TEMPORAL EXTENT OF NASALIZATION RELATIVE TO THE TONGUE ARTICULATION IN FRENCH NASALIZED VOWELS

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ABSTRACT

The goal of this study is to investigate the temporal extent of nasalization in French oral vowels followed by nasal consonants. The extent of nasalization is obtained by measuring the acoustic signal at the nostrils with an appropriate microphone for 14 French speakers. Total duration and percentage of nasalization are extracted for each vowel and statistical tests are performed. Whereas the amount of nasalization was expected to vary as a function of vowel height, results of this study show that the temporal extent of nasalization is related not only to the height dimension but also to the front-back position of the tongue. More specifically, the mid-low vowels [ɛ] and [ɔ] do not pattern together, but rather pattern with the front and back high vowels, respectively. The position of the tongue for these oral vowels is then compared to that of nasal vowels, in order to provide an interpretation of nasal coarticulation phenomenon.

Keywords: duration of nasalization, French nasalized vowels, nasal coarticulation.

1. INTRODUCTION

In the majority of the world languages, phonological nasal vowels originate diachronically from the total nasalization (nasal coarticulation) of an oral vowel (V) by a following nasal consonant (N), and then the fall of the nasal consonant [11]; that is to say that in these cases distinctive nasality in vowels comes from a regressive assimilation.

In languages without oral/nasal contrast in vowels, one can find two different coarticulatory behaviors of nasalization in VN sequences [3, 13]. In one case, most languages have a limited nasalization in oral vowels. In the other case, American English is well known for extensive nasalization of oral vowels followed by a nasal consonant. According to Solé [13], vowels in this language are targeted as nasalized as a result of a phonological rule.

In French, both phonological nasal vowels and contextual nasalized vowels occur. The need to preserve distinction in vowels induces French speakers to limit nasal coarticulation effects during nasalized vowels production. Anticipatory nasalization (VN) is more limited than progressive nasalization (NV).

The simultaneous recording of nasal and acoustic (global = oral + nasal) signals gives a simple way to visualize the onset and the offset time of nasalization during natural speech [16, 10]. Concerning oral vowels followed by nasal consonants, we can measure precisely the duration of the nasalized portion (expressed as percentage of the total vowel length), by superposing the two signals.

As shown in [9] using this methodology, results suggested that nasalization duration would be related to the height of vowels in French, since it can be order as: low vowel [a] 50% > mi-lower vowel [ɛ] 33% > mi-higher vowel [o] 21%.

This relationship between the degree of nasalization and the height of vowels has been demonstrated in several studies. Articulatory research has not only shown that the velum opening is correlated with tongue/jaw height, but that the coarticulatory gestures between the velum and all other articulators are linked in terms of gesture timing [1, 5, 7]. Especially, low vowels are produced with a greater lowering of the velum than the high vowels. This physiological interrelation has been often argued to explain the vowel nasalization diachronic process from Latin to French [14, 12], in which the low vowel [a] has been nasalized first, and then the mid vowels and finally the higher ones. This relationship can be explained on perceptual ground: high and mid-high nasalized vowels are perceived as lower [2, 6] and low vowels need a greater degree of nasalization (synthesis stimuli) to be perceived as nasalized than higher vowels [8].

While most studies have used principally extreme vowels [a, i, u], the current study extends the amount of data including the mid-low vowels [ɛ, ɔ] and the high front vowel [y]. Temporal

measurements (total duration and the duration of the nasalized portion of each vowel) are given in tables, the percentages of nasalization duration calculated are presented on a histogram and the statistically significant groups are computed. Links between the articulatory gestures (velum opening, height and front-back positions of the tongue) for nasalized and nasal vowels are outlined in the discussion.

2. METHODOLOGY

Studies on nasal coarticulation may use several experimental techniques for data collection. The lowering of the velum necessary for the production of nasal sounds is particularly difficult to observe and examine. In nasal and nasalized vowel production, the laryngeal sounds are propagated through the vocal tract, partly through the oral cavities and in another part through the nasal cavity. The speech signal recorded out of the vocal tract contains acoustic information due to both oral and nasal cavities. The recording of the nasal signal by a transducer, placed in the nostril that doesn't hamper speaker's speech, is an indirect but pertinent means to observe the behavior of the velum in oral segments neighboring nasal sounds.

2.1. Procedure

Speech signal was captured by a microphone, placed about 20 cm from the speaker' mouth. At the same time, nasal signal was captured by an electrodynamic's transducer (sensibility: 1 mV for 60 dB, frequency response: 10 Hz to 8 kHz, dynamic range: 30 up to 130 dB SPL). Both signals were recorded with a digital recorder. The two signals were balanced by adjusting gain of each channel to obtain equal amplitude nasal signal and speech signal, in isolated nasal consonants production. Then recordings were transferred at wav, stereo format, at 22050 Hz sampling rate.

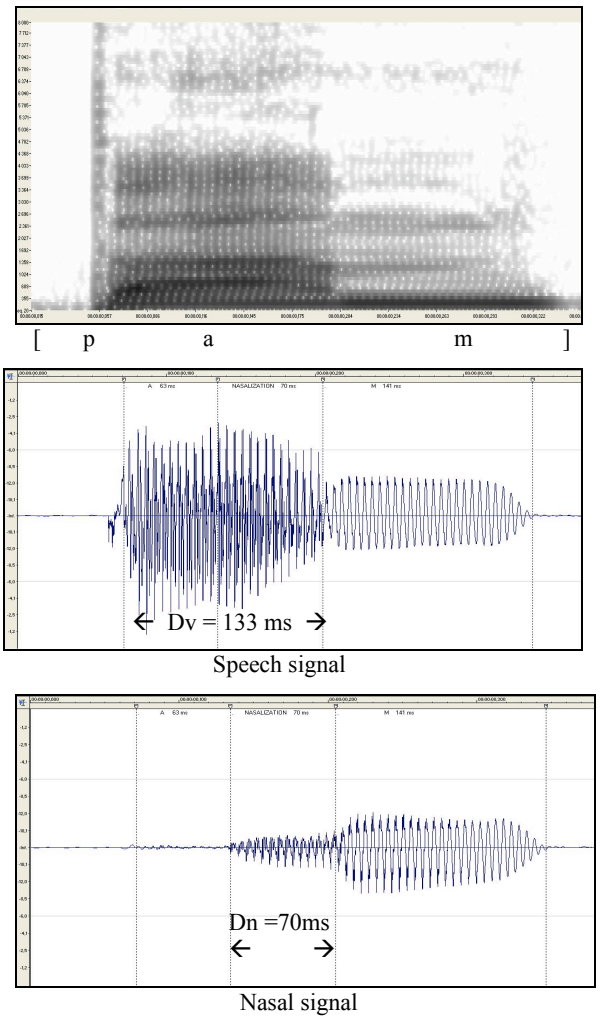
2.2. Speakers and corpus

14 male native speakers of Parisian French were asked to read 5 times stressed CVN syllables of the type [pan]: the first time in isolation, the second time inserted in the carrier sentence "Je répète _ trois fois" ("I repeat _ three times") and the last three time in isolation. Only 2 repetitions were selected per speaker (the 3rd and the 4th repetitions). Consonantal contexts were homorganic: labial [pVm] or coronal [tVn], where V=[a; ɛ, ɔ; i, y, u], these vowels are shared in 3 respective open degrees (low; mid-low; high).

2.3. Temporal measurements

SoundForge was used for measurements. As shown in Figure 1, Dv is the total vowel duration in ms, measured on the speech signal. Dn is the duration of the nasalized portion of the vowel, measured between the onset of nasal signal and the offset of the vowel (on the speech signal). Then we calculate the percentage of nasalization duration on total vowel duration (% nasalization duration = Dn/Dv * 100).

Figure 1: Spectrogram, acoustic waveform, and nasal signal of the utterance of [pam], showing segmentation of Dv = vowel duration, and of Dn = nasalized portion duration.



3. RESULTS

Table 1 presents the mean durations (in ms) of the total vowel duration and of nasalized portion of French nasalized vowels [i, y, ɛ, a, ɔ, u] occurring in labial and coronal contexts ([pVm], [tVn]), and all correspondent standard deviations. Differences in the place of articulation have a significant influence only for the vowel [ɥ], on the total vowel duration (p= .0456) and on the nasalized portion (p= .0302).

Table 1: Mean durations (in ms) and standard deviation (SD) of total vowel duration and nasalized portion of French vowels, in labial and coronal context.

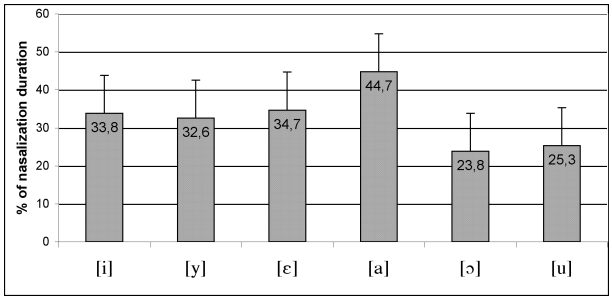
	Total vowel duration				Nasalized vowel portion			
	pVm	*SD*	tVn	*SD*	pVm	*SD*	tVn	*SD*
[i]	105,1	*18,8*	91,7	*27,6*	32,9	*10,1*	32,4	*14,1*
[y]	117,7	*27,9*	109,8	*23,8*	38,3	*16,9*	35,1	*13,9*
[ɛ]	133,0	*26,6*	132,5	*20,0*	43,7	*12,7*	46,7	*14,8*
[a]	133,5	*23,8*	143,3	*18,7*	59,1	*17,3*	64,4	*18,7*
[ɔ]	125,4	*19,4*	143,3	*22,1*	25,3	*9,4*	37,1	*15,8*
[u]	121,1	*27,5*	117,2	*23,3*	30,1	*11,3*	30,4	*14,4*

A pairwise statistical comparison of each mean (PLSD Fisher test) shows the emergence of different groups according to how they pattern together and how they are affected according to the 2 contexts (labial vs. coronal). Results show generally that the lower the vowel the longer its total duration, with the exception of the high vowel [i], which is always shorter than the two other high vowels [y] and [u] and even significantly shorter in coronal context, between [i] and [y] (p= .0431), and between [i] and [u] (p= .0047). We also note that the mean duration of the low vowel [a] is longer than mid-low vowels [ɛ] and [ɔ] for the two contexts together, but that total duration is equal for [ɛ] and [a] in labial context and for [a] and [ɔ] in coronal context. The pairwise comparison between the three low and mid-low vowels is not significant.

Concerning the duration of the nasalized portion of vowels, results show the emergence of a different classification. Specifically, according to the duration of the nasalized portion, we observed 3 groups composed of: (1) the low vowel [a] which is always produced with a significantly longer nasalized portion, (2) the front mid-lower vowel [ɛ] and (3) high vowels [i], [y], [u] and the back mid-open vowel [ɔ] which have the shortest nasalized portion.

In order to bring out results including precedent durations and neutralizing contextual differences, we calculate the percentage of nasalization duration on total vowel duration. This is illustrated in Figure 2 for all vowels in both labial and coronal contexts.

Figure 2: The percentage of nasalization duration for French contextual nasalized vowels.



This expression of nasal coarticulation in percentage distinguishes 3 new groups, which differ significantly. (1) The low vowel [a] has the greatest percentage of nasalization duration, as it was expected from preceding results and literature. But contrary to expectation, the second group emerging is composed of (2) the 3 front vowels: the high [i], [y] and the mid-low [ɛ]. PLSD Fisher test indicates no significant differences between [i] and [y] (p= .3910), nor between [i] and [ɛ] (p= .7874) and between [y] and [ɛ] (p= .2600). The last significant group with the smallest percentage of nasalization duration is composed of 2 back vowels: (3) the high [u] and the mid-low [ɔ], for which the pairwise comparison is not significant (p= .4971).

4. DISCUSSION AND CONCLUSION

This study shows that anticipatory nasal coarticulation in CVN syllables seems to be "controlled" by French speakers in order to keep nasalized vowels distinct from nasal vowels. Oral vowels in nasal context (CVN syllables) are only partially nasalized and the onset of nasalization comes almost always within the second half of vowel duration.

The current results are in general agreement with previous studies cited above, concerning the extreme vowels [a] and [i], the low vowel being always more nasalized in duration than the high one. However, concerning the percentage of nasalization duration of the mid-low vowels [ɛ] and [ɔ], the results of this study shows that they do not pattern together as it was expected according to their common height. The fact that the mid-low vowels ([ɛ] and [ɔ]) pattern with the high vowels

([i, y] and [u], respectively) is rather unexpected. The supposed correlation between the amount of nasalization and vowel height has been taken for granted by many researchers. A consequence of this is that this knowledge could "a priori" influence upon the design of experiments. For example, means of vowel duration and nasalized portion for 3 French speakers in [3] have been investigated for the three assumed groups of vowels: high vowels [i y u], mid-vowels [ɛ o ɔ œ], and low vowel [a]. The choice to group the vowels according to their height may have the effect of blurring the role of the front-back dimension of the tongue. In [9], the restricted corpus does not permit to discern the influence of the front-back difference between [ɛ] and [o], and the results are interpreted as the influence of the difference in height degrees.

The current results provide the opportunity to examine to which extent the front-back dimension of the tongue may also account for the amount of nasalization produced. In order to understand the coarticulation gestures in nasalized vowels and the differences in durations found, it is important to consider observations of the articulation of French nasal vowels and to compare them with the articulatory configuration of nasalized vowels. In [16, 4], it has been shown, through the x-ray data and RMI analysis of the 3 French nasal vowels, that there are 3 different degrees of velum lowering (amplitude) as a function of the position of the posterior part of the tongue. Thus, in the articulation of the posterior nasal vowel /ɔ̃/, the more the tongue is in back position, the smaller the degree of velum opening. This implies that the back position of the tongue may limit the degree of velum lowering. This could also explain the comparable percentage of nasalization duration for the vowels [ɔ, u], which have a similar back position of the tongue. For the front vowels, the results concerning the percentage of nasalization duration could also be interpreted in the same way: the front position of the tongue would permit more amplitude to the lowering of the velum than a posterior configuration. In the case of anterior and posterior vowels sharing the same height degree, the posterior vowel would be less nasalized than the front one. Although there is no statistical significance, the percent duration of nasalized portion of [i] is indeed longer than that of [y], as shown in Figure 2. In addition, low vowels, being systematically produced with a greater lowering of the velum, would exhibit a greater percentage of nasalization duration. Results of the present study clearly show that in order to account for the nasal coarticulation phenomenon, both the hight/low and the front/back dimensions of the vowels should be considered.

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