Phonetic Evidence for the Nasal Coda Shift in Mandarin

國語音節尾鼻音轉換的語音證據

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PHONETIC EVIDENCE FOR THE NASAL CODA SHIFT IN MANDARIN[*†]

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ABSTRACT

This paper presents phonetic evidence to resolve the transcription disagreement concerning the syllable-final nasal shift in the variety of Mandarin spoken in Taiwan. In the word reading experiment, three judges agreed that the rhyme /iŋ/ undergoes a sound change, but they perceived the nasal coda shift differently. Two of them transcribed it as a modification from /iŋ/ to /in/, whereas the other asserted that the velar nasal disappears with its preceding vowel nasalized. In order to resolve this transcription conflict, this study analyzes the acoustic attributes of the speculative sound alterations in question, including /in/, /iŋ/, /i/ and /ĩ/. The phonetic analysis indicates that the Taiwanese participants do not nasalize the preceding vowel deleting the nasal coda but they tend to pronounce the post-vocalic velar nasal as its dental counterpart. This study concludes by discussing the implications of the synchronic variation for the theories of the nasal coda shift in Chinese dialects.

Key words: Phonetic analysis, sound change, nasal coda, Mandarin

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† Mandarin is the official language in China and Taiwan, and is also one of the official languages spoken in Singapore. It is called Putonghua (普通話, "common language") in China, Guoyu (國語, "national language") in Taiwan, Huayu (華語, "Chinese language") in Malaysia and in Singapore. This study does not use "Chinese" because it is often associated with Cantonese, but choose to use Mandarin to emphasize its use as a *lingua franca* spoken in China, Malaysia, Singapore, and Taiwan. (P. Chen 1999)

James H. Yang

1. INTRODUCTION

One of the major sound differences between mainland Mandarin (MM) and Taiwan Mandarin (TM)[1] is the sound change in the nasal codas: the dental and velar ones (/n/ and /ŋ/). However, earlier research on the syllable-final nasal shift in Mandarin displayed conflicting results. Barale (1982) assumed, based on her study of the weakening and loss of final nasal consonants in Beijing Mandarin (BM), that a nasal ending may pass through the following three stages: (1) the nasalization of the nasal-preceding vowel, (2) the loss of the nasal coda, and finally (3) the de-nasalization of the syllable-final vowel.

Approximately a decade later, C-Y Chen (1991) also examined nasal endings in BM, but her findings indicated that the shifts of the nasal endings from /iŋ/ and /əŋ/ respectively to /in/ and /ən/, are in an ongoing process of confusion and interchange. This discovery supports none of Barale's (1982) assumptions.

Like C-Y Chen (1991), Kubler (1985), Li et al. (2005) and Tse (1992) also found that the final velar nasal in TM tends to become the dental following the vowel /i/ or schwa. However, the nasal coda shift occurs sporadically in BM, whereas TM exhibits a regular nasal change.

Furthermore, Hsu and Tse (2007), Ing (1985), and Lin (2002) also reported the merger of the final velar nasal with the dental nasal, but only when the preceding vowel is schwa, excluding the high front vowel /i/. When the nucleus is /i/, the final dental nasal tends to be velarized, in disagreement with the prior findings. The following table summarizes previous research on the syllable-final nasal shift in Mandarin.

[1] In this study, MM refers to the variety of Mandarin spoken in mainland China, and TM refers to the variety of Mandarin spoken in Taiwan, in contrast to Taiwanese Mandarin, the variety spoken with a heavy Southern-Min accent (for a detailed discussion on the definitions of Taiwan Mandarin and Taiwanese Mandarin, see Hsu and Tse, 2007, pp. 1-3).

Table 1. Previous Reports of the Nasal Coda Shift in Mandarin

Nasal Coda Shift	Sound Change Type	Previous Research
VN>nasalized V	Free variation	Barale (1982)
/iŋ/>/in/	Conditioned alteration	C-Y Chen (1991) Kubler (1985) Li et al. (2005) Tse (1992)
/in/>/iŋ/	Conditioned alteration	Hsu and Tse (2007) Ing (1985) Lin (2002)
/əŋ/>/ən/	Conditioned alteration	C-Y Chen (1991) Hsu and Tse (2007) Ing (1985) Li et al. (2005) Lin (2002) Kubler (1985) Tse (1992)

The studies discussed above demonstrate that syllable-final nasal dentalization is the major trend in both BM and TM. However, Ing (1985), Lin (2002), and Hsu and Tse (2007) all found that the dental nasal coda in TM regularly changes into the velar nasal when preceded by the vowel /i/. These conflicting findings might have resulted from different data collection methodologies.

Most crucially, all of the earlier studies, except for Hsu and Tse (2007), rely solely on human transcription, without acoustic analyses as phonetic evidence for their reports. In addition, the prior studies on nasal coda alterations focus on the variety of Mandarin spoken either in Beijing or Taiwan. Accordingly, this research aims to investigate whether nasal endings differ between MM and TM.

2. RESEARCH QUESTIONS

To explore the possible synchronic variation of the syllable-final nasals in the two varieties of Mandarin in question, this study addresses three research questions:

1. Do MM and TM differ in nasal codas?
2. If found, is the nasal alteration a free variation or a conditioned modification?
3. Is the observed nasal coda shift an ongoing or complete sound change?

The first question investigates whether these two varieties of Mandarin undergo a nasal coda shift. It serves to examine whether the synchronic variation of these two varieties of Mandarin manifests itself in nasal endings. Moreover, this study analyzes whether the nasal shift occurs in certain environments or appears without syllabic constraints. The final question examines whether the nasal coda alteration occurs sporadically, regularly, or completely. To address these questions, this study conducts a speech production experiment, which is described in the subsequent section.

3. SPEECH PRODUCTION EXPERIMENT

3.1 Participants

This experiment included 30 native speakers of Mandarin, half from mainland China and half from Taiwan. They were all graduate students in the USA for the first time, having arrived one to five months previous to the experiment. The participants were young adults with an average age of 29, the youngest being 25 years old and the oldest one being 33. Their backgrounds allowed the researcher to investigate whether a final nasal shift occurs in young educated speakers. However, at the time of the experiment, it was not possible to balance the participants with respect to region and gender. The following tables summarize the speakers' sociolinguistic information:

Table 2. Sociolinguistic Backgrounds of the MM Speakers

Speaker	Nationality	Gender	Age
MM1	Beijing, China	Female	28
MM 2	Beijing, China	Female	28
MM 3	Beijing, China	Male	28
MM4	Beijing, China	Male	29
MM5	Beijing, China	Male	32
MM6	Shanghai, China	Female	26
MM7	Shanghai, China	Male	27
MM8	Shanghai, China	Male	29
MM9	Jiangsu, China	Male	30
MM10	Guangdong, China	Female	28
MM11	Guangdong, China	Male	29
MM12	Guangdong, China	Male	31
MM13	Fujian, China	Male	29
MM14	Fujian, China	Male	32
MM15	Hunan, China	Female	28

Table 3. Sociolinguistic Backgrounds of the TM Speakers

Speaker	Nationality	Gender	Age
TM1	Taipei, Taiwan	Female	27
TM2	Taipei, Taiwan	Female	28
TM3	Taipei, Taiwan	Male	30
TM4	Taipei, Taiwan	Male	31
TM5	Taipei, Taiwan	Male	33
TM6	Taichung, Taiwan	Female	25
TM7	Taichung, Taiwan	Female	27
TM8	Taichung, Taiwan	Male	29
TM9	Taichung, Taiwan	Male	30
TM10	Taichung, Taiwan	Male	30
TM11	Kaohsiung, Taiwan	Female	28
TM12	Kaohsiung, Taiwan	Female	28
TM13	Tainan, Taiwan	Female	29
TM14	Tainan, Taiwan	Male	32
TM15	Tainan, Taiwan	Male	33

3.2 Procedures

The participants were interviewed one at a time and tape-recorded during the interview. Each participant was first asked to sign a consent form before answering the questionnaire, which included questions regarding his or her sociolinguistic background. Next, the interview proceeded with a word-list reading task. Because Mandarin has no codas except for the velar and dental nasals when preceded by the three vowels /i, ə, ɑ/ (Duanmu, 2000), this study devised a list of three types of minimal pairs: /iŋ/-/in/, /əŋ/-/ən/ and /ɑŋ/-/ɑn/, as illustrated below:

Table 4. Target Pairs of the Speech Production Experiment

-ing (/iŋ/) vs.-in (/in/)	-eng (/əŋ/) vs. -en (/ən/)	-ang (/ɑŋ/) vs. -an (/ɑn/)
yīng vs. yīn (應 vs. 音)	shèng vs. shèn (勝 vs. 腎)	bāng vs. bān (幫 vs. 班)
bīng vs. bīn (兵 vs. 彬)	chéng vs. chén (乘 vs. 沉)	fàng vs. fàn (放 vs. 飯)
míng vs. mín (明 vs. 民)	zhěng vs. zhěn (拯 vs. 枕)	zhāng vs. zhān (張 vs. 沾)
líng vs. lín (零 vs. 林)	gēng vs. gēn (耕 vs. 根)	huāng vs. huān (荒 vs. 歡)
xīng vs. xīn (星 vs. 心)	péng vs. pén (朋 vs. 盆)	wàng vs. wàn (忘 vs. 萬)
jīng vs. jīn (經 vs. 金)	wēng vs. wēn (翁 vs. 溫)	pàng vs. pàn (胖 vs. 盼)
qīng vs. qīn (清 vs. 親)	mèng vs. mèn (夢 vs. 悶)	páng vs. pán (旁 vs. 盤)
xìng vs. xìn (姓 vs. 信)	bēng vs. bēn (崩 vs. 奔)	táng vs. tán (堂 vs. 談)
bìng vs. bìn (並 vs. 鬢)	fèng vs. fèn (奉 vs. 奮)	dǎng vs. dǎn (黨 vs. 膽)
píng vs. pín (平 vs. 頻)	fēng vs. fēn (風 vs. 分)	kāng vs. kān (康 vs. 刊)
qīng-xìn vs. qīn-xìn (輕信 vs. 親信)	chéng-jiù vs. chén-jiù (成就 vs. 陳舊)	gāng-zi vs. gan-zī (缸子 vs. 竿子)
yīng-qì vs. yīn-qì (英氣 vs. 陰氣)	shēng-gāo vs. shēn-gāo (升高 vs. 身高)	huǎng-yán vs. huǎn-yán (謊言 vs. 緩延)
jīng-yíng vs. jīn-yín (經營 vs. 金銀)		

xīng-xiàng vs. xīn-xiàng (星象 vs. 新象)	shēng-qǐng vs. shēn-qǐng (聲請 vs. 申請)	fāng-àn vs. fān-àn (方案 vs. 翻案)
míng-xiǎng vs. mín-xiǎng (冥想 vs. 民享)	fēn-zhēng vs. fēn-zhēn (紛爭 vs. 分針)	zhǎng-chū vs. zhǎn-chū (長出 vs. 展出)
líng-gǎn vs. lín-gǎn (靈感 vs. 臨感)	zhěng-zhì vs. zhěn-zhì (整治 vs. 診治)	gāng-guǒ vs. gān-guǒ (剛果 vs. 甘果)
jīng-yú vs. jīn-yú (鯨魚 üs. 金魚)	zhèng-fēng vs. zhèn-fēng (政風 vs. 陣風)	bāng-huì vs. bān-huì (幫會 vs. 班會)
qǐng-shì vs. qǐn-shì (請示 vs. 寢室)	fēng-shù vs. fēn-shù (楓樹 vs. 分數)	fāng-cǎo vs. fān-cǎo (芳草 vs. 翻草)
	méng-miàn vs. mén-miàn (蒙面 vs. 門面)	shāng-jī vs. shān-jī (商機 vs. 山雞)

The table presented above is comprised of 54 rhyming pairs, making a total of 108 common Chinese words. If the given word is disyllabic, only its first syllable is examined in this study. In the reading task, all the target words were randomly mixed with 12 irrelevant words.

This study did not employ free talk or group discussion to elicit spontaneous utterances because such approaches might not have collected a sufficient number of target words for sound analysis. Instead, this study utilized word-reading tasks in order to control the speech production and thereby make it possible to compare and quantify the differences in the speakers' pronunciations.

Although the test words were all common in Mandarin, each speaker was told that he or she could ask for definitions of any words new to him or her to avoid reading difficulty caused by lexical unfamiliarity. However, no informant requested a lexical definition. Next, each informant was instructed to press a button and read aloud each word displayed on a computer screen. The recordings were made in a sound booth, using a mounted microphone placed approximately 3 inches away from the speaker's lips.

Following the reading task was an interview; each respondent was asked to identify some minimal pairs differing only in nasal codas. The

informant was also encouraged to talk about his or her view of the linguistic differences in the two varieties of Mandarin in question.

4. FINDINGS

4.1 The Nasal Codas in Taiwan Mandarin

Three judges listened to the sound data collected from the TM speakers, and they all agreed that the nasal coda stays put when preceded by the vowel /ɑ/. They also perceived that the final velar nasal tends to shift to its dental counterpart when the preceding vowel is schwa. However, they had different transcriptions of the syllable-final velar nasal when the preceding vowel is the high front vowel /i/. Two judges maintained that the final velar nasal regularly changes to the dental nasal, but the other claimed that the velar nasal recurrently vanishes, and that the previous vowel is nasalized.

In fact, the velar nasal has been found to be frequently confused with a nasalized vowel. House (1957) explained this misperception "by noting that the velar nasal has primarily just a single resonating cavity with a small, perhaps negligible side-cavity, unlike other nasals, and thus negligible anti-resonances with large bandwidths and is more like that of a nasalized vowel than are those of any other nasal" (cited from Ohala, 1975, p. 298). In this respect, Ohala reminded the reader, "It should be kept in mind, however, that most of the perceptual studies of nasals and nasalized vowels have been done using ENGLISH (sic) speakers as the listeners. Many of the results, then, may be due to facts of ENGLISH (sic), and not due to human universal factors" (1975, p. 295).

Although previous research on nasal codas in Mandarin demonstrated that the final velar nasal is apt to change into its dental counterpart, as indicated in Table 1, Barale (1982) and Zee (1985) contended that the final nasal might eventually vanish, with its preceding vowel nasalized. Furthermore, M. Cheng (1972) observed from his surveys of Chinese dialects that high vowels like /i/ become nasalized far less frequently than low vowels. Nevertheless, no empirical studies have ever reported that the syllable-final velar nasal tends to disappear, with its preceding vowel nasalized.

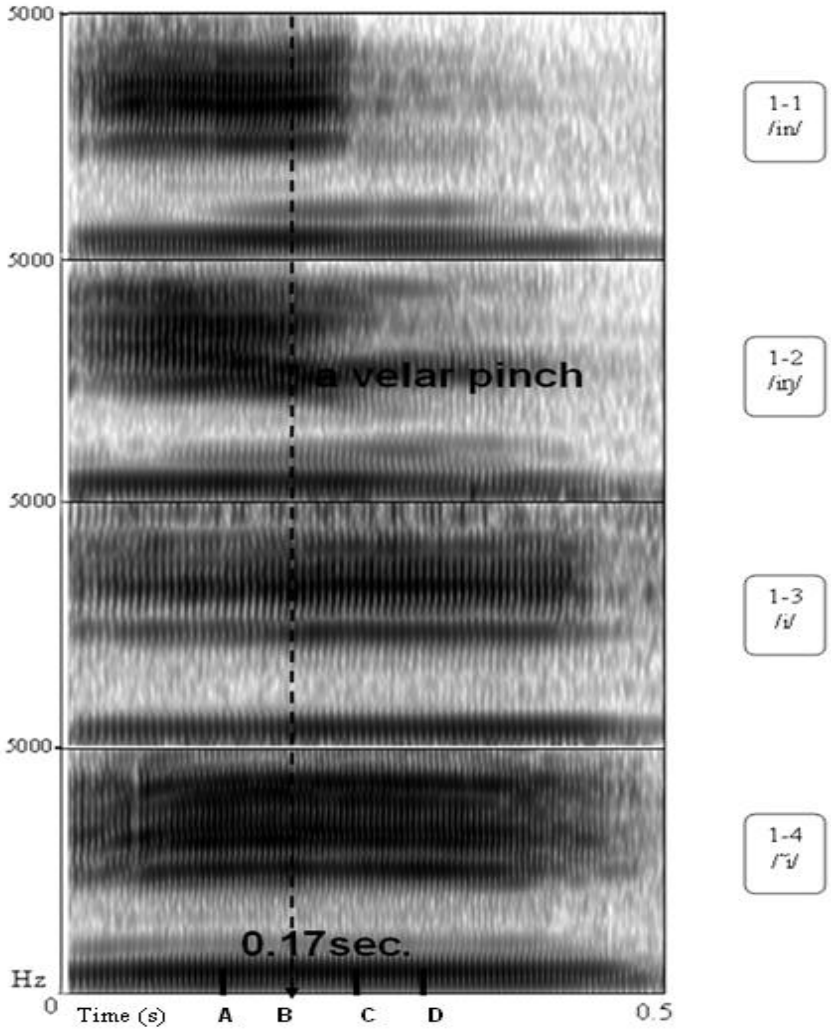
To resolve the unanticipated transcription conflict, this study resorted to the acoustic analysis of the nasal codas in question. A native speaker

of Standard Mandarin (SM) was invited to pronounce four rhymes at a normal rate, and his pronunciation was later analysed phonetically to serve as a point of reference. His pronunciation of the test sounds was double-checked by two native-speaking teachers of Mandarin, both of whom regarded the speaker's articulatory demonstration as "very standard" on a five-point scale. Specifically, the speaker was instructed to use Praat to record his voice in a quiet room at the CD quality settings of 44.100 kHz, 16-bit, and mono. He articulated the vowel /i/ in four different environments:

(1) /in/ (yin,音, *sound*, with the dental nasal /n/)
(2) /iŋ/ (ying, 應, *should*, with the velar nasal /ŋ/)
(3) /i/ (yi, 衣, *clothes*, without any coda)
(4) /ĩ/ (yĩn, only the nasalized vowel)

It should be noted, though, that sound (4), the nasalized high front tense vowel /ĩ/, is a made-up phoneme because nasalized vowels do not appear in SM (Dong, 1992; Da-he Committee, 2008). The following figure displays the spectrograms of his readings:

Figure 1. Spectrograms of the Four Different Sounds: /in/, /iŋ/, /i/, and /ĩ/



As Figure 1 displays above, each of the four sounds has distinct acoustic features. At first glance, the duration of the vowel is the key to measuring whether the vowel is a purely oral one or is followed by a nasal. If the forth formant (F4) of the vowel lasts nearly to the end

approximately at the point of 0.5 second, the sound does not include a nasal coda, as shown in Figures 1-3 and 1-4. On the contrary, a final nasal should have a duration similar to its preceding vowel, because Mandarin is a syllable-timing language, in which the pronunciation of every syllable takes up around the same amount of time (Duanmu, 2000). In other words, if the sound includes both a vowel and a coda, each phoneme should roughly last as long, as shown in Figures 1-1 and 1-2.

However, whether a vowel is a pure or closed one cannot be determined simply by the visual observation of spectrograms. Accordingly, Chen (2000) provided a rigid analysis to distinguish a pure vowel from a rhyme ending with a nasal. She found a significant statistical difference in the formant amplitude because a steep drop occurs in the V:N boundary, whereas no amplitude drop exists in the spectrogram of an open syllable. Her discovery is also reflected in the intensity analysis of the four sounds pronounced by the SM speaker, as demonstrated below:

Table 5. The Intensity Analysis in Standard Mandarin

Test sound	Intensity (dB)			
	Point A	Point B	Point C	Point D
/in/	76	75	52	48
/iŋ/	77	77	52	49
/i/	74	76	77	76
/ĩ/	72	73	73	73

At point C, the intensity began to drop, revealing the V:N boundary for the rhymes /in/ and /iŋ/; by contrast, the intensity does not decrease abruptly for the open syllables /i/ and /ĩ/ but remains fairly constant throughout the open vowels.

In addition, the purely oral vowel /i/ can be differentiated from its nasalized counterpart /ĩ/ because the latter displays an obvious spectral spread, particularly in the region of the first formant (F1). Ladefoged (2003, pp. 135-137) remarked that nasalized /i/ differs from its oral vowel because it has an apparent upward-shifted F1 and increased bandwidth of all formants, particularly F1, as shown in Figures 1-3 and 1-4. These phonetic features exactly parallel Ohala's laboratory observation of nasalized vowels (1975, pp. 293-297). Ohala commented, "It is the region of the first formant, then, where the most significant acoustic changes take place in the nasalization of a vowel" (1975, p.

295). This nasalization detection technique is supported by the sound analysis exhibited by the following table:

Table 6. The First Formant Bandwidth Comparison between /i/ and /ĩ/

Test sound	F1 Bandwidth (Hz)			
	Point A	Point B	Point C	Point D
/i/	328	362	419	466
/ĩ/	773	876	759	802

As presented above, the F1 bandwidth of the pure vowel /i/ is constantly lower than that of its nasalized counterpart /ĩ/, verifying that a nasalized vowel has a higher F1 bandwidth than its oral counterpart.

Last but not least, the place of a velar nasal coda might be determined by the presence of a velar pinch. Ladefoged (2003) observed that when the coda is a velar nasal, the third formant (F3) apparently drops near the end of the vowel towards F2 and forms a velar pinch (pp. 142-145). The following table exhibits the spectral features of the sounds /in/ and /iŋ/ articulated by the SM speaker:

Table 7. The Formant Distance of the Two Rhymes /in/ and /iŋ/

Test sound	Distance between F2 and F3 (Hz) at Point B (i.e., 0.17 second)
/in/	764
/iŋ/	0

The formant analysis indicates that the sound /iŋ/ displays a velar pinch at point B (i.e., at 0.17 second), whereas no lap occurs at the same point for /in/, whose F2 and F3 remain parallel particularly during the vowel realization.

Nevertheless, the velar pinch has been proved to be insufficient because its absence or presence tends to be contextually dependent (e.g. Pickett, 1999; Stevens, 1994). Chen's (2000) acoustic analysis revealed that the place of a nasal coda might be determined from the phonetic attributes of its preceding vowel. She observed, "In comparing vowels followed by [n] as opposed to [ŋ], with or without oral closure, *F*2 frequency is higher for [a]; *F*3 frequency is higher for [i]; and *F*1 frequency is lower and *F*2 frequency is higher for [ə]" (p. 24). She remarked, "The *F*1 and *F*2 frequencies of the formants may be explained by the tongue moving to a higher and a more fronted position for [a] and

[ə] in anticipation of [n] relative to [F]. The *F*3 frequency is influenced by the closeness of front and back cavity resonances for [i]" (p. 24). Her observation was confirmed by the SM speaker's pronunciation, because the *F*3 of the nucleus /i/ is consistently higher when it ends with a dental nasal than when its coda is a velar nasal, as evidenced below:

Table 8. The Third Formant Comparison Between /in/ and /iŋ/

Test sound	F3 (Hz)			
	Point A	Point B	Point C	Point D
/in/	2964	2960	2945	2932
/iŋ/	2662	2475	2579	2620

Taken together, the SM speaker's pronunciation provided a point of reference for understanding the acoustic attributes of the rhymes in question. Nevertheless, it cannot be used to generalize the sound features of other Mandarin speakers.

Accordingly, drawing on the nasal detection techniques presented above, this study examined each TM speaker's readings of the test words with the rhyme /iŋ/, because it was this rhyme that was perceived differently by the three judges; two of them transcribed it as having regularly undergone the shift to /in/, whereas the other contended that the velar nasal recurrently vanishes, with the previous vowel nasalized. First of all, this study investigated whether the V:N boundary existed in each TM speaker's pronunciation of the test words ending with the velar nasal. It examined whether an intensity drop occurred during the realization of the pronunciation. The findings indicate that the intensity of the rhyme /iŋ/ did not remain constant but decreased abruptly at around the middle time of the pronunciation. This result evidences that the Taiwanese participants did not delete the nasal coda of the rhyme /iŋ/, refuting the claim that the nasal coda disappears, and that its preceding vowel is nasalized.

Remarkably, in the TM readings of the test words with the /iŋ/ ending, the F3 frequency was consistently found to be similar to that of the vowel preceding a dental nasal coda. This means that the TM speakers tend to pronounce /iŋ/ as /in/, because its F3 was not found to be lower than that of the vowel ending with a dental nasal. In other words, the minimal pairs were not distinguished but became homophones. For instance, the word *jīngyú* (鯨魚, *whale*) was regularly pronounced by the Taiwanese respondents as *jīnyú* (金魚, *goldfish*). This

lexical neutralization might also be detected by comparing the spectrograms of the minimal pair *jīngyú* and *jīnyú* pronounced by the same Taiwanese participant, as shown below:

Figure 2. Spectrogram of the Word *jīngyú* (鯨魚, *whale*) Pronounced by a Taiwanese Participant

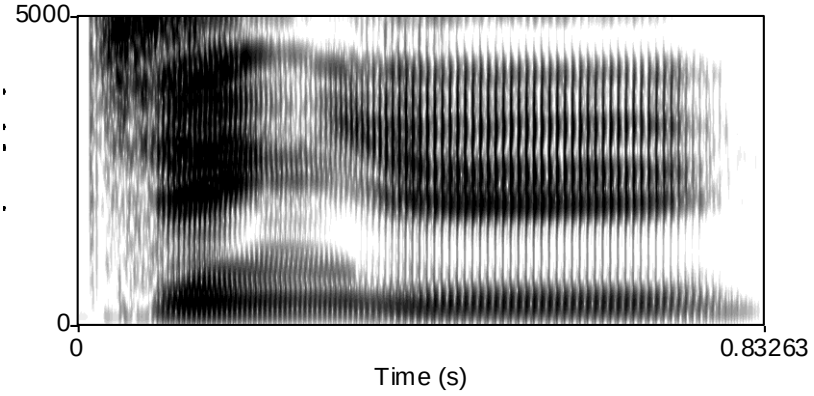
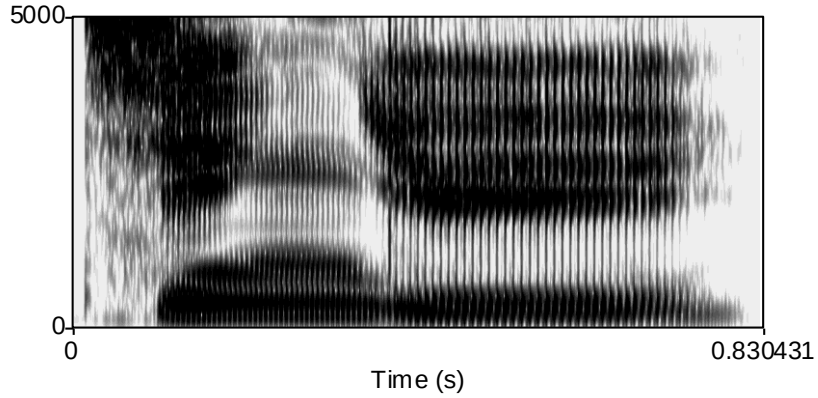


Figure 3. Spectrogram of the Word *jinyu* (金魚, *goldfish*) Pronounced by the Same Taiwanese Informant



At first glance, Figures 2 and 3 look similar to each other. A close inspection of each spectrogram also indicates that their F3 frequencies of the first syllables correspond nearly to each other, confirming that this Taiwanese participant pronounced the minimal pair the same.

In the follow-up interview, this Taiwanese participant also admitted that in his natural speech he did not differentiate the pronunciation of these two words; rather, he confessed that he pronounced the minimal pair in exactly the same way. Interestingly, in the interview, when he was asked to listen to the minimal pair pronounced by the SM speaker, he responded that the "standard" pronunciation of the word *jingyu* sounds artificial to him, and that *jinyu* sounds like the natural, albeit non-standard, way of pronouncing the word in Taiwan.

To sum up, the syllable-final velar nasal neither maintains nor disappears with its preceding vowels nasalized. Rather, it is found to change regularly to its dental counterpart. This sound analysis attested the third transcriber's misperception. Although no reason is apparent for why the velar nasal coda tends to induce vowel nasalization, it is intriguing to note that the rhyme /iŋ/ might be perceived to be more nasalized than other two eligible rhymes, i.e., /əŋ/ and /ɑŋ/.

On the whole, the results demonstrate that the syllable-final nasal shifts from the velar to the dental approximately 97 percent of the time after the vowel /i/, and 95 percent of the time after the vowel /ə/; nevertheless, it does not emerge when following the vowel /ɑ/. Below are the details regarding the observed nasal coda merger of the TM speakers:

Table 9. The Occurrence Percentage of the Nasal Coda Shift in TM

Speaker	**/iŋ/→ /in/**	**/in/→ /iŋ/**	**/əŋ/→ /ən/**	**/ən/→ /əŋ/**	**/ɑŋ/→ /ɑn/**	**/ɑn/→ /ɑŋ/**
TM1	94	0	90	0	0	0
TM2	89	0	100	0	0	0
TM3	100	0	80	20	0	0
TM4	94	0	100	0	0	0
TM5	100	0	90	0	0	0
TM6	89	0	90	0	0	0
TM7	94	0	100	0	0	0
TM8	94	0	90	0	0	0
TM9	100	0	100	10	0	0
TM10	100	0	100	0	0	0
TM11	100	0	100	0	0	0
TM12	100	0	100	0	0	0
TM13	94	0	100	0	0	0
TM14	100	0	90	0	0	0
TM15	100	0	100	0	0	0
Sum	96.53	0	95.33	2	0	0

As shown above, the velar nasal is subject to change into its dental counterpart when preceded by the vowels /i/ and /ə/. This sound modification is formulated by the following phonological rule:

(1) Nasal Fronting:
/ŋ/→[n]/{i, ə}.

Interestingly, this nasal merger leads to lexical neutralization, as illustrated earlier in the minimal pair: *jīngyú* (鯨魚, *whale*) and *jīnyú* (金魚, *goldfish*). In addition, the nasal coda shift from the velar to the dental is not a free variation but a conditioned alteration; the nasal shift occurs only when the preceding vowel is a non-back vowel, i.e., /i/ and schwa, rather than /ɑ/.

Furthermore, the nasal coda shift in TM is not only conditioned by the preceding vowel (Rule 1) but is also blocked by the labial onset, which is regularized as below:

(2) Vowel Labialization:
/əŋ/→[oŋ]/[labial].

This vowel labialization was found to frequently block nasal fronting. However, apart from the sound modifications under the labialization influence, the nasal merger preceded by schwa was found to occur 95 percent of the time.

It appears that this vowel labialization displays articulatory assimilation because the vowel is labialized under the influence of the initial labial consonant. For instance, the sound *meng* (/məŋ/) was not pronounced by the TM speakers as *men* (/mən/) according to Rule 1. Rather, it was consistently pronounced as *mong* (/moŋ/) following Rule 2. Obviously, this vowel labialization rule blocks the nasal fronting rule.

The question that arises from Table 9 is whether the nasal coda shift is an ongoing or complete sound change. This study addressed this research question according to Meade's (2001) category of sound alterations, as shown below:

Table 10. Classification of Phonological Processes (Adapted from Meade, 2001: 85)

Occurrence percentage	Usage
100%	Complete
Over 75%	Full
50%-74%	Regular
25%-49%	Inconsistent
1%-24%	Sporadic
0	Absent

According to Meade's (2001) classification of sound modifications, if a sound change exists all the time, it is a complete sound change. If it occurs more than 75 percent of the time, it is regarded as a full change. If found to take place from 50 to 74 percent of the time, it is considered to be a regular change. By contrast, if it happens less than 50 percent of the time, it is an unstable change. Following Meade's categorical framework, the nasal fronting (Rule 1) in TM qualifies as a full usage. By comparison, other nasal endings remain sporadic or absent. Having discussed the findings from the nasal coda readings of the TM speakers, the following section describes those of the MM speakers.

4.2 The Nasal Codas in Mainland Mandarin

All the judges agreed that the participants from mainland China tended to preserve the rhyme /iŋ/ instead of changing it to /in/. Specifically, the velar nasal coda is retained more than 60 percent of the time, making it a regular usage. By contrast, the shift from /iŋ/ to /in/ occurs merely 39 percent of the time. Accordingly, this nasal merger only takes place inconsistently.

Notably, the mainland Chinese participants changed the rhyme /in/ to /iŋ/ more frequently than other nasal coda alterations. This nasal coda alteration is formulated below:

(3) Nasal Backing
/n/→[ŋ]//i/.

According to Rule 3, the word *lingan* (臨感, *feelings at the moment*) would be read as *linggan* (靈感, *inspiration*), resulting in homophones. This nasal backing occurs 42 percent of the time in the MM speakers' readings. Albeit irregular, it emerges as a sound change competing with its opposite coda shift, i.e., Rule 1, the nasal fronting rule.

Additionally, other nasal endings are found to remain the same in MM, except that the rhyme /əŋ/ is sporadically replaced by /ən/. The detailed findings regarding the nasal endings in MM are presented below:

Table 11. The Occurrence Percentage of the Nasal Coda Shift in MM

Speaker	**/iŋ/→ /in/**	**/in/→ /iŋ/**	**/əŋ/→ /ən/**	**/ən/→ /əŋ/**	**/ɑŋ/→ /ɑn/**	**/ɑn/→ /ɑŋ/**
MM1	5	61	0	0	0	0
MM 2	11	72	0	0	0	0
MM 3	11	72	0	0	0	0
MM 4	5	11	0	0	0	0
MM 5	5	33	0	0	0	0
MM 6	44	11	0	0	0	0
MM 7	56	33	0	0	0	0
MM 8	33	44	0	0	0	0
MM 9	33	72	0	0	0	0
MM10	72	33	0	0	0	0
MM11	50	44	20	0	0	0
MM12	61	72	10	0	0	0
MM13	56	11	0	0	0	0
MM14	72	33	0	0	0	0
MM15	67	33	10	0	0	0
Sum	38.73	42.33	2.67	0	0	0

As a whole, nasal fronting (Rule 1) manifests itself as a full usage in TM, but only as an inconsistent usage in MM. However, Rule 1 is blocked by vowel labialization (Rule 2). Put simply, in TM the final velar nasal preceded by /i/ or schwa tends to change into the dental coda, except that the onset is a labial consonant. By contrast, MM seems to undergo the nasal coda alteration opposite to that of TM. When preceded by the vowel /i/, the dental nasal coda tends to shift to the velar; however, this nasal backing emerges as an inconsistent usage in MM, occurring only 42 percent of the time. Intriguingly, this nasal backing tendency (Rule 3) is totally absent in the TM participants. The following table summarizes the synchronic variation of the nasal endings in these two varieties of Mandarin:

Table 12. Summary of the Nasal Coda Shift in Mandarin

Mandarin	Rule 1 Nasal Fronting /ŋ/→[n]/{i,ə}.	Rule 2 Vowel Labialization /əŋ/→[oŋ]/[labial].	Rule 3 Nasal Backing /n/→[ŋ]//i/.
TM	full usage	full usage	absent
MM	inconsistent usage for the vowel /i/ sporadic usage for schwa	sporadic usage	inconsistent usage

Note: Rule 1 is fully blocked by Rule 2 in TM, but only sporadically blocked in MM.

Having described the nasal coda differences, the following section proceeds to examine the statistical significance of the nasal coda shift in question.

5. STATISTICAL ANALYSES

This study has found that MM and TM differ in the nasal coda alterations, but is this sound difference statistically significant? To address this question, this study compared the sound modification of the nasal fronting (Rule 1) in both MM and TM. The following table displays the t-test results of the final velar nasal shift to the dental coda in MM and TM:

Table 13. The T-test Measure of the Nasal Fronting in MM and TM

Nasal fronting	MM		TM		t	p
	M	SD	M	SD		
/iŋ/ > /in/	7	4.6	17.4	0.74	8.65	0.0001
/əŋ/ > /ən/	0.27	0.59	9.54	0.64	41.12	0.0001

It is noteworthy that, because eight of the 18 test words tend to undergo vowel labialization in TM, the number of test words for the vowel /i/ was 18, while that for schwa was only 10. Accordingly, only 10 of the test words beginning with non-labial consonants were used as the

basis of the comparison for the nasal shift when the preceding vowel was schwa. The discrepancy between the readings of the nasal fronting in MM and TM proves to be significant at a fairly high level ($p<0.0001$), suggesting that these two varieties of Mandarin differ significantly in the realization of the velar nasal coda.

Moreover, the statistical analysis also indicates that MM and TM differ significantly not only in nasal fronting (Rule 1), but also in nasal backing (Rule 3), as shown below:

Table 14. The T-test Measure of the Nasal Backing in MM and TM

Nasal shift	MM		TM		t	p
	M	SD	M	SD		
/in/ > /iŋ/	7.67	4.1	0	0	-7.24	0.0001

It appears that the rhyme shift from /in/ to /iŋ/ is competing with its counterpart from /iŋ/ to /in/. Although nasal backing (Rule 3) appears merely as an inconsistent usage in MM, it serves as a significant feature to distinguish it from TM.

Although the velar nasal coda in TM nearly completely changes to the dental nasal, this nasal coda coalescence is not a free variation, but takes place only when the velar nasal is preceded by either the vowel /i/ or schwa /ə/. Furthermore, this nasal fronting is constrained by vowel labialization when the onset is labial.

By comparison, nasal fronting appears only inconsistently in MM, occurring only 39 percent of the time. By contrast, nasal backing is inconsistent in MM, and it is found to change to the velar nasal 42 percent of the time. It is evident that these two shifts are competing with each other. Notably, the nasal backing tendency does not exist at all in TM. Therefore, albeit an inconsistent usage in MM, it serves as a crucial feature to differentiate MM from TM.

To sum up, TM is characterized by nasal fronting, whereas MM features nasal backing. In TM the velar nasal coda changes nearly completely to the dental nasal but is regularly preserved in MM. Furthermore, MM and TM differ significantly in the realization of the dental nasal coda, which completely remains in TM, but in MM seems to be in an ongoing shift to the velar nasal.

6. THEORETICAL IMPLICATIONS FOR NASAL CODA SHIFTS

The syllable-final nasal variation in Chinese dialects has been studied since the early 1970s. Earlier studies have attempted to predict syllable-final nasal alterations on Chinese dialects, but have generated contradictory generalizations. M. Chen (1972, 1973, 1975) asserted from his research on nasals and nasalization in Chinese dialects that nasal codas tend to change in the specific order: /m/>/n/>/ŋ/. By contrast, Zee (1985) claimed from his study of approximately 20 Chinese dialects that nasal codas tend to undergo two major modifications: one from the bilabial to the dental (/m/>/n/), and the other from the velar to the dental (/ŋ/>/n/). His findings also indicated that the loss of a nasal coda often occurs with the nasalization of its preceding vowel (VN>nasalized V). To summarize, M. Chen (1972, 1973, 1975) maintained that the final nasal tends to shift ultimately to the velar, whereas Zee (1985) contended that the final nasal either changes to the dental nasal or vanishes with the nasalization of the preceding vowel.

In agreement with Zee (1985), some scholars also found that the syllable-final nasal shift from /ŋ/ to /n/ is a common tendency in Chinese dialects (C-Y Chen 1991; Kubler 1985; Li et al. 2005; Tse 1992), as opposed to M. Chen (1972, 1973, 1975), who maintained the opposite direction for the nasal coda shift. Still, others asserted that nasal codas tend to disappear with the nasalization of the preceding vowel (Barale 1982; Hess 1990). What is more complex is that others have found contrary nasal coda shifts following different vowels (Hsu & Tse 2007; Ing 1985; Lin 2002).

Generally speaking, two hypotheses are observed concerning nasal coda alterations in Chinese dialects: (1) the theory of the unidirectionality of the nasal shift from /n/ to /ŋ/ and (2) the theory of tendency of the coda change from /ŋ/ to /n/. In light of the different hypotheses, this study has focused on Mandarin to explore which theory is valid regarding nasal coda modifications. This study has found that the velar nasal coda in TM nearly completely changes to the dental nasal, in support of Zee's (1985) prediction, whereas nasal backing occurs inconsistently in MM, partially supporting M. Chen's (1972, 1973, 1975) theory of the unidirectionality of the nasal shift from /n/ to /ŋ/.

In addition, the results support the phonological divergence theory posited by Labov (1994), who hypothesized that such sociolinguistic variables as region and identity play an important role in the formation of a new language variety in a speech community. As predicted by

Labov's theory, the two varieties of Mandarin in question have been phonologically diverging from each other, instead of converging towards the same linguistic evolution. To summarize, TM speakers tend to pronounce the final velar nasal as its dental counterpart, whereas MM speakers seem to have the contrary tendency: a nasal coda shift from the dental nasal to its velar equivalent.

7. CONCLUSIONS

This study has demonstrated that the velar nasal coda in TM does not remain but changes when preceded by the vowel /i/ and schwa. Furthermore, the nasal merger is blocked by vowel labialization influenced by a labial onset.

This study has also presented acoustic evidence for the coda shift from /iŋ/ to /in/. The phonetic analyses have verified that the velar nasal coda in TM does not disappear, with its preceding vowel nasalized. Rather, it tends to change to its dental counterpart when preceded by the vowel /i/ and schwa /ə/. Interestingly, the opposite nasal coda shift seems to occur in MM: the dental nasal coda in MM changes to the velar 42 percent of the time when preceded by the vowel /i/.

Notably, the respondents from Beijing regularly changed the rhyme /in/ to /iŋ/, although on the whole such a nasal coda shift appears to be an inconsistent usage. Surprisingly, all of the informants from southern China regularly changed the rhyme /iŋ/ to /in/. Future research might expand this study by recruiting an equal number of informants from northern, central and southern China to investigate whether the nasal codas in MM might vary according to speakers' provincial backgrounds.

Another puzzle is that the present study found that TM tends to undergo nasal fronting, whereas Hsu and Tse (2007) observed nasal backing. To be more precise, the findings of this study indicate that the velar nasal coda regularly changes to its dental equivalent when the nucleus is either /i/ or /ə/. However, Hsu and Tse (2007) reported that only when the nucleus is schwa does the velar nasal coda regularly change to its dental counterpart. By contrast, they claimed, when the preceding vowel is /i/, the dental nasal coda frequently shifts to the velar nasal, but this is not observed in the present study. A close inspection reveals that all of the participants in their experiment came from Taipei;

accordingly, it is possible that nasal backing might occur only in northern Taiwan.

Furthermore, the degree of nasal velarization might affect not only perception but also acoustic analyses. The current study included native speakers of Mandarin from both mainland China and Taiwan, while Hsu and Tse (2007) only focused on TM. From the spectral comparisons, this study found that the velar nasal pronounced by the MM speakers yields a noticeable formant pinch, which, however, is indiscernible in the TM speakers' utterances. Additionally, Hsu and Tse (2007) only displayed a spectral comparison to show the acoustic difference between the rhymes /in/ and /iŋ/. Regrettably, their spectral figure did not clearly demonstrate that a velar pinch is visible in the rhyme /iŋ/. Nor did they compare the two rhymes in terms of their *F*3 frequencies—a vital acoustic feature to detect the nasal codas (Chen, 2000). Moreover, although perceived by the authors to change to its velar equivalent, the rhyme /in/ might not exhibit the realization of the velar nasal, but rather the one between the dental and the velar nasals—likely the palatal nasal.

The assumption about the dental nasal shift to the palatal in TM corresponds to the perception of the well-known sound change from the retroflex stridents to the un-retroflex ones in TM. When listening to a TM speaker pronounce such retroflexes as ㄓ (/tʂ/), ㄔ (tʂʰ), ㄕ (/ʂ/), and ㄖ (/ʐ/)[2], MM speakers often comment that the degree of retroflexion is insufficient. This perception gap might indicate that, although TM speakers might manage to articulate the retroflexes, they actually pronounce alveolar retroflexes; by contrast, MM might tend to over-articulate the retroflexes, thus palatalizing the sounds. Future research might investigate whether this speculation can be confirmed by phonetic analyses.

Similarly, the degree of nasal velarization in TM might be perceived as non-standard by speakers of MM. Accordingly, a follow-up experiment might examine whether the nasal backing among TM speakers reflects a nasal coda shift to the velar or to the palatal.

Last but not least, it is worth investigating whether perception influences speech production, as claimed by Ohala (1981, 1993, 2001). Following the reading task, each participant was interviewed; each informant listened to some minimal pairs differing only in nasal codas

2 The four retroflex sounds in Mandarin consist of ㄓ (/tʂ/), ㄔ (tʂʰ), ㄕ (/ʂ/), and ㄖ (/ʐ/); only the latter two phonetic symbols are included in the consonant chart of the IPA. The former two—ㄓ (/tʂ/) and ㄔ (tʂʰ)—were devised by Robert L. Cheng (1985).

and was then asked to identify the pronounced words. Their responses reveal that if they misperceived a test word, they were unable to articulate it accurately. A rigorous survey is needed to explore the cause of the sound change from the perspective of listener perception. All of these inferences presented above remain to be examined in the future.

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國語音節尾鼻音轉換的語音證據

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本研究提出了語音證據，解釋國語音節尾鼻音之變化。雖然三位語音評審一致認為台灣國語裡，韻腳/iŋ/ (ㄧㄥ) 產生了轉變，但他們卻持不同看法；其中兩位認為尾音變成/in/ (ㄧㄣ)，而另外一位則主張軟顎鼻音(ㄥ)因為前面的母音鼻音化而消失。為了解決這樣的歧見，這篇研究分析/in/, /iŋ/, /i/ 和 /ĩ/的語音屬性。結果顯示，台灣受試者並未去除尾鼻音而把母音鼻音化，倒是傾向將尾鼻音轉變成齒鼻音(ㄣ)。最後，這項研究討論國語的尾鼻音轉換，對中國方言語音變化的意涵。

關鍵字：語音分析，語音改變，鼻音韻尾，中文