Findings of this study indicate that different aspects of the sound system emerge depending on the nature of the language investigated. Phonemic inventory, lexicon, written texts, and spontaneous spoken language may yield different pictures of a language, some of which may be seemingly conflicting. In particular, a comparison of lexicon and natural speech in this study reveals the strikingly higher frequencies of the mid vowels and neutral tone in natural speech. This can be attributed to the word frequency distribution that is highly unbalanced. That is, some mid vowels appear in common words that are used at significantly higher frequencies than other words in everyday language, and this makes a notable difference between lexicon and natural speech in Mandarin. The theoretical implication of these findings concerns the fundamental assumption on the inverse relation between the markedness and frequency of occurrence of a sound, i.e., more natural and widespread sounds of a system are characterized as unmarked. Given that the naturalness or functional load of sounds can be measured by their relative frequencies, the present study suggests that *lexicon* should be the language system from which the correlation between the degree of markedness and occurrence frequencies can be found. It conforms to Gamkrelidze (1979: 20) who claims that the textual frequencies may serve only as an indirect reflection of the frequency of sounds in lexicon from which the markedness of sounds should be determined.

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Appendix: Pinyin and IPA Conversion Chart

pinyin	IPA	pinyin	IPA	pinyin	IPA	pinyin	IPA	pinyin	IPA
a	[a]	chan	[tʂʰan]	dei	[tei]	gai	[kai]	huai	[xwai]
ai	[ai]	chang	[tʂʰɑŋ]	den	[tən]	gan	[kan]	huan	[xwan]
an	[an]	chao	[tʂʰɑu]	deng	[təŋ]	gang	[kɑŋ]	huang	[xwɑŋ]
ang	[ɑŋ]	che	[tʂʰɤ]	di	[ti]	gao	[kɑu]	hui	[xwei]
ao	[ɑu]	chen	[tʂʰən]	dian	[tjɛn]	ge	[kɤ]	hun	[xwən]
ba	[pa]	cheng	[tʂʰəŋ]	diang	[tjɑŋ]	gei	[kei]	huo	[xwo]
bai	[pai]	chi	[tʂʰʅ]	diao	[tjɑu]	gen	[kən]	ji	[tɕi]
ban	[pan]	chong	[tʂʰuŋ]	die	[tje]	geng	[kəŋ]	jia	[tɕja]
bang	[pɑŋ]	chou	[tʂʰou]	ding	[tjəŋ]	gong	[kuŋ]	jian	[tɕjɛn]
bao	[pɑu]	chu	[tʂʰu]	diu	[tjou]	gou	[kou]	jiang	[tɕjɑŋ]
bei	[pei]	chua	[tʂʰwa]	dong	[tuŋ]	gu	[ku]	jiao	[tɕjɑu]
ben	[pən]	chuai	[tʂʰwai]	dou	[tou]	gua	[kwa]	jie	[tɕje]
beng	[pəŋ]	chuan	[tʂʰwan]	du	[tu]	guai	[kwai]	jin	[tɕin]
bi	[pi]	chuang	[tʂʰwɑŋ]	duan	[twan]	guan	[kwan]	jing	[tɕjəŋ]
bian	[pjɛn]	chui	[tʂʰwei]	dui	[twei]	guang	[kwɑŋ]	jiong	[tɕjuŋ]
biao	[pjɑu]	chun	[tʂʰwən]	dun	[twən]	gui	[kwei]	jiu	[tɕjou]
bie	[pje]	chuo	[tʂʰwo]	duo	[two]	gun	[kwən]	ju	[tɕy]
bin	[pin]	ci	[tsʰɿ]	e	[ɤ]	guo	[kwo]	juan	[tɕɥɛn]
bing	[pjəŋ]	cong	[tsʰuŋ]	ei	[ei]	ha	[xa]	jue	[tɕɥe]
bo	[pwo]	cou	[tsʰou]	en	[ən]	hai	[xai]	jun	[tɕyn]
bu	[pu]	cu	[tsʰu]	er	[ər]	han	[xan]	ka	[kʰa]
ca	[tsʰa]	cuan	[tsʰwan]	fa	[fa]	hang	[xɑŋ]	kai	[kʰai]
cai	[tsʰai]	cui	[tsʰwei]	fan	[fan]	hao	[xɑu]	kan	[kʰan]
can	[tsʰan]	cun	[tsʰwən]	fang	[fɑŋ]	he	[xɤ]	kang	[kʰɑŋ]
cang	[tsʰɑŋ]	cuo	[tsʰwo]	fei	[fei]	hei	[xei]	kao	[kʰɑu]
cao	[tsʰɑu]	da	[ta]	fen	[fən]	hen	[xən]	ke	[kʰɤ]
ce	[tsʰɤ]	dai	[tai]	feng	[fəŋ]	heng	[xəŋ]	kei	[kʰei]
cen	[tsʰən]	dan	[tan]	fo	[fwo]	hong	[xuŋ]	ken	[kʰən]
ceng	[tsʰəŋ]	dang	[tɑŋ]	fou	[fou]	hou	[xou]	keng	[kʰəŋ]
cha	[tʂʰa]	dao	[tɑu]	fu	[fu]	hu	[xu]	kong	[kʰuŋ]
chai	[tʂʰai]	de	[tɤ]	ga	[ka]	hua	[xwa]	kou	[kʰou]

pinyin	IPA	pinyin	IPA	pinyin	IPA	pinyin	IPA	pinyin	IPA
ku	[kʰu]	luo	[lwo]	ni	[ni]	pin	[pʰin]	run	[rwən]
kua	[kʰwa]	lü	[ly]	nia	[nja]	ping	[pʰjəŋ]	ruo	[rwo]
kuai	[kʰwai]	lüe	[lɥe]	nian	[njɛn]	po	[pʰwo]	sa	[sa]
kuan	[kʰwan]	ma	[ma]	niang	[njɑŋ]	pou	[pʰou]	sai	[sai]
kuang	[kʰwɑŋ]	mai	[mai]	niao	[njɑu]	pu	[pʰu]	san	[san]
kui	[kʰwei]	man	[man]	nie	[nje]	qi	[tɕʰi]	sang	[sɑŋ]
kun	[kʰwən]	mang	[mɑŋ]	nin	[nin]	qia	[tɕʰja]	sao	[sɑu]
kuo	[kʰwo]	mao	[mɑu]	ning	[njəŋ]	qian	[tɕʰjɛn]	se	[sɤ]
la	[la]	me	[mɤ]	niu	[njou]	qiang	[tɕʰjɑŋ]	sei	[sei]
lai	[lai]	mei	[mei]	nong	[nuŋ]	qiao	[tɕʰjɑu]	sen	[sən]
lan	[lan]	men	[mən]	nou	[nou]	qie	[tɕʰje]	seng	[səŋ]
lang	[lɑŋ]	meng	[məŋ]	nu	[nu]	qin	[tɕʰin]	sha	[ʂa]
lao	[lɑu]	mi	[mi]	nuan	[nwan]	qing	[tɕʰiəŋ]	shai	[ʂai]
le	[lɤ]	mian	[mjɛn]	nun	[nwən]	qiong	[tɕʰjuŋ]	shan	[ʂan]
lei	[lei]	miao	[mjɑu]	nuo	[nwo]	qiu	[tɕʰjou]	shang	[ʂɑŋ]
leng	[ləŋ]	mie	[mje]	nü	[ny]	qu	[tɕʰy]	shao	[ʂɑu]
li	[li]	min	[min]	nüe	[nɥe]	quan	[tɕʰɥɛn]	she	[ʂɤ]
lia	[lja]	ming	[mjəŋ]	o	[o]	que	[tɕʰɥe]	shei	[ʂei]
lian	[ljɛn]	miu	[mjou]	ou	[ou]	qun	[tɕʰyn]	shen	[ʂən]
liang	[ljɑŋ]	mo	[mwo]	pa	[pʰa]	ran	[ran]	sheng	[ʂəŋ]
liao	[ljɑu]	mou	[mou]	pai	[pʰai]	rang	[rɑŋ]	shi	[ʂʅ]
lie	[lje]	mu	[mu]	pan	[pʰan]	rao	[rɑu]	shong	[ʂuŋ]
lin	[lin]	na	[na]	pang	[pʰɑŋ]	re	[rɤ]	shou	[ʂou]
ling	[ljəŋ]	nai	[nai]	pao	[pʰɑu]	ren	[rən]	shu	[ʂu]
liu	[ljou]	nan	[nan]	pei	[pʰei]	reng	[rəŋ]	shua	[ʂwa]
lo	[lo]	nang	[nɑŋ]	pen	[pʰən]	ri	[rʅ]	shuai	[ʂwai]
long	[luŋ]	nao	[nɑu]	peng	[pʰəŋ]	rong	[ruŋ]	shuan	[ʂwan]
lou	[lou]	ne	[nɤ]	pi	[pʰi]	rou	[rou]	shuang	[ʂwɑŋ]
lu	[lu]	nei	[nei]	pian	[pʰjɛn]	ru	[ru]	shui	[ʂwei]
luan	[lwan]	nen	[nən]	piao	[pʰjɑu]	ruan	[rwan]	shun	[ʂwən]
lun	[lwən]	neng	[nəŋ]	pie	[pʰje]	rui	[rwei]	shuo	[ʂwo]

pinyin	IPA	pinyin	IPA	pinyin	IPA	pinyin	IPA
si	[sɿ]	wei	[wei]	yue	[ɥe]	zi	[tsɿ]
song	[suŋ]	wen	[wən]	yun	[yn]	zong	[tsuŋ]
sou	[sou]	weng	[wəŋ]	za	[tsa]	zou	[tsou]
su	[su]	wo	[wo]	zai	[tsai]	zu	[tsu]
suan	[swan]	wu	[u]	zan	[tsan]	zuan	[tswan]
sui	[swei]	xi	[ɕi]	zang	[tsɑŋ]	zui	[tswei]
sun	[swən]	xia	[ɕja]	zao	[tsɑu]	zun	[tswən]
suo	[swo]	xian	[ɕjɛn]	ze	[tsɤ]	zuo	[tswo]
ta	[tʰa]	xiang	[ɕjɑŋ]	zei	[tsei]		
tai	[tʰai]	xiao	[ɕjɑu]	zen	[tsən]		
tan	[tʰan]	xie	[ɕje]	zeng	[tsəŋ]		
tang	[tʰɑŋ]	xin	[ɕin]	zha	[ʈʂa]		
tao	[tʰɑu]	xing	[ɕjəŋ]	zhai	[ʈʂai]		
te	[tʰɤ]	xiong	[ɕjuŋ]	zhan	[ʈʂan]		
teng	[tʰəŋ]	xiu	[ɕjou]	zhang	[ʈʂɑŋ]		
ti	[tʰi]	xu	[ɕy]	zhao	[ʈʂɑu]		
tian	[tʰjɛn]	xuan	[ɕɥɛn]	zhe	[ʈʂɤ]		
tiao	[tʰjɑu]	xue	[ɕɥe]	zhei	[ʈʂei]		
tie	[tʰje]	xun	[ɕyn]	zhen	[ʈʂən]		
ting	[tʰjəŋ]	ya	[ja]	zheng	[ʈʂəŋ]		
tong	[tʰuŋ]	yan	[jɛn]	zhi	[ʈʂʅ]		
tou	[tʰou]	yang	[jɑŋ]	zhong	[ʈʂuŋ]		
tu	[tʰu]	yao	[jɑu]	zhou	[ʈʂou]		
tuan	[tʰwan]	ye	[je]	zhu	[ʈʂu]		
tui	[tʰwei]	yi	[i]	zhua	[ʈʂwa]		
tun	[tʰwən]	yin	[in]	zhuai	[ʈʂwai]		
tuo	[tʰwo]	ying	[jəŋ]	zhuan	[ʈʂwan]		
wa	[wa]	yong	[juŋ]	zhuang	[ʈʂwɑŋ]		
wai	[wai]	you	[jou]	zhui	[ʈʂwei]		
wan	[wan]	yu	[y]	zhun	[ʈʂwən]		
wang	[wɑŋ]	yuan	[ɥɛn]	zhuo	[ʈʂwo]		

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