Inter-gestural timing in French nasal vowels: A comparative study of (Liège, Tournai) Northern French vs. (Marseille, Toulouse) Southern French

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Abstract
This paper provides a comparative gestural account of nasal vowels in Southern French (Marseille, Toulouse; France) and in Northern French (Liège, Tournai; Belgium). Timing measurements based on acoustic data confirm a different temporal organisation of the gestures between the two regiolects. We also report on statistical comparisons between phonetic events (such as duration of the SF ‘nasal appendix’ vs. duration of a plain nasal consonant), that help to confront competing hypotheses concerning the underlying phonological representation of SF nasal vowels.

Index Terms: nasal vowels, timing, cross-regiolect variation, experimental phonology

1. Introduction
In French, as in most of the world’s languages, surface distinctive nasal vowels /i/ diachronically arose from homosyllabic oral vowel plus nasal consonant /nv/ sequences following a two-stages process: (i) anticipatory coarticulatory nasalization; (ii) loss of the nasal coda and simultaneousphonologization of the nasalized vowel (/vn/ [ŋn] → /nn/ [ŋ] → /n/ [ŋ]). Some phonologists maintain that the underlying representation of /i/ is /ŋ/ in modern French [2], especially in Southern French [3,4] where the phonetic realization is typically described as [Vn], i.e. as a sequence of an oral vowel portion, a nasalized vowel portion and a nasal (either vowel-like or consonant-like) ‘appendix’ (5,6,7); for an alternative analysis of /i/ = [ŋn]-[ŋ]-[n], see [8]).

To our knowledge, only one aerodynamic study has offered a precise quantification of the phenomenon [7], although on a limited number of speakers that did not allow to assess the well-recognized inter-speaker and intra-regiolect variability, especially in the duration, acoustic nature and potential role of the nasal appendix. Moreover, previous phonetic and phonological studies typically describe these [Vn] sequences in terms of acoustic events, without investigating the gesture constellations these acoustically defined (pseudo-)segments originate from. In our opinion, a phonetic assessment of the phenomenon in terms of articulatory gestures themselves, even if derived from acoustic data, should help to clarify both the phonetic description and the debate on phonological representations.

The first aim of this paper is descriptive. We seek to provide a comparative gestural account of nasal vowels in Northern French (NF) and Southern French (SF), including several regional varieties. We believe that a description of the regiolect-specific gestural patterns is the best way towards a precise and unified account of the production of distinctive nasal vowels in French. A starting hypothesis is that the acoustic variability and complexity can be bound by considering the specific timing of a velum gesture of constant duration relatively to the glottal and oral gestures.

The second aim is to contribute to the debate on the underlying phonological representation of SF nasal vowels. Our contribution is mainly based on the analysis of the extent of articulatory gestures (inferred from acoustic data) governing the emergence of the acoustic (pseudo-)segments. This analysis is based on the comparison between the data with the predictions of two competing hypotheses illustrated in Figure 1.

We propose to consider that, if the underlying representation of SF nasal vowels is /ŋ/ (hypothesis 1; H1 below), then their phonetic implementation in C1VN2 items exclusively resides in a temporal desynchronization between the velum opening gesture on one hand, and the glottal and oral closing gestures on the other hand. The time extent of the velum opening gesture for the nasal vowel, and of the oral closing gesture for the following obstruent c2, is presumably similar in SF to that in NF (see Figure 1). Also, H1 predicts that the synchronized offset of the glottal and velum gestures is preserved in Southern French, finally resulting in a shortened c2.

Figure 1: Schematized gestural scores in C1V2C2N and in C1V2C2N items comparing the predictions of the two competing hypotheses H1 and H2 about the underlying phonological representation (UR) of nasal vowels in SF.
Alternately, if the underlying representation of SF nasal vowels is /v/ (hypothesis 2; H2 below), we posit the emergence of a plain nasal segment $N$, resulting in a lengthening of the velum opening gesture when compared to NF, together with a lengthening of the oral closing gesture in order to maintain the full duration of $C_2$.

2. Material and method

2.1. Speakers and corpus

Forty-eight speakers (24 male, 24 female) were recorded reading word lists including the items of the corpus: 10 speakers from Liège (NF, Belgium), 14 from Tournai (NF, Belgium), 10 from Toulouse (SF, France), 14 from Marseille (SF, France). In each group, the number of male and female speakers was equal. All of them were born, are currently working and have always lived in the selected area. At the time of the recordings, they were between 30 and 60 years old and were all part of the middle class based on their occupation. The corpus is based on French bi-syllabic (pseudo)-word triplets $CV_N, CV_N, CV_N$ ($CV_NV, CV_NV$ are illegal in French), e.g. /hate/, /hûte/, /hanel/, /kotél/, /kûte/, /kone/; /petel/, /pene/.

This corpus was built by: (i) ensuring the homorganicity between the expected nasal appendix in $CV$ and the nasal consonant in $CV_N$; (ii) including whenever possible, given (i), $CV.CV$ = $CV.CV$ and $CV.CV$ = $CV.NV$ minimal pairs. When it was necessary to include pseudo-words, the spelling was adapted to each regiolectal variety, e.g. to ensure the production of a close-nid final vowel.

The corpus is made of 12 triplets, 4 per oral-nasal pair /e~ê/; a~à; ò~ê, where $C_1$ and $C_2$ are mostly voiceless obstruents and the final vowel is /el/. These 12 triplets have been repeated 3 times by the 48 speakers, for a total of 5184 words.

2.2. Segmentation

A manual segmentation was performed by experts using Praat [9] in order to label each phonetic segment and pseudo-segment, i.e. the expected three subparts of the realization of SF nasal vowels. Part of the dataset was segmented by each expert, followed by a cross-validation between the experts. The detection of the onset of vowel nasalization was based on the examination of spectrograms, waveforms and FFT spectra, searching for (a combination of) the following cues: a sharp decrease in $F_1$ intensity, a sharp decrease in $F_3$ intensity, the opening gesture when compared to NF, together with a lengthening of the oral closing gesture in order to maintain the full duration of $C_2$.

2.3. Measures and predictions

Raw measurements consist in the absolute duration of the acoustically defined segments and pseudo-segments, i.e. four durations for $C_1V.NC_2V$ items, and four durations for $C_1N.C_2V$ items, and four durations for $C_1V.NV$ items, for a total of (up to) 14 measures of acoustic duration for each triplet. The corresponding relative (to total word) durations have also been computed. Moreover, the duration of the velum opening gesture was taken as the sum of the durations of the nasalized (pseudo-)segments ($\nu+N^+$, when present). Its duration relative to nasal vowel ($\nu+N^+$) duration has also been computed.

In the following section, a description of the temporal organization of the acoustic (pseudo-)segments is performed, comparing NF and SF, including four regional varieties: Marseille, Toulouse, Liège and Tournai. Then, a comparative analysis of the durations of selected acoustic segments is carried out in order to test the competing hypotheses presented above (see Figure 1). Specifically, H1 predicts that the velum opening gesture is of similar duration across regiolects, whereas H2 predicts that it is longer in SF. H1 also predicts that in SF, the nasal appendix ($C_1V.C_2V$ items) will be shorter than a plain nasal consonant ($C_1N.V$ items), whereas H2 predicts that they will have a similar duration. Finally, H1 predicts that $C_2$ will be shorter in $C_1V.C_2V$ items than in $C_1V.C_2N$ items in SF, whereas H2 again predicts a similar duration.

3. Results

3.1. Overall temporal organization

Figure 2 plots the overall absolute mean durations per (pseudo) segment in the three different item types comparing NF and SF. Asterisks stand for significant differences (at .05 level) according to independent samples t-tests.

Figure 2 illustrates the fact that NF and SF differ in three respects:

(i) The phonetic realization of the nasal vowel (and the following obstruent) in $C_1V.C_2V$ items, which is examined in detail below.

(ii) The duration of penultimate vowels: unstressed vowels are significantly longer in NF than in SF in $C_1V.C_2V$ items (NF: mean=99ms; SD=20ms vs. SF: mean=81ms; SD=16ms; t(1690)=14.553, p<.001) and $C_1N.VN$ items (NF: mean=99ms; SD=21ms vs. SF: mean=87ms; SD=18ms; t(1690)=12.759, p<.001). Long vowels, especially in penultimate syllables, have been reported to correlate with typical Belgian French accent [11,12].

(iii) $N$ onsets in $C_1V.NV$ items, which are also slightly but significantly longer in NF (mean=101ms; SD=23ms) than in SF (mean=97ms; SD=19ms; t(1690)=8.565, p<.0001.

3.2. Temporal organization in nasal vowels

Figure 3 plots the absolute acoustic durations of the (up to 3) (pseudo-)segments involved in the phonetic realizations of distinctive nasal vowels in $C_1V.NV$ items comparing the four regional varieties: Marseille SF, Toulouse SF, Liège NF and Tournai NF.
Figure 2. Mean absolute durations of the acoustic (pseudo-)segments comparing NF and SF in C₁VC₂V (left panel), C₁VC₂V (middle panel) and C₁VNV (right panel) items. Asterisks indicate significant cross-regiolect duration differences according to t-tests.

Figure 3. Mean absolute durations of the acoustic (pseudo-) segments involved in the phonetic realization of nasal vowels in C₁V)C₂V items in the four regional varieties.

A separate MANOVA has been performed on this data subset with V, V and N acoustic durations as dependent variables and Regional Variety (Marseille, Toulouse, Liège, Tournai) as the independent variable, revealing that the Regional Variety factor yields significant variations in the durations of all three (pseudo-)segments (V: F(3,1688)=366.176, p<.0001; V: F(3,1688)=2627.315, p<.0001; N: F(3,1688)=5076.386, p<.0001). Bonferroni Post Hoc tests revealed that the four regional varieties are significantly different from each other in both V and V duration. Concerning N durations, there is no significant difference between Liège (mean=6ms) and Tournai (mean=6ms), all other comparisons being significant.

These results indicate that the phonetic realization of distinct nasal vowels is regiolect(al variety)-specific. In NF, vowel nasalization is delayed with respect to the onset of the vowel. The delay is longer in Liège than in Tournai. However, the major part of the vowel is nasalized (V/(V+V)*100= 68% in Liège and 77% in Tournai) and there is virtually no nasal appendix. In SF, vowel nasalization is also delayed, even more so than in NF. There is a short nasalized vocalic portion, then a large nasal appendix N. Nasal vowels are longer in Marseille than in Toulouse but the relative proportion of the 3 (pseudo-) segments is similar (as evidenced by Bonferroni post hoc tests following a MANOVA with relative-to-total-nasal-vowel-realization V, V and N acoustic durations as dependent variables and Regional Variety as independent variable).

3.3. Testing competing phonological hypotheses

In order to test the two competing hypotheses H1 and H2, three measures have been statistically compared: (i) the duration of the velum opening gesture in SF vs. in NF; (ii) in SF, the duration of the nasal appendix (C₁V,C₂V items) vs. that of a plain nasal consonant (C₁V,NV items); in SF, C₂ duration in C₁V,C₂V items vs. C₁V,C₂V items.

3.3.1. Duration of the velum opening gesture across regiolects

A separate MANOVA has been performed, with the absolute and the relative (to nasal vowel) duration of the velum opening gesture as dependent variables and Regional Variety as independent variable. Regional Variety yields significant variations in both dependent variables: absolute duration: F(3,1688)=89.335, p<.0001; relative duration: F(3,1688)=160.917, p<.0001. The results of (Bonferroni) Post Hoc tests are illustrated in Figure 4, showing that the velum opening gesture cannot be considered as longer in SF than in NF regional varieties.

3.3.2. Duration of N vs. plain N in SF

Two separate paired samples t-tests revealed that in both SF regional varieties the nasal appendix in C₁V,C₂V items is significantly shorter than the plain nasal consonant in C₁V,NV items (Figure 5): Marseille: t(503)=−5.828, p<.0001; Toulouse: t(359)=−5.759, p<.0001.

3.3.3. C₂ duration in SF

Two separate paired samples t-tests revealed that in both SF regional varieties C₂ duration is shorter when following a nasal vowel (C₁V,C₂V) than when following an oral vowel (C₁V,C₂V) (Figure 6): Marseille: t(503)=49.463, p<.0001; Toulouse: t(359)=48.356, p<.0001.
4. Discussion

In this study, we achieved a first quantified comparative description of NF vs. SF nasal vowels including regional variation. Our interpretation of acoustic data in terms of gestural patterns allows us to propose a unified account of the production of distinctive nasal vowels in NF vs. SF. Results show that the cross-regiolect acoustic variability and the apparent complexity of SF nasal vowels can be accounted for by considering a velum opening gesture of constant duration, which is differently timed relatively to the glottal and oral closing gestures. Specifically, in NF vowel nasalization can be delayed with respect to the onset of the glottal closing gesture (the major part of the vowel still being nasalized), but the offset of the velum gesture coincides with both the offset of the glottal gesture and the onset of the oral closing gesture for the following obstruent. In SF the (same-size-)velum opening gesture is further delayed with respect to vowel onset, leaving only a small part of the vowel nasalized, then it is partly coproduced with the oral closing gesture, resulting in the emergence of a nasal appendix and a shortage of the following oral obstruent.

The second aim of this study was to contribute to the debate on the underlying phonological representation of SF nasal vowels. We compared our data with the predictions of two competing hypotheses: the underlying representation of SF nasal vowels is /VN/ (H1) vs. /N/ (H2).

Overall, our results are in line with H1 in that the phonetic implementation of nasal vowels in SF can be described as a temporal desynchronisation between the velum opening gesture on one hand, and the glottal and oral closing gestures on the other hand. The time extent of the velum opening gesture, whether inferred from absolute (acoustic) durations or relative-to-nasal-vowel duration, is not larger in Marseille and Toulouse SF than in Liège and Tournai NF. If the underlying representation of SF nasal vowels was /N/ (H2), we would have expected the emergence of a plain nasal segment N, resulting in a lengthening of the velum opening gesture when compared to NF, together with a lengthening of the oral closing gesture in order to maintain the full duration of C2 (see Figure 1). However, the data show that the "nasal appendix remains shorter than a plain (intervocalic) N in SF, whereas C2 is shortened when following a nasal vowel. As a consequence, one can conclude with H1 that the underlying representation of SF nasal vowels is /VN/, which phonetic implementation involves a simple desynchronisation between the otherwise preserved velum gesture on one hand, and oral and glottal gestures on the other hand.

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6. References