ORAL ARTICULATION OF NASAL VOWELS IN FRENCH

Christopher Carignan

University of Illinois at Urbana-Champaign, USA
ccarign2@illinois.edu

ABSTRACT

EMA, aerodynamic, and acoustic signals were combined in order to observe lingual and labial articulation of oral and nasal vowels in Northern Metropolitan French (NMF) and Quebec French (QF). Inter-speaker variation observed in oral articulation suggests the importance of motor equivalence in the acoustic dispersion of each vowel system. Inter-dialectal differences observed are suggestive of important characteristics of vowel nasality. When the oral articulation of a nasal vowel enhances the acoustic effect of nasalization, it is possible that the degree of naso-pharyngeal coupling can be reduced while still conveying nasality of the vowel. However, when oral articulation minimizes the acoustic effect of nasalization, the emergence of a nasal consonant may convey nasality of the vowel instead. This suggests that inter-dialectal differences in the nasal vowel systems of QF and NMF can be explained, in part, by inherent characteristics of vowel nasality rather than by circumstances specific to the evolutionary development of French.

Keywords: vowel nasalization, French, articulation, aerodynamics, EMA

1. INTRODUCTION

The phonetics and phonology of vowel nasalization have been studied for some time, but the oral articulation of nasal vowels has been largely overlooked in both the phonetics and phonology literature. The acoustic consequences of nasalization (shifting formants, increased bandwidths, introduction of anti-formants) obscure the oral configuration of a nasal vowel [10, 13, 17, 21]. Nevertheless, in a great deal of work on vowel nasalization, oral and nasal vowel congeners (e.g. [a] and [ã]) are analyzed as if they differed in nothing more than coupling between the naso-pharyngeal and oral tracts [18, 19, 20]. In other words, it is sometimes assumed that nasal vowels are produced with the same lingual and labial configurations as their oral equivalents, and that acoustic differences between nasal and oral congeners is due solely to the effects of naso-pharyngeal coupling.

During oral sounds, the changing values of the formants can be mapped with some precision onto the changing configuration of the vocal tract [15, 24]. Nasal coupling, however, introduces spectral changes that obscure the configuration of the oral articulators. Thus, direct observations of oral articulatory position and movement are essential to fully understanding nasal vowel production and can help bridge the gap between existing knowledge of the acoustic and articulatory characteristics of vowel nasality. A growing body of articulatory research suggests that oral and nasal vowel congeners vary with respect to more than the presence or absence of naso-pharyngeal coupling [1, 2, 3, 9, 23, 28]. Using X-ray tracings of the vocal tract profiles of two male Northern Metropolitan French speakers, Zerling [28] observed that the tongue body was slightly more retracted during the productions of the nasal vowels [ɑ̃] and [ɔ̃] than during the production of their oral counterparts [ɑ] and [ɔ]. Bothorel, et al. [2] used tracings of X-ray frames and labiograms to investigate the tongue and lip articulations of two male speakers and two female Northern Metropolitan French speakers during the production of the oral/nasal vowel pairs /ɔ/-/ɔ̃/, /œ/-/œ̃/, and /ɛ/-/ɛ̃/. The tracings suggest that three of the four speakers have a more retracted tongue body during /ɔ/ than during /ɔ̃/, which partially contradicts the findings of Zerling [28]. An MRI study of two male and two female Belgian French speakers suggests that speakers use oral articulation to compensate for differences in nasal tract configuration [9]. Lingual and labial differences have also been found between the phonemic oral and nasal vowels of Hindi [23]. Finally, oral co-articulation of vowel nasalization is not restricted to languages with phonemic nasal vowels. Speakers of English raise the tongue for /i/ and lower it for /a/ when these vowels undergo co-articulatory nasalization before a nasal consonant [1, 3], perhaps as a way of compensating for the acoustic effects of nasalization.

2. METHODOLOGY

This study focuses on the lingual and labial articulation of oral and nasal vowels in two dialects of French: Northern Metropolitan French (NMF) and Quebec French (QF). Three female speakers of NMF and two female speakers of QF were recorded. The speakers produced oral and nasal vowels from a list containing, in balanced distribution, three pairs of oral and phonemically nasal vowels /a,ã,ɛ,ɛ̃,o,õ/ shared by both dialects. The target vowels appeared in CV syllables of real monosyllabic and disyllabic French words (e.g. *paon* /pã/ 'peacock' and *papa* /papa/ 'daddy'), where C is a voiceless velar, alveolar or bilabial plosive. The words appeared in the carrier phrase *Il retape* X *parfois* ('He sometimes types X again') and presented to the speakers on a computer screen. The position of lingual and labial flesh points were measured using a Carstens AG500 Electromagnetic Articulograph (EMA) system while simultaneous nasal flow was sampled using a vented nasal mask.

Three EMA sensors were placed on the midline of the tongue at even intervals: at 1 cm from the tongue tip (TT), at the tongue dorsum (TB), and at the midpoint between these two sensors (TM). Measurements of the *z*-dimension (upward / downward displacement) and *x*-dimension (forward / backward displacement) were used to infer the position of TT, TM, and TB during speech. In order to observe labial articulation, four sensors were placed around the mouth: on the upper lip, on the lower lip, and at both corners of the mouth. Lip aperture was calculated by measuring the area of the polynomial created by the coordinates of the four sensors around the mouth. The *x*-dimension measurements of the upper and lower lip sensors were used to calculate lip protrusion. Nasal flow was measured with a low-flow pressure transducer. Audio was recorded using a head-mounted directional microphone. These articulatory, acoustic, and aerodynamic signals were automatically synchronized in time.

The segments of the target word were annotated manually. The first boundary was set at the beginning of the vowel, specified as the beginning of periodicity in the acoustic signal. The second boundary was set at the end of the vowel, using an empirically determined acoustic threshold. The third annotation boundary was set at the end of the closure of the following /p/ (from the word "parfois" in the carrier phrase).

The data were measured and normalized using both native and custom-written functions in Matlab 7.11. Maximum and average values during the vowel were logged using simple arithmetic functions. The time-varying position data for each sensor were automatically divided into ten contiguous frames (each one-tenth the length of the original token). Samples were averaged inside each frame to generate exactly ten samples for each token. The average position during the fifth frame was logged and used as the normalized vowel midpoint.

Sensor errors were detected by plotting the trajectories of each vowel in each onset condition, and then manually selecting clear outliers. Error rates for a single sensor were on average less than 10%. These errors were removed from the data set prior to further analysis. Statistical analyses were performed using one-way ANOVA tests in R 2.11.1. Lingual data were separated by speaker, by place of articulation of the onset consonant, and by vowel before being submitted to ANOVA. Labial data were separated by speaker and by vowel. In each analysis, the articulatory measure was the dependent variable and vowel nasality (oral / nasal) was the independent variable.

For the acoustic measurements, a 512 point FFT was taken at the midpoint of the segmented vowel in the acoustic signal (sampled at 16 kHz), and an LPC was applied, with 14 poles for oral vowels and 28 poles for nasal vowels. The predicted F1 and F2 values were logged, compared against the FFT spectra and hand-corrected as needed.

3. RESULTS

Preliminary results for both NMF and QF suggest that speakers of a given dialect maintain similar intra-dialectal acoustic dispersion patterns, though they may use different articulatory configurations to achieve these particular acoustic distinctions.

Results for NMF confirm some of the previous lingual and labial findings [2, 9, 28] as well as reports of a counter-clockwise chain shift in the acoustic realizations of the three phonemic nasal vowels /ɛ̃/, /ã/ and /õ/ with respect to their oral congeners [11, 12, 16, 25]. This acoustic chain shift can be largely accounted for by lingual configuration. The phonemically nasal /ɛ̃/ is centralized in the lingual articulatory space: it is produced by all three speakers with both a significantly lower and more retracted tongue position than oral /ɛ/. In addition to the lowered, retracted production of /ɛ̃/, two of the three speakers produced /ã/ with a more lowered, retracted tongue configuration than for /a/, and two of the three speakers produced /õ/ with a more raised and fronted tongue configuration than for /o/. Though the acoustic dispersion in NMF may generally be accounted for by lingual configuration, there are some discrepancies. In these cases, both labial configuration and the acoustic effect of velopharygeal coupling (i.e. centralization of F1) instead may account for the distinctiveness of each vowel. Specifically, for the three speakers of NMF, F1 and F2 of /ã/, /õ/ and /o/ are lowered to a greater degree than can be accounted for by their lingual configurations, yet two speakers produced these vowels with relatively small lip aperture (the lip aperture for one speaker could not be estimated due to errors in the upper lip sensor). All three speakers produced these vowels with greater lip protrusion, albeit to varying degrees for each speaker and each vowel. A constriction at the lips will lower all formants [24], thus these labial configurations can explain the lowering of F1 and F2 which lingual configuration cannot. Additionally, inter-speaker variation was found for the lingual productions of /õ/ and /o/, which can help explain the contradictory findings of Bothorel, et al. [2] and Zerling [28].

Results for QF confirm reports a clockwise shift in the acoustic realizations of three of the four QF phonemic nasal vowels /ɛ̃/, /œ̃/, /ã/ and /õ/ with respect to their oral congeners [8, 25]. This acoustic chain shift can be largely accounted for by lingual configuration, although not completely. Both QF speakers produced a raised and fronted nasal /ɛ̃/ with respect to oral /ɛ/, and a lowered nasal /õ/ with respect to oral /o/. Inter-speaker variability could be observed in the anteriority of /õ/ and in both the anteriority and height of /ã/, though the acoustic dispersion was the same. Differences in labial configuration can partially account for this discrepancy. Labial aperture measurements suggest that one of the speakers produced both /ã/ and /õ/ with greater labial aperture than /a/ and /o/, respectively, thus maintaining acoustic distinction that cannot be accounted for completely by lingual configuration. The lingual productions of [ɛ̃] offer particularly interesting illustrations of the fact that, contrary to previous general descriptions [25], the front nasal is diphthongized in open syllables in the speech of these two QF speakers, and is not restricted to closed syllables.

4. DISCUSSION

The results from this study corroborate some of the previous articulatory findings for NMF [2, 9, 28] and general observations for QF [25], and add to the current knowledge of both vowel system dispersion and vowel nasality in general. For both dialects, inter-speaker variability in lingual and labial configuration was observed for both oral and nasal vowels. Nevertheless, the acoustic dispersion for a given dialect was similar across speakers within the dialect. These discrepancies suggest that one of the important mechanisms involved in the dispersion of the vowel spaces of these dialects could be *motor equivalence*, i.e., “the capacity of a motor system to achieve the same end-product with considerable variation in the individual components that contribute to that output” [14].

The results from this study also suggest that motor equivalence may be involved with vowel nasality itself. Due to the centralization of /ɛ̃/ in NMF, the resulting increase of F1 and decrease of F2 may enhance the percept of nasalization [4, 5, 6, 26, 27]. Engwall, et al. [9] found that there was almost no difference in velopharyngeal opening (inferred via proportional nasal flow) between the productions of /ɛ̃/ and /ɛ/ for one of the four speakers studied. The authors claim that this speaker instead modified oral articulation to distinguish the two vowels. In an aerodynamic study of nasal vowels in Belgian French, Delvaux, et al. [5] observed no significant difference in proportional nasal flow during the production of /ɛ̃/ with respect to /ɛ/. The authors argue that, despite the absence of naso-pharyngeal coupling in nasal /ɛ̃/, the acoustic effects of nasality could be mimicked with a lowered, retracted lingual articulation. This is precisely the lingual configuration observed for the three NMF speakers in the current study. For the two QF speakers, /ɛ̃/ is moved to the periphery of the articulatory space: it has a higher and more fronted tongue position than oral /ɛ/. Such an articulation could minimize the percept of nasalization by lowering F1 and raising F2. However, the QF speakers also present evidence of an epenthetic nasal consonant following this vowel: the nasal flow peak occurs between the vowel offset and the burst of the following /p/ and is accompanied by a higher tongue position. Thus, in the case of QF /ɛ̃/

nasality may be signaled through the realization of a nasal consonant, since the acoustic effects of the raised, fronted lingual articulation of this nasal vowel might otherwise minimize the percept of nasality. In the light of motor equivalence, naso-pharyngeal coupling and lingual articulation may work together to "achieve the same end-product": vowel nasality. Indeed both articulatory centralization and denasalization are historically attested among French nasal vowels [7, 22].

5. CONCLUSIONS

Admitting possible structural motivations for the observed inter-dialectal differences, it is clear that speakers of NMF and QF in this study produce phonemic nasal vowels shared by both systems in different ways. Furthermore, inter-speaker variation of oral articulation was found within both dialects, although the acoustic distinctions of a given vowel system were similar across speakers, suggesting the importance of motor equivalence in the dispersion of these vowel systems. Finally, in the light of the current results as well as findings from previous research [4, 5, 6, 9], it seems that when the oral articulation of a nasal vowel enhances the acoustic effect of nasalization, the degree of naso-pharyngeal coupling can be reduced while still conveying nasality of the vowel. On the other hand, when oral articulation minimizes the acoustic effect of nasalization, the emergence of a nasal consonant may convey nasality of the vowel instead.

6. REFERENCES

[1] Arai, T. 2004. Comparing Tongue Positions of Vowels in Oral and Nasal Contexts. *http://www.splab.net/papers/2004/2004_25.pdf*

[2] Botherel, A., Simon, P., Wioland, F., Zerling, J.-P. 1986. Cinéradiographie des voyelles et consonnes du français. *Travaux de l'Institut de Phonétique de Strasbourg* 18.

[3] Carignan, C., Shosted, R., Shih, C., Rong, P. Submitted. Articulatory compensation for nasality: An EMA study of lingual position during nasalized vowels.

[4] Delvaux, V. 2009. Perception du contraste de nasalité vocalique en français. *J. French Language Studies* 19, 25-59.

[5] Delvaux, V., Demolin, D., Harmegnies, B., Soquet, A. 2008. The aerodynamics of nasalization in French. *J. Phonetics* 36, 578-606.

[6] Delvaux, V., Demolin, D., Soquet, A., Kingston, J. 2004. La perception des voyelles nasales du français. *XXVèmes Journeés d'étude sur la parole, Fès*, 157-160.

[7] Demolin, D., Teston, B. 1998. Aerodynamic and articulatory aspects of French nasal vowels. *Travaux Interdisciplinaires du Laboratoire Parole et Langage d'Aix-en-Provence (TIPA)* 18, 50-59.

[8] Dumas, D. 1984. *Nos façons de parler: les prononciations en français québécois*. Sillery, Quebec: Presses de l'Université de Québec.

[9] Engwall, O., Delvaux, V., Metens, T. 2006. Interspeaker variation in the articulation of nasal vowels. *Proc. 7th ISSP*, 3-10.

[10] Feng, G., Castelli, E. 1996. Some acoustic features of nasal and nasalized vowels: A target for vowel nasalization. *J. Acoust. Soc. Am.* 99(6), 3694-3706.

[11] Fónagy, I. 1989. Le français change le visage. *Revue Romaine* 24(2), 225-254.

[12] Hansen, A. 2001. Lexical diffusion as factor of phonetic change: The case of modern French nasal vowels. *Language Variation and Change* 13(2), 209-252.

[13] Hawkins, S., Stevens, K.N. 1985. Acoustic and perceptual correlates of the non-nasal distinction for vowels. *J. Acoust. Soc. Am.* 77(4), 1560-1575.

[14] Hughes, O.M., Abbs, J.H. 1976. Labial-mandibular coordination in the production of speech: Implications for the operation of motor equivalence. *Phonetica* 44,199-221.

[15] Iskarous, K. 2010. Vowel Constrictions are Recoverable from Formants. *J. Phonetics* 38, 375-387.

[16] Maddieson, I. 1984. *Patterns of Sounds*. Cambridge: Cambridge University Press.

[17] Maeda, S. 1993. Acoustics of vowel nasalization and articulatory shifts in French nasal vowels. In Huffman, M.K., Krakow, R.A. (eds.), *Phonetics and Phonology: Vol. 5: Nasals, Nasalization and the Velum*. New York: Academic Press, 147-167.

[18] Morais-Barbosa, J. 1962. Les voyelles nasales portugaises: interprétation phonologique. *Proc. 4th ICPhS* (Helsinki 1961), 691-708.

[19] Narangg, C., Becker, D. 1971. Aspiration and nasalisation in the generative phonology of Hindi-Urdu. *Language* 47, 646-667.

[20] Paradis, C., Prunet, J.-F. 2000. Nasal vowels as two segments: Evidence from borrowings. *Language* 76(2), 324-357.

[21] Pruthi, T., Epsy-Wilson, C.Y., Story, B.H. 2007. Simulation and analysis of nasalized vowels based on magnetic resonance imaging data. *J. Acoust. Soc. Am.* 121, 3858-3873.

[22] Sampson, R. 1999. *Nasal Vowel Evolution in Romance*. Oxford: Oxford University Press.

[23] Shosted, R., Carignan, C. Rong, P. Submitted. Motor equivalence in the production of phonemic nasal vowels: Evidence from Hindi.

[24] Stevens, K.N. 1998. *Acoustic Phonetics*. Cambridge: MIT Press.

[25] Walker, D.C. 1984. The Pronunciation of Canadian French. Ottawa, University of Ottawa Press. *http://people.ucalgary.ca/~dcwalker/PronCF.pdf*

[26] Wright, J.T. 1975. Effects of vowel nasalization on the perception of vowel height. In Ferguson, C.A., Hyman, L.M., Ohala, J.J. (eds.), *Nasálfest. Papers from a Symposium on Nasals and Nasalization*. Stanford University: Language Univerisals Project, 373-388.

[27] Wright, J.T. 1986. Nasalized vowels in the perceptual vowel space. In Ohala, J.J., Jaeger, J.J. (eds.), *Experimental Phonology*. Orlando: Academic Press, 45-67.

[28] Zerling, J.P. 1984. Phénomènes de nasalité et de nasalization vocaliques: Étude cinéradiographique pour deux locuteurs. *Travaux de l'Institut de Phonétique de Strasbourg* 16, 241-266.