

# Temporal Properties of the Nasals and Nasalization in Cantonese

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## ABSTRACT

This paper is an investigation of the temporal properties of the nasals and vowel nasalization in Cantonese by analyzing synchronized nasal and oral airflows. The nasal airflow volume for the vowels in both oral and nasal contexts and for the syllable-final nasals [-m, -n, -ŋ] were also obtained. Results show that (i) the vowel duration in the (C)VN syllables is negatively correlated with the duration for the following nasals [-m, -n, -ŋ]; (ii) the vowel duration in the (C)VN syllables is positively correlated with the duration of nasalization; (iii) the vowel duration in the (C)VN syllables is positively correlated with the nasal airflow volume for the vowel and for the nasalized portion; (iv) the degree of nasalization is inversely correlated with the tongue height of the vowel; and (v) the nasal duration is positively correlated with the total nasal airflow volume for the nasals.

## 1. INTRODUCTION

The physiological characteristics of the nasal consonants and vowel nasalization have been studied in a number of languages, such as in French [1], Akan [2], Yoruba [3], Australian English [4], Southern Mexico language [5] and various European languages [6]. The present study analyses the temporal properties of the rimes in the (C)VN (N = [-m], [-n] or [-ŋ]) in Cantonese [7], using the *Scicon PCquirer* multi-channel data acquisition system for obtaining the oral and nasal airflows. It aims to determine (i) the correlation between the vowel duration and the nasal duration in the (C)VN syllables; (ii) the correlation between the vowel duration and the duration of nasalization in the (C)VN syllables; (iii) the correlation between the vowel duration in the (C)VN syllables and the nasal airflow volume for the vowel; (iv) the factors affecting different degrees of nasalization; and (v) the correlation between the nasal duration for the nasals in the (C)VN syllables and the total nasal airflow volume for the nasals.

## 2. METHOD

### 2.1. Subjects

2 male native speakers of Cantonese served as the subjects. Both were university students in their early twenties at the time of data elicitation.

### 2.2. Test material and recording

Two sets of word lists were used, one for the vowels in the nasal contexts and the other for the vowels in the oral contexts.

The first set consisted of 3 randomized lists of 34 meaningful test monosyllables of the (C)VN structures, associated with a long tone (i.e., a high level 55, a mid level 33, a low-mid level 22, a low-mid to low falling 21, a low-mid to high rising 35, or a low-mid to mid rising 13). The rimes in the test words are listed in Table 1.

Rime type	Rimes in the test monosyllables
V[m]	[im, am, ɐm]
V[n]	[in, yn, ɔn, un, an, ɐn, ɐŋ]
V[ŋ]	[ɛŋ, œŋ, ɔŋ, aŋ, ɪŋ, uŋ, ɐŋ]

Table 1: The rimes in the test monosyllabic words in Cantonese are listed.

The second set consisted of 3 randomized lists of meaningful test monosyllables of the (C)V or (C)VS syllables, associated with a long tone or a short tone (i.e., 5, 3 or 2). The vowels used in this set were the same as those in the first set. Each test word was embedded in a carrier sentence, [ŋɔl tɔkɩ \_\_\_\_ peiɩ leiɩ t<sup>h</sup>ɛŋ] “I read \_\_\_\_ for you (to) listen”. The recordings were performed in a sound-proof booth (IAC), using the *Scicon PCquirer* multi-channel data acquisition system fitted with oral and nasal masks and a microphone. The speakers, wearing the masks, were instructed to utter the test words at a normal rate of speech. Three readings of each word list were recorded.

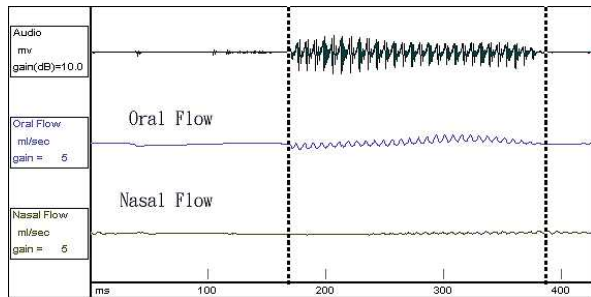
### 2.3 Analysis

In this study, audio signals were captured at a default sampling rate of 11,000 Hz and the DC channel (for both oral and nasal flows) at a default 1,375 Hz. The speech data were then analyzed, using the *Scicon PCquirer 5.0* software. The audio signals together with oral and nasal flow data were concurrently transferred to the interface system through the audio and airflow transducers and subsequently filtered, digitized and then stored into the computer. The amplitudes (in ml/sec) of the nasal airflow curve were measured and logged. The logged data were used to compute the area under the nasal airflow curve. The area is taken to be the amount of nasal airflow volume (in ml). Delimiting the boundaries of the vowel and nasal segments were made with the aid of the waveform displays and wide-band spectrograms.

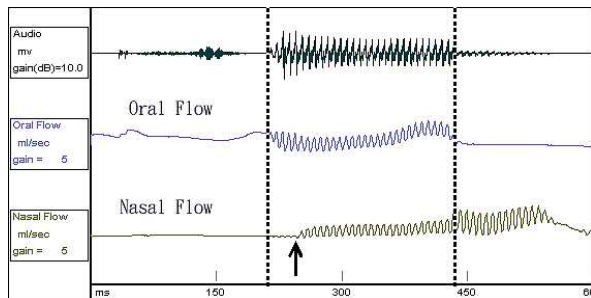
The duration of nasalization is determined by comparing the production of vowels in the oral contexts with their nasalized counterparts in the nasal contexts. For example, the nasal flow traces in Figure 1a and 1b, where an oral form of [a] in (C)V and a nasalized form of [a] in (C)V[n], are presented for one of the two speakers. The vertical broken lines delimit the vowel boundaries. The arrow in Figure 1b marks the onset of

the nasal flows. The overlap between the oral and nasal flows indicates that a large portion of vowel [a] is nasalized in the alveolar nasal context.

a) S1: Oral form of [a] in (C)V syllables



b) S1: Nasalized form of [a] in (C)V[n] syllables



Figures 1a and 1b: The oral and nasal flow traces for an oral vowel and a nasalized vowel (Speaker 1).

### 3. RESULTS AND DISCUSSION

#### 3.1. Result 1 – Temporal pattern in general environment

As the results for the 2 speakers are similar, the data from one speaker is presented here. In Figure 2, it is found that there is a negative correlation between the vowel duration and the nasal duration in the (C)VN syllables in Cantonese. The correlation is significant at the 0.01 level ( $r = -0.858$ ), using Pearson's product-moment coefficient of linear correlation test (two-tailed). Vowels are categorized into 2 groups according to their duration. The long vowels [i, y, ε, œ, a, ɔ, u] have a duration of more than 100 ms, while the short vowels [ɪ, ʊ, ɐ, ʊ] have a duration of less than 100 ms.

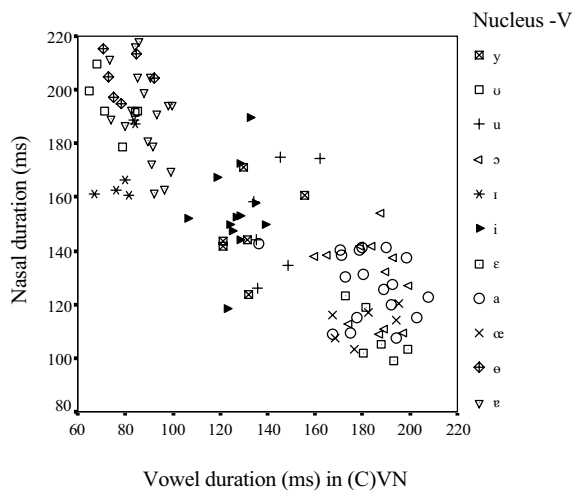


Figure 2: A scatter diagram of the vowel duration and nasal duration of 102 (C)VN syllables.

In this study, the degree of vowel nasalization in the (C)VN syllables is determined by the duration of the nasalized portion of the vowel (i.e., the duration between the sharp onset of the nasal flow and the end of the vowel). The pattern of vowel nasalization in the (C)VN syllables in Cantonese is characterized as being partial. The nasal flow starts at the point where the duration between the point and the end of the vowel is approximately the final 40% - 90% of the entire vowel duration. The degree of the vowel nasalization changes according to with different vowel durations. In Figure 3, the positive correlation is significant at the 0.01 level ( $r = 0.729$ ) between the vowel duration and the duration of the nasalized portion of the vowel. In other words, the long vowels have a higher degree of vowel nasalization than the short vowels.

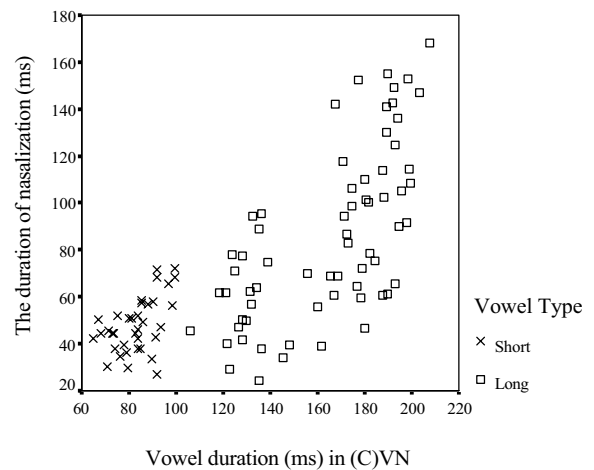


Figure 3: A scatter diagram of the vowel duration and the duration of nasalization of 102 (C)VN syllables.

There are also some idiosyncrasies in the relationship between the segment duration (in ms) and the nasal airflow volume (in ml). Figures 4 is a scatter diagram of the vowel duration and the nasal airflow volume for the vowels of 102 (C)VN syllables. There is a positive correlation between the vowel duration in (C)VN syllables and the total amount of nasal airflow volume for the vowel segment. A positive correlation between them is significant at the 0.01 level ( $r = 0.687$ ). In Figure 5, a similar relationship is observed between the vowel duration and nasal airflow volume for the nasalized portion of the vowel in the (C)VN syllable.

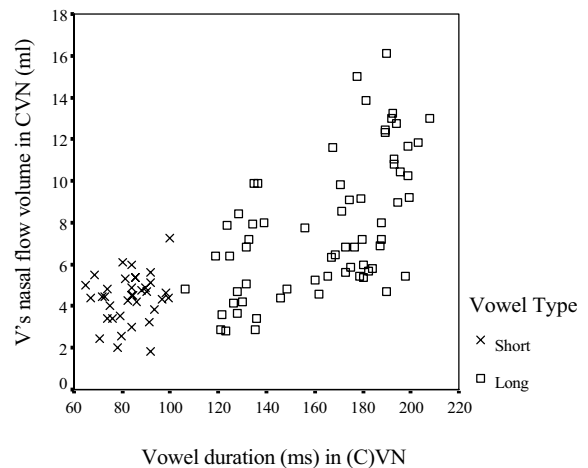


Figure 4: A scatter diagram of the vowel duration and the nasal airflow volume for the vowels of 102 (C)VN syllables.

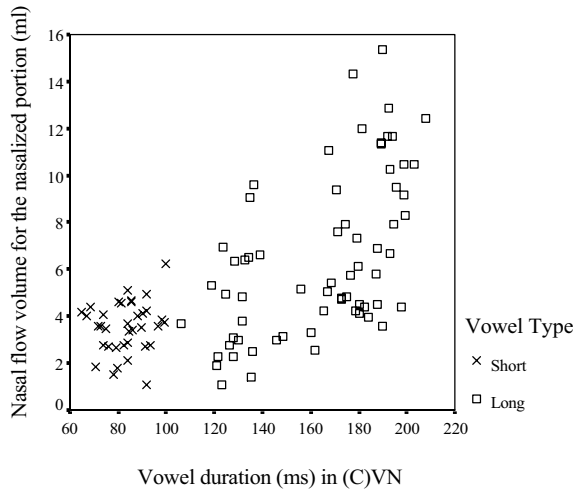


Figure 5: A scatter diagram of the vowel duration and nasal airflow volume for the nasalized portion of the vowel of 102 (C)VN syllables.

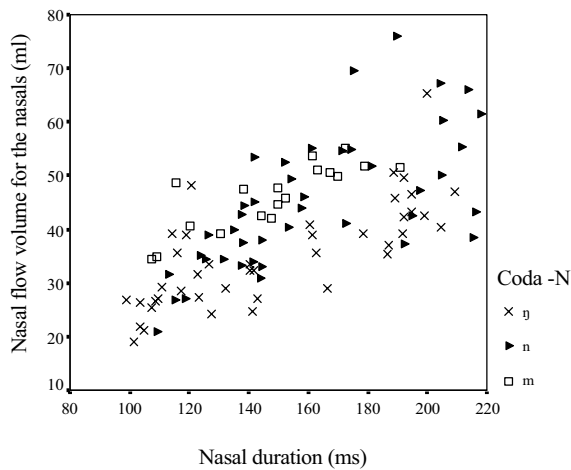


Figure 6: A scatter diagram of the nasal duration and nasal airflow volume for the nasals.

A positive correlation between them is significant at the 0.01 level ( $r = 0.633$ ). In other words, for the long vowels, there is a larger amount of nasal airflow volume for the whole vowel segment and for the nasalized portion than the short vowels.

The relationship between the segment duration and the amount of the nasal airflow volume is not confined to the vowels only. As can be seen in Figure 6, there is also a positive correlation between the nasal duration and the amount of nasal airflow volume for the nasal segments. Correlation between them is significant at the 0.01 level ( $r = 0.672$ ).

Based on the above data, it is observed that in the production of (C)VN syllables, if the vowel is a long vowel (i.e., [i, y, ε, œ, a, ɔ, u]), it will have a longer duration of nasalization, and a larger amount of nasal airflow volume for the whole vowel segment and for the nasalized portion. By then, the following nasals (i.e., [m, n, ŋ]) will have a shorter duration with a smaller amount of nasal airflow volume. The change in the vowel duration that accompanies the variation in the nasal duration seems to be important in affecting the duration of vowel nasalization.

### 3.2. Result 2 – Temporal pattern for different vowels in the same nasal contexts

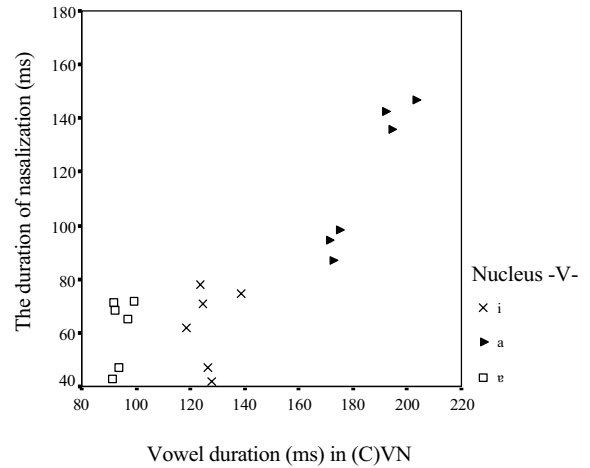


Figure 7: The duration of nasalization for vowels [i, a, ε] in (C)V[m] syllables.

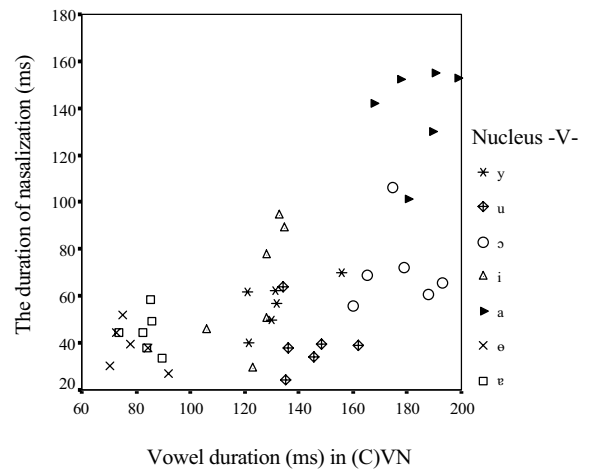


Figure 8: The duration of nasalization for vowels [i, y, ɔ, u, a, ε, ε] in (C)V[n] syllables.

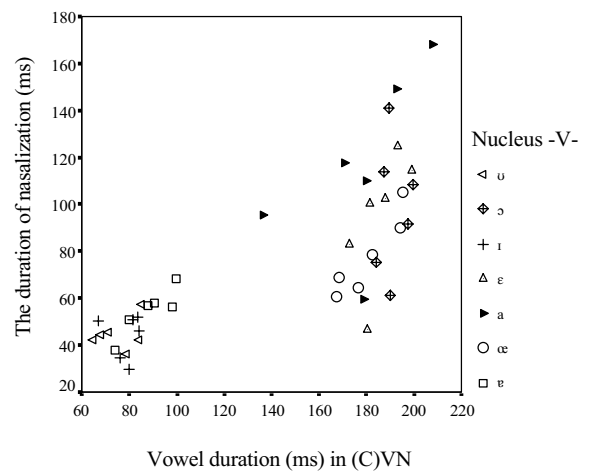


Figure 9: The duration of nasalization for vowels [ε, œ, ɔ, a, ɪ, u, ε] in the (C)V[ŋ] syllables.

As shown in Figures 7, 8 and 9, the duration of vowel nasalization depends on the vowel type. In the case of the long vowels, there is a tendency for the low vowels to have a longer duration of nasalization than the other non-low long vowels in Cantonese. In Figure 7, in the bilabial nasal context, the low vowel [a] have a longer duration of nasalization than the high vowel [i]. In Figure 8, in the alveolar nasal context, the low vowel [a] have a longer duration of nasalization than the non-low vowels [i, y, u, ɔ]. In Figure 9, in the velar nasal context, the low vowel [a] also have a longer duration of nasalization than the non-low vowels [ɛ, œ, ɔ]. Based on the above observation, it is concluded that vowel [a] consistently has a long duration of nasalization in 3 nasal contexts.

Compared with the long vowels, the duration of nasalization for the short vowels is shorter. However, for the short vowels, there is also a tendency for the non-high vowels to have a longer duration of nasalization than the other non-low short vowels in Cantonese. In Figure 8, in the alveolar nasal context, the non-high vowel [ɐ] have a longer duration of nasalization than the non-low vowel [ə]. In Figure 9, in the velar nasal context, the non-high vowel [ɐ] also have a longer duration of nasalization than non-low vowels [i, u]. Nevertheless, the nasalization for the short vowel [ɐ] is far weaker than the nasalization for the long vowel [a] because of its shorter duration of nasalization and its smaller amount of nasal airflow volume for the nasalized portion.

### 3.3 Result 3 – Temporal pattern for the same vowels in different nasal contexts

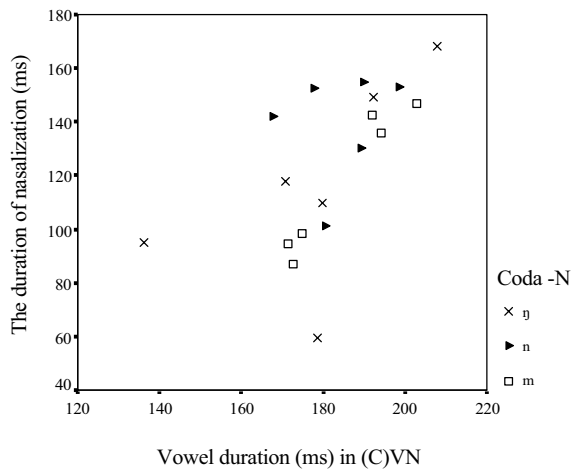


Figure 10: The duration of nasalization for [a] in different nasal contexts.

As shown in Figures 10 and 11, the duration of vowel nasalization also depends on the nasal type that follows. In Figure 10, there is a tendency for the long vowel [a] to have a longer duration of nasalization in the alveolar nasal context. In Figure 11, there is a tendency for the short vowel [ɐ] to have a longer duration of nasalization in the bilabial nasal context. The change in the nasal context that accompanies the variation in the duration of vowel nasalization seems to be important in affecting the degree of vowel nasalization.

It should be pointed out that there is no intra-speaker and inter-speaker variation for the production of the test syllables in Cantonese. Two speakers performed consistently in the three repetitions of the test words.

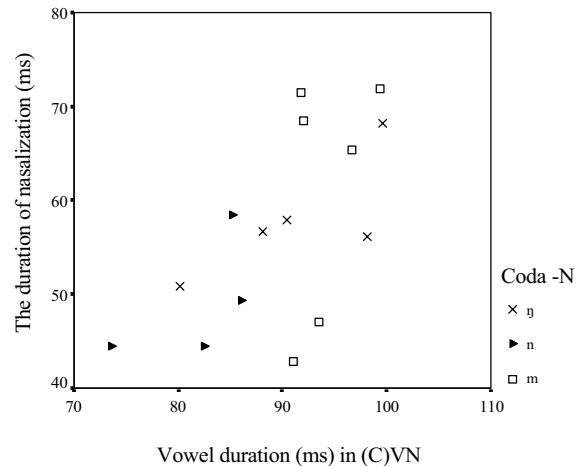


Figure 11: The duration of nasalization for vowel [ɐ] in different nasal contexts.

## 4. CONCLUDING REMARKS

Based on the physiological data from Cantonese, it is concluded that (i) the vowel duration in the (C)VN syllables is negatively correlated with the duration for the following nasals [-m, -n, -ŋ]; (ii) the vowel duration in the (C)VN syllables is positively correlated with the duration of nasalization; (iii) the vowel duration in the (C)VN syllables is positively correlated with the nasal airflow volume for the vowel and for the nasalized portion; (iv) the degree of nasalization is inversely correlated with the tongue height of the vowel; and (v) the nasal duration is positively correlated with the total nasal airflow volume for the nasals.

## 5. REFERENCES

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