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ELECTROMYOGRAPHIC STUDY OF THE VELUM IN FRENCH

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Introduction

A parallel study of velar movement using fiberscopic observation has been presented previously (Benguerel, Hirose, Sawashima and Ushijima, 1975). Of interest are not only the time patterns of velar movements, but also the relationship between actual movement and motor commands. In this paper, we deal with the electromyographic (EMG) data which were recorded in part simultaneously with the fiberscopic data. The aim of this paper is thus to attempt to correlate velar height, velar movement and EMG activity of velar muscles (particularly the levator palatini) during velar coarticulation. Since French has both nasal consonants – as most languages – and (phonemically) nasalized vowels, it should be possible to observe differences, if any, in the muscular control of these two categories of sounds.

Experimental Procedure

In the following, C and V (without any subscript) stand for consonant and vowel respectively, whether oral or nasal(ized). The subscript "o" restricts each category to oral sounds, while the subscript "n" restricts C to nasal consonants and V to nasalized vowels.

The subject for this study was a male native speaker of French, originally from Lausanne, Switzerland. He had also served as subject of the fiberscopic experiment. He read 21 types of utterances subdivided into five groups. The utterances were read in randomized order within each group. Each utterance was repeated at least 10 times, and separated from the next one by a breathing pause of a few seconds. The list of 21 utterance types is given in Table I. They were produced with normal intonation and without emphatic stress.

Conventional hooked-wire bipolar electrodes were inserted perorally and under topical anesthesia into the levator palatini (LP) and the palatoglossus (PG). The detailed procedure has been described elsewhere (Hirose, 1971).

The EMG signals were suitably amplified and together with the audio signal, they were recorded on a 7-channel FM tape recorder. They were subsequently computer-processed in the following way:

a) A to D conversion, into 6-bit numbers, at a sampling frequency of 4 kHz; the absolute values were obtained, summed and smoothed, using a time window of 10 ms;
b) each processed token was displayed (EMG channels + audio) and a time mark entered for alignment with the other tokens of the same type; the alignment point was a predetermined speech event that could be identified with ease in the audio signal, e. g. the onset of a nasal consonant or the release of a closure or of a constriction;
c) all tokens of one type were then averaged with respect to the chosen alignment point.

Table I. List of Test Utterances.

Group 1.	/tat/	Group 2A.	/repeteanadøfwa/
	/tãt/		/repeteanãdøfwa/
	/sas/	Group 3.	/katɔrzfraʒil/
	/sãs/		/katɔrzfrãʒin/
Group 2.	/ana/		/katɔrzfrɛgat/
	/ɛnɛ/		/katɔrzfrɛ̃gal/
	/ɔnɔ/		/katɔrzfrodøz/
	/anã/		/katɔrzfrɔ̃døz/
	/ɛnɛ̃/	Group 4.	/krenəle/
	/ɔnɔ̃/		/kreenɛrvøzmã/
			/kreeenɛrʒikmã/

Results

Group 1: CVC's in isolation

Fig. 1 shows averaged EMG curves for /tat/ and /tãt/ sequences, whereas Fig. 2 shows corresponding curves for /sas/ and /sãs/. For each sequence, the three plots show, from the top down, LP activity, PG activity and average speech power.

As far as LP activity is concerned, /tVt/ and /sVs/ sequences are quite similar. They differ, however, in their PG activity: it appears that lowering of the velum, whether for /ã/, or at the release of the final /t /, is accompanied by increased PG activity. Although final /s/'s are also followed by velum lowering, as evidenced by the fiberscopic data, no such PG activity is observed.

LP activity during V_o is present, but at a relatively low level. In the case of V_n, LP suppression is visible, starting near the beginning of the initial consonant and lasting through the first half of V_n. Considerable PG activity is also observed during /CV_nC/ sequences, starting at the beginning of the initial consonant and decreasing back to a low level by the end of V_n. This period of PG activity in fact appears to correspond to the period of LP suppression. We will postpone the discussion of this PG activity until after the presentation of the data of groups 2 and 3.

Group 2: VCV's in isolation.

The two main categories of sequences in this group are /V_onV_o/ and /V_onV_n/ sequences. Fig. 3 illustrates the contrast /ana/ vs. /anã/. All /V_onV_o/ sequences show LP suppression, starting during the first half or third of the initial vowel and ceasing in or shortly after the middle of /n/. For all /V_onV_n/ sequences on the other hand, LP suppression starts also during V_o, but it continues all through the utterance.

PG activity in /V_onV_o/ sequences is very low, while among /V_onV_n/ sequences, it is strong on or before /ã/; moderate on or before /ɔ̃/ and negligible on /ɛ̃/, as illustrated by Fig. 4.

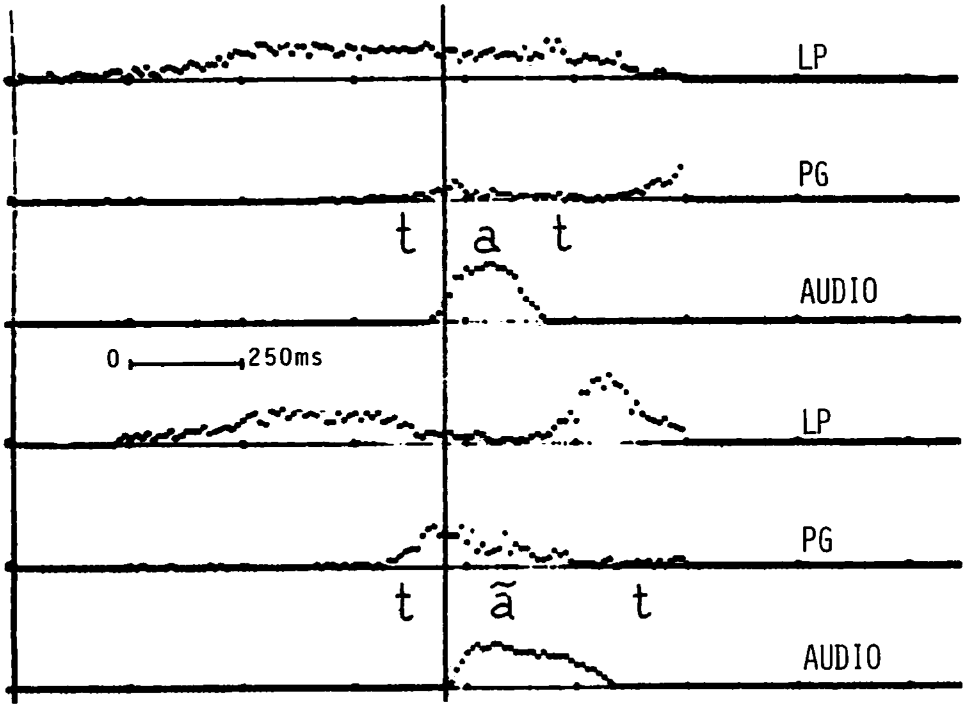

Fig. 1: Comparison of /tat/ and /tãt/ in isolation.

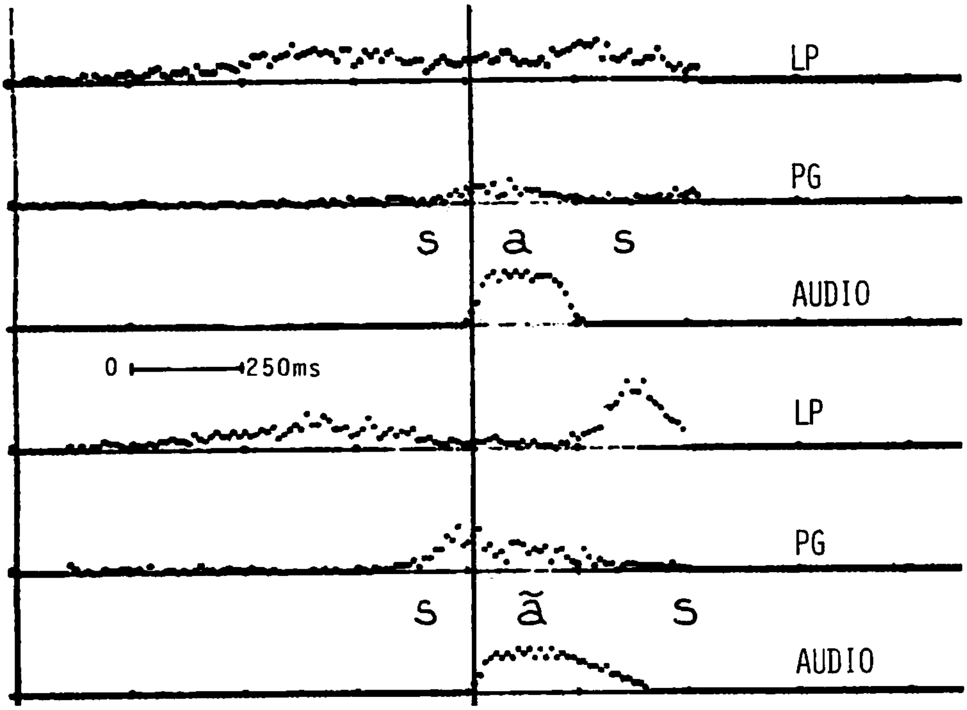

Fig. 2: Comparison of /sas/ and /sãs/ in isolation.

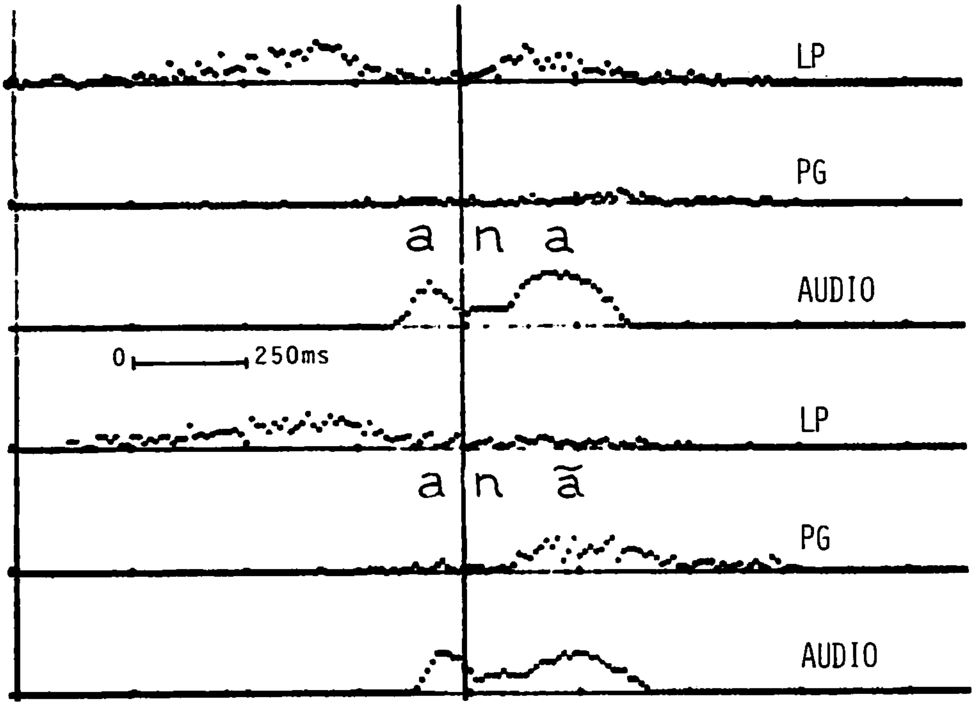

Fig. 3: Comparison of /ana/ and /anã/ in isolation.

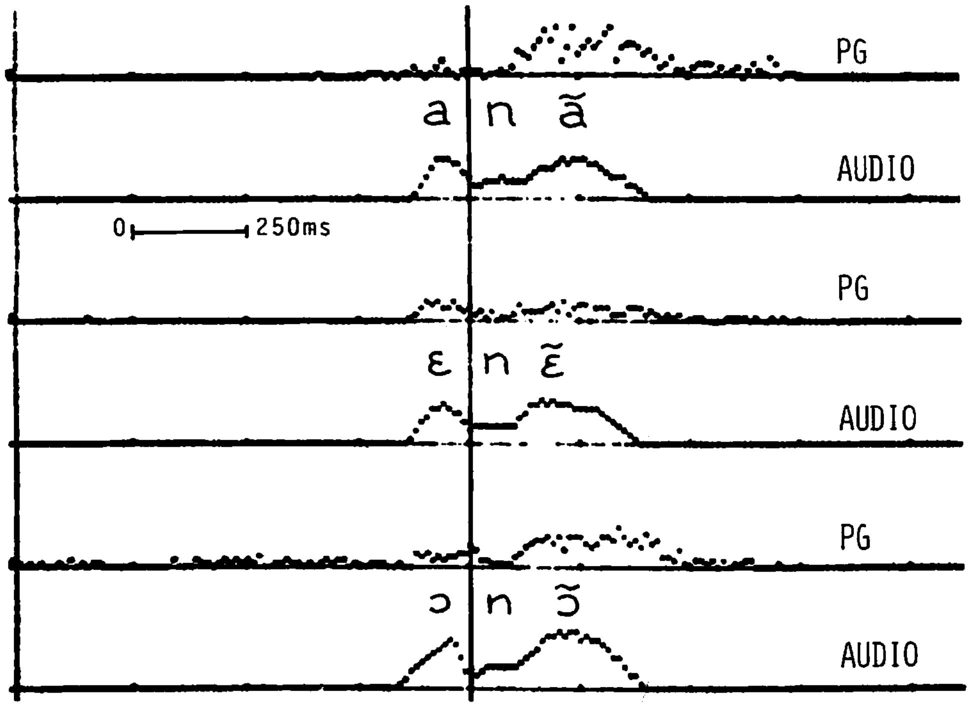

Fig. 4: Comparison of PG activity for /anã/, /ɛnɛ̃/ and /ɔnɔ̃/.

Group 3: /VCV/'s in frame.

This group tests a subset of the items of Group 2, namely /-ana-/ and /-anã-/, in the frame sentence "répétez (CVC) deux fois". As evidenced by our fiberscopic study (Fig. 5, Benguerel et al., 1975), the velum starts lowering at the release of /t/ (in "répétez") and reaches its lowest position in the middle of the nasal consonant; for the /-ana-/ sequence, it immediately starts on its way up, reaching a maximum height at the release of /d/; for the /-anã-/ sequence, it stays near its lowest height well into the nasalized vowel, then rises extremely fast to reach full closure synchronously with the oral closure for /d/ and then to maximum height at the release of /d/. As shown in Fig. 5, LP suppression is quite noticeable and starts well before /a/, for both types of sequences; for /-ana-/, suppression ceases in the middle of /n/ and LP activity resumes for the rest of the utterance; for /-anã-/, suppression lasts through the middle of /ã/,

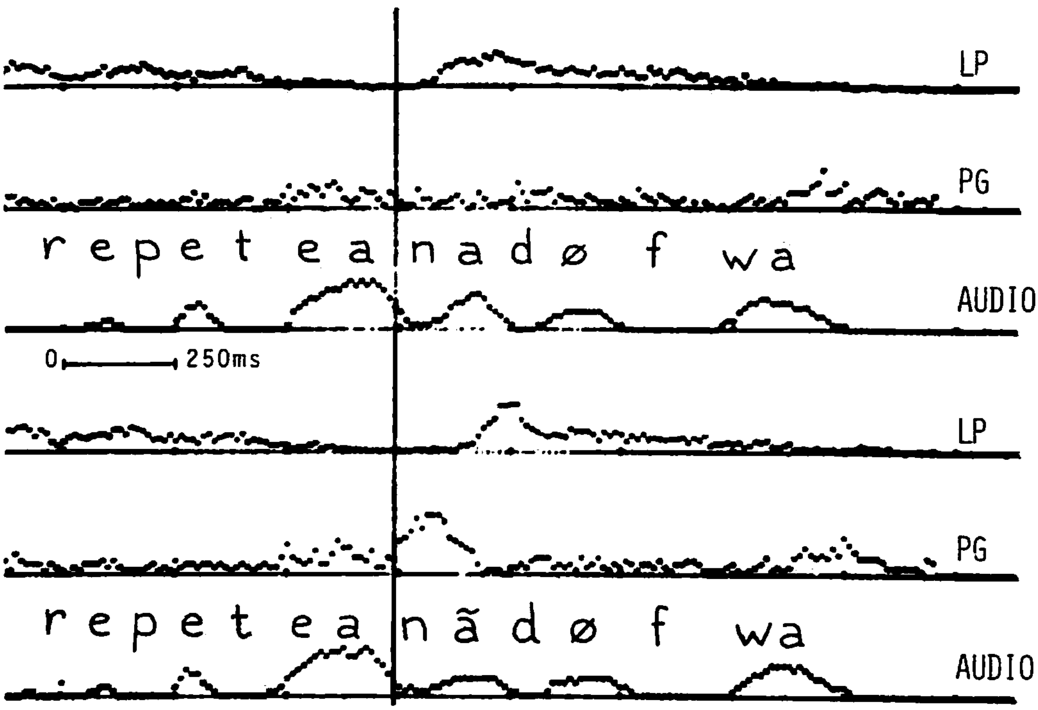

Fig. 5: Comparison of /ana/ and /anã/ in the frame sentence "répétez ______ deux fois".

then LP activity resumes with a very rapid increase peaking at the beginning of /d/. For the rest of the utterance, both types of sequences have a similar low LP activity pattern.

As for the /VCV/ sequences in isolation, PG activity is very low for /ana/, but shows a strong peak for /anã/, at the beginning of /ã/. No data is available on other /-VCV_n-/ sequences, but at this point, on the basis of data from Groups 1, 2 and 3, it appears that PG activity on and before a nasalized vowel is more likely due to a combination of place of articulation and nasalization than to nasalization alone. Lubker et al.(1972), in their model of velopharyngeal function, suggested that while LP activity ceases to provide an open "gate" for the production of nasals, the PG provides a brief and simultaneous "pull" to facilitate lowering of the velum. The data of this study appears to bring some support for this model: /anã/ and /ɛnɛ̃/ sequences show a higher degree of PG activity than /ɔnɔ̃/ during the nasalized vowel, but this is in agreement with our fiberscopic study (Benguerel et al., 1975) in which /ã/ and /ɛ̃/ were found to have a velar height markedly lower than /ɔ̃/, both in isolation and in context. For /V_oCV_o/ sequences, degree of PG activity varies in the reverse way, i.e., almost nil for /a/, higher for /ɛ/ and /ɔ/. From the fiberscopic study, we know that /a/ has the least velar height, /ɔ/ the greatest. One would thus expect the PG "pull" for /n/ to be greater when the environment is a vowel with high velum position (/ɔ/), than when it is a vowel with low velum position (/a/).

In attempting to correlate velar movement and EMG activity, one must be very careful not to equate the two. The amount of EMG activity is known to be proportional to the mechanical work necessary to achieve the required articulatory position (MacNeilage, 1972). Thus, if this mechanical work is to be produced in a given time interval, one ought to expect the amplitude of EMG activity of a particular muscle at a given time to correlate with the velocity of the movement, inasmuch as this muscle indeed contributes actively and directly to this movement.

The relation velar position—EMG activity is much more complex since it results from some kind of integration of velocity in which the boundary conditions are strongly context-dependent.

Group 4: /-CCCCV-/ sequences.

In the /-$CCCCV_o$-/ sequences, LP activity starts with an increase to a relatively low maximum, before the release of the initial /k/. Following this maximum, LP activity decreases gradually to a low level, without ever appearing to be suppressed. These same sequences all show negligible PG activity all through the utterance.

In /katɔrzfrV_n-/ sequences, LP activity also starts well before the release of /k/ and then decreases during the first two syllables. For approximately the last 3/4 of the consonant cluster and the first half of the nasalized vowel, LP activity is suppressed, restarting in the middle of V_n to reach a peak at the beginning of the following consonant, and decreasing to a low level for the rest of the utterance. As for PG activity, it starts increasing approximately at the beginning of LP suppression, peaks at the onset of V and returns to a low level in the middle of V_n. The highest peak of PG activity is found again for /ã/, whereas lower values are obtained for /ɛ̃/ and /ɔ̃/. Fig. 6 illustrates the above observation for two types of sequences: /-CCCCa-/ and /-CCCCã-/.

The LP and PG activity described above correlate with velar movements observed in the fiberscopic study: in particular the sharp LP activity increase during the second half of V_n parallels the very rapid closure of the velopharyngeal port at the transition -V_nC-, whereas the slower (LP activity increase preceding the utterance corresponds to the slower

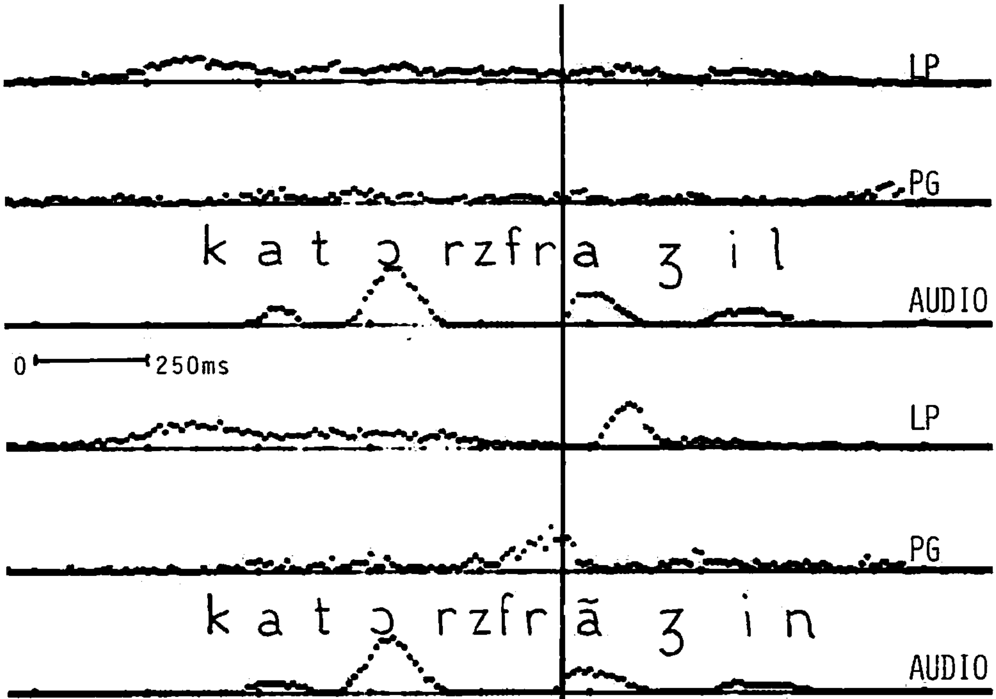

Fig. 6: Comparison of the two sequences "quatorze fragiles" and "quatorze frangines"

velopharyngeal closure necessary for the initial /k/. PG activity, on the other hand, simultaneous with LP suppression, corresponds to velum lowering for V_n .

Group 5: /kre(e(e))—/ sequences.

Each utterance in this group contained the consonant /n/ preceded by one, two or three successive /e/('s). A t-test showed that vowel durations for single, double and triple /e/ were all significantly different beyond the 0. 001 level, average durations being respectively 99. 4 ms, 278. 5 ms, and 345. 3 ms.

LP activity, shown in Fig. 7, follows a course consistent with the previous observations: it increases to a low maximum before the release of initial /k/, then is suppressed starting during /e/ (or before, in the case of single /e/), and increases rapidly to a peak from the middle of /n/. The durations of LP suppression, measured up to the point of alignment (oral closure of /n/) do not indicate any significant difference between single, double and triple /e/, the longest duration measured being that for /ee/. PG activity as displayed in Fig. 8, shows some complementary pattern to that of LP, this being most evident in /kre–/ sequences, and gradually less in the other two types. Since for all three types, the vowel preceding /n/ is the same, the difference in level of PG activity could only be attributed to the duration of the prenasal vocalic segment.

One purpose of this group of sequences was to test the scope of the look-ahead strategy for nasalization, in case such a strategy is applicable. Our fiberscopic data indicates that if velar position for oral French vowels is assigned a feature value 0 (corresponding to any position between closed

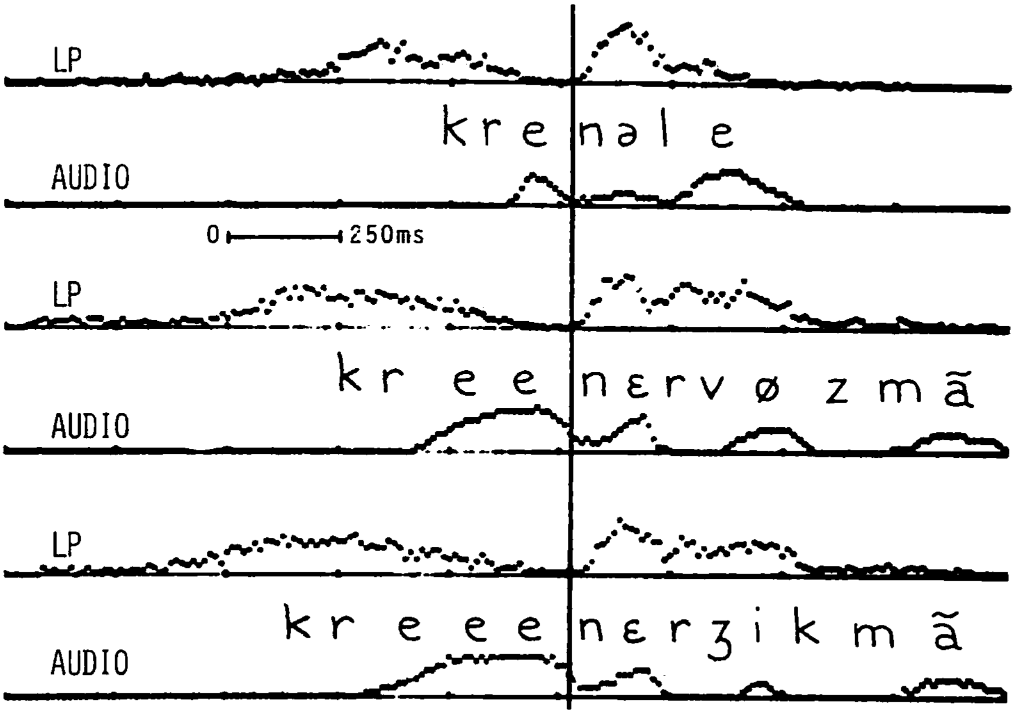

Fig. 7: Comparison of LP activity for the three utterances: "crénelé", "créé nerveusement" and "créé énergiquement".

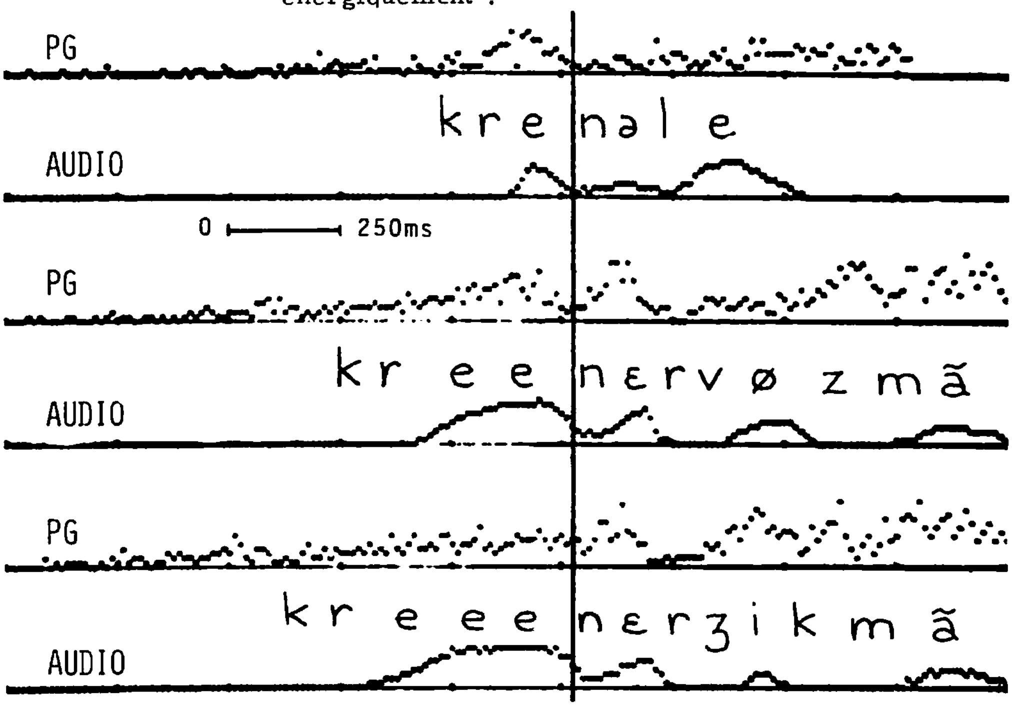

Fig. 8: Comparison of PG activity for the same three utterances as above.

pharyngeal port (feature value +) and fully open (feature value –)) the look-ahead could not extend beyond two upcoming oral vowels. The present EMG data corroborates the fiberscopic data: the beginning of LP suppression does not occur earlier for the /kreee-/ sequences than for the /kree-/ sequences, in fact very slightly later. It thus seems that if the look-ahead strategy is to be maintained in the case of nasalization in French, two options are available:

1) instead of assigning the feature value 0 to oral vowels, as it has been proposed for English vowels (Moll and Daniloff, 1971), the feature value + should be assigned to oral French vowels;

2) as has been suggested for Japanese (Ushijima and Hirose, 1974b) where a similar limitation of anticipatory velar coarticulation was observed, one could assign an upper bound to the look-ahead, either in terms of linguistic units (syllables, or phones for example) or in absolute terms. The first proposal seems particularly hard to support: one would have to explain the partly lowered velum position two segments ahead of the nasal consonant despite the + feature value for oral vowels. The second proposal presents some difficulties too, but its discussion will have to await evidence from further data.

As for Japanese syllabic nasals, where no carryover suppression of EMG activity was observed (Ushijima and Hirose, 1974a), but not as for Japanese syllable initial nasal consonants where carryover suppression was found (ibidem), the data of the present study do not show any clear carryover suppression of EMG activity. For example, Fig. 6 shows that for the sequence /katɔrzfrãʒin/, LP suppression starts during /z/, a voiced fricative, two segments ahead of /a/; LP suppression, however, ceases before /ʒ/, another voiced fricative, which follows /a/ immediately.

Discussion

From the EMG data presented here, it appears that nasality cannot be considered as a "one muscle—one parameter" system, particularly in the case of nasalized vowels, where PG activity seems to complement LP suppression, to different degrees depending on the nasalized vowel. Thus Lubker et al.'s proposal (Lubker and May, 1973; Lubker et al., 1972) of a model of velopharyngeal function in which LP activity ceases for the production of nasals, while PG simultaneously provides a brief "pull" to facilitate lowering of the velum, gets support from our data as far as nasalized vowels are concerned. For nasal consonants however, support for this model from our data is somewhat weak. Sequences of Group 5 indicate a sharper peak of PG activity when the /e(e(e))/ is shorter; this would suggest that the "pull" would be stronger (thus the velar closure faster) for the shorter vocalic segment. Our fiberscopic data, however, does not show that in a clear way but more data of the same type could bring support for this model.

The possible dependence of PG activity on the duration of the prenasal vocalic segment is to be related to the suggestion made earlier that EMG activity does not simply reflect how far the system under investigation has to move, but how fast it has to do it. Fig. 5 illustrates this point: in the upper sequence (/-anad-/), the velum has from the end of /n/ to the beginning of /d/ to rise, whereas in the lower sequence (/-anãd-/ it can do so starting only after the middle of /ã/.

Lubker and May (1973) claim that EMG activity of PG during speech production can be accounted for by four modes. Although none of these four modes is in contradiction with our data, it is rather clear that, in our data, C_n in VCV sequences is characterized by no LP and no PG activity whereas V_n in the same sequences is characterized by LP suppression and concomitant PG activity. Only this last case would correspond to Lubker and May's 4th mode, whereas the case of C_n (in our mode) would have to correspond to some 5th mode. It appears that representation of muscle contraction state should not be done in terms of a binary system, but of at least a ternary system (with the states (average to strong) contraction, holding and suppression). Depending on the number of muscles involved, the number of resulting combinations could be considerable, although not all combinations may be physiologically realized, for example, the simultaneous contraction of LP and PG.

Summary and Conclusions

EMG recordings from the levator palatini and from the palatoglossus of a male French speaker lead us to summarize as follows:

1) velum control and nasalization are not controlled by a simple binary mechanism; in particular nasalized vowels and nasal consonants are found to be controlled in different ways;

2) anticipatory coarticulation is observed in numerous instances, both for V_n and C_n, whereas carryover coarticulation is not observed in the case of EMG suppression. Contraction coarticulation is much more difficult to detect; it was observed in some cases, nevertheless, for example for PG, when LP is suppressed (Fig. 6);

3) a modification of the look-ahead strategy for nasalization appears to be in order , either through a feature value assignment different from 0 for nasals, or through a limitation of the look-ahead scope;

4) no syllable boundary effect was observed for anticipatory coarticulation; this is in agreement with other coarticulation data for French (Benguerel and Cowan, 1974) but not with data on Japanese (Ushijima and Hirose, 1974).

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