# 台湾語における鼻音 : 口音の対立と鼻音化の度合い

KAWASAKI, Takako / 川﨑, 貴子

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# Nasal-Oral Contrast and the Degree of Nasalization in Taiwanese*

Takako KAWASAKI

**Abstract**

Recent phonetic and phonological studies have shown that the degree of coarticulation is constrained by the contrast in the inventory. This study investigates whether the contrastive difference extends its effect to the acoustic degree of phonemic/phonological nasalization. Taiwanese has both nasal and oral vowels. In this research, we compared the degree of nasalization between CV and NV: The nasality is contrastive in the former and not in the latter. The vowel in NV syllables is always nasalized in Taiwanese. If the degree of nasalization is affected by the contextual difference in nasal contrast, the nasality of CV is expected to be greater than in NV. The results of the study show that the nasality was greater in a contrastive environment than in a non-contrastive environment. Consequently, the results of this study suggest that output contrast has an impact on the acoustic effects of phonology.

## 1 Introduction

In recent studies (Manuel, 1987; 1990), it has been argued that phonetic coarticulation is limited by the phonemic inventory of a language. In her studies of V-to-V[1] coarticuation, Manuel (1987; 1990) argued that the coarticulation is constrained by output constraints that preserve the perceptual contrast among vowels. However, it is not clear whether such a perceptual contrast has an influence on the degree of acoustic effect of the phonological process. In this study, we investigated whether the differences in contrast across phonological environments affect the degree of the phonemic/phonological process within a language.

Taiwanese, a dialect of Southern Min, has phonemic nasal and oral vowels. However, the phonological environment where the contrast appears is restricted. In Taiwanese, a vowel in a CV syllable is either oral or nasal—i.e., contrastive; however, a vowel in an N$\tilde{V}$ syllable is always nasalized, and oral vowels cannot occur in this environment. (see Chung, 1996; Pan, 2004).

In this study, we examined whether the nasal quantity of the nasalized vowel is acoustically different in contrastive and non-contrastive environments in Taiwanese. In a contrastive environment, the nasality of the vowel must be perceived based on the auditory signals of the vowel. On the other hand,

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[1] Throughout this paper, C stands for an oral voiceless consonant, V for an oral vowel, N for a nasal consonant and $\tilde{V}$ for a nasal vowel.

the nasality of the vowel is predictable from the neighboring segments in a non-contrastive environment. If the output perceptual constraints are operative (as in the coarticulation process), the degree of nasalization is expected to be greater in a contrastive environment than in a non-contrastive environment.

In this research, the nasalization of nasal vowels in two types of syllables were compared: CṼ, where nasal-oral contrast is permitted, and NṼ, where such a contrast is not permitted. If the amount of acoustic cues of nasalization differs between contrastive and non-contrastive environments, the amount of acoustic cues of nasalization should differ between these two types of syllables.

### *1.1 Taiwanese Inventory*

Taiwanese has three nasal consonants in its phonemic inventory; /m, n, and ŋ/. They are contrastive both in onset and in coda. See the data in (1).

(1) Nasal Consonant[2]

| | | |
|---|---|---|
| a. | mẽ <LL> | “to condemn” |
| b. | nẽ <LL> + san <HL> | “to sundry clothes” (‘nẽ”s underlying tone is <LR>) |
| c. | ŋẽ <LL> | “stiff” |
| d. | am <LF> | “dark” |
| e. | an <LR> | “tense” |
| f. | aŋ <LR> | “dark red” |

Taiwanese has 6 oral vowels; 4 of them have nasal counterparts. The nasal-oral contrast of vowels is shown in (2).

(2) Nasal vs. Oral Vowels

| | | | | | |
|---|---|---|---|---|---|
| a. | ti <LL> | “chopsticks” | vs. | tĩ<LL> | “fall” |
| b. | pi <LL> | “to prepare” | vs. | pĩ<LL> | “illness” |
| c. | ta <LL> | “to step on” | vs. | tã<LL> + kiʏ<LL> | “to carry” |
| d. | te <LL> | “bag” | vs. | tẽ<LL> | “to pinch” |

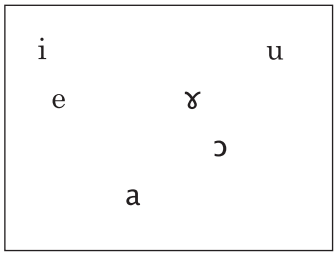
The phonemic inventories of Taiwanese consonants and vowels are provided in (3).

[2] Taiwanese has 7 tonal patterns. The tones are specified as follows: HL—high level; HF—high falling; LL—low level; LR; low rising; LF—low falling; HS—high short; LS—low short.

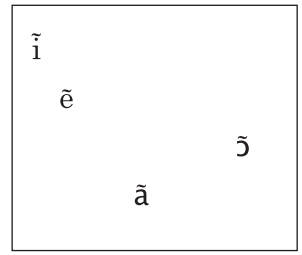
(3) Taiwanese phonemic inventory: consonants and vowels[3]

| | Bilabial | Alveolar | Palatal | Velar | Glottal |
|---|---|---|---|---|---|
| **Plosive** | p $p^h$ b | t $t^h$ ts $ts^h$ | | k $k^h$ g | ʔ |
| **Nasal** | m | n | | ŋ | |
| **Fricative** | | s z | | | h |
| **Approximant** | w | | j | | |
| **Lateral Approximant** | | l(d) | | | |

Taiwanese Oral Vowels




Nasal Vowels




Although Taiwanese has nasal-oral contrasts in its vowels, the contrast is limited to a non-nasal context. As already mentioned, a vowel in an NṼ syllable is always nasalized, while a vowel in a (C)VN is always oral (Chung, 1996; Pan, 2004). If the difference in contrast affects the degree of nasality, the acoustic quantity of nasality of the same vowel should vary across the conditions. That is, the nasality in CṼ is expected to be greater than in NṼ of the same vowel.

### *1.2 Acoustic Correlates of Vowel Nasality*

Nasalization is accomplished by the lowering of the velum that leads to the coupling between the nasal and oral tracts. This coupling leads to several acoustic consequences: the reduction of the F1 amplitude, an increase of the bandwidths of lower formant frequencies, and the occurrence of anti-formants (Fant, 1960; Hawking & Stevens, 1985; Stevens, 1998). In addition to these, vowel nasalization is reported to introduce additional nasal peaks: one at around 200 Hz, which is caused by the coupling to the sinuses (Hattori et al, 1958; Maeda, 1982), and another peak at around 1,000Hz, which is cased by the coupling to the nasal tract (Chen, 1995, 1997, Stevens, 1998, and others). From these acoustic characteristics of vowel nasalization, Chen (1995, 1997) has proposed two methods to quantify vowel nasalization: A1 (the amplitude of F1) minus P0 (the amplitude of the nasal peak around 200Hz), and A1 minus P1 (the amplitude of the nasal peak around 1,000Hz). Her proposal incorporates both the reduction of the first formant amplitude and the introduction of nasal peaks into nasal quantification. The values of A1-P0 and A1-P1 are expected to be lower the greater the nasality becomes.

[3] In addition to these vowels, Taiwanese has 8 oral, and 6 nasal diphthongs, and 2 oral and 2 nasal triphthongs.

Although Chen's measurements have shown a higher correlation than the measurement of A1 alone, they have problems. That is, P0 and P1 are affected by F1 and F2, depending on the vowels in question. The P0 of a high vowel is highly affected by its F1, and P1 is often affected by its F1. Because of this problem, Chen's study (1997) has concluded that A1-P1 is better for measuring nasalization in high vowels and A1-P0 is better for low vowels. This study adopted Chen's measurements, using A1-P1 for high vowels, and A1-P0 for mid- and low vowels, to quantify vowel nasalization.

Since the degree of nasalization varies greatly between speakers and its acoustic cue is hard to measure, the acoustic comparison of nasality in vowels is not common. However, recent aerodynamic studies of nasal vowels have revealed a difference in transition of the nasal airflow in various contexts (Cohn, 1990; Pan, 2004; Delvaux et al,. 2008, and others). In her study of Taiwanese, Pan found that vowels are nasalized at the onset or the offset when preceded or followed by a nasal consonant, and the middle point of the vowel is not nasalized by coarticulation. In addition, Delvaux et al. (2008) found in their study of French that the nasal vowels have a plateau of nasal airflow in the middle of the vowel. Based on their findings (Pan, 2004; Delvaux et al., 2008), the degree of nasality at the midpoint of the vowel seems to be a reasonable correlate of the nasality of the nasal vowel, since the effect of coarticulation is either none or minimized.

This study compared the degree of nasality of four syllable types: CV, NṼ, CVN, and, CṼ. For each syllable type, we measured A1-P1 for high vowels and A1-P0 for mid- and low vowels at the initial, middle, and final points of each vowel, and compared nasal transition. The first type of syllable was oral consonant + oral vowel, so nasality should not be expected i.e., there should be a high A 1-P1/A1-P0. The second type of syllable was nasal consonant + nasal vowel. In this type of syllable, the initial portion of the vowel was expected to be nasalized due to coarticulation in addition to the phonemic nasalization. The third type of syllable was oral consonant + oral vowel + nasal coda. The vowel here was oral, but nasalization was expected at the offset of the vowel due to the coarticulation to the following nasal consonant. The fourth type of syllable was oral consonant + nasal vowel. The vowel was expected to be nasalized, but its nasality should be solely phonemic and not from coarticulation. Therefore, the nasality of the vowel in CṼ was expected to be lower (i.e., a high A1-P1/A1-P0) than the vowel in NṼ, at the onset of the vowel. By comparing the degree of nasality at the midpoint, the effect of coarticulation was avoided.

## 2. Method

Recording was conducted in the phonetic lab at the University of British Colombia. One female native speaker of Taiwanese[4] was asked to produce Taiwanese words for recording. The subject spoke both Taiwan Mandarin and English in addition to Taiwanese.

The words used in this study are given in (4). Since Taiwanese is a tone language, tone might affect the nasality of vowels. Therefore, only words with high flat tones were selected.

[4] In Taiwan, Taiwan Mandarin is the dominant language: Taiwanese is a second language for most of the younger generation. The subject identified herself as a bilingual speaker of Taiwanese and Taiwan Mandarin, with English as her second language.

(4) Recorded Taiwanese Words

| | | word | gloss |
|---|---|---|---|
| I. | CV | ti | “pig” |
| | | te | “a kind of food made of oyster” |
| | | ta | “dry” |
| II. | NV | ni | “to pick up” |
| | | ma | “grandmother” |
| | | me | “to grasp” |
| III. | CVN | tiŋ | “lamp” |
| | | tɤŋ | “to catch fish” |
| | | tan | “medicine” |
| IV. | CṼ | tĩ | “sweet” |
| | | sẽ | “to give birth” |
| | | tã | “to carry on shoulders” |

There were 12 monosyllable words: three words in each of the four syllable types 1) CV, 2) NṼ, 3) CVN, and 4) CṼ. The three words in each group had a high, mid-[5], and a low vowel, respectively.

The words were produced with a carrier phrase, (tsi<HL> gi<LL> tʰak<LS> tsɤ<HF> ___). Each word was produced five times. The acoustic signals were recorded onto a Sony MZ-M200 Portable Hi-MD recorder with a Sony ECM-DS70P Stereo Microphone. The sampling rate of recording was 44.1kHz.

The FFT spectra were created over a 30-ms Hamming window at three locations of each vowel: at the onset, the midpoint, and offset. In the open syllable words 1), 2), and 4), the vowel was at the utterance final and became breathy.[6] Since the breathiness in vowels has similar acoustic effects (Stevens, 1998; Arai, 2006), the final 10 % of the vowel was excluded from calculation in the open syllables. The three positions of the measurements were calculated over the reduced portion of the vowels. A1, P0, and P1 were measured from the spectra. Then A1-P0 and A1-P1 were calculated.

## 3. Results

The calculated A1-P1 value for high vowel and the A1-P0 value for mid and low vowels at each point of the vowels are plotted in Figures 1.1-1.3. Each point indicates the mean value of five repetitions and the error bar shows the standard deviation. As mentioned earlier, the lower the values of A1-P1/1-P0, the greater the nasality.

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[5] /e/ in a closed syllable is rare in Taiwanese, and we could not find a word /teN/ with a high flat tone. Therefore, /ɤ/ was used instead of /e/ for CVN.

[6] The breathiness could have been avoided by embedding the target words in a frame sentence that placed a word after the target words. We did not use such a strategy because the tone changes when followed by another word because of tonal sandhi.

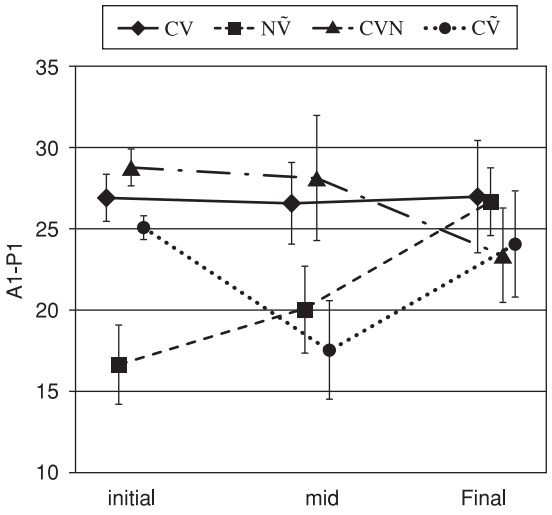


**Figure 1.1. Transition of mean A1-P1: high vowel**

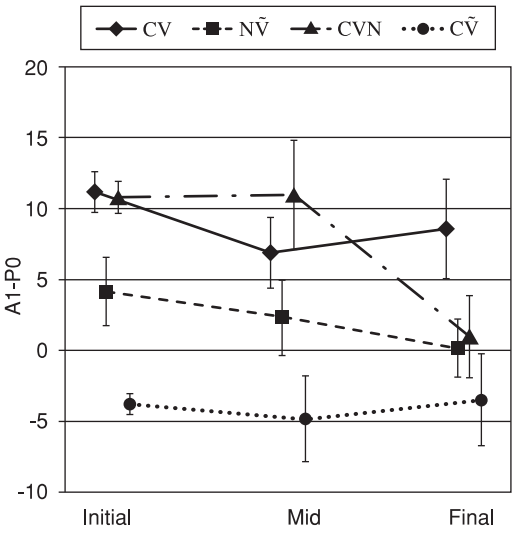


**Figure 1.2. Transition of mean A1-P0: mid vowel**

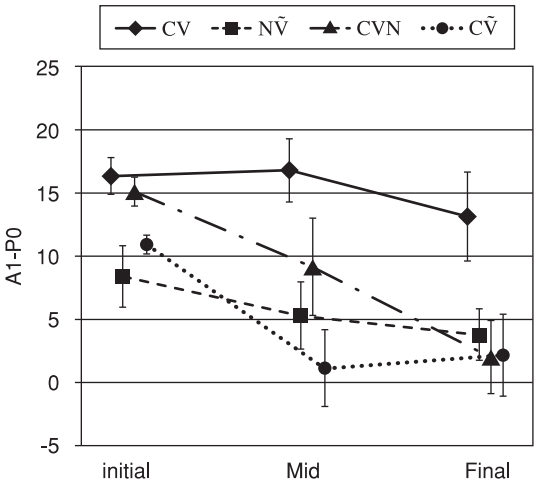


**Figure 1.3. Transition of mean A1-P0: low vowel**

By comparing the transition of the nasalities, we find that the nasality of NṼ at the onset of the vowel is the greatest for high and low vowels, and the second lowest for the mid vowel. This result is expected as a consequence of the coarticulation to the onset nasal. Similarly, the nasality of CVN becomes greater at the offset of the vowel. On the other hand, the nasal transition of CṼ has its peak at the middle point, and the mean nasality of CṼ at the midpoint is the greatest among the four types. This result confirms the findings of the aerodynamic studies by Pan (2004) and Delveaux et al (2008).

The table in (5) shows the mean values of nasality and the SD of each syllable type at the mid-point.

(5) The mean A1-P1/A1-P0 at the midpoint

| | Syllable Type | Mean A1-P1/A1-P0 | SD |
|---|---|---|---|
| High V. (A1-P1) | CV | 26.54 | 3.5 |
| | NṼ | 20.02 | 3.7 |
| | CVN | 28.16 | 3.9 |
| | CṼ | 17.5 | 4.1 |
| Mid V. (A1-P0) | CV | 6.88 | 1.75 |
| | NṼ | 2.32 | 0.65 |
| | CVN | 11.00 | 2.24 |
| | CṼ | -4.82 | 2.98 |
| Low V. (A1-P0) | CV | 16.80 | 2.50 |
| | NṼ | 5.32 | 2.67 |
| | CVN | 9.18 | 3.85 |
| | CṼ | 1.16 | 3.02 |

The nasal quantities of a high vowel were significantly different across the four syllable types, ($F^{7}$(1.106, 4.442) = 11.78, $p < .05$), but planned contrasts did not find the difference between the NṼ and CṼ to be significant, ($F$ (1, 4) = 4.85, $p > .05$). The nasalities of mid- and low vowels were significantly different across syllable types, ($F$ (3. 12) = 95.81, $p < .01$ for mid vowels and $F$ (3, 12) = 34.29, $p < .01$ for low vowels). For mid- and low vowels, planned contrasts revealed that the nasalities of CṼ are significantly greater than those of NṼ, ($F$ = (1, 4) = 23.44, $p < .01$ for mid vowels, and $F$ (1, 4) = 13.25, $p < .05$ for low vowels). Thus, we have found that the quantity of vowel nasality in CṼ is significantly greater than in NṼ for mid and low vowels, but the difference in the case of high vowels was not statistically significant.

## 4. Discussion

Although the results of the high vowel comparison were not conclusive, the results of the present study showed that the nasality of a nasal vowel is greater in a CṼ context, where oral-nasal contrast is present, than in a NṼ context, where vowel nasality is not contrastive. The transition of nasality and the statistical results at the midpoint suggest that the degree of nasality is affected by contextual contrastthat is, the nasality is greater in a contrastive environment than in a non-contrastive environment. This further suggests that contextual contrast might affect the degree of acoustic effects of phonological processes.

This study was based only on the production of a single native speaker. Considering the variations of nasality across the speakers, the results should be confirmed by follow-up experiments including

[7] Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2$ (5) = 12.07, $p < .05$. Therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity.

more speakers. Also, the current study is based only on Taiwanese. Extension to other languages is necessary to confirm the results.

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