FEATURES OF THE ACOUSTICAL AND PHYSIOLOGICAL STRUCTURE OF THE FRENCH NASAL VOWELS. *)

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The purpose of this work was to examine the validity of the general opinion on the articulation of the French nasal or nasalized vowels, as stated by Maurice Grammont in his "Traité pratique de prononciation française", p. 55 (Paris 1958). This I have done partly by resuming and comparing the results of former investigations of the subject, partly by doing instrumental work.

All scholars, except Durand (1), agree in finding that the first formant of nasalized vowels is weakened compared to the first formant of the corresponding oral vowels, and the same is often found to be true of the higher formants, too. Moreover, many investigators find that nasal formants are added at 1000 c/s, 2000 c/s, etc., which can also be found in the nasal consonants. Delattre (2) and Fujimura (3) find a nasal formant at some 250 c/s. Fant (4) is of the opinion that "the intensity reduction of the first formant is the major perceptive cue for nasalization."

My own work was done in order to compare French nasal and oral vowels in similar surroundings, and further to search for acoustical features shared by nasal vowels and nasal consonants. These investigations were made during 1965. A material of 95 french words with nasal and oral vowels: [ɛ], [a] , [ɑ], [ø] ; [œ]; [o] , [ɔ]; [ɛ̃], [œ̃], [ɑ̃], [õ] (the narrowest oral vowels were of no value for comparison) in stressed position and in different surroundings (e.g. hais: hein, c'est: sain, mais: main), plus 6 phrases with the same vowels for control, were recorded - twice for each person - on magnetic tape (BASF LGS 35) with a Lyrec tape recorder; 4 French male subjects with an acceptable Paris accent were used. (With my present experience, I should prefer fewer words and more persons and recordings for greater statistic certainty.) - Afterwards, the second recording of each person was analysed acoustically by means of the Sound Spectrograph (Sonagraph). Wide, narrow, and section

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spectrograms were taken of all vowels. Furthermore, I made double flow-graphs (mouth and nose air-flow) of a restricted material (27 words), using the Electro-Aerometer constructed by Svend Smith and Børge Frøkjær-Jensen.*) 4 subjects were used for this recording: the first and third of the men from the acoustical recording, plus two French women with the same linguistic characteristics. I made a tape recording of what was said into the aerometer for control. Here, too, two recordings of each person were made - each with the words in two different orders to minimize the influence of rhythmization (one of the women said the 95 word list twice), and the second recording was measured.

On the spectrograms, I measured F_o and the first 4 vowel formants, plus extra resonances of interest (not always visible). I compared the spectra of the oral and nasal vowels, also observing how they develop in time. For one single vowel I took cross-sections at different sampling points.

To visualize the particular quality of the nasal vowels, I plotted them with the oral vowels in a two-dimensional chart (mel scale), with F1 and F2 as coordinates. It is seen that [ɛ̃] and [œ̃] lie close together around [œ] with a tendency towards [a], [ɑ̃] tends towards [ɔ] , and [õ] lies between [ɔ] and [o] (cp. Fig. 1, which represents one male informant).

From the acoustical analysis I conclude that the following acoustical features separate the French nasal vowels from the oral vowels:

1. F1 is weakened (sometimes not in [ɑ̃]).
2. The low formant Fu appears at about 2oo c/s; it is probably equal to the first formant N1 of the nasal consonants.
3. The other formants are weakened, especially F3.
4. Extra formants may occur at about 1ooo c/s and 2ooo c/s, sometimes at 3ooo; they are probably identical with N2-N4 (4) of the nasal consonants; these formants are generally weak.

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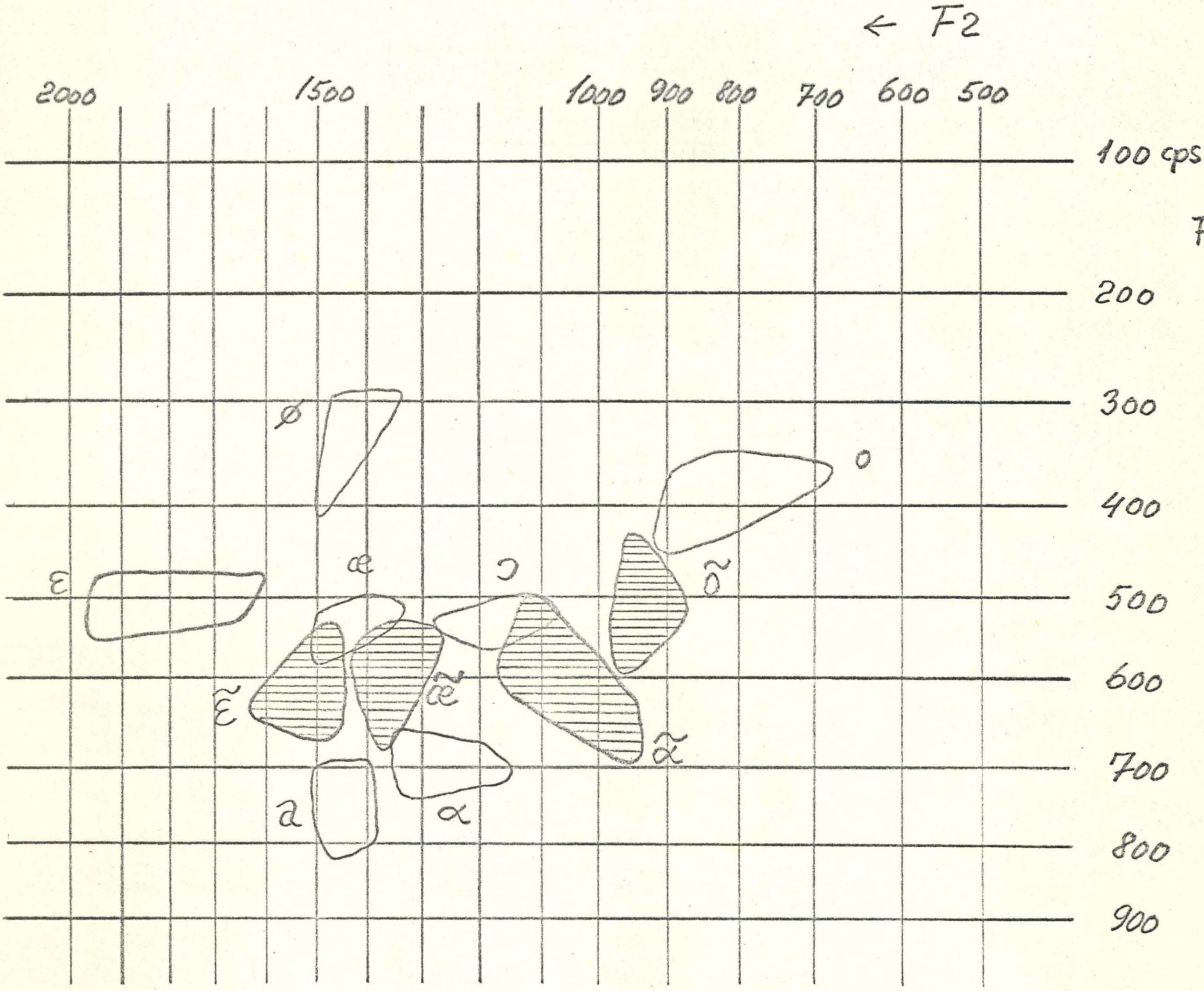
*) The air-flow opens a rubber valve, through which a light beam hits a photo-electrical cell, and the current from the cell is amplified and recorded on a Mingograph.


← F2
2000
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œ
ɔ
õ
ɛ̃
œ̃
ɑ̃
a
ɑ

Fig. 1

5. The degree of nasalization is generally constant in isolated vowels (except that [õ] often changes). In context, however, the degree of nasalization increases from the beginning of the vowel to the end, so that the vowel probably often ends in a nasal consonant - in final position [N], before an occlusive a nasal consonant with the same point of articulation as the occlusive (3). After an occlusive one can often see an oral phase in the first part of the vowel, and the features mentioned (1.-4.) appear after some csecs. The features found in the nasal vowels are also seen in oral vowels adjacent to a nasal consonant, only to a smaller degree, and especially in the part of the vowel that is close to the consonant.

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For illustration I tabulate the average formants for subject no. 3:

F_o: average: 1o9 cps; variation: 93 c/s - 143 c/s.

Vowel	Fu	F1	F2	F3	F4
[ɛ]	(193)	514+	1798+	2619	3728
[a]	(19o)	752+	1453+	2449	3657
[ɑ]	?	7o5+	1244+	2415	3662
[ø]	((171))	334+	1429(+)	2162	3262
[œ]	(c.2oo)	531+	1429+	2356	3452
[o]	(175)	39o+	815	229o	(3286)
[ɔ]	(188)	518+	11o5(+)	241o	346o
[ɛ̃]	2o8+	629	1518(+)	2732	3649
[ɑ̃]	197+	6o1	1o54(+)	2283	3532
[œ̃]	219+	586	1359+	2455	3516
[õ]	218+	514	933	2118(?) (2833?)	3248

+ means a relatively strong formant, (+) means a weaker formant. Formant frequencies in brackets are uncertain.

As for air-flow, I recorded the expiration and inspiration by the nose, the expiration by the mouth; and the vibrations of the vocal chords (oscillogram from a throat microphone) at a speed of 1oo mm per sec. The extension of each vowel was determined by comparing all four curves, and I measured the middle height of the two expiration curves above a zero line drawn between the lowest points of these curves. Examples are given in Fig. 2.

As these measures are relative, I invented the factor q = the ratio between nose expiration and mouth expiration for a given sound. With a certain reservation, q expresses the relative degree of nasalization. As expected, q is very low (practically zero) for the oral vowels, and many times higher for the nasal vowels - when q of the corresponding oral vowel has any positive value at all, that of the nasal vowel is mostly 1o-2o times higher. The q-values of oral vowels may be due to a general "nasal" pronunciation, except in very open vowels (see later). In nasal surroundings the q-value of oral vowels are often higher than in "pure" oral vowels.

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For illustration I give the q-values of subject no. 3:

Vowel	q	q (normalized)
[ɛ̃]	o.86 (o.87)	1.o (1.o)
[œ̃]	o.97	1.13 (1.12)
[ɑ̃]	2.1 (1.6)	2.4 (1.8)
[ɔ̃]	2.8 (1.14)	3.3 (1.3)

The numbers in parentheses are based upon the entire vowel, the others on the nasal phase only (if such a "phase" occurred).

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The result of the physiological part of the investigation can be expressed as follows:

In the articulation of Paris-french nasal vowels, the velum is lowered, either before or simultaneously with the onset of voice. [ɔ̃] (and sometimes [ɑ̃]) is more strongly nasalized than the others (maybe this has something to do with the small mouth opening in [ɔ̃]). Oral vowels before nasal consonants are slightly nasalized towards the consonant; the same is probably

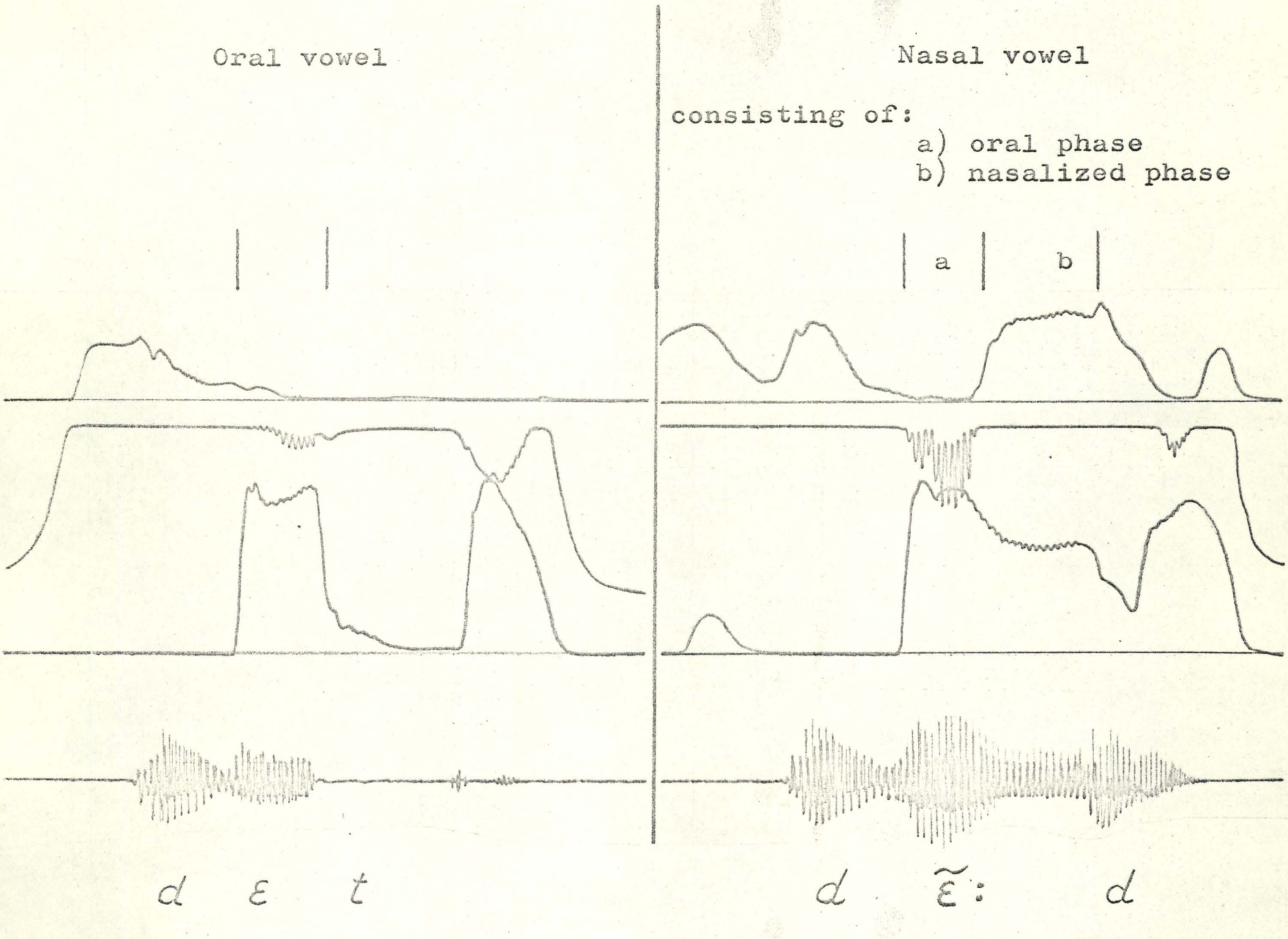

Fig. 2.

Curves from top to bottom:

(1) nasal egressive air,

(2) nasal ingressive air (less integration than (1) and (3)),

(3) oral egressive air,

(4) oscillogram.

true after nasal consonants, and, in any case, between two nasals. In the open oral vowels, the velum is supposed to touch the back wall of the pharynx rather loosely, so that the passage to the nose is not entirely cut off.

I should have liked to supplement these investigations with an examination of synthetic vowels; however, this has not been possible; but I can refer to the results of Delattre (5), House & Stevens (6), and Fant (4).

The final result of the work can be resumed this way:

The nasal vowels of Paris French are presumably produced with the glottis, the tongue, and the jaw articulating as in the corresponding oral vowels. There is, however, a lowering of the velum which causes complicated changes in the vowel spectra, the main elements of which are a reduction of F1, the appearance of Fu at about 200 c/s, and the extra formants, especially at 1000 c/s and 2000 c/s; these three features are probably mainly due to the nose-pharynx cavity (3). The most strongly nasalized vowel is [õ] , after that follows [ɑ̃] , then [ɛ̃] and [œ̃]. In the final part of the vowel, the vowel formants often disappear; maybe the word then ends with a uvular nasal consonant [N] , maybe it is just a result of the relaxation of the articulatory organs. The nasal element is different for the different nasal vowels, inasmuch as their degree of nasalization is different. - As for the timbre, [ɛ̃] and [œ̃] are close together between [ɛ], [œ] , and [a] , [ɑ̃] coincides almost with [ɔ], and [õ] lies between [ɔ] and [o].

So, Grammont was not quite wrong!

Table for comparison of different studies on nasality.

Feature	Joos	Smith	Durand	Delattre	House	Fujimura	Fant	Ego
F1(÷)	+	+		+	+	(+)	+	+
F2, often (÷)′	+	+		+	(+)		+	(+)
F3(÷)`		+		+	+		+	+
F4+ or `		+		(+)	?			(+) subject 4
Fu		+		+		+	?	+
Fx1 1000	+	+		(+)cons.	?	?	+	(+)
Fx2 2000		+		+	?	?	+	(+)
F÷500						+		
F÷900-1800					+		+	(+) subject 4
Fx 7500			+					

(÷): weakened. +: extra strong. ′: rises. `: descends.

Fx: extra formant. F÷: anti-formant.

References:

(1) M. Durand, "De la formation des voyelles nasales", Studia Linguistica VII (1953), pp. 33-53.

(2) P. Delattre, "Les attributs acoustiques de la nasalité", Studia Linguistica VIII (1954), p. 1.

(3) Hattori, Yamamoto, Fujimura, "Nasalization of Vowels in Relation to Nasals", JASA 30,1, pp. 267-274.

(4) G. Fant, Acoustic Theory of Speech Production (Haag, 1960).

(5) Delattre et al., "An Experimental Study of the Acoustic Determinants of Vowel Color", Proc. VIIth Intern. Congr. Ling. (London, 1952).

(6) House & Stevens, "Analog Studies of Nasalization of Vowels", Journ. of Speech and Hearing Disorders 21 (1956), pp. 218-232.