Hefei Mandarin

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Hefei Mandarin is a Chinese dialect spoken in Hefei, the capital city of Anhui Province, China, as illustrated in Figure 1. According to *The Language Atlas of China* (1987), Hefei Mandarin is a sub-branch of Jianghuai Mandarin, i.e. the varieties of Mandarin dialects distributed between the Yangtze River and the Huai River. While its syllable structure is

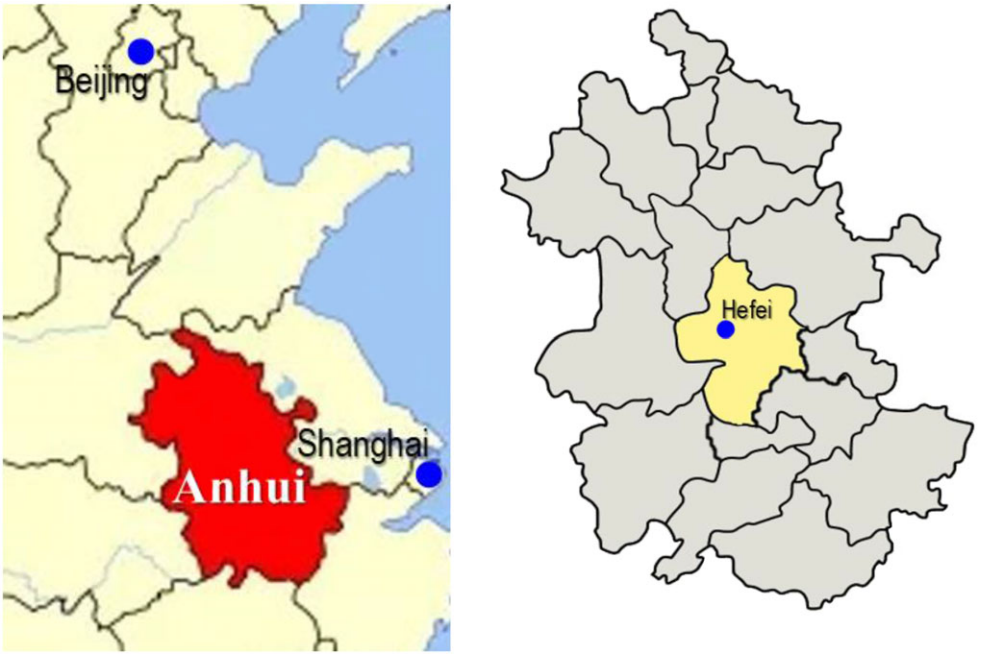

Figure 1 (Colour online) Geographic location of Hefei. (Maps adapted from Wikipedia.)

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relatively simple, Hefei Mandarin has a rich vowel inventory and various types of rimes, including three contrastive high back vowels /ɯ o ɤ/, non-nasalized vs. nasalized vowels as syllable rimes such as /i/ vs. /ĩ/, and three syllabic consonants [ɹ̩ ɻ̩ʷ ɻ̩] (Li 1936; Meng 1962, 1997; Li 1994, 1997; Wang 1996; Kong 2003, 2004, 2006; Kong & Zhang 2006; Kong, Wu & Li 2019).

The segments and tones of Hefei Mandarin described in this study are based on the production of a male native speaker of Hefei Mandarin, who was 41 years old at the time of the data collection. The speaker has been living in the old city area of Hefei, where the speakers' accent is typical of Hefei Mandarin. The speaker reported no speech or hearing impairment. The recording was done at a sampling rate of 44.1 kHz in a sound attenuated booth and the acoustic measurements were performed using Praat (Boersma & Weenink 2020).

Consonants

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
Plosive	p pʰ		t tʰ			k kʰ
Affricate			ts tsʰ	tʃ tʃʰ	tɕ tɕʰ	
Nasal	m		n			ŋ
Fricative		f	s z	ʃ	ɕ ʑ	x
Approximant			ɹ			
Lateral approximant			l			

p	pɔ^{31}	包	‘bag’	ɹ	ɹɯ^{24}	如	‘similar’
pʰ	pʰɔ^{24}	跑	‘to run’	tʃ	tʃɯ^{213}	主	‘master’
m	ma^{213}	马	‘horse’	tʃʰ	tʃʰɔ^{31}	抄	‘to copy’
f	fi^{31}	飞	‘to fly’	ʃ	ʃɯ^{53}	树	‘tree’
t	ta^{213}	打	‘to hit’	tɕ	tɕɔ^{31}	交	‘to submit’
tʰ	tʰɯ^{213}	土	‘soil’	tɕʰ	tɕʰɔ^{24}	桥	‘bridge’
ts	tswɐʔ^{4}	作	‘to do’	ɕ	ɕɔ^{213}	小	‘little’
tsʰ	tsʰɯ^{31}	粗	‘thick’	ʑ	ʑĩ^{31}	烟	‘cigar’
n	tɕin^{31}	金	‘gold’	k	kɔ^{31}	高	‘high’
s	sɯ^{31}	梳	‘comb’	kʰ	kʰɔ^{213}	考	‘to examine’
z	zɻ^{w213}	雨	‘rain’	ŋ	təŋ^{31}	冬	‘winter’
l	lɯ^{213}	鲁	‘crass’	x	xɯ^{213}	虎	‘tiger’

Based on the speaker's production, a total of 24 non-syllabic consonants are identified for Hefei Mandarin. In addition to the consonants of Hefei Mandarin described in the literature (Meng 1962, 1997; Li 1994, 1997; Wang 1996), a consonant /ʑ/ is observed in the speaker's production, such as the onset of the syllable [ʑĩ^{31}] 烟 ‘cigar’, which is the voiced counterpart

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Table 1 Mean VOT values (ms) of unaspirated vs. aspirated stops in Hefei Mandarin.

	Bilabial /p p^h/		Alveolar /t t^h/		Velar /k k^h/	
	Mean	SD	Mean	SD	Mean	SD
Unaspirated	9	1.0	14	1.7	24	1.0
Aspirated	81	7.8	90	1.5	87	24.9

of the alveolo-palatal fricative /ɕ/.[1] Among the consonants, /n/ and /ŋ/ can only serve as syllable coda, such as in the syllables [tən^{31}] 灯 'lamp' and [təŋ^{31}] 冬 'winter'.

Plosives in Hefei Mandarin have three places of articulation, with a contrast between aspirated and unaspirated plosives at each place: bilabial /p p^h/, as in [pɔ^{31}] 包 'bag' and [p^hɔ^{24}] 跑 'to run', alveolar /t t^h/, as in [ta^{213}] 打 'to hit' and [t^hɯ^{213}] 土 'soil', and velar /k k^h/, as in [kɔ^{31}] 高 'high' and [k^hɔ^{213}] 考 'to examine'. Table 1 shows the mean VOT values of the unaspirated and aspirated plosives in different places of articulation, each based on the measurement of three tokens in Praat focusing on the interval between the release burst and the first cycle of the periodic wave of its following vowel. Apart from these plosives, a glottal stop [ʔ] appears as a coda that co-occurs with Tone 5, a short high tone transcribed phonetically as level 4 using Chao numerals, such as in the syllable [tswɐʔ^4] 作 'to do'. It is not listed as a phonemic consonant because it exists in Hefei Mandarin only as an accompanying property of Tone 5 and it is not contrastive with any other consonants when tone is involved.

Affricates in Hefei Mandarin also occur at three places of articulation with a distinction between aspirated and unaspirated affricates: alveolar /ts ts^h/, as in [tswɐʔ^4] 作 'to do' and /ts^hɯ^{31}/ 粗 'thick', postalveolar /tʃ $tʃ^h$/, as in [tʃɯ^{213}] 主 'master' and [$tʃ^h$ɔ^{31}] 抄 'to copy', and alveolo-palatal /tɕ $tɕ^h$/, as in [tɕɔ^{31}] 交 'to submit' and [$tɕ^h$ɔ^{24}] 桥 'bridge'.[2] The postalveolar affricates /tʃ $tʃ^h$/ and their fricative counterpart /ʃ/ are usually referred to as retroflex sibilants in the Chinese literature of Hefei Mandarin and are consequently represented as /tʂ $tʂ^h$ ʂ/. In Hefei Mandarin, however, they sound more postalveolar than retroflex.

Hefei Mandarin has fricatives at five places of articulation: labiodental /f/, as in [fi^{31}] 飞 'to fly', alveolar /s z/, as in [sɻ^{213}] 死 'dead' and [zɻ^{w213}] 雨 'rain', postalveolar /ʃ/, as in [ʃɯ^{53}] 树 'tree', alveolo-palatal /ɕ/, as in [ɕɔ^{213}] 小 'little', and velar /x/, as in [xɯ^{213}] 虎 'tiger'. Sample FFT spectra of the voiceless fricatives in Hefei Mandarin are provided in Figure 2, sampled at the midpoint of the fricatives using a 15 ms Hamming window. As shown in Figure 2, the three sibilant fricatives differ in the distribution of their energy: /s/ has its concentration in the high frequency range above 5000 Hz; /ʃ/ has more energy than /ɕ/ above 5000 Hz; the energy of /ɕ/ is centered around 3000–4000 Hz.

Syllabic consonants

Hefei Mandarin has syllabic consonants such as the nucleus of the syllable [zɻ^{213}] 椅 'chair' as illustrated in Figure 3. Similar syllabic consonants in languages such as Standard Mandarin, e.g. the [ɻ] in [sɻ^{55}] 思 'to think' with the same place of articulation as its preceding consonant, are usually referred to as apical vowels (Karlgren 1915/1926, Chao 1930,

[1] The authors would like to thank the two anonymous reviewers and the editors for the relevant observation and suggestion.

[2] Syllables such as [tɕ^{h}ɔ^{24}] 桥 'bridge' and [ɕɔ^{213}] 小 'little' are conventionally transcribed as [tɕ^{h}iɔ^{24}] and [ɕiɔ^{213}] in the Chinese literature of Hefei Mandarin. As observed from the speaker's production, the [i] part in the rime can be analyzed as the transition between an alveolo-palatal onset sibilant and a following vowel. The syllables are thus transcribed without an [i] in the rime.

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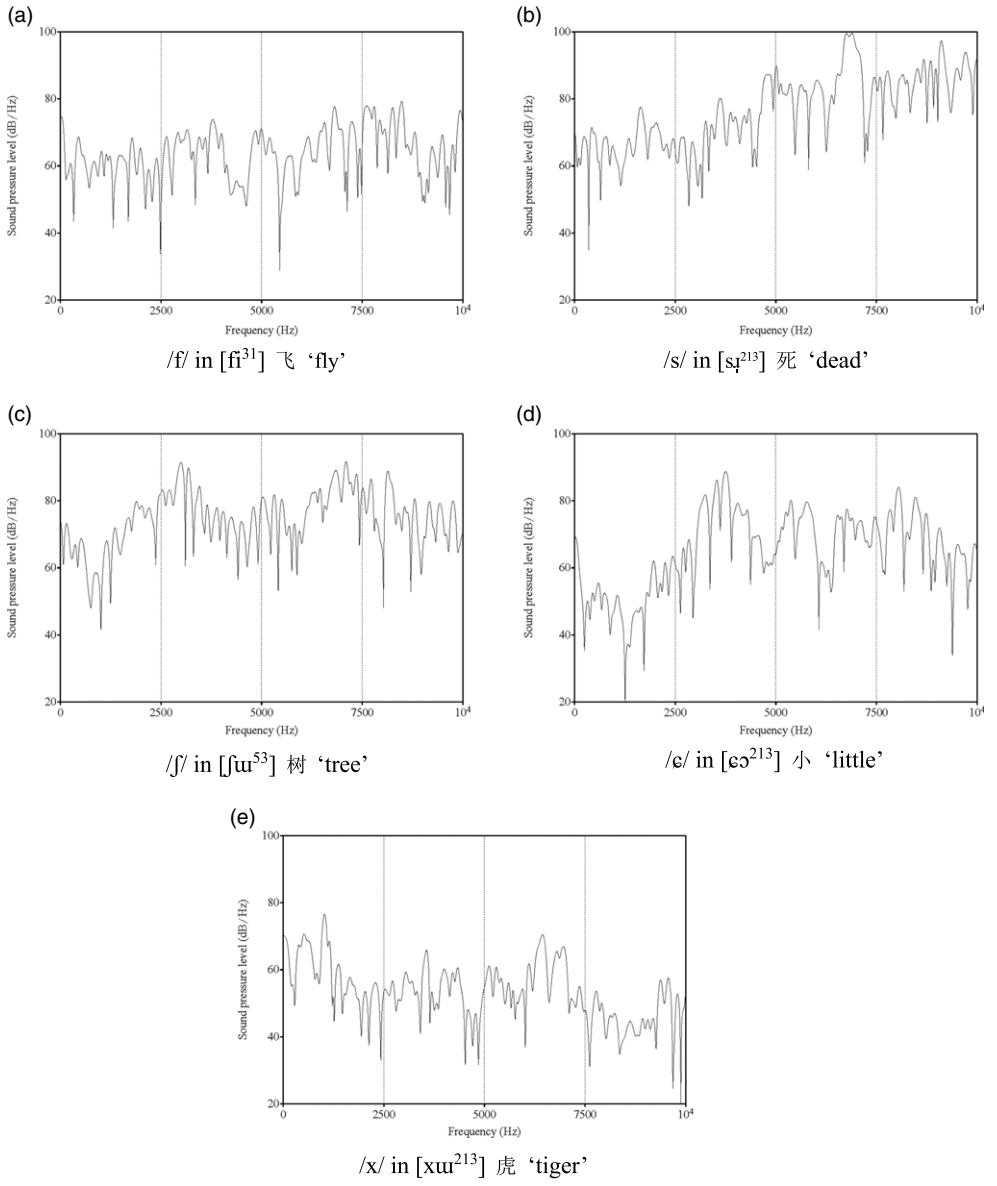

Figure 2 Sample FFT spectra of the voiceless fricatives in Hefei Mandarin.

Baron 1974, Lee-Kim 2014). The spectrogram in Figure 3 shows a distinction between the voiced alveolar fricative [z] and the alveolar syllabic segment [ɻ] in particular in that there is stronger frication noise in the [z] portion than in the [ɻ] portion.

There are three syllabic consonants in Hefei Mandarin, the unrounded alveolar [ɻ], the rounded alveolar [ɻ^{w}], and the unrounded postalveolar [ɻ̠], as illustrated in Table 2.[3] The syllabic segments in Hefei Mandarin differ from those in most other languages such as Standard

[3] The three syllabic consonants are conventionally represented as ʅ ʮ ʯ in the Chinese literature of Hefei Mandarin.

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Table 2 Distribution of syllabic consonants in Hefei Mandarin.

Bilabial onsets			Alveolar onsets				Postalveolar onsets		
ɹ̩	pɹ̩	pʰɹ̩	mɹ̩	tsɹ̩	tsʰɹ̩	sɹ̩	zɹ̩		
ɹ̩ʷ				tsɹ̩ʷ	tsʰɹ̩ʷ	sɹ̩ʷ	zɹ̩ʷ		
ɻ̩								tʃɻ̩	tʃʰɻ̩	ʃɻ̩

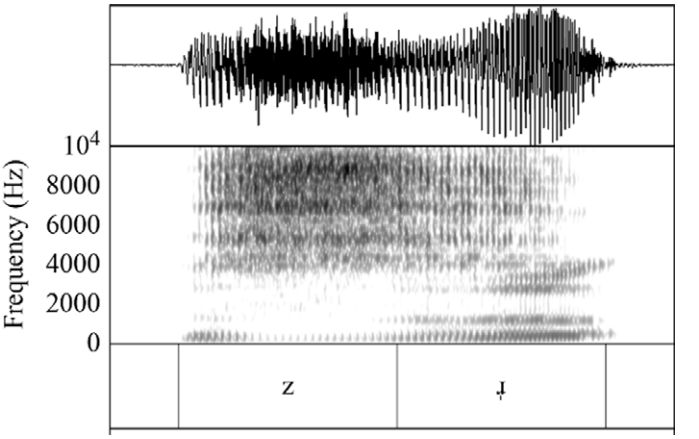

Figure 3 Waveform and spectrogram of [zɹ̩^{213}] 椅 'chair' in Hefei Mandarin.

Mandarin in that it has the rounded alveolar [ɹ̩^{w}], which contrasts with the unrounded alveolar [ɹ̩], as in [zɹ̩^{213}] 椅 'chair' vs. [zɹ̩^{w213}] 雨 'rain'. In addition, the [ɹ̩] in Hefei Mandarin also distinguishes itself from its counterparts in languages such as Standard Mandarin in that, apart from appearing after homorganic consonants such as /ts ts^{h} s z/, it also appears after non-homorganic consonants such as the bilabial /m p p^{h}/, as in [pɹ̩^{213}] 比 'to compare', [pʰɹ̩^{213}] 痞 'naughty', and [mɹ̩^{213}] 米 'rice'.

Figure 4 illustrates the speaker's lip gestures when producing the three syllabic consonants. It can be seen that the syllabic segment [ɹ̩^{w}] involves a lip rounding that is absent from the other two syllabic segments. In addition, the vertical aperture in producing [ɻ̩][4] is a bit larger compared with that used in producing [ɹ̩]. The syllabic consonants [ɹ̩ ɹ̩^{w} ɻ̩] in Hefei Mandarin are observed to have clear formant structures (Wan 2014, Kong et al. 2019), similar to their counterparts in languages such as Standard Mandarin (Lee 2005).

Figure 5 shows the waveform and spectrogram of [ɹ̩ ɹ̩^{w} ɹ̩] produced by the speaker. The mean values of the first three formants and durations of the three syllabic segments are shown in Table 3, each based on nine tokens. In terms of the mean values of F1, [ɹ̩^{w}] is the lowest; in terms of F2, [ɹ̩] and [ɹ̩^{w}] both are lower than [ɻ̩]; in terms of F3, [ɹ̩] is higher than [ɹ̩^{w}] and [ɻ̩]. Of the three sounds, the lowest F1 and F2 values for [ɹ̩^{w}] are presumably related to its lip rounding. The source of the relatively low F3 in [ɻ̩] awaits future instrumental investigation to find out if it predominantly originates from pharyngealization (Catford 1988) or a large front cavity (Narayanan, Byrd & Kaun 1999).

Frication noise has been observed in syllabic consonants in various Chinese languages, e.g. Xining Chinese (Zhang & Zhu 1987) and Wu Chinese (Qian 1992, Shi 1998, Zhu 2004, Hu 2007, Faytak 2018, Hu & Ling 2019). While there is a clear distinction between a voiced fricative and a syllabic segment, e.g. [z] vs. [ɹ̩] as illustrated in Figure 3 above, the syllabic

[4] For typographical convenience, the retroflex symbol is used instead of a 'retracted' diacritic underneath the alveolar symbol.

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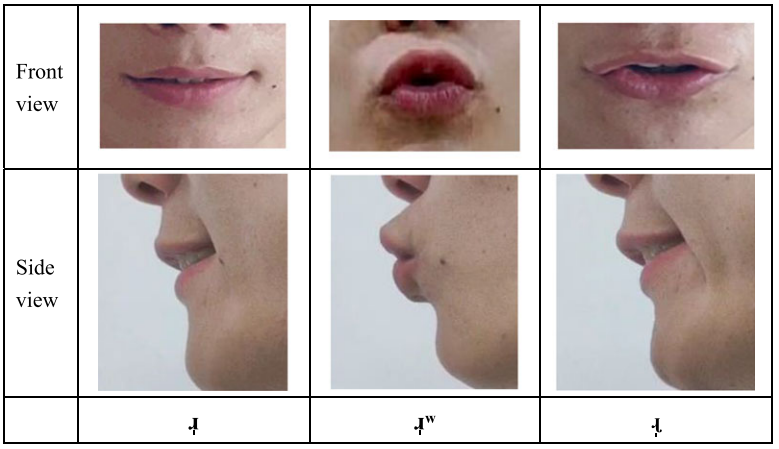

Figure 4 (Colour online) Lip gestures for [ɻ ɻʷ ɻ̩] as in [sɻ^{213}] 死 'dead', [sɻ^{w213}] 许 'a surname', and [tʃɻ̩^{213}] 纸 'paper'.

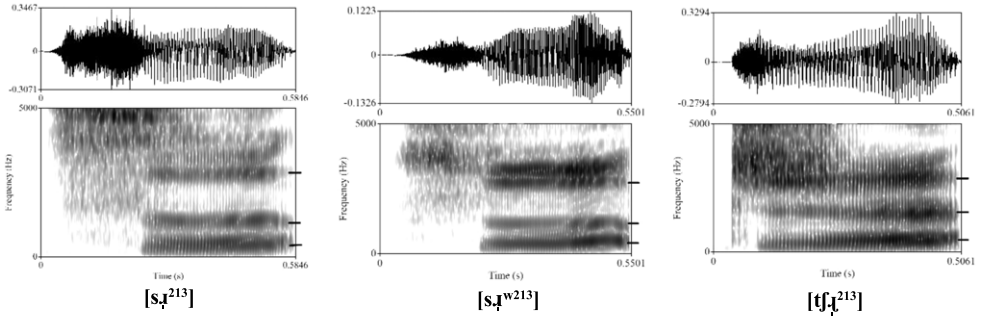

Figure 5 Waveform and spectrogram of [sɻ^{213}] 死 'dead', [sɻ^{w213}] 许 'a surname', and [tʃɻ̩^{213}] 纸 'paper'.

Table 3 Mean F1, F2, F3 (Hz) and duration (ms) of [ɻ ɻʷ ɻ̩] in Hefei Mandarin.

	F1 (Hz)		F2 (Hz)		F3 (Hz)		Duration (ms)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ɻ	492	77.2	1505	171.6	3101	112.0	411	47.6
ɻʷ	468	48.2	1388	137.5	2904	50.2	338	23.9
ɻ̩	571	107.6	1752	109.6	2854	88.5	350	30.2

consonants in Hefei Mandarin have been reported to include audible fricative noise in previous studies (Hou 2007, 2009; Kong et al. 2019, among others). For a quantified assessment of frication noise in the syllabic consonants, harmonic-to-noise ratios (HNR) (de Krom 1993, Maniwa, Jongman & Wade 2009) were measured for the three syllabic segments in Hefei Mandarin, by which a higher value indicates more periodicity and a lower value indicates more noise. The results of the HNR measurement are presented in Table 4, which are based on nine tokens for each segment, with a window size of 10 ms at the middle points. The measurement of the high front vowel /i/ is added as a baseline for comparison. As shown in

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Table 4 Mean HNR values of the syllabic consonants [ɹ̩ ɹ̩ʷ ɻ̩] and [i] in Hefei Mandarin.

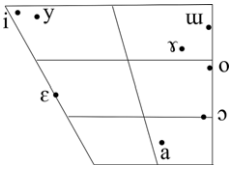
	HNR (0–10 KHz)	SD
ɹ̩	16	1.2
ɹ̩ʷ	22	1.7
ɻ̩	16	1.6
i	23	3.5

Table 4, the mean HNR values for [ɹ̩] and [ɻ̩] were in general lower than that of /i/, indicating a greater proportion of aperiodic energy in the two syllabic segments, consistent with the results of visual inspection in previous studies such as Kong et al. (2019). On the other hand, Table 4 shows similar mean HNR values of /i/ and [ɹ̩ʷ], indicating that [ɹ̩ʷ] involves more periodic energy as compared with [ɹ̩] and [ɻ̩].[5]

Vowels

The speaker's production indicated 13 monophthongs in Hefei Mandarin, including eight non-nasalized vowels and five nasalized vowels, and nine diphthongs.

Non-nasalized monophthongs



i	ɕi^{24}	斜	'to lean'
y	tɕ^{h}y^{24}	茄	'eggplant'
ɛ	sɛ^{31}	腮	'cheek'
a	ta^{213}	打	'to hit'
ɯ	xɯ^{213}	虎	'tiger'
ɤ	xɤ^{213}	吼	'to shout'
o	xo^{213}	火	'fire'
ɔ	pɔ^{31}	包	'bag'

The eight non-nasalized monophthongs include /i y ɛ ɯ ɤ o ɔ a/, in which /a/ is adopted to denote a low central vowel instead of a low front vowel. For the eight monophthongs, Table 5 illustrates the mean values of their first three formants and the durations. For the first five

[5] The relative lack of frication noise in [ɹ̩ʷ] is possibly related to its lip rounding, which increases the length of the tube and makes it harder to create noise with an alveolar constriction as compared with [ɹ̩]. The precise reason for this phenomenon awaits future aerodynamic study.

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Table 5 Mean F1, F2, F3 (Hz) and duration (ms) of monophthongs in Hefei Mandarin.

	F1 (Hz)		F2 (Hz)		F3 (Hz)		Duration (ms)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
i	332	35.0	2184	88.6	2918	92.2	290	35.9
y	376	24.0	1974	21.3	2476	57.6	223	17.5
ɛ	558	42.3	1907	31.2	2560	13.3	180	20.8
a	873	81.2	1298	62.2	2569	89.9	307	20.1
ɔ	657	61.7	1075	10.6	2892	105.0	225	69.4
ɯ	420	42.6	1017	79.5	2768	42.6	289	85.6
o	514	5.4	1008	170.9	2992	168.6	311	21.4
ɤ	472	54.3	1241	40.9	2810	112.8	247	71.0

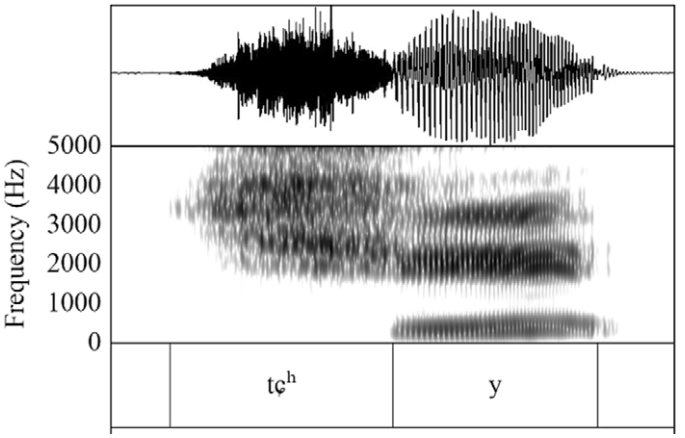

Figure 6 [tɕʰy^{24}] 茄 'eggplant' in Hefei Mandarin.

vowels, the formant values were based on four tokens per vowel measured at the midpoints and, for the last three vowels, the measurement was based on 15 tokens per vowel.[6]

The two high front vowels /i/ and /y/ are distinguished by lip rounding. For the rounded /y/, there has been previous description of it as a diphthong [ye] (Li 1997). The production by the speaker in this study does not show characteristics of a diphthong, as in the syllable [tɕʰy^{24}] 茄 'eggplant' in Figure 6. Therefore, the vowel is transcribed as a monophthong, consistent with previous studies such as Wan (2014).

Hefei Mandarin has three contrastive high back vowels /ɯ ɤ o/, as in the monosyllabic triplet [xɯ^{213}] 虎 'tiger', [xɤ^{213}] 吼 'to shout', and [xo^{213}] 火 'fire'.[7] As shown in Table 5, in terms of F1, the mean value of /ɯ/ (420 Hz) is lower than those of /o/ (514 Hz) and /ɤ/ (472 Hz), corresponding to its relatively high tongue position; in terms of F2, the mean value of /ɯ/ (1017 Hz) is close to that of /o/ (1008 Hz), both of which are lower than the F2 of /ɤ/ (1241 Hz); in terms of F3, the mean values of /ɯ/ (2768 Hz) and /ɤ/ (2810 Hz) are lower than the F3 of /o/ (2992 Hz). The lip gestures of the three vowels are presented in Figure 7, which shows that the aperture is larger in /ɯ/ and /ɤ/ than in /o/ and that the protrusion is more obvious in /o/ than in /ɯ/ and /ɤ/. Note that the three vowels /ɯ ɤ o/ are usually transcribed

[6] The difference in token number resulted from the limited time and resources of the data collection.
[7] The vowel /ɯ/ involves some lip compression and its narrow transcription can be [ɯ^{β}].

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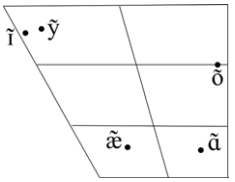
Figure 7 (Colour online) Lip gestures of /ɯ/ /ɤ/ and /o/ in Hefei Mandarin as in the syllables [xɯ^{213}] 虎 'tiger', [xɤ^{213}] 吼 'shout', and [xo^{213}] 火 'fire'.

as /u ɯ ʊ/, respectively, in the literature, primarily based on impressionistic description (Li 1997, Meng 1997). The production of the speaker in this study, as illustrated in Figure 7, supported their transcription respectively as /ɯ ɤ o/.

Nasalized vowels



ĩ	zĩ^{31}	烟	'cigar'
ỹ	zỹ^{53}	院	'yard'
õ	õ^{213}	碗	'bowl'
æ̃	xæ̃^{31}	憨	'good-tempered'
ɑ̃	xɑ̃^{31}	夯	'to strengthen'

There are five nasalized vowels in Hefei Mandarin /ĩ ỹ õ æ̃ ɑ̃/, which have been recognized to historically derive from syllable rimes in the form of vowel-nasal sequences (Li 1997). Of the five, the three high nasalized vowels, /ĩ/ as in [zĩ^{31}] 烟 'cigar', /ỹ/ as in [zỹ^{53}] 院 'yard', and /õ/ as in [õ^{213}] 碗 'bowl', have non-nasalized counterparts /i y o/ respectively; the other two, /æ̃/ as in [xæ̃^{31}] 憨 'good-tempered' and /ɑ̃/ as in [xɑ̃^{31}] 夯 'to strengthen', have no non-nasalized counterparts. Table 6 presents the mean formants values (in Hz) of the nasalized vowels, each based on 3 tokens, and their non-nasalized counterparts as recalled from Table 5. It can be seen that, in terms of mean values, /ĩ/ and /ỹ/ have relatively higher F1 values and similar F2 values as compared with their non-nasalized counterparts /i/ and /y/ respectively; on the other hand, /õ/ has a relatively lower F1 and a higher F2 as compared with /o/.

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Table 6 Mean F1 and F2 (Hz) of nasalized vs. non-nasalized vowels.

	F1 (Hz)		F2 (Hz)	
	Mean	SD	Mean	SD
ĩ	580	34.6	2168	132.2
i	332	35.0	2184	88.6
ỹ	582	153.4	2040	13.4
y	376	24.0	1974	21.3
õ	355	5.7	1661	28.3
o	514	5.4	1008	170.9

Diphthongs

The speaker's production showed nine diphthongs that can serve as syllabic nuclei in Hefei Mandarin, as illustrated in Figure 8. Of the nine, six do not involve nasalized vowels, i.e. /eɪ jɯ jɔ wi wɛ wa/ as in Figure 8(a), and three involve nasalized vowels, i.e. /jã wæ̃ wã/ as in Figure 8(b). Table 7 presents the mean F1 values and F2 values of these diphthongs, each based on the measurements of four tokens at 20% and 80% of the vowels.

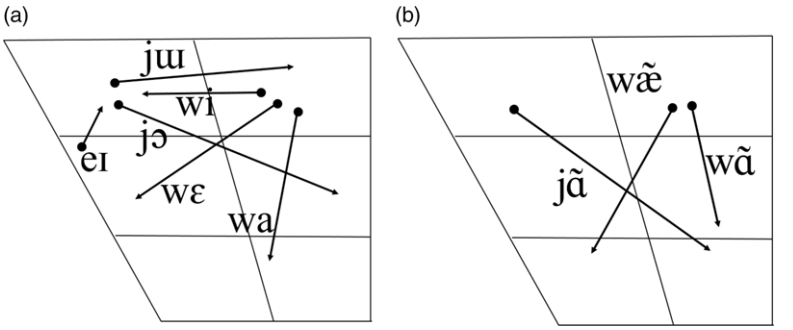

Figure 8 Schematic illustration of diphthongs in Hefei Mandarin: (a) diphthongs involving no nasalized vowels; (b) diphthongs involving nasalized vowels.

Table 7 Mean F1 and F2 of the diphthongs measured at 20% and 80% of the vowels.

	F1 (Hz)				F2 (Hz)			
	20%		80%		20%		80%	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
eɪ	543	67.4	436	49.6	2134	186.7	2081	170.5
jɯ	377	244.6	388	28.8	2153	199.1	1349	161.7
jɔ	385	78.0	670	53.5	1977	227.5	1107	131.4
wi	388	51.8	369	39.4	1102	271.1	2297	170.1
wɛ	462	54.3	676	87.0	1072	201.7	1855	139.3
wa	514	113.0	892	106.6	1031	251.6	1285	129.6
jã	421	106.3	776	127.9	1970	152.6	1292	102.3
wæ̃	490	74.2	752	159.5	1243	436.2	1580	144.6
wã	502	98.8	726	110.9	1094	456.7	1190	172.1

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eɪ	peɪ^{31}	杯	‘cup’
jɯ	tjɯ^{31}	丢	‘to lose’
jɔ	pʰjɔ^{31}	飘	‘to float’
wi	tʃʰwi^{31}	吹	‘to blow’
wɛ	xwɛ^{24}	怀	‘bosom’
wa	kwa^{31}	瓜	‘melon’

jɑ̃	ljɑ̃^{213}	两	‘two’
wæ̃	wæ̃^{53}	万	‘ten thousand’
wɑ̃	wɑ̃^{53}	忘	‘to forget’

Of the diphthongs in Figure 9, /eɪ/ has been described as /e/ in the literature (Li 1997).[8] The production of the speaker in this study showed that the vowel surfaced as a diphthong [eɪ], e.g. the rime in [teɪ^{53}] 队 ‘team’ as in Figure 9(a). It is interesting to observe that, in some lexical items, the vowel /e/ as reported in the literature turned out to be indistinguishable from the vowel /i/, e.g. the rime in [si^{53}] 碎 ‘fragmentary’ in Figure 9(b), reminiscent of previous report on the similar formant values of /e/ and /i/ (Hou 2007, Wan 2014). It is also possible that a general neutralization of /e/ into /i/ is in progress, as embodied in the vowel difference in Figure 9(a) vs. Figure 9(b), which awaits further study to understand its detailed mechanism.

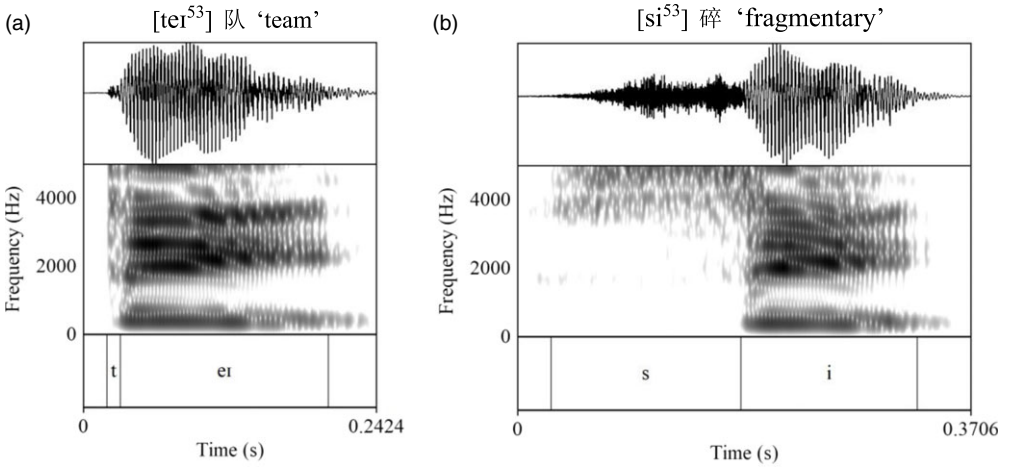

Figure 9 Examples of /eɪ/ and /i/ in Hefei Mandarin.

Apart from the nine diphthongs in Figure 8 above, two others are usually reported in the Chinese literature of Hefei Mandarin, i.e. [iɛ] and [ia], with example syllables such as [tɕiɛ^{31}] 街 ‘street’ and [tɕia^{31}] 家 ‘home’. These two are not included as diphthongs in the current study based on the fact that they appear only after the alveolo-palatal sibilants /ɕ tɕ tɕʰ/ and the assumed [i] component is brief and analyzable as the formant transition between an alveolo-palatal sibilant onset and a following vowel /ɛ/ or /a/. Following treatment of similar cases in other Chinese languages (Lee-Kim 2014 for Standard Mandarin, Chen & Gussenhoven 2015 for Shanghainese, and Zeng 2020 for Xiangxiang Chinese, among others), the relevant syllables are treated as [tɕɛ^{31}] 街 ‘street’ and [tɕa^{31}] respectively, in which the rimes are recognized as [ɛ] and [a].

[8] The vowel /eɪ/ is sometimes produced higher and can be transcribed as [ɪi].

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Syllable structure

Similar to other Chinese dialects, Hefei Mandarin has a relatively simple syllable structure, which can be summarized into three types. The first type is in the form of (C)V, in which the onset (C) is optional, and all the consonants can serve as onset except [n] and [ŋ]; the vowel V is obligatory, as a monophthong, a diphthong, or a syllabic consonant. For this type of syllable, the combinations of onset consonants and vowels, including the three syllabic consonants, are summarized in Table 8.

Table 8 (C)V syllables in Hefei Mandarin.

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
i		+	+		+	
ɨ	+		+			
ɨʷ			+			
ɻ̩				+		
y					+	
ɛ	+		+	+	+	+
ɯ	+	+	+	+	+	+
ɤ			+	+		+
o	+	+	+	+		+
ɔ	+		+	+	+	+
a	+		+	+	+	+
ĩ	+		+		+	
ỹ					+	
õ	+		+	+		+
æ̃	+	+	+	+		+
ɑ̃	+	+	+	+	+	+

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
eɪ	+	+	+	+		+
jɯ			+			
jɔ	+		+			
wi					+	+
wɛ					+	+
wa					+	+
jɑ̃			+			
wæ̃				+		+
wɑ̃				+		+

The second type has a nasal coda /n/ or /ŋ/. The rimes with nasal coda in Hefei Mandarin are listed below and their combinations with onset consonants are illustrated in Table 9. It needs to be noted that the vocalic segment /ə/ and the sequence /wə/ do not appear independently as a monophthong or a diphthong.

in	tɕin^{31}	金	‘gold’	əŋ	təŋ^{31}	冬	‘winter’
yn	ɕyn^{31}	熏	‘smelly’				
ən	tən^{31}	灯	‘lamp’				
wən	kwən^{213}	滚	‘to roll’				

The third type includes syllables ending with a glottal stop coda, which is an accompanying property of Tone 5. The rimes with a glottal stop coda in Hefei Mandarin are listed

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Table 9 (C)VN syllables in Hefei Mandarin.

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
in	+		+		+	
yn					+	
ən	+	+	+	+		+
wən				+		+

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
əŋ	+	+	+	+		+

below, with their combinations with onset consonants in Table 10. Similar to the cases in the second type of rimes, the vocalic segments [ə ɐ] and the sequences [iə wə yə iɐ wɐ yɐ] do not appear independently as monophthongs or diphthongs.

əʔ	məʔ^{4}	木	'wood'	ɐʔ	tʰɐʔ^{4}	塔	'tower'
iəʔ	pʰiəʔ^{4}	劈	'to cut'	iɐʔ	tʰiɐʔ^{4}	铁	'iron'
uəʔ	kʰuəʔ^{4}	哭	'cry'	wɐʔ	kwɐʔ^{4}	国	'country'
yəʔ	lyəʔ^{4}	律	'discipline'	yɐʔ	ɕyɐʔ^{4}	血	'blood'

Table 10 (C)VG syllables in Hefei Mandarin.

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
əʔ	+	+		+	+	
iəʔ	+		+			
uəʔ			+	+		+
yəʔ			+		+	

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Alveolo-palatal	Velar
ɐʔ	+	+		+	+	+
iɐʔ	+					
wɐʔ			+	+	+	+
yɐʔ			+		+	

Tones

Lexical tones

Hefei Mandarin has five lexical tones, for which the speaker's production shows the following tonal values:

Tone 1	xɯ^{31}	呼	'interjection'
Tone 2	xɯ^{24}	胡	'alien'
Tone 3	xɯ^{213}	虎	'tiger'
Tone 4	xɯ^{53}	护	'to protect'
Tone 5	xuəʔ^{4}	忽	'suddenly'

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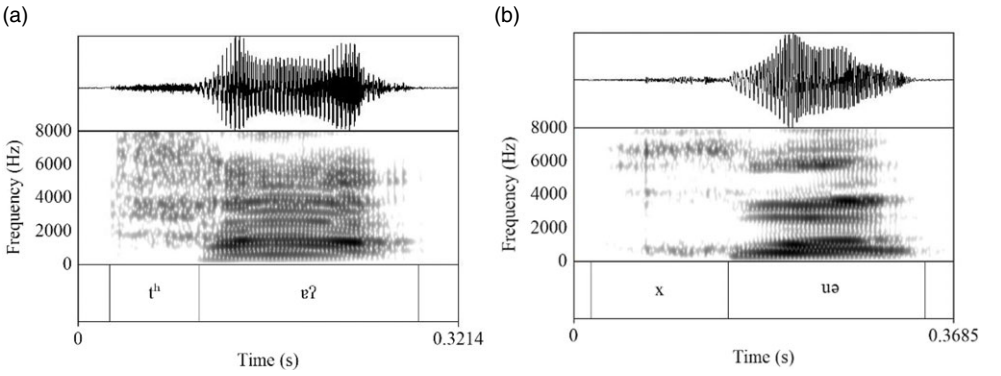

[tʰɐʔ^{4}] 塔 'tower' [xuə^{4}] 忽 'suddenly'.

Figure 10 Variation in the presence/absence of coda stop in Tone 5.

Of the five, Tones 1–4 appear in open syllables, such as [xɯ^{213}] 虎 'tiger', or syllables with a nasal coda, such as [kwən^{213}] 滚 'to roll'. The production of Tone 3 (213) is observed to involve harsh voice and a narrow transcription of [xɯ] 虎 'tiger' can be [xɯ̰]. Tone 5 is a short tone with an accompanying coda glottal stop [ʔ], such as [tʰɐʔ^{4}] 塔 'tower' (Li 1994, 1997). As is true for its counterparts in other Chinese languages, Tone 5 is conventionally referred to as an 'entering tone' or 'checked tone' in the Chinese literature and is usually represented using one digit, such as 4 in Chao numerals, indicating its short duration.

While Tone 5 in Hefei Mandarin is generally recognized as involving a glottal stop coda [ʔ], the production of the speaker showed variation as to the presence/absence of [ʔ] in the relevant syllables. As illustrated in Figure 10, the token of 塔 'tower' involves a glottal stop, i.e. [tʰɐʔ^{4}], while the token of 忽 'suddenly' has no glottal stop, i.e. [xuə^{4}], although other tokens of 忽 'suddenly' may involve a glottal stop. Similar loss of glottal stops in checked-tone syllables is widely observed in Chinese languages and, in Taiwanese Min for example, over 80% of the [ʔ] codas were found to be omitted in checked-tone syllables (Pan 2017). The variable loss of the [ʔ] is also noticeable when a Tone-5 syllable appears in sequences in Hefei Mandarin, for example, 合肥 'Hefei' turned out to be [xɐ^{2} fi^{24}] instead of [xɐʔ^{2} fi^{24}] and 北风 'north wind' surfaced as [pɐ^{4} fəŋ^{31}] instead of [pɐʔ^{4} fəŋ^{31}].

Figure 11 illustrates the f0 trajectories of the five lexical tones as in the syllable [xɯ] for Tone 1 to Tone 4 and [xuəʔ] for Tone 5. Each tonal contour was obtained by averaging across nine tokens (three repetitions of three syllables) produced by the speaker. Tone 1 surfaces as a low falling tone (31 in Chao numerals), Tone 2 a rising tone (24), Tone 3 a dipping contour tone (213), T4 a high falling tone (53), and T5 a short high tone (4), which is also the shortest among the five. For Tone 5, while its f0 trajectory may sometimes appear as a short rising contour, the short duration (usually no more than 100 ms) generally leads to a single tonal target in perception, i.e. a short high tone corresponding to 4 in Chao numerals.

Tone sandhi

As is true of many other Chinese dialects, tone sandhi occurs in Hefei Mandarin, by which a syllable bearing a lexical tone may surface with a different f0 contour when appearing in the neighborhood of another tone (Chen 2000). Description of tone sandhi in Hefei Mandarin in the literature generally focused on disyllabic sequences (Li 1994, Meng 1997, Kong 2003), in which sandhi occurs to the first tone. Of the 25 disyllabic combinations of the five lexical tones, six are reported to involve tone sandhi, including (with Tone abbreviated as 'T') T1T1, T1T4, T3T3, T5T2, T5T3, and T5T5 (Li 1994, Meng 1997, Kong 2003). The production of

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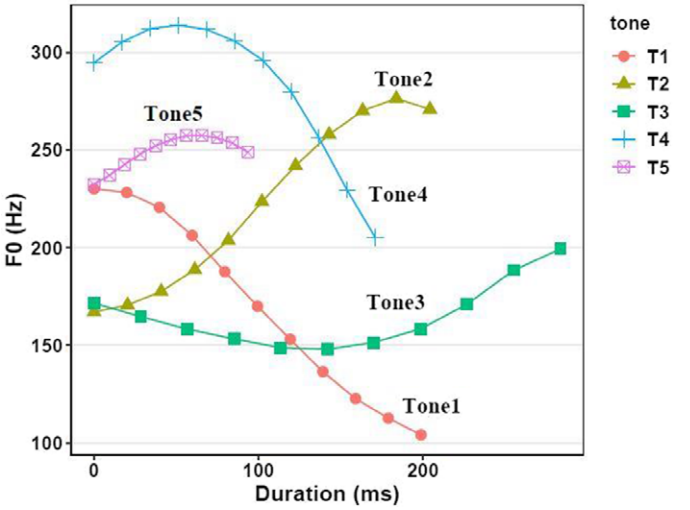

Figure 11 (Colour online) F0 contours of lexical tones in Hefei Mandarin.

the speaker in this study confirmed the existence of tone sandhi in all these sequences except T1T4, which was not observed to involve any sandhi. On the other hand, the combination of Tone 3 and Tone 1 (T3T1) turned out to involve a tone sandhi on the first tone, which is not well documented in the literature to the best of our knowledge. In T3T1, the initial T3 surfaces as a rising contour equal to Tone 2 /24/, e.g. /213/ → [24] on the first syllable of [ɕiɑ̃^{24} tɕa^{31}] 想家 'homesick'. The following is a summary of the six tone sandhi patterns in Hefei Mandarin using Chao numerals:

(a) T1T1: /31 + 31/ → [24 + 31]
(b) T3T1: /213 + 31/ → [24 + 31]
(c) T3T3: /213 + 213/ → [24 + 213]
(d) T5T2: /4 + 24/ → [2 + 24]
(e) T5T3: /4 + 213/ → [2 + 213]
(f) T5T5: /4 + 4/ → [2 + 4]

In (a)–(c), the initial tone in the sandhi form is indistinguishable from Tone 2 (T2) while in (d)–(f), the initial tone appears as [2], which is different from any tones in Figure 11.

These six tone sandhi sequences are illustrated in Figure 12, each averaged on three tokens, with the canonical forms indicating the f0 contour of a lexical tone in isolation. More specifically, Figure 12 shows that, in T1T1 (e.g. [ʃɔ^{24} pɔ^{31}] 烧包 'to get carried away'), the initial T1 /31/ appears as a rising contour [24];[9] in T3T3 (e.g. [ʃɯ^{24} pjɔ^{213}] 手表 'watch'), the initial T3 /214/ is realized as a rising contour [24]; in T5T2 (e.g. [xɐ^{2} fi^{24}] 合肥 'Hefei'),

[9] In the sequences T1T1 (a) and T3T1 (b) in Figure 12, the f0 contours of the second tone (T1 in both cases) differ slightly from its canonical form, as illustrated in (a) and (b), by having a slightly higher starting point of f0. Similarly, for the second T3 in Figure 12(c), the starting f0 seems to be a bit higher than its canonical form as in Figure 11. A likely explanation for the discrepancy in both cases is that these come from tonal coarticulation (Shen 1990), in which the high-ending f0 in the first tone leads to a higher starting f0 in the second tone. Therefore, the relevant deviation from the canonical forms is not regarded as tone sandhi in this study.

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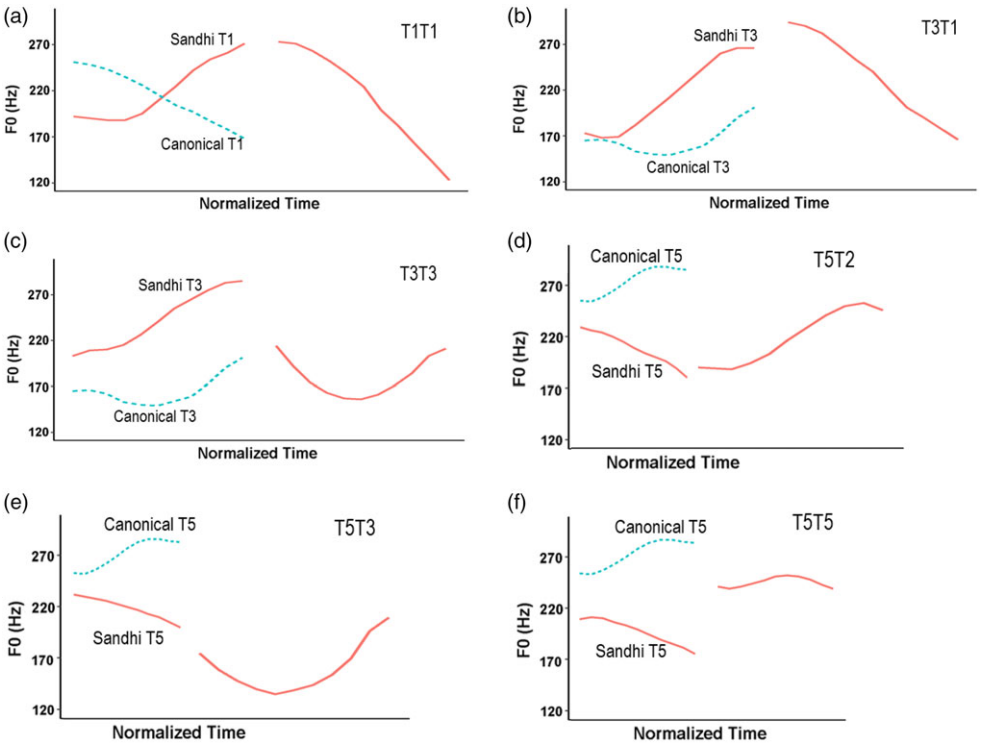

Figure 12 (Colour online) F0 contours of tone sandhi in Hefei Mandarin.

T5T3 (e.g. [fɐʔ^{2} k^{h}õ^{213}] 罚款 'fine'), and T5T5 (e.g. [məʔ^{2} luəʔ^{4}] 目录 'index'), the initial T5 (a short high tone as /4/) surfaces as a short low tone [2]. In the last three cases (T5T2, T5T3 and T5T5), the first tone is short and usually no longer than 100 ms, as lexical tones in Figure 11 and as sandhi forms in Figure 12. While the sandhi forms of the first T5 appear as a falling f0 contour in T5T2 (d), T5T3 (e), and T5T5 (f), the short duration generally leads to a perceived short low tone, similar to the recognition of a lexical Tone 5 as a short high tone in Figure 11. Therefore, the sandhi form of Tone 5 is recognized as 2 in (d), (e) and (f), instead of a contour with two digits.

Neutral tone

Neutral tone is a tonal phenomenon widely observed across Chinese languages, by which a lexical item such as a monosyllabic suffix is unspecified for tone in the lexicon or loses its lexical tone when appearing in an unstressed position (J. Wang 1997, 2000, 2002; Z. Wang 1999). For the tonal values of neutral tones, different patterns exist across Chinese languages, such as adopting a mid or low tone or taking the ending point of a preceding tone in a stressed syllable (Wang 2002, 2004a, b; Li 2004).

Neutral tone in Hefei Mandarin (Li 1997, Kong 2006) mainly occurs in suffixes such as [tsɻ] 子 as in [pɔ^{31} tsɻ^{0}] 包子 'steamed dumpling' ('dumpling '+suffix). As a convention in the Chinese literature, a neutral tone is often represented as T0 to indicate its difference from the lexical tones. In Hefei Mandarin, the duration of a neutral tone is usually shorter than the duration of a normal lexical tone, except the checked Tone 5 (Kong 2003, 2006, 2019). Table 11 reports the mean durations of tones in disyllabic sequences such as [pɔ^{31} tsɻ^{0}] 包子 'steamed dumpling', in which the initial tones are lexical tones and the second tones are neutral tones. The results were based on the measurements of six tokens for each

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Table 11 Mean durations of lexical tone and neutral tone in disyllabic sequences.

	Lexical tone		Neutral tone		Duration ratio of neutral tone to lexical tone
	Mean	SD	Mean	SD	
T1+T0	176	21.0	101	17.5	0.57
T2+T0	179	10.4	113	9.1	0.63
T3+T0	192	27.3	148	5.1	0.77
T4+T0	187	7.6	77	7.1	0.41
T5+T0	102	20.0	86	11.0	0.85

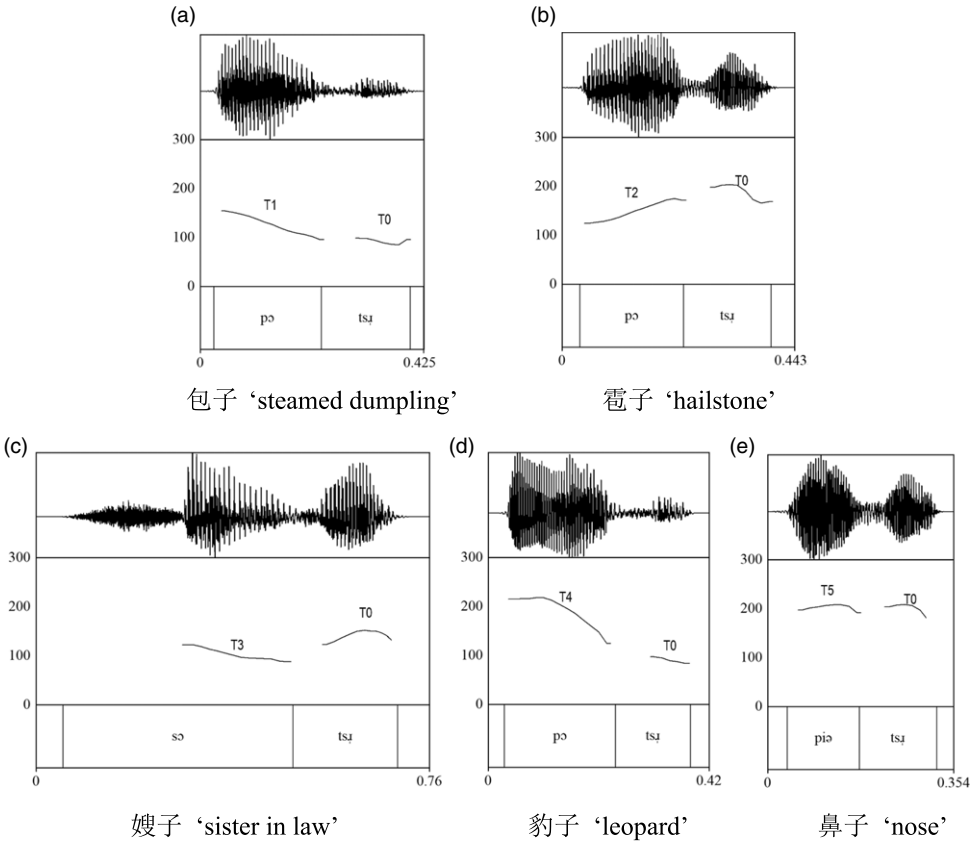

Figure 13 F0 contour of disyllabic sequences involving neutral tone in Hefei Mandarin.

tonal combination, all of which have the suffix [tsɻ] 子. As shown in Table 11, the neutral tone syllable is in general shorter than the initial lexical tone, including Tone 5 which is already shorter than the other four tones.

The tonal target of neutral tone in Hefei Mandarin, as in disyllabic sequences, was reported to be relatively low when its preceding tone is Tone 1 and Tone 4, mid when its preceding tone is Tone 3, and relatively high when its preceding tone is Tone 2 and Tone 5

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(Kong 2003).[10] The production of neutral tone by the speaker in this study generally conforms with what was reported in the literature. Figure 13 gives examples of the f0 trajectories of disyllabic sequences with neutral tone as the second syllable. When the initial tone is Tone 1 (31) or Tone 4 (53), the neutral tone appears as low, as in [pɔ^{31} tsɻ^{0}] 包子 'steamed dumpling' (Figure 13(a)) and [pɔ^{53} tsɻ^{0}] 豹子 'leopard' (Figure 13(d)); when the initial tone is Tone 2 (24) or Tone 5 (4), the neutral tone surfaces as high, as in [pɔ^{24} tsɻ^{0}] 雹子 'hailstone' (Figure 13(b)) and [piə^{4} tsɻ^{0}] 鼻子 'nose' (Figure 13(e)).[11] In all these four cases, it seems that the neutral tone is an extension of the f0 contour of its preceding syllable, which is consistent with the description in Kong (2003). For the combination of Tone 3 and neutral tone (T3+T0), the production of the speaker showed that, as in Figure 13(c), the initial syllable surfaces as a mid-falling contour where the neutral tone hits a relatively high target. Considering the isolated form of Tone 3 as 213, it seems that the complex contour of Tone 3 is split between the two syllables in [sɔ^{21} tsɻ^{3}] 嫂子 'sister in law' (Figure 13(c)).

Transcription of the recorded passage

The transcription below is broad allophonic, i.e. with the segments transcribed phonemically and the sandhi tones transcribed as the phonetic forms. In the transcription below, line C includes the Chinese text, line B includes the broad allophonic transcription, and line T gives the English translation of the Chinese text. Tones are marked for individual syllables and, wherever applicable, sandhi tones are given in (). For syllables with a Tone 5, i.e. the checked tone, the glottalization associated with T5 is transcribed when present. The recorded passage includes some cases of lenition, presumably related to its nature as connected speech, for example, the lack of obvious closure in some affricates such as /ts/.

C: 北风跟日头

B: pɐ^{4} fəŋ^{31} kən^{31} ɹəʔ^{4} tʰɤ^{0}

T: 'The North Wind and the Sun'

C: 有回子北风跟日头在那奥子争论哈个本事大。

B: jɯ^{213} xwi^{24} tsə^{0} | pɐ^{4} fəŋ^{31} kən^{31} ɹəʔ^{4} tʰɤ^{0} | tsɛ^{53} la^{53} ɔ^{53} tsə^{0} tsən^{31} lən^{53} | xa^{213} kə^{0} pən^{213} sɻ^{53} ta^{53} ||

T: Once, north wind and sun were there disputing whose ability is stronger.

C: 争来争去，就是不分高低。第个时候，

B: tsən^{31} lɛ^{24} tsən^{31} tsʰɻʷ^{53} | tɕɯ^{53} ʃʅ^{53} pəʔ^{4} fən^{31} kɔ$^{31(24)}$ tsɻ^{31} || ti^{53} kə^{0} ʃʅ^{24} xɤ^{53} |

T: Arguing back and forth, there is no result who is stronger. At this time,

[10] In the connected speech of Hefei Mandarin, the pitch value of a neutral tone can be influenced by its adjacent f0 targets, such as lexical tones or intonational boundary tones (Kong 2003).

[11] Figure 13(e), the [piə^{4}] 鼻 'nose' bears Tone 5. As noted earlier, the glottal stop [ʔ] is variably dropped, so is the case in [piə^{4} tsɻ^{0}] 鼻子 'nose'.

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C: 来之一个走路的，他身上穿件厚大氅。

B: lɛ^{24} tʃə^{0} i^{31} kə^{0} tsɤ^{213} lɯ^{53} tə^{0} ‖ tʰa^{31} ʃən^{31} ʃã^{53} tʃʰwæ̃^{31} tɕĩ^{53} xɤ^{53} ta^{53} tʃʰq̃^{213} ‖

T: there came a traveler, who was wearing a thick cloak.

C: 他们就讲好之，哈个能叫第个走路的

B: tʰa^{31} mən^{0} tɕɯ^{53} tɕq̃$^{213(24)}$ xɔ^{213} tʃə^{0} ‖ xa^{213} kə^{0} lən^{24} tɕɔ^{53} ti^{53} kə^{0} tsɤ^{213} lɯ^{53} tə^{0} |

T: They then agreed that whoever could let the traveler

C: 脱掉厚大氅，就算哈个的本事大。

B: tʰɐʔ^{4} tjɔ^{53} xɤ^{53} ta^{53} tʃʰq̃^{213} | tɕɯ^{53} sõ^{53} xa^{213} kə^{0} tə^{0} pən^{213} sɻ^{53} ta^{53} ‖

T: take off his cloak will be regarded as the stronger.

C: 北风就出劲吹将起来。哈晓得他吹的越凶，

B: pɐ^{4} fəŋ^{31} tɕɯ^{53} tʃuəʔ^{4} tɕin^{53} | tʃʰwi^{31} tɕq̃^{31} tsʰɻ^{213} lɛ^{24} ‖ xa^{213} ɕɔ^{213} təʔ^{4} tʰa^{31} tʃʰwi^{31} tə^{0} yɐʔ^{4} ɕəŋ^{31} |

T: The north wind then blew with effort. As he did not know, the harder he blew,

C: 那个走路的就把大氅裹得越紧。

B: la^{53} kə^{0} tsɤ^{213} lɯ^{53} tə^{0} | tɕɯ^{53}pa^{213}ta^{53} tʃʰq̃^{213} ko^{213} təʔ^{4} yɐʔ^{4} tɕin^{213} ‖

T: the closer the traveler wrapped himself in the cloak.

C: 后来北风没法子，只好就算之。

B: xɤ^{53} lɛ^{24} pɐ^{4} fəŋ^{31} məʔ^{4} fɐʔ^{4} tsɻ^{0} | tʃɻ̩$^{213(24)}$ xɔ^{213} tɕɯ^{53} sõ^{53} tʃə^{0} ‖

T: Later, the north wind had no way out, and he had to give up.

C: 过一霎，日头出来之。他热乎乎一晒，

B: ko^{53} i^{31} ʃɐʔ^{4} | ɹəʔ^{4} tʰɤ^{0} tʃʰuəʔ^{4} lɛ^{24} tʃə^{0} ‖ tʰa^{31} ɹɐʔ^{4} xɯ^{31} xɯ^{31} i^{31} ʃɛ^{53}|

T: After a while, the sun came out. He warmly shone for a while.

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C: 那个走路的跟着就把厚大氅脱的之。

B: la^{53} kə^{0} tsɤ^{213} lɯ^{53} tə^{0} | kən^{31} tʃə^{0} tɕɯ^{53} pa^{213} xɤ^{53} ta^{53} tʃʰɑ̃^{213} tʰɐʔ^{4} tə^{0} tʃə^{0} ‖

T: The traveler then took off his thick cloak.

C: 第会子北风只好承认，

B: ti^{53} xwi^{31} tsɻ^{0} | pɐ^{4} fəŋ^{31} tʃɻ̩$^{213(24)}$ xɔ^{213} tʃʰən^{24} ɹən^{53} |

T: At this time, the north wind had to admit that,

C: 他两个当中还是日头本事大。

B: tʰa^{31} ljɑ̃^{213} kə^{0} tɑ̃$^{31(24)}$ tʃəŋ^{31} | xɛ^{24} ʃɻ̩^{53} ɹəʔ^{4} tʰɤ^{0} pən^{213} sɻ^{53} ta^{53} ‖

T: among them, the sun is the stronger one.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S0025100322000081.

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