Vowel Nasalization and Nasal Loss in Italian

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ABSTRACT

This paper examines pre-nasal consonant vowel nasalization and nasal consonant loss in Italian using airflow and acoustic waveform data. Speech material consists of Italian words containing VNC sequences where V = /i/ or /a/ and C=voiced and voiceless consonants with different manners and places of articulation. The results show that voiceless fricatives are most conducive to nasalization and nasal loss, and that the process is favored in the presence of a high vowel.

1. INTRODUCTION

Processes of pre-nasal consonant vowel nasalization in VN(C) sequences are common. Historically they may give rise to sound changes involving the development of distinctive nasal vowels and the loss of the post-vocalic nasal consonants.

V nasalization and nasal C loss seem to be favored in the presence of certain properties of the V and C sounds, as well as certain contextual conditions, though opinion varies as to the weight to assign to the different factors in providing the optimal environment for nasal loss. Low Vs may provide a better context for nasalization than high Vs, as the velum tends to be lower in the production of a low than a high V [1]. On the other hand, high Vs may be perceived as more nasal than low Vs because of the greater airflow required for their production [cf. 4 for a review]. The intrinsic characteristics of the post nasal C (place, manner and voicing) have also been reported to affect V nasalization. Post nasal voiceless obstruents, and fricatives in particular, may be more effective in promoting nasal loss than other segment types. In nasal + fricative sequences, the articulatory constraints on the velum required for the production of a nasal and following oral C would cause an anticipation of the velic closure required for the oral segment [8]. Perceptually, the turbulence associated with frication combined with the voicing of the adjacent V may have an effect of perceived nasalization [8]. Nasal Cs may then be harder to detect before final voiceless fricatives than before stops [8, 9].

The temporal characteristics of the segments involved have also been studied in relation to processes of V nasalization. The long V found after nasal C loss in a reconstructed VNC sequence has been traditionally considered to be due to compensatory lengthening. However, a link between (long) V duration and nasalization has been reported in accounts of developments of nasal Vs in prenasal contexts [4] and the effects of V duration on perceived nasality have been given experimental support [11]. Post-nasal C-voicing, affecting the duration of preceding coarticulated Vs and nasals, may also affect V nasalization, but no systematic study has yet been undertaken to ascertain its effects. Finally, research on coarticulation as well as on velic movement patterns has shown that the amount of temporal overlap in the production of adjacent segments is influenced by non segmental factors, such as position of the segment in the syllable, in the sentence and in relation to stress and speaking rate [5].

Languages, however, differ in the extent and timing of velic lowering and in degree of coarticulated nasalization [1, 10]. This calls for more investigation on velic movement patterns and contextual nasalization in different languages.

This paper investigates V nasalization and nasal loss in Italian, the hypothesis being that if such processes are found in the language, they would be most likely to occur in the context of a following voiceless fricative. The study also examines the effects of V height, word stress, and place, manner and voicing of post nasal C.

2. STUDIES OF ITALIAN NASAL CLUSTERS

Standard Italian has a 7-phoneme vowel inventory, with no nasal Vs. Italian nasal consonants are homorganic with the following C. Coarticulatory nasalization has been found to be very limited in Italian and shows a tendency to be more carryover than anticipatory [2].

Indications of nasalization processes and nasal C loss involving Northern Italian come from several sources. Northern dialects provide examples of developments of distinctive V nasalization and nasal C loss occurring in various segmental and non segmental contexts [4]. According to Mioni and Trumper [7], V nasalization and nasal loss is a gradual process, largely depending on the consonantal context, the style used and the regional variety of Italian spoken. At its intermediate stages the process shows up as an ‘oronasal transition sound, characterized as an open transition between two segments or a prenasalization of the following oral segment’. In a palatographic study of VC1C2V coarticulation in (Northern) Italian [3] evidence was found of a process ranging from unassimilated C1C2 to complete assimilation in /ntʃ/, /nʃ/ and /nr/ clusters, with examples of almost complete deletion of the gesture for the nasal C1 in /nʃ/ clusters for one of the three subjects, and complete deletion of the nasal C gesture in /nr/ clusters in almost all cases. On the perceptual side, a study [6] found a strong effect of V non-distinctive nasalization on the perception of the preceding C, showing that the V more than the C contributes to judgements of nasality in Italian.

3. METHOD

The material consists of simultaneous nasal and oral flow, and acoustic waveform data, collected for 26 meaningful Italian bisyllabic and trisyllabic words containing VNC sequences and 26 comparable VCC words (for ex., *campi*, *cappi; t’infondo, diffondo*) read five times by two Northern

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Italian speakers in a carrier sentence (52 x 5 x 2). The following VNC sequences allowed by the phonotactics of Italian were chosen: /n/ + [p, b]; /n/ + [f, v], /n/ + [t, d]; /n/ + [s]; /n/ + [r]; /n/ + [S]; /n/ + [k, g]. The preceding V contexts were [i] and [a]. Stress was on V1 in bisyllables and on V2 in trisyllables (ex., *'Banfi* vs *fan'fare).* The corpus was designed to test the effects of the following factors: a) following C type; b) voicing of following C; c) pre-nasal V height; d) word stress position. Another subset of across words VNC sequences recorded to test the effect of word boundary was excluded from the present analysis.

Airflow was transduced with a two-chamber Rothenberg mask. The audio signal was recorded by a high quality microphone placed about 1 cm from the mask. Data collected with a nasograph had to be discarded because of technical problems. All signals were digitized and logged directly onto a PC at a sampling rate of 8kHz. The nasal flow was 70 Hz low-pass filtered using a Khron-Hite filter, model 3364. The data was analyzed using the Windaq software, which allows simultaneous representation of oral flow, nasal flow, and acoustic waveform. While several types of measurements were taken, only the following measurements will be reported here: 1) acoustic duration in ms of the segments in the VNC sequence and in the control; 2) duration in ms of the portion of the nasal flow in prenasal V C; 3) percentages of V nasalization in each condition. As for nasal loss, four evidential categories were used to subdivide the data into clear cases of presence of nasal C or nasalized V, or ambiguous cases in either direction. In all these cases, the criterion for clear nasal C was the simultaneous occurrence of periodic signal, nasal flow, and oral flow close to the baseline. In such cases, the peak of the nasal flow typically occurs within the end of the periodic signal for the nasal C. Clear nasalized V were considered to be evidenced by the simultaneous occurrence of oral and nasal flow during the acoustic period.

4. RESULTS

4.1. Effects of manner of articulation, V height and stress

Tables 1 and 2 show the effects of manner of articulation for the two speakers by comparing duration of the prenasal V; duration of V nasalization and percentage of nasalization. Data on the duration of control V are provided for comparison.

The data show rather high intersubject and intrasubject variation, which is reflected in the high S.D. and partly explained by the grouping of all the data regardless of the different contextual conditions. For speaker G (Table 1), manner of articulation has a significant effect on all the parameters considered. The effect is in the direction predicted with fricatives and trills having longer and more nasalized Vs than stops. This effect is particularly clear before trills, where the V is nasalized by 96% of its total duration (S.D.=0.05). In a comparison with the control Vs, all the target Vs are significantly longer. The duration values of the preconsonantal nasal stop, not reported in the table because of space constraints, also show a significant effect of manner of articulation, with full nasal Cs before stops and weak to no nasal in the other two contexts (/_stop=93.3, /_fricative=25.2, /_trill=0; p<.0001). It appears, then, that the temporal characteristics of Vs and nasal Cs in VNC sequences are interrelated, as will be also seen below.

Tables 1 and 2. Effects of manner of articulation on V nasalization (Spkr G - top and Spkr A - bottom).

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
stop	115.3	42.1	63.9	51.6	0.52	0.32	100.1	34.9
fricative	173.2	61.2	131.2	57.8	0.75	0.21	125.9	48.7
trill	140.2	37.4	135.2	38.1	0.96	0.05	99.6	7.0
Prob**.**	p<.0001		p<.0001		p<.0001		p=0.0027	

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
stop	89.1	36.4	37.1	33.8	0.42	0.37	84.4	28.4
fricative	104.8	42.4	53.0	61.0	0.43	0.45	100.5	34.5
trill	96.6	33.4	29.4	19.3	0.38	0.37	87.2	21.5
Prob**.**	non signif		non signif.		non signif		p=0.01	

As for speaker A (Table 2), a trend is observable of longer V duration before fricatives and trills than before stops. As for the preconsonantal nasal stop, it has a longer duration before stops than fricatives and trills (/_stop=105.1, /_fric=86.5, /_trill=81.8; p<.0008). The data also show that vowels are less nasalized than for speaker G, and that the percentage of nasalization is about the same in the three contexts examined. A comparison with the duration of the control Vs shows no significantly longer duration in the target Vs than in the control. This speaker then shows a tendency to have less nasalized vowels than speaker G, and this tendency will be found in all the conditions observed.

Overall, the data show that manner of articulation has an effect on the duration of the preceding V and nasal C segments. When compared with fricatives and trills, stops are preceded by shorter Vs and longer nasal Cs, and Vs are, in at least one of the two speakers, less nasalized. [Because of space constraints, VNC_{trill} sequences will be further discussed elsewhere, and so will place of articulation].

Tables 3 and 4 show the effects of V height for speakers G and A respectively. For both speakers /a/ is significantly longer than /i/ (for both, p<.0001). For speaker G V height has a significant effect on the duration of V nasalization, while for speaker A the trend is not significant. Also, for speaker G, a comparison with the duration values of the control Vs shows that both high and low Vs are longer before /n/. Interestingly, both speakers show an about equal percentage of nasalization in the two V contexts, indicating that V height does not affect the percentage of V nasalization. The data thus indicate that the lowering of the velum in anticipation of the nasal C occurs at about the same time after V onset regardless of V height.

Finally Tables 5 and 6 show the effect of stress. For both speakers, stress has a significant effect on V duration, stressed Vs being longer than unstressed ones. For speaker G (Table 5) V duration is longer in the prenasal context than in the control. Also for G, stress has a significant effect on nasalization, with stressed Vs being more nasalized than unstressed Vs. Both speakers show similar percentages of V nasalization in the two stress conditions. Here again, the data show that the articulatory gesture of velum lowering in anticipation of the nasal C occurs independently of the duration of the V gesture.

Tables 3 and 4. Effects of vowel height on V nasalization. (Spkr G – top and Spkr A - bottom).

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
high	111.9	33.4	76.6	48.3	0.64	0.31	91.2	21.5
low	157.3	63.2	101.3	70.8	0.60	0.30	124.4	48.0
prob.	p<.0001		p=0.02		non signif.		p<.0001	

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
high	79.0	34.1	39.4	43.8	0.43	0.39	77.0	16.6
low	108.3	37.9	44.9	46.5	0.41	0.41	101.3	36.1
prob.	p<.0001		non signif.		non signif.		p<.0001	

Tables 5 and 6. Effects of stress on V1 nasalization. (Spkr G– top and Spkr A - bottom).

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
unstressed	111.5	34.6	75.8	47.6	0.62	0.31	91.5	21.4
stressed	192.7	67.0	128.4	83.0	0.61	0.28	156.7	45.0
prob.	p<.0001		p<.0001		non signif.		p<.0001	

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
unstressed	81.9	29.5	40.8	44.0	0.45	0.42	78.2	17.2
stressed	129.9	39.2	46.5	52.8	0.35	0.35	122.2	37.5
prob.	p<.0001		non signif.		non signif.		p<.0001	

4.2. Effect of voicing in following stop and fricative

The analysis of the effects of voicing in the following stop did not yield very significant results. Both speakers have longer Vs when the following C is voiceless than when it is voiced (respectively, G: 121.7 ms vs 101.2 ms; A: 90.3 ms vs 86.3 ms), but this difference is somewhat significant only for speaker G. ($p< 0.04$). All the other values on V duration/nasalization are not significant. As for the nasal C duration, both speakers have a significantly longer nasal C before the voiced than the voiceless stop. The values are 108.1 ms and 86.6 ms for speaker G, and 96.6 ms and 83.6 ms for speaker A (for both speakers, $p<0.0001$). Here again, the data point to an effect of temporal interplay between Vs and Cs in VNC sequences, by showing shorter Vs and longer Ns before voiced stops, and longer Vs and shorter Ns before voiceless stops.

Tables 7 and 8 illustrate the effect of voicing in the following fricative. For speaker G (Table 7) Vs are significantly longer and more nasalized before voiceless than voiced fricatives. As seen before, in the voiced and voiceless conditions the percentages of nasalization are about equal. The data on /n/ duration, not reported in the table, are 96.3 ms and 4.8 ms in the following voiced and voiceless fricative contexts respectively. The differences in V and nasal C duration in the two contexts are explained on articulatory as well as perceptual grounds. In the voiceless context, the anticipation of devoicing for the fricative impedes the perception of the C nasality and creates the condition for a longer nasalized V. In the voiced context, the presence of voicing has no disruptive effect on the perception of the nasal stop, which is maintained even though it is modified in the coarticulation with the following fricative. For speaker A (Table 8), voicing only affects V duration, both in the control and in the target sequences. As will be seen below, his data are the result of a different production strategy whereby the nasal stop is preserved, even though articulatorily modified, in most of its occurrences.

Tables 7 and 8. Effects of voicing on V nasalization in VNC sequences where C=Fricative (Spkr G – top and Spkr A - bottom).

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
voiced	113.4	11.9	79.1	27.6	0.70	0.25	125.7	32.4
voiceless	190.4	58.8	146.1	55.6	0.77	0.19	126.0	52.9
prob.	p=.0002		p=.0007		non signif.		non signif.	

Category	Duration of V		Duration of nasalization		Percent. of nasalization		Duration of control V	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
voiced	77.8	19.6	27.4	44.5	0.28	0.46	84.3	17.8
voiceless	112.5	44.2	60.3	63.6	0.46	0.44	105.1	36.8
prob.	p=0.02		non signif.		non signif.		p=0.09	

4.3. Evidence of nasal loss before voiceless fricatives

None of the contexts of following stop, whether voiceless or voiced, seems to provide a favorable environment for nasal loss: the nasal consonant is evident in 100% (160/160) of all cases. In all the instances of VNC_{stop} sequences, the configurations were found to meet our criterion for unambiguous presence of nasal, i.e., simultaneous occurrence of periodic signal, presence of nasal flow, oral flow close to the baseline, and nasal peak typically occurring within the end of the periodic signal for the nasal C.

As for fricatives, Tables 9 represents the tabulation of the evidential categories for the presence of /n/ in the voiceless condition. In all these cases, the simultaneous occurrence of oral and nasal flow during the acoustic period, with no clear discontinuity in at least two of the three parameters, was taken as evidence of clear nasalized V. When there was a cooccurrence of periodic signal, oral and nasal flow, but also presence of some discontinuity in one or more of the three parameters, the case was considered ambiguous. A typical ambiguous configuration would have smoothly rising nasal flow for the duration of the acoustic signal for V, some discontinuity in acoustic signal and oral flow off the baseline.

The data show alternating realizations of /n/, from present to ambiguous to absent. This variation is largely due to

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the different behavior of the two speakers, i.e., one (G) tends to produce more sequences with a nasalized V and no nasal C, while the other (A) has more nasal Cs and less nasalized Vs. The different behavior of the two speakers is evident particularly in the context of preceding /a/ where the 'more conservative' speaker A always has a nasal C, while in the context of /i/ he has no nasal Cs before /f/ but always produces a nasal in the context of /s/ and in the majority of cases in the context of /S/ (60%). An examination of all the configurations for the $VNC_{vclessFric}$ sequences shows, however, that both speakers have varying realizations of the same sequence, such that they could be said to be part of the same process, though they differ markedly in the frequency with which they adopt either strategy. The simultaneous occurrence of nasal and oral flow in this context indicates that the articulators do not achieve a complete closure for the nasal stop in preparation for the following fricative segment, which results in the weakening of the nasal C itself. However, the fact that in these cases the nasal peak occurs at the boundary of the acoustic signal and the beginning of the frication indicates that the speakers intend a nasal C (as opposed to a phonologically nasalized V where the nasal peak would occur well within the end of the acoustic signal). Thus, a possible interpretation of the overall pattern found is that, given a difficult articulatory transition, the high variation is due to greater or lesser 'precision' in the articulation of the sequence. The data do not seem to suggest that this is due to rate of speech –the more 'conservative' speaker A speaks faster than G-, but may be due to style. More data are needed to throw light on this issue, but this variation was predicted by [7] in a non-experimental study of this variety of Italian.

Table 9. Evidential categories for /n/ + voiceless fricatives. The numbers refer to individual cases.

Context	**Clear Nasal**	**Ambig. Nasal**	**Ambig. Nasal V + C**	**Clear nasal V**
prec. **unstressed /i/**	8/30		3/30	19/30
prec. **unstressed /a/**	11/20	1/20	1/20	7/20
prec. **stressed /a/**	10/20		2/20	8/20

With regard to context, the nasal C is more frequently absent in the context of preceding unstressed /i/ (56% absent); this percentage is lower after /a/, both stressed and unstressed (combined effect of 37.5%). The higher percentage of cases of zero nasal after /i/ than /a/ seems to confirm previous findings that high airflow Vs, by being acoustically and perceptually more evidently nasalized than low Vs, may provide a better environments for nasal C loss than low Vs.

As for the VN[v] sequences, the nasal stop never disappears before [v], though there are three cases of ambiguous nasal V in the context of preceding unstressed /i/. The configuration for this sequence shows simultaneous acoustic signal, nasal flow and oral flow not going to the baseline. Here, again, the pattern can be explained as non complete closure for the nasal stop in the context of a following fricative, which is preserved because the presence of voicing has no disruptive effect on the nasality of the C. This pattern can probably be explained as an assimilation of the nasal C to the following labiodental fricative C.

5. CONCLUSIONS

The two speakers in this study often display very dissimilar behavior in their production strategies of VNC sequences. Further investigation using more subjects is needed to throw definitive light on some of the issues arisen in the present analysis. However, the data point to some relevant results on nasalization processes in Italian. Manner of articulation is an important factor, and fricatives and trills are more conducive to V nasalization than stops. The effects of V height and stress cannot be considered conclusive on the basis of the present data. However, the data show that the lowering of the velum in anticipation of the nasal consonant occurs at about the same time after V onset regardless of V duration, as affected by V height, stress or voicing. Voiceless fricatives have the strongest effect and offer the best environment for developments of nasal loss. There are indications that the process is favored by a preceding high vowel. The analysis of the configurations for the VNC sequences leads to the conclusion that the speakers intend to produce the nasal C even when it is not there acoustically. Finally, the large variation found in the data is probably to be taken as an indication of coexisting alternative production strategies in the language and show that, in spite of considerable differences between speakers, language perception is largely unaffected.

REFERENCES

[1] H. Clumeck, "Patterns of soft palate movements in six languages", *Journal of Phonetics,* 4, pp. 337-351, 1976.

[2] E. Farnetani, "A pilot study of the articulation of /n/ in Italian using electropalatography and airflow measurements", *15e Journées d'Etudes sur la Parole,* GALF, Aix en Provence, pp. 23-26, 1986.

[3] E.Farnetani & M.G. Busà, "Consonant-to-consonant interactions in clusters: Categorical or continuous processes?", *Quaderni del Centro di Studi per le Ricerche di Fonetica del CNR*, XIII, pp. 219-245, 1994.

[4] J. Hajeck, *Universals of Sound Change in Nasalization,* Oxford, Blackwell, 1997.

[5] R.A. Krakow, "Nonsegmental influences on velum movement patterns: syllables, sentences, stress, and speaking rate", in M.K. Huffman & R.A. Krakow (eds.), *Nasals, Nasalization, and the Velum,* San Diego, Academic Press, pp. 87-116.

[6] P. Maturi, "The perception of consonantal nasality in Italian: conditioning factors", *Actes du XXIIème Congres International des Sciences Phonetiques,* Aix en Provence, 5, pp.50-53, 1991.

[7] A. Mioni & J. Trumper, "Per un'analisi del 'continuum' linguistico veneto", *Aspetti Sociolinguistici dell'Italia Contemporanea,* Roma, Bulzoni, pp. 329-372, 1977.

[8] J. Ohala, "The phonetics of sound change", in C. Jones, (ed.), *Historical linguistics: Problems and perspectives,* London, Longman, pp. 237-78, 1993.

[9] J. Ohala & M.G. Busà, "Nasal loss before voiceless fricatives A perceptually-based sound change, *Rivista di Linguistica,* 7, 1, pp. 125-144, 1995.

[10] M.-J. Solé, "Phonetic and phonological processes: the case of nasalization", *Language and Speech*, 35, 29-43.

[11] D.H. Whalen and P. S. Beddor, "Connections between nasality and vowel duration and height: Elucidation of the Eastern Algonquian intrusive nasal", *Language*, 65, 547-486.