PHONETIC IMPLEMENTATION OF NASALITY IN TAIWANESE (AND FRENCH): AERODYNAMIC CASE STUDIES

Yueh-chin Chang, Feng-fan Hsieh & Yu-lun Hsieh

Graduate Institute of Linguistics, National Tsing Hua University, Taiwan
ycchang@mx.nthu.edu.tw; ffhsieh@mx.nthu.edu.tw; morpheus.h@gmail.com

ABSTRACT

This paper aims at systematically investigating the aerodynamics of nasalization in Taiwanese, a language that has a nasality contrast in its vowels but are subject to stricter restrictions on nasality distribution than French. Our results show that i) the onset consonantal effects on nasal anticipatory coarticulation are subtly different between the two languages; in particular, voiced stops avoid nasal contexts in Taiwanese, ii) in onset positions, aspirated stops and fricatives induce more nasal coarticulation, iii) coda [n] triggers the least anticipatory vowel nasalization in both languages, iv) the production of nasal vowels are generally the same and vowel height is positively correlated with nasalization in both languages, v) that French has more nasal airflow volume than Taiwanese does, but no significant difference could be found as far as nasal airflow duration is concerned. Taken together, our results confirm that phonological patterning does have a bearing on phonetic implementation.

Keywords: Taiwanese, French, nasalization, vowel, coarticulation, aerodynamics

1. INTRODUCTION

The purpose of this paper is two-fold. First, we conducted a systematic aerodynamic experiment of nasalization in Taiwanese (Southern Min), a Sinitic language with a lexical contrast of nasality in vowels. Our study enriches the typology of phonetic implementation of nasality because that is an understudied topic and novel data will be reported. Second, we partly replicated previous aerodynamic experiments of nasalization in French [6, 7] and compared our results with those of former work, and, more importantly, with those we obtained from the Taiwanese data. Our hypothesis is that there must be a sharp difference between the two languages, even though both have a phonemic contrast of nasality in vowels. This is because the distribution of nasality in Taiwanese is highly constrained: i) a voiced obstruent is not compatible with a nasal vowel, e.g. *bã, while a nasal onset is not compatible with an oral vowel, e.g. *ma; ii) a nasal nucleus cannot be followed by a non-nasal coda, e.g. *ãk or a nasal coda, e.g. *ãŋ; iii) a nasal onset does not co-occur with a nasal coda, e.g. *maŋ or mãŋ. In other words, only the following sequences are attested in Taiwanese: [ba], [baŋ], [bak], and [mã], leading to the conventional analysis (e.g. [12]), according to which voiced obstruents and nasals are in allophonic variation, e.g. [b]~[m]. By contrast, voiceless (un)aspirated obstruents and non-nasal sonorants can be freely combined with nasal a vowel, e.g. [pa], [pã], [sa], [sã],[wa], [wã], [p^ha], [p^hã], etc. the distribution of nasality in French is not likewise constrained. Therefore, our main research question is: how is nasalization aerodynamically manifested in a language without a "ubiquitous" phonemic contrast of nasality, like Taiwanese?

The above discussion has also been anecdotally supported by our casual observation that many Taiwanese-speaking students surprisingly have difficulties in acquiring French nasal vowels. One possible explanation will be that nasalization is implemented in a systematically different manner between Taiwanese and French, even though cross-linguistic perceptual studies of nasalization, using synthesized speech, show that the listeners are able to distinguish oral and nasal vowels in the identification task regardless of the phonological status of nasalization in their native languages [2]. So it is likely that nasality is implemented in different ways in the two languages, hence the difficulties in L2 acquisition.

In this paper, the issues to be explored include the following: i) the aerodynamics of production of nasal vowels, ii) the effects of consonants on contextual nasalization, and iii) whether vowel height is significantly related to the degree of nasalization.

2. EXPERIMENT

2.1. Procedure

Airflow and acoustical data were collected with PCquirer (Scicon R&D Inc.) in a soundproof

recording room at the NTHU Phonetics Laboratory. The recordings consisted of three channels; the first one was the acoustic waveform with a sampling rate of 11 kHz, and the other two channels tracked the oral and nasal airflow, with a sampling rate of 1375 Hz. These data were then further processed in Praat [3]. Segmentation was conducted according to the waveforms and spectrograms and then the Praat scripts composed by the third author were utilized to automatically identify and calculate the temporal and volumetric measurements (see Sec. 2.3. for more details).

2.2. Speakers and corpus

We recruited 4 native speakers of Taiwanese (in their 20s) and 2 of French (in their 30s) for this study. No speech related impairments were reported. They were paid for their participation.

The Taiwanese materials consist of four types of structures, namely, CV, CVN, CṼ, and NṼ. The test materials include 4 oral vowels and their nasal counterparts, namely, [i, e, a, u] and [ĩ, ẽ, ã, ĩũ] (Note that [ũ] cannot stand alone), while the consonants are [p, t, k, p^h, t^h, k^h, b, g, s, h, m, n, ŋ] (where [d] is not a phoneme). The stimuli were embedded in a carrier sentence and were repeated three times, which gives a total number of approximately 900 tokens for each participant. The tones of these words are either level or falling, in order to better match the stress patterns in other non-tonal languages.

Regarding the French test materials, there are 3 oral vowels [ɛ, a, ɔ] and their nasal counterparts, and the following consonants were used: [p, t, k, s, m, n] in onset and coda positions. The number of tokens is approximately 150.

2.3. Measurements

Following the methods similar to those in [6] and [7], we conducted two types of measurement on the airflow data, as in (1) and (2).

(1) Percentage of nasalized time

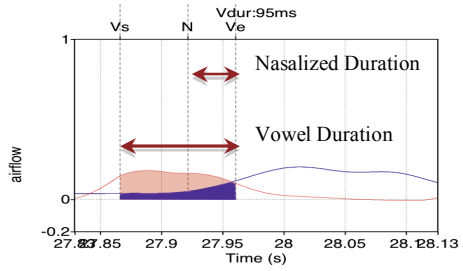
$$= \frac{\text{Nasalized Duration}}{\text{Total Vowel Duration}} \times 100\%$$

(2) Percentage of nasal flow volume

$$= \frac{\text{Nasal Flow (Blue)}}{\text{Nasal Flow (Blue)} + \text{Oral Flow (Red)}} \times 100\%$$

An illustration of these measurements is given in Figure 1. On the temporal domain, we calculated the percentage of the nasalized duration of the vowel (1), which refers to the temporal duration of nasalization on vowels, and on the volumetric domain, we calculated the percentage of nasal flow in the total airflow (2). This represents the portion of air coming out from the nasal cavity during the production of vowel.

Figure 1: Airflow data and the temporal and volumetric measurements. Red line represents the oral flow, and blue line represents the nasal flow.



3. RESULTS

3.1. Nasal vs. oral vowels

The results in Table 1 show that there is a sharp distinction between nasal and oral vowels in CV in Taiwanese, while no distinction can be found between the vowels in NṼ and CṼ ($F(1,820) = 0.043$, $p>0.05$) for the nasal flow volume. But for the nasal flow duration, the CṼ context has a slightly delayed nasal onset. Our results thus confirm the general impression that nasality is neutralized when in the NṼ context.

Table 1: Nasality of vowels in Taiwanese CV and NṼ contexts.

Taiwanese	% of nasal flow volume	% of nasalized time
CV	22.9%	
CṼ	56.9%	97.1%
NṼ	56.6%	99.6%
CVN	24.8%	41.8%

In French, the contrasts between nasal and oral vowels are distinct across all contexts in Table 2, conforming to the results reported in previous work such as [6].

Table 2: Nasality of vowels in various contexts in French.

French	% of nasal flow volume	% of nasalized time
CV	30.5%	
CṼ	67.7%	88.3%
NV	50.7%	
NṼ	75.8%	98.8%
CVN	40.9%	45.5%

With respect to nasal vowel volume, Taiwanese nasal vowels are smaller in quantity than their French counterparts.

Regarding vowel height, we can see in Table 3 that high nasal vowels have more nasal flow and shorter nasal flow duration in Taiwanese ($F(1,554)=98.861$, $p<0.05$ for volume and $F(1,554)=4.207$, $p<0.05$ for duration). Similarly, more nasal flow is attested for high vowels in CVN. The present results are again similar to those from French [6].

Table 3: The differences of nasalization between high vowels and low vowels in different contexts (Taiwanese).

	High vowels vs. Low vowels	
	% of nasal flow volume	% of nasalized time
C$\tilde{V}$	65% vs. 50%*	96% vs. 98%
N$\tilde{V}$	70% vs. 54%*	99% vs. 99.7%
CVN	26% vs. 24 %*	43% vs. 41%

(where *=significant at the 0.05 level.)

3.2. Contextual nasalization in CVN

In the CVN contexts, our principal finding was that Taiwanese has an earlier nasal onset time than French does. More precisely, the average nasal flow duration in Taiwanese is 41.8%, whereas it's 35% in French. The mean nasal flow volumes are about the same: 41.8% vs. 40.9% in Taiwanese and French, respectively.

A closer examination of onset effects on nasalization reveals that there are no systematic differences with respect to places, while significant distinctions can be found in terms of consonantal manners.

Table 4: The effects of onsets on the degrees of nasalization in the Taiwanese CVN contexts.

Onset	% of nasal flow volume	% of nasalized time
Vls. Asp. Stop	32%	44%
Fricative	32%	42%
Vd. Stop	26%	33%
Vls. Unasp. Stop	26%	32%

More specifically, we see in Table 4 that voiceless aspirated stops and fricatives "induce" a statistically significant earlier nasal onset than voiced and voiceless unaspirated stops ($p<0.05$). The results of a post-hoc test show that the differences between voiceless aspirated stops and fricatives and those between voiced stops and voiceless unaspirated stops are both not significant ($p=0.8$ and $p=0.95$, respectively), suggesting that aspiration and frication are more compatible with the lowering of velum.

In Table 5, substantial differences can be found both in nasal flow volume and duration, when different coda places are taken into consideration ($F(2,1719)=9.184$, $p<0.05$). The results of a post-hoc test show that vowels preceding the coda [n] have a reduced extent of nasalization ($p<0.05$). The similar effect is also found in our French data: vowels followed by [n] have less nasalization both in flow volume and duration ($p<0.05$).

Table 5: The effects of codas on the degrees of nasalization in the Taiwanese and French CVN contexts.

	Taiwanese			French	
Coda	[m]	[n]	[ŋ]	[m]	[n]
% of nasal flow volume	31%	25%	33%	44%	38%
% of nasalized time	40%	34%	41%	40%	30%

4. DISCUSSION

4.1. Anticipatory coarticulation in CVN

The most important finding in this study is that anticipatory nasal coarticulation is more significant when voiceless aspirated stops and fricatives are in onset position than when voiced stops and voiceless aspirated stops are in the same contexts. We believe this finding does not really challenge former studies if phonological patterning is taken into account. Some discussion is in order. First, the present results confirm Cohn's [5] study that shows aspiration can be nasalized in American English (cf. the nasal harmony hierarchy in [13]) and Shosted's [9] and [10] results that more nasal airflow is found in nasal contexts in English and French (but see [8], for example). On the other hand, voiced stops have been claimed to be more compatible with nasality (e.g. postnasal voicing; see also [13] and references cited therein) but this robust generalization is surprisingly not attested in Taiwanese, i.e., voiced stops do *not* "induce" more anticipatory nasal coarticulation. It is clearly attributable to the fact that nasals and voiced stops are in complimentary distribution, e.g. *[bã] and *[ma] (see section 1). Thus, it is not unexpected that oral segments avoid adjacent nasal contexts to a great extent.

Second, we found that the nasal transitions may be up to 44% of an oral vowel, indicating that a cline-like pattern (or [0nasal] in [5]), even though Taiwanese has a nasality contrast in it. This is reminiscent of Cohn's [5] analysis of nasality in French, according to which [-nasal] is deleted after [+nasal] and subsequently unspecified for [nasal], But since the nasal transition in Taiwanese is significantly reduced when voiced stops and

voiceless unaspirated stops are in onset positions, it remains to be seen whether the vowels in the CVN contexts are [-nasal] or [0nasal]. Nevertheless, it is safe to say that nasality is implemented in (slightly) distinct ways between the two languages.

4.2. Vowel height and nasality

In previous studies, no universal relationship between tongue height and nasality has been established. Our results showed that nasality is positively correlated with vowel height in Taiwanese and French. To our knowledge, only a few languages have been reported to have greater portions of nasal airflow in high vowels than in non-high vowels, such as Gujarati, Hindi [1], Swedish [4], and French [6], while most studies such as [1, 4], among many others, claim that in most languages, high vowels are realized with a tighter velum opening in nasal environments, which may result in relatively less nasal airflow. Given the above conflicting results in mind, it remains to be seen whether or not the relationship between vowel height and nasality is "controlled or automatic". We leave this issue open.

4.3. Nasalization in codas

In coda position, a consistent pattern is that non-coronal codas have significantly more nasal airflow and longer nasal airflow duration, irrespective of the fact that French nasal codas are released [6, 7] and their Taiwanese counterparts aren't. We conjecture that it may be difficult to maintain a full coronal closure in nasal production for aerodynamic reasons.

Finally, it should be noted that our results also confirmed a casual impression that French is "more nasalized" than Taiwanese. More precisely, Taiwanese has less nasal airflow volume than French does, although no significant difference could be found as far as nasal airflow duration is concerned. Perhaps that explains why Taiwanese speakers have difficulties in acquiring French nasal vowels. It merits a separate study.

5. CONCLUSION

Phonetic implementation of nasality is complicated by many factors. In this study, our principal finding is that while the aerodynamics of production of nasal vowels are more or less the same in French and Taiwanese, the consonantal effects on anticipatory coarticulation are not uniform between the two languages. We argued that phonological patterning plays an important role in phonetic implementation, resulting in a rare case whereby voiced stops avoid nasalization. It has also been confirmed that aspiration, frication and vowel height have an affinity to nasality.

6. ACKNOWLEDGEMENTS

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