AN ACOUSTIC AND PERCEPTUAL STUDY OF VOWEL NASALITY IN TAIWANESE

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1. Introduction

The contrast between nasal vowels and oral vowels is phonemic in Taiwanese, however, their distributions are not entirely contrastive. For example, nasal nuclei do not occur when the coda is a nasal. It is analyzed that historically the nasal feature of the nasal coda spreads leftward to the nucleus, when the vocalic nasalization is rephonologized, the nasal coda is lost. Therefore, it has been generally concluded that there is no phonemic nasalization in the vowel preceding nasal codas in Taiwanese (Ang, 2002; Li, 1990; Lien, 2000; Wang, 1999). On the other hand, as a universal phenomenon constrained by our speech mechanism, phonetic nasalization can take place in the vicinity of nasal consonants (Cohn, 1990; Ladefoged, 1996). The issue under debate then is whether nasal vowels and oral vowels in nasal contexts are truly distinguishable, or the constraint of their distributions is simply phonological (Chung, 1996).

Syllables like CṼN and ṼN are illegal in Taiwanese. To account for this phonologically, Chung posited a nasal domain where onsets and nuclei form one domain and codas form one domain (see (1)). By the percolation principle, if one segment in a domain is nasal, then the other segment in the same domain has to be nasal as well. Only one nasal domain is allowed tautosyllabically in Taiwanese, and that is why the syllable types above are not allowed. Ang (2002) challenged Chung's division of a syllable into two domains with evidence from transyllabic nasal spreading, which presupposes the nasal spreading from nucleus to coda. He used ranking of constraints in Optimality Theory to account for nasal spreading anomalies which were not well explained by previous phonological rules. However, as suggested by Chung, to validate these phonological patterns, we need to resort to acoustic studies to see to what extent phonemic nasalization (i.e., nasal vowels) and phonetic nasalization (i.e., nasalized oral vowels) are distinguished. That is, if indeed the nasality between nasal vowels and nasalized oral vowels is categorically different to native speakers, we would be able to maintain the analyses in phonology literature. If not, the vowel in VN may well be treated the same as a "true" nasal vowel.

(1) [(Onset Nucleus)(Coda)]$_\sigma$

USTWPL 4: 17-26, 2008.

This study used acoustic and perceptual data to investigate the nasality between nasal vowels and nasalized oral vowels in Taiwanese. The general goal is to test whether Taiwanese speakers could produce and perceive a clear distinction between these two classes of vowels.

1.1 Phonemic contrast between nasal vowels and oral vowels in Taiwanese

Taiwanese, also known as Taiwan Southern Min, is widely spoken in Taiwan, several southeastern provinces of China, and among overseas Chinese in Southeast Asia. Although it is considered a dialect of Chinese, it is not mutually intelligible with other dialects. There are six oral vowels [i, e, a, ɔ, o, u] and four nasal vowels [ĩ , ẽ, ã, ɔ̃] in Taiwanese. The contrast of vowel nasalization is phonemic. That is, oral vowels and nasal vowels can distinguish minimal pairs, for example, i 'to play, gamble' and ĩ 'yard'; pe 'father' and pẽ 'sick'.

1.2 Previous and current research

A nasal vowel is produced by the gesture of lowering the velum, which establishes an acoustic coupling between the oral tract and the nasal tract. In literature of nasality, it is generally agreed that the lowering in amplitude and widening of the first oral formant indicates vowel nasalization. In perceiving nasality, Hawkins and Stevens (1985) claimed that the low-frequency peak, the widening of its bandwidth and the presence of a pole-zero pair due to acoustic coupling play a fundamental role. To characterize the acoustic features of nasal and nasalized vowels, Feng and Castelli (1996) proposed that nasalization of vowels can be considered as a dynamic trend from an oral configuration toward the pharyngonasal configuration, with nasalized oral vowels at some point in the continuum and "true" nasal vowels at the end. In terms of nasality in Taiwanese, Wang (1998) conducted a concept formation experiment where subjects were asked to identify presence of oral vowels in syllables containing nasal vowels. The results showed that subjects did not make a distinction between nasal vowels and oral vowels. Pan (2004), on the other hand, studied the airflow of oral vowels in nasal contexts (preceded or followed by nasal consonants) and found that only the onset or the offset of the oral vowels was nasalized, but not at the center of the nuclei. She claimed that the absence of nasality at the center of the oral vowel is the strategy used by speakers to distinguish between nasal vowels and oral vowels in nasal contexts. The previous two studies focused on the nasality of vowels in relation to the category of their onset, whereas in this study, I will investigate to what extent nasal codas affect the preceding vowel and compare nasality between Ṽ and VN as well as between CṼ and CVN[1]. I will examine the F1 values between nasal vowel and nasalized oral vowels at the

[1] Data of the syllable type NṼ were also collected. However, knowing that Ṽ would be extra nasalized because of the preceding nasal consonant, these vowel excerpts were not used for V-Ṽ pairs in the perception experiment.

25%, 50%, and 75% points of the vocalic portion and see if indeed, in the spirit of Pan, nasalization of oral vowels is absent at the center of the nuclei.

2 Method

The recording was conducted in the phonetics lab at University of Illinois. An AKG C520 head-worn condenser microphone was used to record acoustic signals onto a Marantz PMD570 recorder. One female Taiwanese native speaker was asked to read the words containing the vowels under study in carrier phrases. Since Taiwanese is a tonal language, the factor of tones has been held constant to avoid unforeseen variation: A. The syntactic structure of the carrier phrases does not subject words to tone sandhi. B. The words used to exhibit nasal-oral vowel contrasts are of the same tone. The subject was asked to read each sentence three times and a total of 48 utterances were recorded.

For the perception component of the study, five proficient Taiwanese speakers, who are graduate students at University of Illinois, participated in the similarity task. The subjects speak Taiwanese fluently but do not identify themselves as genuine native speakers simply because Mandarin Chinese is still their predominant language in daily life. In the perception task, the vocalic portions in the recording were extracted to serve as stimuli. The 120ms medial excerpts, which retain the original pitch contour, were presented in pairs to the subjects, with the subjects being asked to decide whether the words were the same or different. Note that the subjects were not to decide whether the two sounds are identical but whether the two words denote the same meaning (the extracted vowels, nasal or non-nasal, are meaningful words). This was to prevent the subjects from making decisions based on acoustic cues such as amplitude or pitch that are not the factors under study. The task was administered using E-prime. The word pairs were played with a beep between them, followed by a screen asking if the words were the same or different. The users would press the “s” key for same pairs and “d” for different pairs. Distractors were used in the experiment and were embedded in the word spreadsheet.

3. Results

3.1 Results for production experiment

In this study, F1 values of nasal vowels are compared using the Welch Two Sample t-test to those of nasalized oral vowels. If the calculated p-value is below the 0.05 significance threshold, then the null hypothesis which states that the two classes of vowels do not differ is rejected in favor of an alternative hypothesis—the two vowel classes do differ.

Let’s begin with [ĩ] and [i]. We see in Figure 1 that the F1 curves are roughly parallel, which suggests that not much distinction was made by the subject between the two vowels. The Welch Two Sample t-test results indicate that the mean F1 values are only significantly different at the 50% point ($t = 4.9078$, $df = 5.862$, p-value = 0.00287), but not statistically different at the 25% and 75% points ($t = 2.1752$, $df = 6.283$, p-value = 0.07051; $t = 1.8444$, $df = 9.413$, p-value = 0.09677).

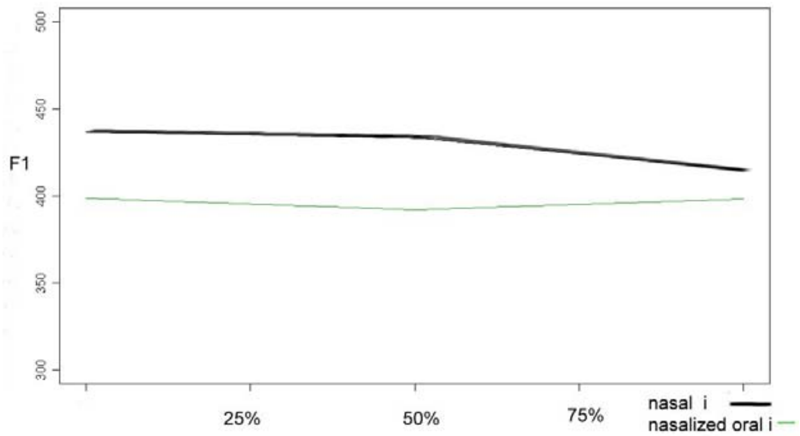

Figure 1. *Mean values of F1 for [ĩ] and nasalized oral [i] at the 25%, 50% and 75% of the vocalic portion*

For [ẽ] and [e], we observe a larger variation between the F1 curves (see Figure 2), especially at the beginning and medial parts. Indeed, significant difference between the means of F1 indicates that the subject made a clear distinction between [ẽ] and nasalized [e] ($t = 14.6979$, $df = 9.273$, p-value = 9.777e-08; $t = 14.713$, $df = 9.954$, p-value = 4.435e-08; $t = 2.7728$, $df = 6.107$, p-value = 0.03171). Note that it is bewildering why F1 in nasalized front vowels (i.e., [i] and [e]) should go up while the oral configuration moves toward the pharyngonasal configuration, as in the case of phonetic nasalization. In addition, the uptick in the final portion of the oral vowel appears to occur only in front vowels.

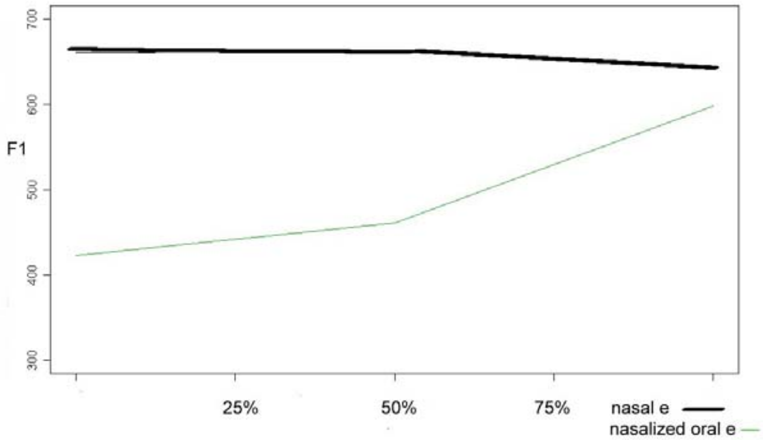

Figure 2. *Mean values of F1 for [ẽ] and nasalized oral [e] at the 25%, 50% and 75% of the vocalic portion*

In Figure 3, we see that the F1 curves of [ã] and [a] cross at around the 50% point. As a result, the statistical analysis shows that the two vowel classes are not significantly different at the 50% point ($t = 0.9619$, $df = 9.868$, p-value = 0.3591), but are statistically different at the 25% and 75% points ($t = -2.3753$, $df = 7.703$, p-value = 0.04604; $t = 4.5227$, $df = 6.265$, p-value = 0.003598). As opposed to the F1 trajectories of ĩ –i and ẽ –e, the F1 trajectories of ã-a diverge when approaching the vowel-consonant transition. I cannot further explain the pattern of convergence at the midpoint and divergence at two ends but claim that the subject somehow made a distinction between the nasal and nasalized oral [a].

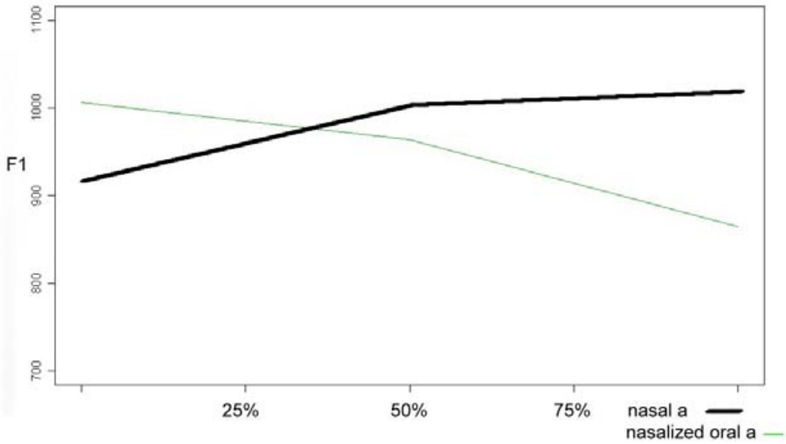

Figure 3. *Mean values of F1 for [ã] and nasalized oral [a] at the 25%, 50% and 75% of the vocalic portion*

As for [ɔ̃] and [ɔ], the F1 curves are parallel until the midpoint of the vowel when they start to branch out. The T-test was run between the mean F1 values between two [ɔ̃] and [ɔ] at different percentage points and the results show that there is no significant difference of F1 values across the temporal axis. That is, the subject may not be able to effectively distinguish between the nasal [ɔ̃] and nasalized [ɔ] in production.

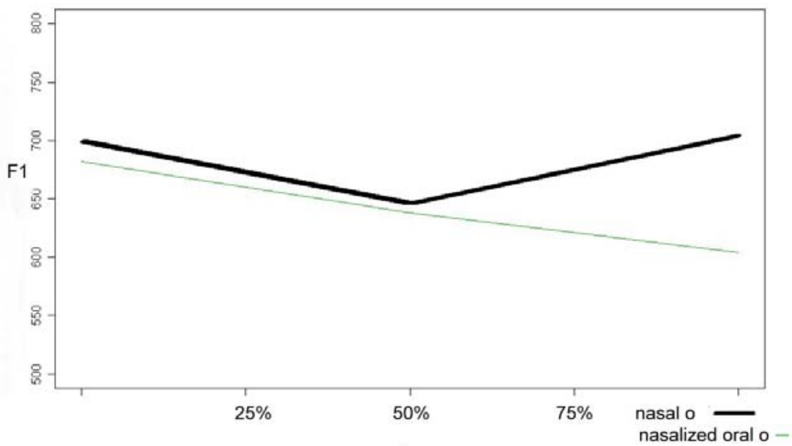

Figure 4. *Mean values of F1 for [ɔ̃] and nasalized oral [ɔ] at the 25%, 50% and 75% of the vocalic portion*

A quick summary of the production results: the subject was able to make a distinction between [ẽ] and [e], but not between [ĩ] and [i] or [ɔ̃] and [ɔ]. It is puzzling whether the subject distinguished between [ã] and [a], given that F1 values of [ã] and [a] are not statistically different at the 50% point, but are significantly different at the other two points. I cannot speculate further but mention this note of interest.

3.2 Results for perception experiment

The goal of this study is to investigate whether Taiwanese speakers can successfully make distinctions between a phonemic nasal vowel and a phonetically nasalized oral vowel. In the previous section, it is shown that the subject distinguished between some vowel pairs but not the others. In this section, the results of the perception experiment are presented and the relationship between production and perception discussed. In analyzing the data, I will use d-prime, the difference of z-scores of the Hit rate (the vowel pair is correctly identified as different) and False Alarm rate (the vowel pair is falsely identified as the different), to measure speakers' sensitivity to the contrast between nasal vowels and nasalized oral vowels. High d-prime indicates that speakers can accurately distinguish two classes of sounds. That is, nasal vowels are essentially different from nasalized oral vowels in perception. Low d-prime indicates speakers' insensitivity to the contrast, which in turns suggests that the distinction between nasal vowels and oral vowels in nasal contexts might not be phonemic.

There were forty vowel pairs (including eight pairs of distractors) in the perception task that the five subjects had to identify as the same or different. The subjects correctly identified 76% of the nasal-oral vowel pairs as different and mistakenly identified 26% of the nasal-nasal or oral-oral vowel pairs as different in the perception task. The difference between the z-scores of Hit and False Alarm was calculated, yielding d-prime of 1.35. The results suggest that the subjects are to some extent sensitive to the distinction between nasal vowels and nasalized oral vowels. From the previous section of production results, we observe that the subjects did not make the same degree of nasal-oral vowel distinction across the vowels under study. To see if that's the case with perception, we turn from a global discussion of the perception results to an examination of each vowel pair.

In perception of [ĩ] and [i], the ratio of Hit to False Alarm is 0.55 to 0.15, suggesting that the task is somehow difficult. As a result, d-prime is 1.16, lower than the d-prime generated for general nasal-oral vowel distinction. This indicates that the subjects are less sensitive to ĩ-i distinction as opposed to other nasal-oral vowel contrasts.

For identification of [ẽ] and [e], it appears that all the subjects made perfect distinction between [ẽ] and [e] (the Hit rate is 1). However, according to the Signal Detection Theory, perfect accuracy (P=1) should be treated as P=0.5; that is, statistically, perfect accuracy is achieved purely by chance. As a result, we have d-prime of 1.64, which is above that of general nasal-oral vowel distinction. Suffice it to say that ẽ-e distinction is relatively easy compared to other vowel pairs.

In terms of distinction between [ã] and [a], a high ratio of Hit to False Alarm (0.95: 0.45), in turn generates high d-prime: 1.77. This indicates that the subjects are quite sensitive to the contrast. And in fact, the subjects did best in distinguishing between [ã] and [a] among all nasal-oral vowel pairs.

Lastly, the subjects were least sensitive to distinction between [ɔ̃] and [ɔ]. The Hit rate is very close to the False Alarm rate, hereby yielding a low d-prime 0.25.

To summarize, d-prime is used to measure subjects' sensitivity to the nasal-nasalized oral vowel contrast for the perception task. As seen in the analyses, the subjects were sensitive to the distinction of [ã] and [a] as well as [ẽ] and [e]. On the other hand, they show uncertainty in distinguishing between [ĩ] and [i] and exhibit low sensitivity to the ɔ̃-ɔ distinction.

4. Discussion and Conclusion

The goal of this study is to investigate whether Taiwanese speakers can produce and perceive contrast between nasal vowels and oral vowels in nasal contexts. The production results indicated that the subject made no or little distinction between [ĩ] and [i] as well as [ɔ̃] and [ɔ]. But the subject did distinguish between [ẽ] and [e] and potentially, [ã] and [a]. What's worth noting is that the midpoint F1 values of [i, a, ɔ] are not significantly different from those of their nasal counterparts, indicating that they are similar to nasal vowels in terms of nasality at the midpoint. This result is counter to Pan's (2004) findings in that she claimed absence of nasality at the center of the vowel nuclei enhances nasal-oral vowel contrasts.

As for the perception task, the five subjects appeared to be able to make nasal-oral vowel contrasts. When looking closely at each vowel pair, we observe that the subjects had the most difficulty distinguishing between [ĩ] and [i] and [ɔ̃] and [ɔ], but exhibited sensitivity to ã-a and ẽ-e distinction. As a result, a correlation between production and perception is observed in that [ĩ] and [i] and [ɔ̃] and [ɔ] are difficult to produce as well as to perceive.

Although the correlation is a positive indicator for this study, there are some potential problems that could undermine the validity of the findings. First of all, if the subject from whom the stimuli were obtained did not make good distinctions between [ĩ] and [i] and [ɔ̃] and [ɔ] to begin with, I suspect that the perceivers could effectively distinguish these two vowel pairs based on the stimuli. According to House & Steven (1956), a greater degree of velopharyngeal opening (i.e., nasality) is obtained on the low vowels than on the high vowels. Although Barbone (1981) later argued against this account, saying that the air flow data did not support a simple relationship between velophrayngeal aperture size and vowel height, this study does not shed light on the asymmetry of vowel height/frontness in relation to nasality, given that ã-a and ẽ-e appear to be easier to produce and perceive. Another concern about the perception performance lies in word frequency. Some stimuli were undoubtedly more familiar to the participants or occur more frequently in speech. Therefore, word frequency may have influenced the participants' performance, especially when they were asked to make judgment based on word meaning of the stimuli. In all respects, the data we have here could be too small to be suggestive of anything insofar as the acoustics are reflective of nasalization; further acoustic as well as articulatory data need to be examined to investigate the factor of vowel height/frontness in nasalization.

Another drawback to note about the production of [ẽ] and [e] is that the words containing [e] were somehow produced with an [i] characteristic because of the subject's dialect. For example, for the word *milk*, it could be pronounced as leŋ or liŋ due to dialectal variation. In a pilot study, a perceiver made a comment on the supposed-to-be [e], saying it sounded more like an [ɪ]. In this case, we do not know whether the perceivers were indeed asked to distinguish between [ẽ] and [e], or [ẽ] and [i]. If it is the latter, we can not attribute high d-prime to successful distinction of the nasal-oral contrast. Of course, in future studies, including more subjects in the production experiment would help with this problem.

Due to the scope of this project, only F1 is examined in investigating the nasality of vowels. However, other correlates such as other spectral peak in the low-frequency region should also be studied in order to obtain more exhaustive results about nasality differences between nasal vowels and oral vowels in nasal contexts in Taiwanese. In addition, studies of nasality would not be complete without aerodynamic experiments. A nasal airflow study would allow us to make better inferences about the velopharyngeal activity in nasality of nasal vowels as opposed to nasalized oral vowels, hereby furthering our understanding of vocalic nasalization in Taiwanese.

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Appendix A

Words list:

Ṽ	**CṼ**	**VN**	**CVN**
ĩ 33 'yard'	tĩ 33 'full'	in 33 'they'	tin 33 'group'
ẽ 55 'infant'	kẽ 55 'thick soup'	eŋ 55 'outstanding'	leŋ 55 'milk'
ã 51 'lean close to'	kã 51 'dare'	am51 'night'	lam 51 'hug'
ɔ̃ 33 'noise made to lullaby babies'	kɔ̃ 33 'snore'	ɔŋ 33 'prosperous'	bɔŋ 33 'hope'

Note: The data were obtained using an online dictionary (http://203.64.42.21/iug/Ungian/soannteng/chil/Taihoa.asp) as a reference. Please be notified that the speakers I consulted with did not entirely agree with all the pronunciation of the data. It could be that the speakers speak a different dialect, or in the worst scenario—the dictionary is not accurate itself.

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