ACOUSTIC ANALYSIS OF VOWEL NASALIZATION IN TAIZHOU CHINESE

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ABSTRACT

This study investigates the nasality of the nasal vowels, [ĩ ũ ẽ], and the nasalized V[ŋ] rhymes, [iŋ əŋ aŋ ɔŋ], in Taizhou Chinese. It also examines the weakening of the final nasal in the V[ŋ] rhymes. Praat was used to perform A1-H1, A1-P1, and MaxDA3 measurements of the test nasal vowels and V[ŋ] rhymes and their comparable oral counterparts produced by ten native Taizhou speakers. The analyzed data show that (i) [ĩ] and [ũ] are nasalized throughout; (ii) [ẽ] is partially or nearly denasalized, which is accompanied by the diphthongization of the oral counterpart [e]; (iii) in [əŋ aŋ ɔŋ], the vowel is nasalized throughout, while the final [ŋ] may be dropped when preceded by the non-back vowel [ə] or [a]; and (iv) in [iŋ], [i] is nasalized throughout when [ŋ] is retained, but nasalized partly when [ŋ] is dropped.

Keywords: Nasal vowels, nasalized rhymes, acoustic analysis, degree of nasality, Taizhou Chinese

1. INTRODUCTION

Taizhou Chinese (TZC) is spoken in Jiangsu Province on the north bank of the Yangtze River, the boundary region of Jiang-Huai Mandarin and Northern Wu [1]. Most of the dialects, including TZC, in the Jiang-Huai Mandarin group consist of nasal vowels [2, 3, 4, 5, 6]. Based on the vowel formant data in a recent study [7], the vowel system of TZC includes [i/ɿ y ɯ u e o ɚ ɑ ĩ ũ ẽ] in (C)V syllables, [i u e ɔ ə a] in (C)V[ʔ] syllables, and [i ɔ ə a] in (C)V[ŋ] syllables. Aside from the nasal vowels, [ĩ ũ ẽ], in (C)V syllables, the vowels, [i ɔ ə a], in (C)V[ŋ] syllables are naturally nasalized due to the assimilation effect from the syllable-final nasal [ŋ]. According to [4] and [5], the syllable-final [ŋ] in TZC is weakened, as the tongue dorsum may not raise high enough to make complete closure in the mouth cavity. The weakening and nasalization effect of [ŋ] may cause the syllables to change from (C)V[ŋ] to (C)Ṽ, merging into the (C)V syllables that contain a nasal vowel. Furthermore, it is pointed out in [3] and [8] that the nasality of the nasal vowel [ẽ] in (C)V syllables is weak. The denasalization of [ẽ] may cause a merger of [ẽ] and [e] in (C)V syllables.

This study investigates the nasality of the nasal vowels [ĩ ũ ẽ] in (C)V syllables and the nasalized rhymes [iŋ əŋ aŋ ɔŋ] in (C)V[ŋ] syllables of TZC through performing acoustic analysis. It also examines the weakening of the final nasal in the V[ŋ] rhymes.

2. METHOD

2.1. Speakers

Speech samples for acoustic analysis were collected from five male and five female speakers, aged 50 to 60 years, who were born and grew up in the city of Taizhou. Compared to younger speakers, older speakers are more common to use TZC as the primary language in daily communications, although they also speak Putonghua to people, in particular the non-Taizhou speakers.

2.2. Test materials

Test words with Ṽ or V[ŋ]	Test words with V or V[ʔ]
[pĩ^{44}] 變 (change) [tĩ^{44}] 電 (electricity) [iŋ^{45}] 贏 (win) [tiŋ^{44}] 定 (certainly)	[iʔ^{4}] 一 (one) [tiʔ^{4}] 跌 (tumble)
[ũ^{45}] 完 (completion) [kũ^{44}] 貫 (through)	[u^{45}] 鵝 (goose) [ku^{44}] 過 (pass)
[ẽ^{44}] 案 (case) [tẽ^{44}] 旦 (dawn)	[e^{44}] 愛 (love) [te^{44}] 帶 (bring)
[ɔŋ^{45}] 橫 (horizontal) [kɔŋ^{44}] 貢 (devotion)	[ɔ^{44}] 奧 (mystery) [kɔ^{44}] 告 (tell)
[aŋ^{45}] 昂 (raise) [kaŋ^{44}] 杠(dumbbell)	[ɑ^{45}] 牙 (tooth) [pɑ^{44}] 爸 (father)
[əŋ^{21}] 硬 (hard) [təŋ^{44}] 凳 (chair)	[ɚ^{213}] 耳 (ear) [ɚ^{45}] 兒 (kid)

Table 1: Test words for nasality measurement

The test materials included a set of monosyllabic words in TZC that contain the three nasal vowels [ĩ ũ ẽ] in (C)V syllables and the four nasalized rhymes [iŋ əŋ aŋ ɔŋ] in (C)V[ŋ] syllables. For comparison purposes, the monosyllabic words that contain the comparable oral counterparts [u e ɚ ɑ ɔ] in (C)V syllables and [i] in (C)V[ʔ] syllables were also analyzed. Note that the oral vowel [i] in (C)V[ʔ] syllables used for comparison is because [i] in (C)V syllables is apicalized to become [ɿ] [8]. As shown in Table 1, each of the target vowels or rhymes occurs in two test words which are meaningful and commonly used in TZC. The test words were presented in Chinese characters in a randomized list.

The speakers uttered the test words at a normal speech rate and repeated the word list five times.

2.3. Data analysis

The target vowels or rhymes in the test words were acoustically analyzed for the degree of nasality. There is an array of acoustic parameters commonly used to quantify the vowel nasality, such as (i) A1-H1 (difference in amplitude between the first formant A1 and the first harmonic H1), (ii) A1-P0 (difference in amplitude between the first formant and the nasal formant at 250Hz or 450Hz, whichever has a higher amplitude, and (iii) A1-P1 (difference in amplitude between the first formant and the nasal formant at 950Hz) [9, 10, 11, 12]. Based on the evaluation results in [13] and [14], A1-H1 and A1-P0 are more accurate than the other parameters to signal the nasalization of non-high vowels, whereas A1-P1 is more appropriate for quantifying the nasality of high vowels. In this study, two parameters, A1-P1 and A1-H1, were used for doing nasality measurement. For the high front vowels [i ĩ] and the rhyme [iŋ] that contains [i], A1-P1 was used. For the non-high vowels [e ẽ ɐ̃ ɑ ɔ] and the rhymes [əŋ aŋ ɔŋ] that contain [ə a ɔ], A1-H1 was used. For the high back vowels [u ũ], A1-H1, rather than A1-P1, was used. This is because the second formant of [u ũ] is close to the nasal formant at 950Hz, which may cause a boost to the amplitude of the nasal formant.

Using the Nasality Auto-measure Praat script [15], the measurements of A1-H1 and A1-P1 were made at every 10% of the duration of the vowel or rhyme in the test words. The value of A1-H1 or A1-P1 is inversely correlated to the degree of nasality, i.e., a smaller value of A1-H1 or A1-P1 suggesting a higher degree of nasality.

For the test V[ŋ] rhymes, the third formant amplitude at every 10% of the duration of the rhymes was also measured. The maximum difference in the third formant amplitude (MaxDA3) between two successive time points was taken to indicate the location of the boundary between the vowel and the final nasal in the V[ŋ] rhymes. This is in reference to the method used in [12], which is based on the visual inspection of a large reduction in energy of the vowel formants near the boundary between a preceding vowel and a following nasal consonant. In the present study, the spectrograms of the V[ŋ] rhymes, [iŋ əŋ aŋ ɔŋ], show a large reduction in energy of the third and higher formants near the end of the rhymes with a strong final nasal. Thus, the MaxDA3 is taken and it is expected to be large for the V[ŋ] rhymes as compared with the oral counterparts. In other words, a small MaxDA3 for the V[ŋ] rhymes indicates the weakening or drop of the final nasal in the rhymes.

In order to compare the degree of nasality across the different types of vowels and rhymes and across different speakers, all the measured values of A1-H1, A1-P1, and MaxDA3 of the test vowels and rhymes were normalized for each speaker by converting the values into z-score.

3. RESULTS & DISCUSSION

3.1. Nasal vowels in (C)V syllables

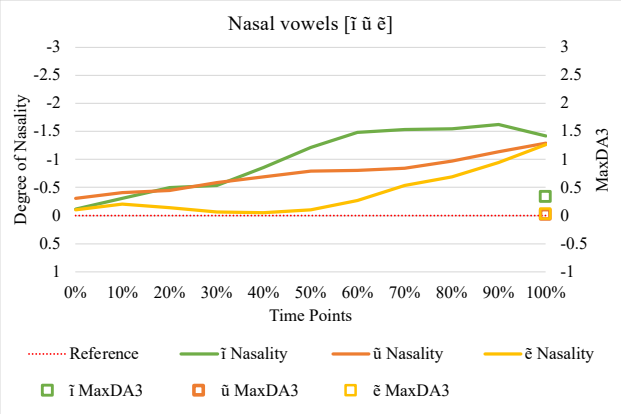

Figure 1: Degree of nasality and MaxDA3 for the nasal vowels [ĩ ũ ẽ] in (C)V syllables

Figure 1 shows the degree of nasality for the three nasal vowels [ĩ ũ ẽ] in (C)V syllables. It is computed by subtracting the mean value (n = 100, i.e., 2 test words per vowel x 5 repetitions per test word x 10 speakers) of A1-H1 or A1-P1 (in z-score) for an oral counterpart from that of the corresponding nasal vowel. The values of the oral counterparts ([i u e]) are set as '0' and used as reference (red dotted line) for comparison. Since the value is inversely correlated to the degree of nasality, the values of the nasal vowels are smaller than the reference and below zero. The figure also presents the MaxDA3 values (in z-score) of the three nasal vowels which minus those of the oral counterparts (set as '0' and used as reference). A small value of MaxDA3 suggests that the presence of a post-vowel nasal consonant is unlikely.

As shown in Figure 1, for all the three nasal vowels [ĩ ũ ẽ] (solid lines) the degree of nasality is increasing and becoming high towards to the vowel offset. The increase in nasality is not because of the presence of a post-vowel nasal as evidenced by the MaxDA3 values of the three vowels. As can be seen, the MaxDA3 is slightly above the reference '0' for [ĩ] (green square) and it is almost '0' for [ũ] (orange square) and [ẽ] (yellow square), indicating the unlikelihood to have a nasal consonant after [ĩ ũ ẽ]. A comparison of the three nasal vowels shows that the degree of nasality is lower for the mid vowel [ẽ] (yellow solid line) than the two high vowels [ĩ ũ] (green and orange solid lines). For [ẽ], the degree of

nasality is close to the reference '0' line during the first half of the vowel, while it increases during the second half of the vowel. For [ĩ] and [ũ], the degree of nasality is above '0' and increases continuously from the vowel onset to the vowel offset. Thus, the results suggest that the mid vowel [ẽ] is lesser nasalized than the two high vowels [ĩ] and [ũ]. While both [ĩ] and [ũ] are nasalized throughout, [ẽ] is partially denasalized, with no nasalization during the first half of the vowel. The data agree with the report in [3] and [8] that the nasality of the nasal vowel [ẽ] in (C)V syllables is weak.

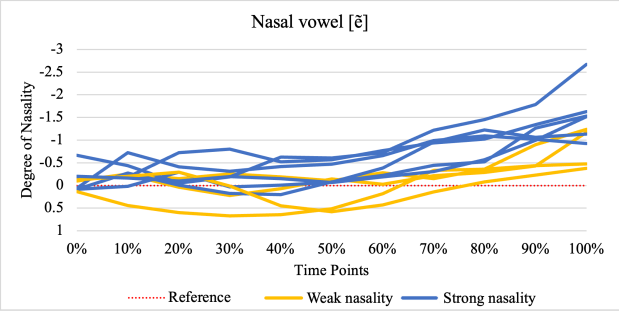

Figure 2: Degree of nasality of the nasal vowel [ẽ] for 10 individual speakers

For the vowel [ẽ], the between-speaker variation in the degree of nasality is actually large. Figure 2 presents the degree of nasality of [ẽ] for each of the ten speakers in this study. As can be seen, the nasality of [ẽ] is weaker for four speakers (yellow solid lines) the other six speakers (blue solid lines). For the former four speakers, the degree of nasality of [ẽ] is below or around the reference '0' value throughout the vowel, although a mild rise may occur near the vowel offset. The data suggest that for these speakers the vowel [ẽ] is nearly denasalized throughout. The denasalization of [ẽ] may cause a merger of [ẽ] and the oral [e] in TZC.

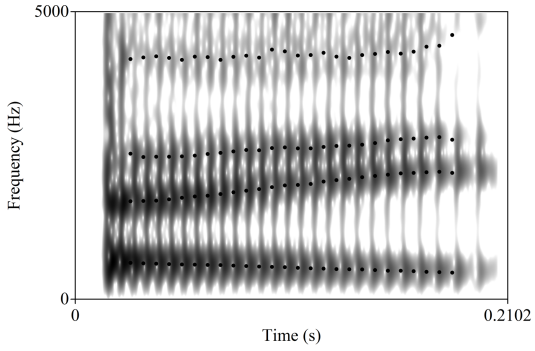

Figure 3: Superimposed formant trajectories on the spectrogram of the diphthongized [e] in [e^{44}] 愛 produced by a male speaker

Accompanying the denasalization of [ẽ], the diphthongization of the oral [e], changing from a monophthong to [eɪ], is observed. Figure 3 presents a case in which the vowel [e] is produced with the changing formants ($F_1F_2F_3$) by a male speaker. As shown in the figure, the continuous decrease in F_1 and increase in F_2 suggest that [e] changes to a high front vowel towards to the end. Table 2 presents the mean values (n = 50, i.e., 2 test words per vowel x 5 repetitions per test word x 5 speakers of the same gender) of F_1 and F_2 (in Hz) at the time points of 20% and 80% of the vowels [ẽ] and [e] for the five speakers of each gender in this study. Compared with [ẽ], there is a marked increase in F_2 from the first to the second time point for [e], which suggests [e] is fronted near the end. Also, there is a decrease in F_1 between the two time points for [e], which suggests [e] is raised, although the change is less pronounced for the male speakers due to cross-speaker and cross-token variations. In this study, no diphthongization of [e] is observed for three male speakers, while [e] is diphthongized in over 40% (one male and all five female speakers) or all 100% (one male speaker) of the test tokens for the other seven speakers. Four out of the latter seven speakers produce the diphthongized [e] and the denasalized [ẽ]. The parallel change in [ẽ] (denasalization) and [e] (diphthongization) is probably for maintaining the distinction between the two vowel phonemes.

Speakers	Formants	[ẽ]		[e]	
		20%	80%	20%	80%
Male	F_1	529	596	498	471
	F_2	2050	2008	1894	2031
Female	F_1	555	613	603	519
	F_2	2551	2484	2312	2482

Table 2: Mean values (in Hz) of F_1 and F_2 at the time points of 20% and 80% of [ẽ] and [e] for the male and female speakers in this study

3.2. V[ŋ] rhymes

Figure 4 and Figure 5 show the degree of nasality and the MaxDA3 for the test nasalized V[ŋ] rhymes in this study. Agreeing with the report in [4] and [5], this study observes that the final nasal in the V[ŋ] rhymes, [əŋ aŋ iŋ] (except for [ɔŋ]), is not always strong and the V-N boundary between the preceding vowel and the final nasal in the rhymes is not clear in some of the test tokens. These rhymes are thus divided into [əŋ aŋ iŋ] and [ə^{ŋ} a^{ŋ} i^{ŋ}]. In Figure 4 and Figure 5, the markers (circles) that represent the MaxDA3 values of [ɔŋ əŋ aŋ iŋ] with a strong final nasal are placed at the location of the V-N boundary of the rhymes, whereas the markers (squares) that represent the MaxDA3 values of [ə^{ŋ} a^{ŋ} i^{ŋ}] with a weak final nasal are placed at the end of the rhymes.

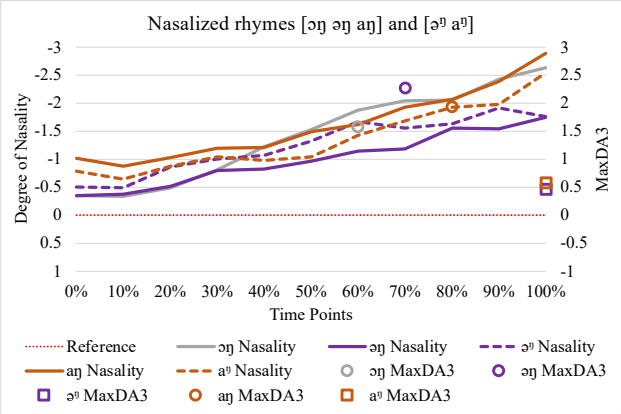

Figure 4: Degree of nasality and MaxDA3 for the nasalized rhymes [ɔŋ əŋ aŋ] and [əᵑ aᵑ]

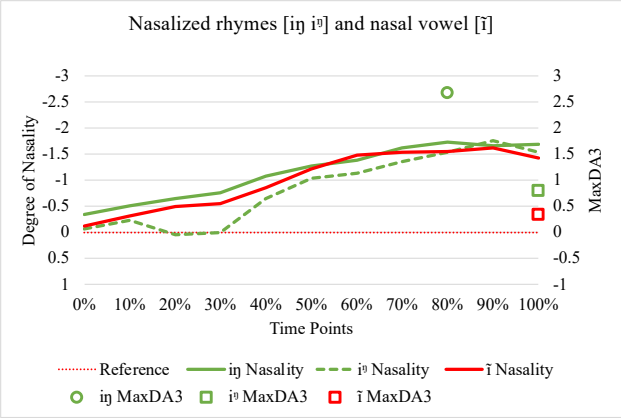

Figure 5: Degree of nasality and MaxDA3 for the nasalized rhymes [iŋ iᵑ] and the nasal vowel [ĩ]

As shown in Figure 4, the value of MaxDA3 is noticeably large for [ɔŋ əŋ aŋ], but small and close to the reference '0' for [əᵑ aᵑ]. The data prove that the final nasal is strong and retained in [ɔŋ əŋ aŋ], but weak or nearly dropped in [əᵑ aᵑ]. In spite of the difference in the final nasal between [ɔŋ əŋ aŋ] and [əᵑ aᵑ], the two types of rhymes are similar in the degree of nasality. For [ɔŋ əŋ aŋ] (solid lines) and [əᵑ aᵑ] (dashed lines), the degree of nasality of the entire rhyme is above the reference '0' and increases continuously towards to the end of the rhyme. Naturally, the increase in nasality for [ɔŋ əŋ aŋ] is related to the presence of the final nasal in the rhymes. In these rhymes, the final nasal also causes the preceding vowel to have nasalization throughout. As for [əᵑ aᵑ], while the final nasal is weakened and nearly dropped, the nasality is retained on the preceding vowel in the rhymes, although the degree of nasality is lower near the vowel onset than the vowel offset. Nonetheless, the degree of nasality is above the reference '0' throughout the vowel in [əᵑ aᵑ], and it is similar to the degree of nasality of [əŋ aŋ]. The nasality data therefore suggest that the rhymes [ɔŋ əŋ aŋ] contain a nasal vowel and they are actually [ɔ̃ŋ ə̃ŋ ãŋ]. As for the rhymes [əᵑ aᵑ], they contain a single nasal vowel [ə̃] or [ã], changing from the structure of VN to Ṽ. Since the vowel inventory of TZC does not include the nasal vowels [ə̃] and [ã], no merger is resulting from the change in the rhymes [əᵑ] and [aᵑ].

In Figure 5, the degree of nasality and the MaxDA3 values for the rhymes [iŋ iᵑ] are in comparison with those for the nasal vowel [ĩ] in (C)V syllables. As can be seen, the MaxDA3 of [iᵑ] (green square) is similar to that of the nasal vowel [ĩ] (red square) and near the reference '0', whereas the MaxDA3 is markedly large for [iŋ] (green circle). The MaxDA3 data indicate that the final nasal is weakened or nearly dropped in [iᵑ], but retained in [iŋ]. Despite the weakening of the final nasal in [iᵑ], the nasality of the rhyme is retained. As shown in Figure 5, while the degree of nasality of [iᵑ] (green dashed line) is low and close to the reference '0' during the initial 30% of the rhyme, it largely increases during the following 70% of the rhyme and becomes similar to the degree of nasality of the nasal vowel [ĩ] (red solid line). The nasality data suggest that the vowel in [iᵑ] is nasalized, but properly it is partially nasalized with no nasalization near the vowel onset, which is different from the nasal vowel [ĩ] with nasalization throughout. It follows that even the final nasal in [iᵑ] is dropped, the vowel in the rhyme is still distinguishable from the nasal vowel [ĩ] in (C)V syllables. As for [iŋ], the degree of nasality (green solid line) is above the reference '0' throughout the rhyme and it increases continuously towards to the end due to the presence of the final nasal in the rhyme. In general, the degree of nasality of [iŋ] is similar to that of the nasal vowel [ĩ] (red solid line), suggesting that [iŋ] is actually [ĩŋ], containing a nasal vowel [ĩ]. Since the final nasal in [ĩŋ] is retained, the nasalization change in the vowel of the rhyme does not result in a merger with the nasal vowel [ĩ] in (C)V syllables.

4. CONCLUSION

To sum up, the nasal vowels and the vowels in the nasalized V[ŋ] rhymes in TZC vary in the degree of nasality. For the nasal vowels, the degree of nasality is lower for the mid vowel [ẽ] than the high vowels [ĩ ũ], and denasalization of [ẽ] is observed for some speakers. In the rhymes [ɔŋ əŋ aŋ iŋ], the vowel is nasalized, and the final nasal may be dropped when preceded by the non-back vowels [i ə a]. The degree of nasality of [ɔŋ əŋ aŋ] is high, regardless of whether the final nasal is retained or dropped. As for the rhyme [iŋ], the degree of nasality is high when the final nasal is retained but reduced when the final nasal is dropped. For future studies, aerodynamic data will be obtained to further substantiate the characteristics of vowel nasalization in TZC.

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