ANTICIPATORY LABIAL ACTIVITY IN THE PRODUCTION OF FRENCH ROUNDED VOWELS

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ABSTRACT

In this [1]investigation, movement data on articulator gestures are examined, in order to understand timing principles underlying the production of French rounded vowels. The extent of anticipatory labial and lingual activities, tied to vowel production, is analyzed in different consonantal contexts. X-ray and acoustic data are acquired from two speakers producing sentences at two speaking rates. Results show that anticipatory extents are comparable in single consonant contexts, and that loading the obstruent interval with a sequence of plosives restrains the anticipatory gestures. Increasing speaking rate provokes speeding up of articulatory activity and compression of acoustic durations, but does not significantly modify the relative timing of these anticipatory gestures.

1. INTRODUCTION

Rounding is a linguistically relevant gesture in French, and its influences on adjacent segments may be more or less remarkable. The anticipatory extent of such a gesture is said to be a production mechanism, related to the coordination of relatively sluggish physiological speech structures. However, this anticipatory phenomenon would also offer early acoustic information that listeners had evolved ability to exploit. Various models in speech production have provided contradictory accounts of the nature and extent of such anticipatory gestures. Our view is that the extension of gestures does not obey optimal linguistic requirements. Rather, anticipatory behaviour may emerge when gestural overlap is a linguistically viable configuration, and thus its extent would largely depend on factors such as the nature of the adjacent or neighbouring segments, the articulators coming into conflict in producing the sound sequences, speaker specific strategies…

This research will observe for the presence or absence of anticipatory labial and tongue activities in the production of rounded vowels. Anticipatory activity will be examined for two speakers, in different consonantal contexts and in different speech rates, to be able to evaluate its domain, its degree of variability and its robustness [1].

2. METHOD

The corpus consisted of 58 sentences that embedded the target words. The words chosen allowed investigating: (1) the influence of anticipatory vocalic coarticulation on consonant types [p, t, k, b, d, g]; (2) the temporal extent of anticipatory labial activity across consonant sequences [kt]. The corpus provided the following sequences: (1) Vunrounded + C^1 + Vrounded; 2) Vunrounded + C^2 + Vrounded (where there was no intrusive vowel between C^1 and C^2). The unrounded vowels were either [i] or [a] and the rounded vowels were either [u] or [y]. Two speakers uttered the speech samples at two speaking rates (normal and fast). X-rays and a simultaneous audio recording of the speakers' production were obtained under medical care.

With the help of a grid, measurement parameters for vocal tract configurations were determined on mid-sagittal profiles related to: (1) upper lip position, horizontal and vertical displacements; (2) lower lip position, horizontal and vertical displacements; (3) lip opening or the vertical distance between the upper and lower lips; (4) jaw position, vertical and horizontal displacements; (5) tongue-tip vertical displacement, monitored following a specific point in the alveolar region of the grid, where contact woud be located; and (6) tongue-body displacement, monitored following a specific point in the velar region of the grid, where either contact or minimum constriction would occurr. Temporal events were detected on the audio signal and specific timing relations between these events allowed determining, in the VCV domain, acoustic durations that correspond to articulatory opening and closing gestures.

3. GENERAL COMMENTS

3.1. Behaviour of articulators

The displacement of the jaw did not show any remarkable contribution to the anticipatory characteristics that will be discussed below. However, its movements, although of little amplitude, did reveal its nature as a carrier of the lower lip and of the tongue body, with movements being positively correlated in all cases. Protrusion of the upper lip was always accompanied by a vertical upward displacement, without this vertical displacement showing any decisive contribution to labial anticipation in terms of movement amplitudes. It has been shown [2], however, that peak velocity, associated with this raising movement, may be relevant in distinguishing anticipatory influences from different vowels. The protrusion of the upper lip was highly correlated with that of the lower lip. As intra-class correlations were significantly high, values were then collapsed across all classes and conditions in order to observe the global scenario. Scattergrams in Figure 1 indicate the close relationship between these two structures. However, it was the upper lip protrusion that demonstrated, in general, more regular and prominent behaviour than the lower lip. Protrusion measurements, in this research, will henceforth focus only on the activity of the upper lip. Moreover, as upper lip protrusion was always negatively correlated with lip opening, within and across classes and conditions (Figure 2), it becomes a good candidate in analyzing the coarticulatory effects of the two rounded vowels studied here. In one instance, however, Speaker M.M. did not show perceptible upper lip protrusion (in the consonant sequence context); it was lip opening that seemed to ensure the anticipatory activity. Vowel anticipatory extents were similar in both the voiced and voiceless contexts. Thus only results pertaining to the voiceless category will be presented here. The activiy of all articulators was sped up with increased speaking rate. In some instances, gestures occured simultaneously in fast speech, even within a single structure like the tongue [1], where the tongue body occlusion may coincide with that of the tongue tip, as in the sequence [ikty].

3.2. Acoustic durations

Durations of both vocalic and consonantal portions of the acoustic signal were compressed in fast speech, reflecting the global speeding up of articulatory activity. However, consonant closures were more resistant than vowels to reduction of their durations. This was especially true in the consonant sequence context [kt]. Noticeable reduction of the rounded vowels in fast speech did not seem to affect the anticipatory extent of the vowel gestures, as we shall see later.

4. RESULTS AND DISCUSSION

4.1. Timing of articulatory gestures

4.1.1. The bilabial context [apu]

It is interesting to understand the timing of the gestures participating in the production of the rounded vowel, in a bilabial consonantal context, where the lips are used for both approximation and protrusion. The temporal coordination of protrusion of the upper lip and vertical displacelment of the tongue body are closely examined. The former's behaviour is closely tied to the production of the vowel, with possible conflicting demands coming, however, from bilabial closure; whilst the latter's activity is essentially related to the production of the vowel. In normal speech, results show that protrusion begins before lip contact, and increases (4 mm for both subjects) through lip closure. Maximum protrusion (of 10 mm for A. K. and 7 mm for M.M.) is observed during the configuration of the rounded vowel. The displacement of the tongue body indicates that the gesture for vowel constriction of the rounded vowel is also initiated before lip closure, varying through this closure by 4 mm and 6 mm for A.E. and M.M. respectively, and attaining a maximum value of 11 mm of variation for both speakers, which corresponds to minimum constriction, i.e. when the surface of the tongue is closest to the palate. Increasing speech rate does not significantly modify the timing of these articulators, nor does it alter the amplitude of articulator displacements. These results reveal similar strategies for both speakers, showing that the anticipatory labial activity of the rounded vowel is also accompanied by an anticipatory tongue body gesture of this vowel. It is, nonetheless, lawful to believe that the protrusion of the upper lip, in this context, may portray both the linguistic vowel gesture and the labial component of the consonant. The next two contexts should give better insights into this question.

4.1.2. The tongue tip context [atu]

The articulators monitored in this context for anticipatory behaviour are: upper lip protrusion, lower lip vertical displacement, lip opening, and tongue tongue body vertical displacement. Compared with the previous context, more structures are available in this case to analyse the anticipatory phenomena of the rounding gesture, since only tongue tip is actively recruited in producing the consonant (Figure 3). The data shows (Figure 4, Speaker A.E.), in normal speech, that protrusion is gradual (frames 1112 - 1115) before tongue tip contact (frame 116), and increases by 9 mm from contact "onset" to "release" (frames 1116 - 1121). Infact, maximum protrusion is attained during the final obstruent configuration of the consonant. The vertical displacement of the lower lip, contributing also to the rounding gesture, begins its upward movement (frames 1113-1115) before consonantal closure. During this tongue tip closure, the lower lip continues its upward trajectory, varying by 5 mm during the obstruent phase of the vocal tract, with maximum displacement taking place during the obstruent configurations (frames 1120 - 1121). Lip opening is negatively correlated with upper lip protrusion. It diminishes before tongue tip contact (Figure 3), and a reduction of 10 mm is registered during contact. The vertical displacement of the tongue body, reflecting the size of the constriction for the rounded vowel in the back cavity, also initiates its elevation before the obstruent phase of the apical consonant. The vocalic constriction is further reduced by 7 mm during apical contact (frames 1116 - 1121). These timing patterns are structurally the same for Speaker M.M, although her gestures are relatively lower in amplitude; this point will be taken up again later. Increasing speaking rate does not modify the global timing of the articulators either. Taken together, these results confirm the above mentioned finding, that both the rounding gesture and the constriction gesture for the production of the vowel are anticipated well beyond the non labial consonant, and up to the late configurations of the unrounded vowel. What happens to the labial gestures (protrusion and lip opening), when the tongue body gesture for the vowel is also recruited for the production of the consonant? In other terms, would the tongue gesture conflict have any consequence on the anticipatory extent of the other structures, even when these structures are anatomically independent? The following sequence provides elements of response to this question.

4.1.3.The tongue body context [aku]

The timing of upper lip protrusion, of the vertical displacement of the lower lip and of lip opening are examined here in order to account for anticipatory phenomena. In a normal speech rate, protrusion begins before tongue dorsum contact and increases during the contact (by 6 mm for A.E. but only by 2 mm for M.M.). The lower lip vertical displacement is not significant before consonantal contact, but increases during the obstruent configuration (6 mm for A.E. and 4 mm for M.M.). Lip opening reduces (5 mm and 3 mm for Speakers A.E. and M.M. respectively), from a relatively stable configuration for vowel [a], to tongue body contact, and continues its reduction (4 mm for both speakers) through the closure. At a fast speaking rate, the timing of articulators is globally the same, with displacement values being less remarkable, in this prosodic context also, for speaker M.M. On a whole, no compensation strategies are observed: labial anticipatory activity is neither extended in time nor enhanced in amplitude when the tongue body vowel gesture is in conflict with the consonant gesture [3]. On the contrary, the anticipatory gesture of the lower lip vertical displacement does no longer go beyond the obstruent phase, as was the case in the apical context. This tendency for vowel [u] gesture spreading to diminish, when the vocal tract is obstructed in the velar region is more noticeable in Speaker M.M., who in general has less pronounced amplitude variations. What happens when the obstruent phase is loaded with two consonants? The next section deals with this question.

4.1.4. Consonant sequences [ikty]

The articulators observed for anticipatory effects in this context are the following: upper lip protrusion, lower lip vertical displacement, and lip opening. In normal speech rate, and for Speaker A.E., upper lip protrusion becomes significant only after the end of tongue dorsum contact, increasing by 4 mm in the occlusion phase of the apical consonant. For Speaker M.M., however, upper lip protrusion is hardly perceptible, and does not vary (1 mm) along the entire sequence. The lower lip vertical displacement, for Speaker A.E., starts its rising movement after the obstruent phase of the velar consonant; it varies by 4 mm within the obstruent phase of the apical consonant. For Speaker M.M., the scenario is similar, with a comparable variation in amplitude. Lip opening for Speaker A.E., like upper lip protrusion, only diminishes after tongue body contact, varying by 7 mm during the end of the tongue dorsum obstruent phase and the end of the tongue tip obstruent phase. For speaker M.M., while upper lip protrusion did not seem relevant in the production of the sequence, the size of lip opening reduces (by 6 mm), as from the tongue body obstruent configuration to the tongue tip obstruent configuration. In fast speech, the timing of the different gestures is comparable to that of normal speech rate, for both speakers. To summarize, when the upper lip protrusion gesture is not efficient for Speaker M.M., it is lip opening that seems to ensure the anticipatory extent of the vowel. It should be noted here that the tongue body lowering movement after the obstruent phase, begins before contact for the apical consonant, and varies by 4 mm for both speakers, in both speech rates. This lowering of the tongue body is not only related to consonant release, but also to an extension of the rounded vowel gesture into the apical configuration. In all cases, no gesture goes beyond the tongue dorsum occlusion phase; they may at best coincide with the begining of that phase.

5. CONCLUSIONS

5.1. The extent of anticipatory vocalic gestures

In the single consonant context, the French rounded vowel [u] was produced with all of the labial components extending beyond the consonant, into the late configurations of the [a] vowel [4]. When the tongue body gesture was not sollicited for the production of the velar consonant, its elevation, to obtain the desired constriction of the rounded vowel, also extended over the preceding consonant into the first vowel. Loading the obstruent phase with a sequence of two plosives, seems to restrict the anticipatory influences from the rounded vowel on the consonants [5]: this sequence of plosives thus seems quite resistant to the anticipatory effects of the vowel, even when that vowel is the highly rounded French vowel [y]. Nevertheless, the anticipatory phenomenon is still noticeable [6]. One example of delaying a gesture until a previous one had been implemented — because of gesture conflict — was found in this investigation [7]. These different strategies reveal, on a whole, similarity between the two speakers. The extension of articulatory movements seems to be implemented whenever physiologically possible without any application of formal rules. Advantage would then be taken by listeners, of speakers' ability to overlap gestures.

5.2. The perceptual extent of anticipatory gestures

Positing that listeners exploit early motoric cues related to upcoming speech elements, future work will be carried out on the perceptual effects of these anticipatory vocalic gestures. Some gestures are naturally visible (lip rounding) and others could be uncovered by experimental techniques (lingual gestures). The pertinent question is to find out the auditory-acoustic extent of these gestures. In other words, what is the extent of their audible portions ?

NOTE

1. In loving memory of Christian Benoît.

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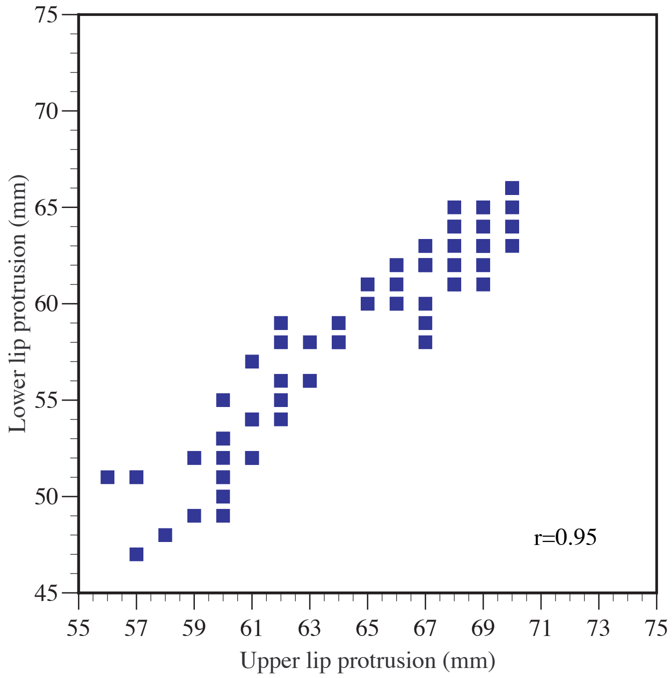

Figure 1. Scattergrams of lower lip protrusion as a function of upper lip protrusion. All conditions collapsed.

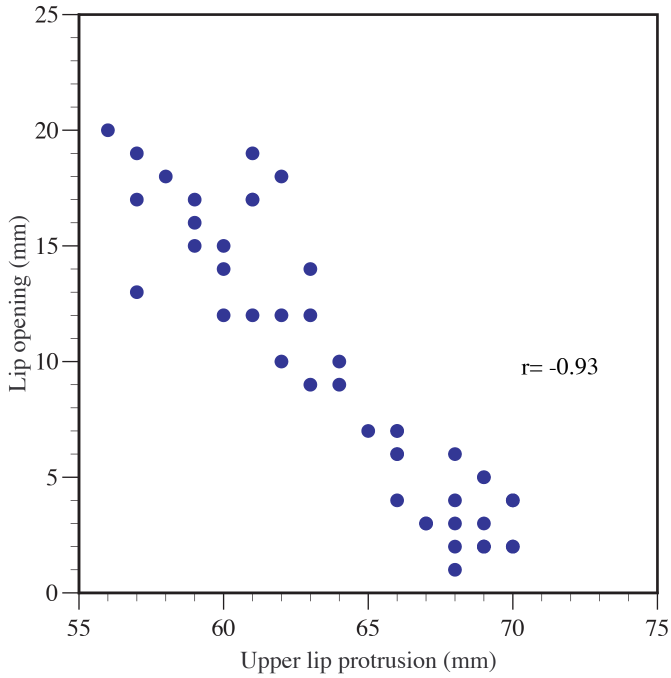

Figure 2. Scattergrams of upper lip protrusion as a function of lip opening. All conditions collapsed.

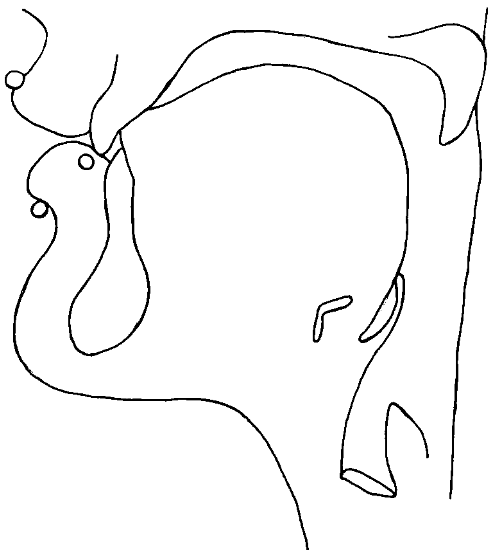

Figure 3. Vocal tract sagittal profile for [atu]. Normal speech.

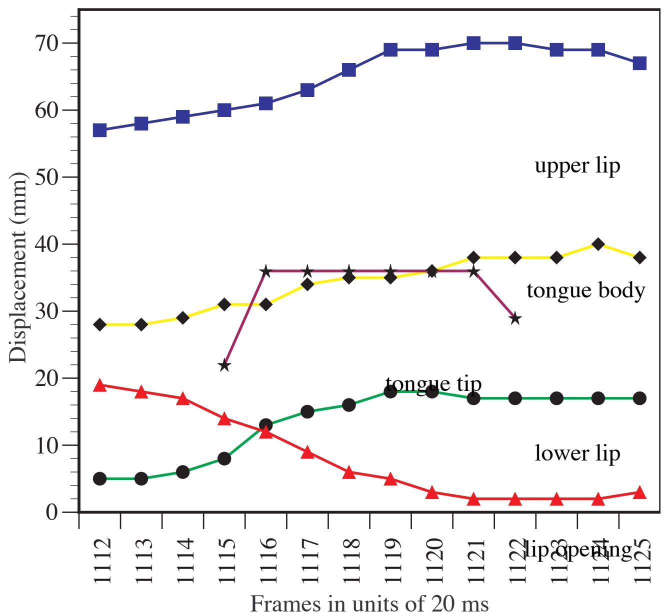

Figure 4. Frame by frame analysis for [atu]. Normal speech.