Nasal airflow in French Spontaneous Speech.

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The goal of this paper is to compare the degree of anticipatory and carryover phenomena in the behaviour of the velum during the production of French spontaneous speech, and to compare the data with the same speech material, but read. Airflow through the nose and the mouth were taken as an indirect indication of the velum behaviour. French is a language of special interest because there is a phonological contrast between oral and nasal vowels. The results show a tendency for nasal airflow to start before the nasal and a strong propensity to spread after the nasal. No differences could be established between speaking styles (spontaneous vs read speech) regarding nasal airflow anticipation and carryover.

1. Introduction

Our work deals with aerodynamic data. Nasal airflow measurements were collected as an indirect indication of the degree of opening of the velopharyngeal port as there is a valid correlation between air flow and opening when the cross sectional area is less than 0.4 cm2 (Warren et al 1987). The presence of airflow indicates that the velopharyngeal port is open but its absence does not signify that the velopharyngeal port is closed. Furthermore, lowering of the velum starts before velopharyngeal port opening (Benguerel et al, 1977).

While aerodynamic measurements are only an indirect way of collecting data on velic behaviour, they have however the advantage of being non-invasive which is essential for studying spontaneous speech.

French is of particular interest because there is a phonological contrast between oral and nasal vowels (achieved by velopharyngeal port opening). All former aerodynamic studies for French dealt with read speech (Durand 1953, Benguerel 1974, Cohn 1990, Ohala & Ohala, 1991). This paper provides new data on spontaneous speech. Because of the phonological contrast, it is expected that velic coarticulation should be of a lesser extent in French (as compared to English, for example). However, as it takes some time for the velum to lower and to rise again (50 ms according to Ohala, 1975), a minimum amount of coarticulation is expected. It was hypothesised that less coarticulatory phenomena (anticipation and carryover) would happen in read, better articulated, speech, as compared to spontaneous speech.

Spontaneous conversations were recorded while the speaker was chatting with the experimenter between periods of recording read speech during the first session. As it takes some time to set up and calibrate the instruments, the speaker was asked to keep the two nasal tubes, the oral mask and the pair of plate electrodes on his (her) neck on during the complete recording sessions. The spontaneous data obtained in this way sound fairly natural.

2. Experimental procedure

Instrumentation

Nasal airflow was measured with a pressure transducer attached to two tubes inserted in the nostrils and secured by rubber plugs. Oral airflow was measured with a tube inserted in a soft rubber mask that interfered very little with jaw lowering and not at all with lip movements. Sound was recorded with a microphone external to the mask. Electroglottographic (EGG) data were also recorded. Eva work station and Phonedit software (Teston and Galinder, 1990) were used.

In order to verify the adequacy of the response time, airflow data were acquired from two different stations (EVA2 and Pcquirer), with the same speaker saying the sentence: “ton tonton tond ton tonton” [**tɔ̃ tɔ̃tɔ̃ tɔ̃ tɔ̃ tɔ̃tɔ̃**] ‘your uncle shaves your uncle’. The synchronisation between the burst on the waveform and a sharp rise in the airflow at the release of the stop was taken as an indication of a good response time of the machine (Barry & Kuenzel, 1975). There were no major differences between the two devices (see figures 1 and 2).

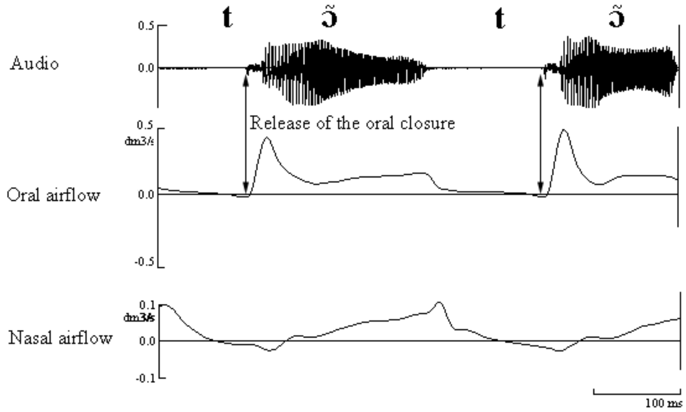

Figure 1. Waveform and aerodynamic data of the word “ton” [tɔ̃] ‘your’. The arrows show that the stop burst is well aligned with the increasing of oral airflow. (Data collected with Eva workstation).

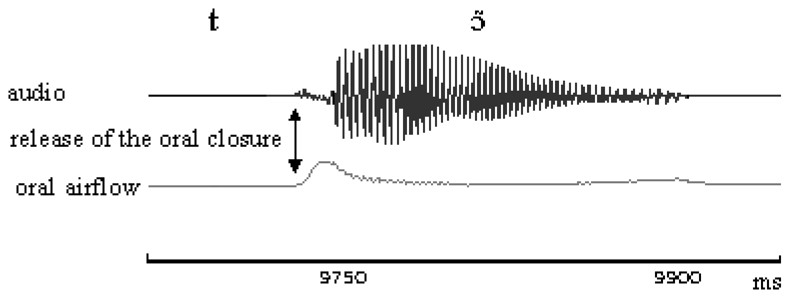

Figure 2. Waveform and aerodynamic data for the word “ton” [tɔ̃] ‘your’. The two arrows show that the stop burst is well aligned with the increase of oral airflow. (Data collected with PCquirer).

As reported by Benguerel (1974), a short phase of negative airflow before a nasal was observed (figure 1). It corresponds to an increase of volume in the nasal cavity at the beginning of the lowering of the velum. It was considered as an indication of adequacy of the instrument. An accurate determination of the response time of the nasal airflow is however a complicated problem. It remains as a task for the future (Ohala, personal communication).

Subjects and Speech material

The total corpus analysed consists of 11 minutes of spontaneous speech uttered by three females (1mn 46s; 1 mn 20 s; 3 mn 18 s) and one male (4 mn 36 s), speaking Standard French. Spontaneous conversations were recorded during breaks between periods of recording read speech. The topics of discussion range from holidays, to previous studies on nasalization, and troubles with computers. The conversations were orthographically transcribed. During a second recording session, each speaker was asked to read and record a great part of what he (she) had said spontaneously during his (her) first session. It was then possible to compare the read and spontaneous styles on the same material.

Audio, aerodynamic and glottographic signals were segmented and phonetically transcribed with the aid of spectrographic representation. Priority to the auditory impressions was given in case of conflicting evidence.

Nasal phones at the beginning and at the end of utterances were discarded as respiration can contaminate the data (Van Hattum et al, 1967). Occurrences containing more than two nasals were also discarded when it was impossible to separate anticipatory from carryover influence, as for example in [**sɛ̃ sɑ̃ sɛ̃kɑ̃t fʁɑ̃**] “cinq cent cinquante francs” ‘five hundred and fifty francs’.

As shown in figure 3, **anticipation** means that NAF (Nasal Air Flow) starts before the onset of the nasal, **delay** that NAF starts after the onset of the nasal and **carryover** indicates that NAF spreads over the following phone.

Figures 4 and 5 illustrate anticipation and carryover nasalisation, respectively, with examples from spontaneous speech.

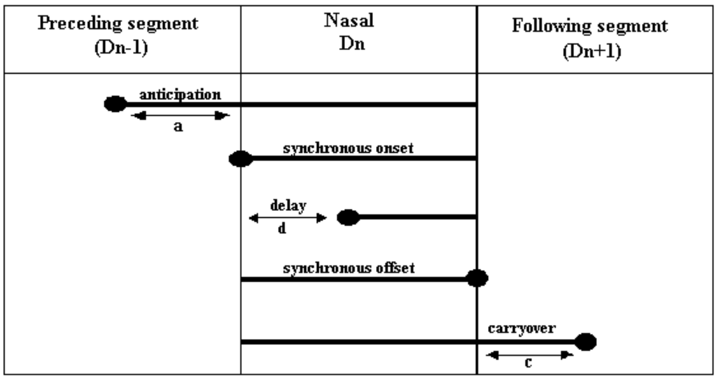

Figure 3. Criteria for classifying nasal airflow as Anticipatory (a), synchronous, Delayed (d), and Carryover (c) based on the timing of the nasal airflow onset and offset relatively to the nasal phone boundary. (Dn = duration of the nasal phone; Dn-1 refers to the duration of the phone preceding the nasal and Dn+1refers to the duration of the phone following the nasal phone)

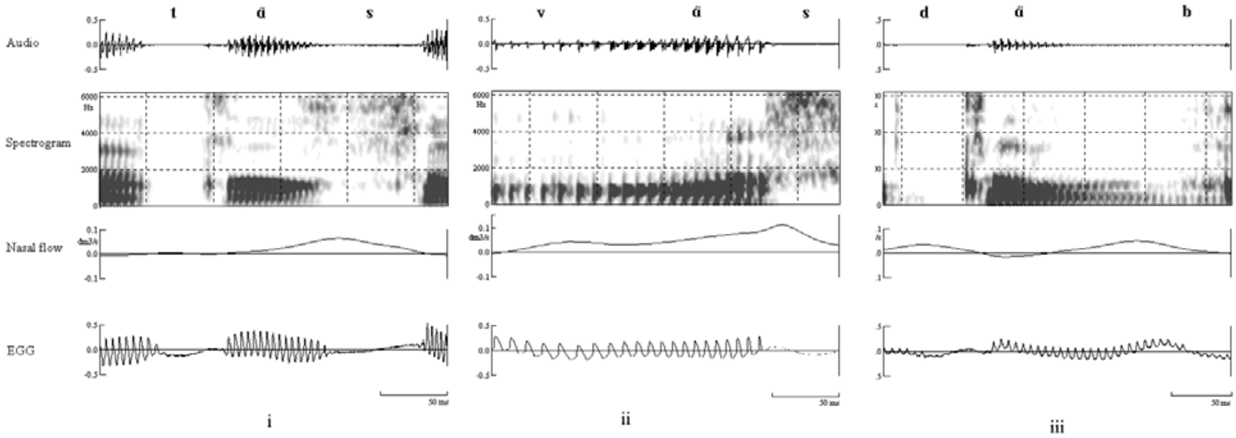

Figure 4. Data illustrating the criteria used for characterizing anticipation. (i) synchronous onset of NAF, in the word "attention" [**atɑ̃sjɔ̃**] 'be careful'. (ii) anticipation in "Provence"[**pʁɔvɑ̃s**]. (iii) delay in "d'embouts" [**dɑ̃bu**] 'nozzles'. Data taken from spontaneous speech.

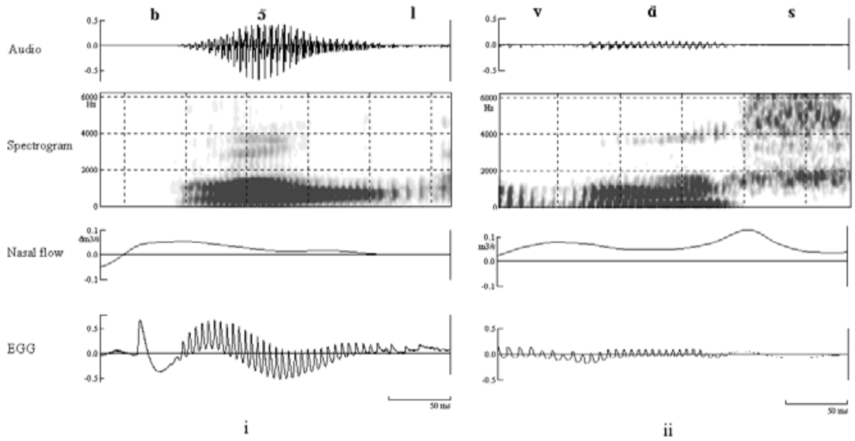

Figure 5. Data illustrating the criteria used for characterizing carryover. (i) synchronous offset of NAF, in the word "bon" [**bɔ̃**] 'good'. (ii) carryover in "Provence"[**pʁɔvɑ̃s**]. Data taken from spontaneous speech.

The following measurements were made (table1):

-The **mean duration** of anticipation (mean$_a$) delay (mean$_d$) and carryover (mean$_c$).

-The **ratio** between the mean duration of anticipation and the mean duration of the proceding phone (Dn-1). If the ratio is greater than 1, it means that anticipatory velic opening starts before the onset of the preceding phone.

-The **ratio** between the duration of delay and the total duration of the nasal.

-The **ratio** between the mean duration of carryover and the mean duration of the following phone (Dn+1). If the ratio is greater than 1, it means that nasal flow spreads after the end of the phone following the nasal.

Table 1: Calculations.

Phenomena	Mean Duration	Ratio
Anticipation	Mean $_a$	$\frac{a}{Dn-1}$
Synchronous	= 0	**= 0**
Delay	Mean $_d$	$\frac{d}{Dn}$
Carryover.	Mean $_c$	$\frac{c}{Dn+1}$

3. Results and discussion

3.1 Anticipation

Table 2 presents the distribution of presence and absence of anticipatory nasal airflow across the contexts of a vowel or voiced/voiceless consonant before a nasal vowel, and of an oral vowel before a nasal consonant. Table 3 gives an overview of the total number of items in the four anticipation contexts as well as the relative frequencies of anticipation, synchronous onset and delay of nasal airflow in these contexts.

In **V+Ṽ**context, there is a tendency (18/32, 56%) to anticipate nasalization during an oral vowel. In most cases, NAF is starting during the preceding phone (ratio=1.3). Some perception tests should be conducted to find out if the nasalized preceding phone is still perceived as oral. A nasalised vowel is not identified by French listeners as phonemically nasal because nasal vowels in French differ from oral, not only by the presence of nasal airflow but also by a special articulatory setting (Zerling, 1984).

Because low vowels are realised with a lower velum (Passavant, 1863) and because they need a lower velum to be perceived as nasal (Benguerel & Lafargue 1981; Maeda, 1982), the results for high and low vowels were presented separately. The higher oral pressure during high vowels favours nasal leaks. There was not enough data in the present study to establish a significant difference between the two vowel types.

In **C+V** there is a clear difference depending on the voicing of C. This is in agreement with the results of Ohala & Ohala (1991). When C is voiced, anticipation prevails (78/100, 78%). In some cases like for example in **“**C’est bon ?” [**sɛ bɔ̃**] ‘is it all right ?’ (see figure 6 (i)), the labial voiced stop /b/ preceding the nasal vowel /**ɔ̃**/ seems completely nasalized with no burst visible on the spectrogram and with the presence of formants. Out of context, it sounds like a nasal.

When **C** is unvoiced, anticipation only happens in one third of the cases (31/90, 34%) and there are many cases of delay (in read speech, for stops: 15/32, 46%). In the cases of anticipation, like in the example on figure 6 (ii) “vacances” [**vakɑ̃s**] ‘holidays’, nasal airflow seems not sufficient to prevent the building up of oral pressure and the burst is still visible on the spectrogram.

In **V+N** a large variability was observed. There were as many cases of anticipation as synchronous onset of NAF (75/162, 46%).
Table 4 shows the results with both styles merged together. No clear tendency towards anticipation (53%) or synchronous onset of nasal airflow (47%) can be seen.
Table 5 reveals no clear differences between read and spontaneous styles

Contexts		Style	Anticipation: NAF before onset: number of items	mean $_a$	$\frac{a}{Dn-1}$	No anticipation: NAF Synchronous: Number of items	NAF after onset (Delay): number of items	mean $_d$	$\frac{d}{Dn}$
V+Ṽ	High vowels	***Spon***	9	112ms	1.3	1	3	34 ms	0.3
		Read	8	91ms	0.9	4	1	33 ms	0.5
	Low vowels	***Spon***	-	-	-	2	1	23 ms	0.4
		Read	1	-	-	1	1	18 ms	0.2
	Total		**18**			**8**	**6**		
C^{voised}+Ṽ	Stops	***Spon***	14	71 ms	1.1	1	1	47 ms	0.4
		Read	9	75 ms	1	2	5	53 ms	0.3
	Fricatives	***Spon***	22	53 ms	0.9	7	2	38 ms	0.3
		Read	29	70 ms	1	2	-	-	-
	Laterals	***Spon***	2	76 ms	2.7	1	-	-	-
		Read	2	36 ms	1.1	-	1	64 ms	0.6
	Total		**78**			**13**	**9**		
$C^{unvoiced}$+Ṽ	Stops	***Spon***	10	61 ms	0.6	15	7	23 ms	0.2
		Read	4	16 ms	O.2	13	15	45 ms	0.3
	Fricatives	***Spon***	8	68 ms	0.7	3	2	35 ms	0.2
		Read	9	77 ms	0.7	1	3	46 ms	0.4
	Total		**31**			**32**	**27**		
V+N	High vowels	***Spon***	24	77 ms	1.2	33	4	32 ms	0.3
		Read	29	55 ms	0.8	26	6	24 ms	0.4
	Low vowels	***Spon***	9	54 ms	0.7	10	1	13 ms	0.1
		Read	13	59 ms	0.5	6	1	22 ms	0.4
	Total		**75**			**75**	**12**		
			202			**128**	**54**		

Table 2: Results. Anticipation: Number of items, Mean$_a$, ratio between the duration of anticipation and the total length of the preceding phone. Synchronous: number of items with NAF starting at the onset. Delay: number of items, Mean duration of delay, ratio of the duration of the delay on the total duration of the nasal

Table 3: Total number of items in all contexts where NAF starts before, at the onset or after the onset of the nasal phone.

Contexts	Total number of items	anticipation %	synchronous %	delay %
V+Ṽ	32	56%	25%	19%
C^{voiced}+Ṽ	100	78%	13%	9%
C^{unvoiced}+Ṽ	90	34%	36%	30%
V+N	162	46%	46%	8%
Total	**384**	**53%**	**33%**	**14%**

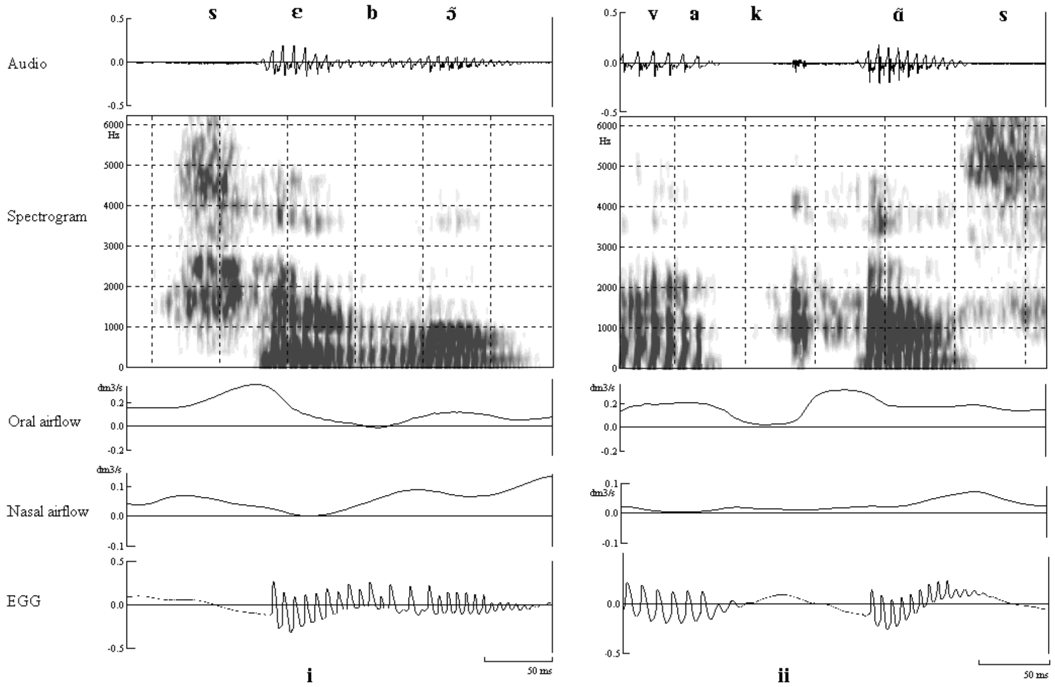

Figure 6. Examples of anticipatory nasal airflow. (i) “C’est bon” [**sɛ bɔ̃**] ‘is it all right’. (ii) “vacances” [**vakɑ̃s**] ‘holidays’ (spontaneous speech)

Context	anticipation	No anticipation
V+Ṽ	18	14
C^{voiced}+Ṽ	78	22
C^{unvoiced}+Ṽ	31	59
V+N	75	87
Total	**202 (53%)**	**182 (47%)**

Table 4: Comparison between anticipation and no anticipation (both spontaneous and read speech styles merged).

	Spontaneous		Read	
	anticipation	No anticipation	anticipation	No anticipation
V+Ṽ	9	7	9	7
C^{voiced}+Ṽ	38	12	40	10
C^{unvoiced}+Ṽ	18	27	13	32
V+N	33	48	42	39
Total	**98 (51%)**	**94(49%)**	**104(54%)**	**88(46%)**

Table 5: Comparison between the two styles, spontaneous and read.

3.2 **Carryover**

Table 6 illustrates the presence or absence of carryover airflow across the contexts of a nasal vowel before an oral vowel or a voiced/voiceless consonant, and of a nasal consonant before an oral vowel. Table 7 gives an overview of the total number of items in the four carryover contexts as well as the relative frequencies of presence and absence of carryover nasal airflow in these contexts.

Table 6: Results. No carryover: number of items. Carryover: number of items, Mean duration of carryover, ratio between the duration of carryover and the total length of the following phone.

Contexts		Style	no carryover nb of items	carryover nb of items	Mean c	$\frac{c}{Dn+1}$
Ṽ+V	High vowels	*Spon*	5	2	149 ms	1.3
		Read	2	5	121 ms	0.8
	Low vowels	*Spon*	-	4	110 ms	1.3
		Read	2	2	110 ms	0.1
	Total		**9**	**13**		
Ṽ+C[voiced]	Stops	*Spon*	3	14	83 ms	1
		Read	1	16	88 ms	1
	Fricatives	*Spon*	2	12	62 ms	1
		Read	-	14	57 ms	0.7
	Laterals	*Spon*	-	4	130 ms	2
		Read	-	4	119 ms	2
	Total		**6**	**64**		
Ṽ+C[unvoiced]	Stops	*Spon*	5	48	67 ms	0.7
		Read	4	52	56 ms	0.6
	Fricatives	*Spon*	3	29	72 ms	0.8
		Read	2	30	69 ms	0.6
	Total		**14**	**159**		
N+V	High vowels	*Spon*	2	50	121 ms	1.4
		Read	-	52	133ms	1.5
	Low vowels	*Spon*	1	8	171 ms	1.7
		Read	1	8	121 ms	1.6
	Total		**4**	**118**		
			33	**354**		

Table 7: Total number of items in all contexts where NAF ends at the offset of the nasal (no carryover) or spread on the following phone (carryover).

Contexts	Total number of items	No carryover %	carryover %
Ṽ +V	22	40%	60%
Ṽ +C[voised]	70	8%	92%
Ṽ+ C[unvoiced]	173	8%	92%
N+ V	122	3%	97%
Total	**387**	**9%**	**91%**

While in [-nasal] [+nasal] contexts, no clear difference appears between anticipation and synchronous onset of NAF, or between styles, the results are very different for carryover, even if in **Ṽ+V** context there is only a slight tendency for nasal airflow to spread on the following phone (13/22, 59%).

In **Ṽ+C**, in almost all cases, there is a carryover of nasal airflow on the following phone (64/70, 91%, when C is voiced and 159/14, 92%, when C is unvoiced). However, there is a difference in the mean duration and ratio of airflow depending on the voicing. When C is unvoiced, the ratio of the carryover does not exceed 0.8 (the next phoneme is not completely nasalized); the ratio is 1 when C is voiced (the next phoneme is completely nasalized). As shown in Fig. 7, nasal airflow continues almost throughout the following stop in *descendent vers* [desɑ̃d vɛɹ] 'going down to' '7(ii) and in *maisons qu'étaient* [**mɛzɔ̃ ketɛ**] 'house that were' (7(i)),even irrespective of a word boundary after the nasal vowel in the latter case. The maximal level of nasal airflow corresponds to the beginning of the oral closure. The burst is visible on the spectrogram and it still sounds like a stop (at least to the authors). As suggested by a rewiever of this paper, the upward excursion in the nasal graph in the /k/ case may be related to velic raising for stop closure, as the velum slides along the pharynx wall, pushed by tongue-dorsum/velum contact. This articulatory configuration acts like a piston creating a nasal air stream independent of air from the lungs. This may not be the only explanation, since the same phenomenon was observed for non velar stops.

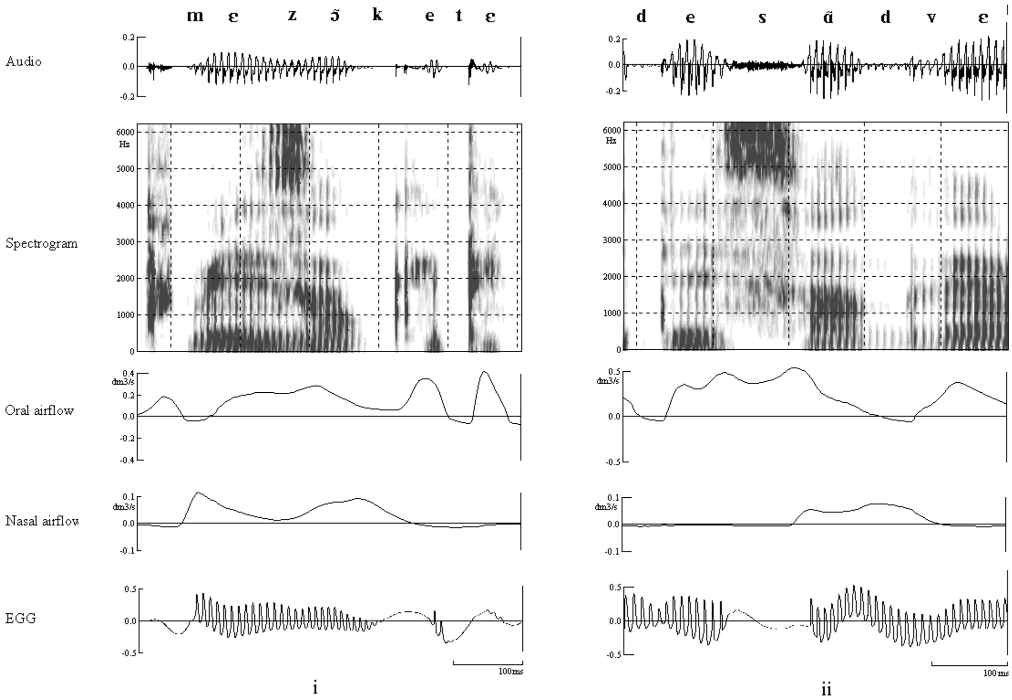

Figure 7. Example of (i)“maisons qu’étaient” [**mɛzɔ̃ ketɛ**] ‘houses that were’. (ii) “descendent vers” [**desɑ̃d vɛʁ**] ‘going down to’.

There are some well-known cases of complete assimilation of unvoiced stops in French in words like “maintenant” [**mɛ̃tnɑ̃**] ‘now’. The pronunciation can vary from [**mɛtənɑ̃**] in hypoarticulated speech, to [**mɛnɑ̃**] in spontaneous speech (figure 8). In the latter case, the voiceless stop is completely assimilated (or considered as absent). Dell (1986) postulated that no assimilation could occur in a sequence of [nasal] + [unvoiced stop] + [sonorant]. Our data (figure 7) provide counter evidence.

In **N+V** context, carryover seems to be the rule. (118/122, 97%).

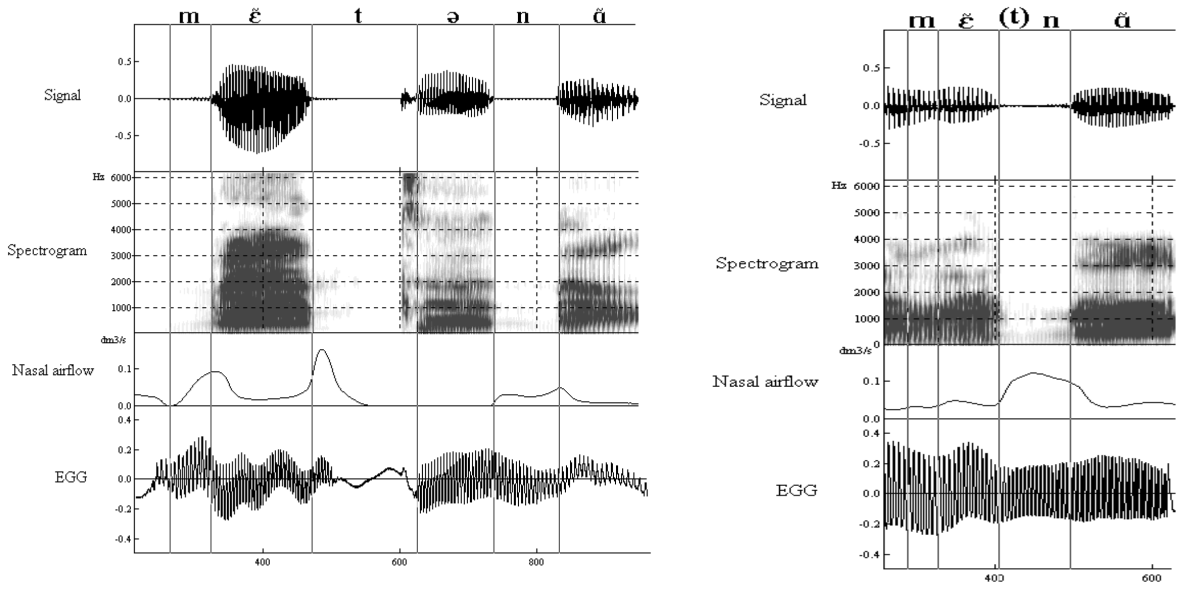

Figure 8. Example of the production of the same word “maintenant” [**mɛ̃tnɑ̃**] ‘now’ by the same speaker. The item on the left was extracted from a read corpus and the item on the right from spontaneous speech.

Table 8: Comparison between styles.

	Spontaneous		Read	
	No carryover	carryover	No carryover	carryover
Ṽ+V	5	6	4	7
Ṽ+C	13	107	7	116
N+V	3	58	1	60
Total	**21(11%)**	**171(89%)**	**12(6%)**	**183(94%)**

Table 8 shows that there are no real differences between styles.

When compared with Cohn’s results, our data differ only with regard to NAF before the nasal (see table 9). The present study could establish no clear tendency on either way. The results are in agreement for NAF spreading after the nasal.

Table 9. Summary of the results obtained by Cohn (1990) in an aerodynamic study of words inserted in frame sentences in French compared to the results obtained in this study.

Contexts	**Anticipation**		Contexts	***Carryover***	
	Cohn	**Present study**		**Cohn**	**Present study**
V+Ṽ	*anticipation*	56% :anticipation 19% : delay	**Ṽ+V**	*carryover*	59% carryover
C+Ṽ	*no anticipation* *delay*	**C** voiced : 78% anticipation 9% : delay **C** unvoiced : 34% anticipation 30% : delay	**Ṽ+V** **V + t**	*carryover* *no carryover*	92% carryover
V+N	*anticipation*	46% : anticipation 7% : delay	**N+V**	*carryover*	97% carryover

4. Conclusion

It was hypothesised that less coarticulatory phenomena (anticipation and carry-over) would happen in read speech, as compared to spontaneous speech. Our data does not confirm such a trend.

The nasal airflow tends to appear before or at the onset of a nasal in both styles. A clear difference was observed depending on the identity of the surrounding phonemes. A majority of anticipatory phenomenon were found in the context C+Ṽ with a clear difference depending on the voicing of the consonant. When C is voiced there is a majority of occurrences where NAF precedes the nasal vowel.

On the other end, a vast majority of items with NAF spreading after the offset of the nasal were observed in all contexts reported in this study.

In conclusion, no clear differences could be established between speaking styles, neither for anticipatory nor carryover phenomena. More data are however needed to confirm the present results, to investigate more systematically inter and intra-speakers differences, the effect of rate of speech and styles, such as hyperarticulated and hypoarticulated speech.

Perception tests are also needed to determine how nasalised vowels and consonants are perceived out of context.

A reliable way remains to be found to compute the magnitude of nasal airflow in order to confirm Benguerel & al (1977) finding that there is a difference in the opening of the velopharyngeal port between the syllable [**na**] and [**nɑ̃**].

Acknowledgements

We would like to thank J. J. Ohala for valuable comments. We wish also to thanks K. Kohler, A. Simpson and the reviewers for their helpful suggestions.

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