Compensating for a Bite Block in /t/ and /d/ in French : Electropalatography Study

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Abstract

This paper deals with various movements of the tongue in perturbed speech. The activity of the jaw has been neutralized by mean of bite block in order to observe immediate compensatory tongue movement when the jaw was blocked. Electropalatography was used to monitor linguopalatal contact patterns in French /t/ and /d /in normal and in bite-block speech. We thus observed how spatial and temporal changes of the tongue configurations palliate the immobilization of the mandible. Results showed that the presence of bite block immediatly modified the duration and the amplitude of the complete closure and effects of bite block were speaker dependent. Linguo-palatal contacts were made further forward than in normal speech, and reached a different articulatory target.

1 Introduction

Studies on oral-articulatory perturbations have provided valuable insights into motor equivalence, or how different muscle activation patterns can achieve the same articulatory or acoustic goals. It's well known that fonctional dependences exist between the jaw and the tongue which together formed part of a coordinative structure [1] [2] [3]. So articulatory compensations could be immediatly achieved as a consequence of this inter-articulatory coordination [1]. In particular, previous studies on vowels of steady-state structural perturbations caused by the insertion of a bite block into the mouth have revealed that articulatory compensation made by adjusting articulator positions allowed the phoneme-specific acoustic goal to be achieved [4] [5] [6].

But, few works have studied the production of consonant with bite blocks even if there is somewhat less flexibility in consonant production as compared to the production of vowels. Moreover certain consonants require greater articulatory precision than others. Somme authors have studied the production of /t/ and /s/ in English and in Arabic languages, in normal and bite block speech and their articulatory and perceptual results suggested the speakers did not compensated completly. Compensation was not instantaneous and some information pertaining to specific parameter values were encoded in central representations [6] [7]. The original approach of the present study consists of producing French consonants /t/ and /d/ with bite block and comparing our results with those made in the same condition, but in other languages. We used the paradigm of bite block speech to infer compensatory movements of the tongue, thus reaching other articulatory target.

Previous results of an articulatory study showed that bite block induced different spatio-temporal modifications: although a necessary constriction was achieved, we could note a reduction as well as a reinforcement of the general movement of the tongue. See [8] for details.

Therefore, the aim of this paper is to study the spatio temporal modifications of the medial phase of the consonant, specifically on the complete closure (defined as the total obstruction of the oral airflow) and its location which can be free to vary within the antero-posterior dimension : the bite block are not only expected to reduce the area of tongue palate contact but to shift forward the place of articulation.

2 Method

The corpus was composed of Consonant-Vowel-Consonant (CVC) sequences embedded in the carrier phrase: "Il ne dit pas CVC encore" (He doesn't say CVC again). The item studied were C1V syllables containing /t/ and /d/ stops, alternately /a/ and /i/ respectively the most open and closed vowels in the French vocalic system, repeated twelve times by two French speakers, in normal and bite block speech.

To fix the jaw, we fashioned acrylic bite blocks wiht a thermo malleable dentistry paste, making individual indentations for tooth cups to prevent slipping. When held between the molar teeth, bite blocks were adjusted to ensure a vertical distance of 17 mm measured between the central incisors for both speakers. Bite block size was chosen based on previous researchs with bite blocks.

Recordings were made using the electropalatography (EPG) system of Reading [10] wich allowed a spatio temporal analysis of the linguo palatal (LP) contacts. Even though both speakers were used to wearing artificial palate and making recordings with, we allowed a thirty minute adaptation period during the calibration of the recording system. However, recordings were made immediately after the insertion of the bite block into the mounth. EPG used an acrylic 1,5 mm thick palate created from a molding of the hard palate of our speakers. Sixty two contact electrodes were placed in eight rows, six on the first anterior row and eight on the others. The articulation zone of alveolar stop consonants was empirically defined as being the most anterior area of the palate represented by the four first anterior rows of the hard palate [10]. Measures were collected and based on a manual segmentation of the temporal evolution curve of the LP contacts coupled with the LP contact patterns of each EPG frames, the both simultanously with the acoustic signal.

Articulatory parameters were taken on the complete closure. Complete closure duration was defined as the interval between first total closure (the first EPG frame showing a complete row contacted) and closure release (the first EPG frame showing an opening in the complete row contacted). It's important to note that in bite blok speech, the mean rate of measurable complete closure was the good 88% score for both spaekers. Of course, in this case, the main obstacle to successful measurement was lack of the total closure on the EPG patterns. The maximum number of LP contacts was taken during this interval. In order to detect the distribution of the LP contacts, the center of gravity was calculated on the antero-posterior axis of the palate. The axis of reference was the median horizontal limit between the four anterior rows (–1 à –4) and the four posterior rows (+1 à +4). So the further the center of gravity receded, the more we could observe a negative value. This factor was relevant to inform us on changes in the area of articulation.

3 Results

3.1 Duration of the complete closure

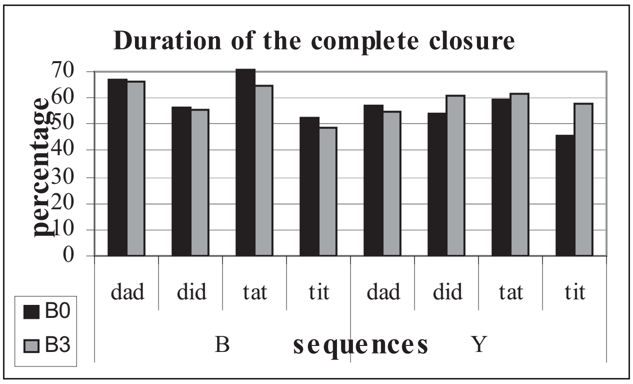

Figure 1*: Mean duration relative to the entire consonant*

As can be seen in Figure 1 which shows the mean duration of the closure relative to the entire consonant, the effect of the bite block was speaker dependant. For speaker B, closure duration had a tendency to be significantly shorter in perturbed speech than in normal speech and the influence of the bite block was consequent [F (3,161)=4,492; p=0,0047]. The mean difference between the bite block and normal speech samples was -2,96 %. For speaker Y, the duration of closure was lenghtened of 4,70% in bite block speech, excepted for the sequence /dad/ which presented a decrease of -2,59 %. However, for this speaker, it seems that the effects of the bite block had no significant influence on the duration of the closure [F (3,167)=2,355; p=0,073].

3.2 Amplitude: Number of LP contacts

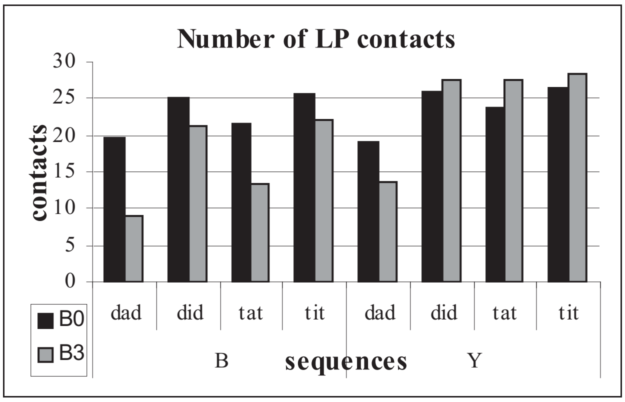

Figure 2: *Amplitude of LP contacts*

Speaker B contacted fewer sensors in bite block speech than in normal speech in all sequences. There was a mean difference of -6,52 sensors contacted between perturbed and normal speech. The /dad/ sequence was the most affected by the bite block as it lost -10,66. For this speaker, amplitude of contacts was reduced with block. Indeed, there was a direct relationship between the influence of the bite block and the number of LP contacts [F (3,175)=53,44; p<0,0001]. Speaker Y tended to contact more sensors in the bite block condition than in the normal condition, apart from the /dad/ sequence. The lowest mean difference between perturbed and normal speech was of +2,42 sensors contacted.

Althought the bite block made hace varied the duration and the amplitude, variations differed stongly according to the speakers ; not including the /dad/ sequence for which we noted a similar spatial reduction of the amplitude and shortening of the complete closure for the both speakers.

3.3 Area of contacts : Center of gravity of LP contacts location.

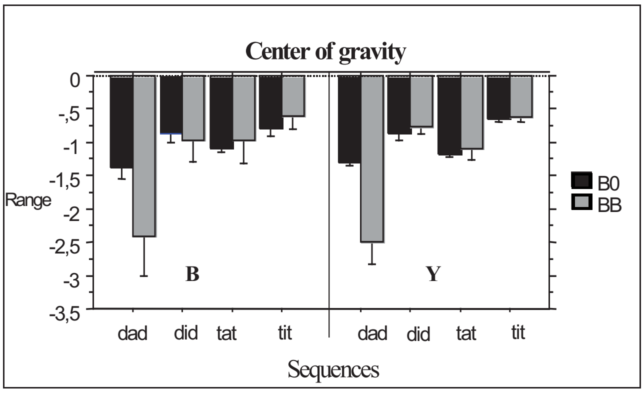

Figure 3: *Center of gravity of LP contacts*

Morever the center of gravity shifted to the front part of the palate of 1,02 raw for the speaker B and of 1,21 rows for spaeker Y. For the both speakers, only /dad/ articulation was significatively shift forward on the palate, the values became more and more negative. Other sequences did not show an important differences in the anterio posterior location. The effects of bite block were not speaker dependant [F(3,176) = 0,247; p= 0,6196].

But it seems that the effects of the bite block on the center of gravity depend on the sequence, statistical data confirms this [F(3,176)=30,938; p<0,0001]. On producing this sequence, both speakers showed a imilar anteriorization of the complete closure in response to the perturbation, although we noted that responses varied for the other sequences. This could confirms displacement of the closure and not only a spatio temporal reduction. Thus, in order to find an 'apicalisation' phenomenon, we calculated a regression between the centre of gravity and the number of LP contacts.

3.4 Correlation between the area and the anterio posterior location of the LP contacts

As we can see in figure 4, no significant correlation (R^2= 0,329) was found between the center of gravity and the occurence of LP contacts in the anterior area of the palate. In normal speech, we suppose that the tongue blade and the apex draw together a movement to touch the alveolar region of the palate. But, when the mandible was fixed, the tongue blade no longer supported the apex and it seemed to adopt an arched movement to allow the apex to extend its movement and thus reach the dental region of the palate. There was no progression in the number of contacts from the posterior to the anterior region since the laterals contacts are not required. The apex alone moved directly towards the dental ridge, without touching the lateral parts of the palate since the jaw was blocked in an abnormal open position. This could confirm our experiment shows a displacement of the articulation as it shifted forward on the palate, which we could called 'apicalisation', in response to the perturbation.

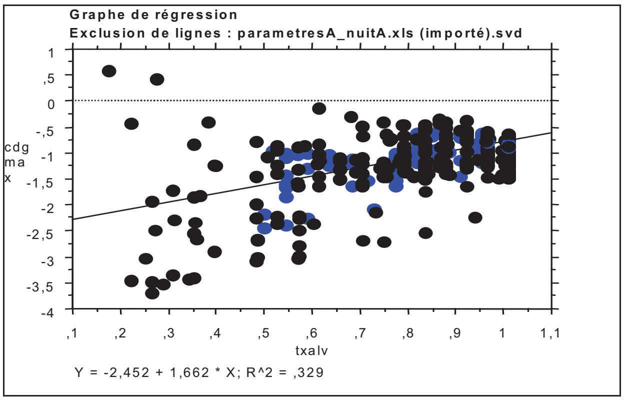

Figure 4: *Correlation between LP contacts and the center of gravity*

4 Discussion

The bite block induced spatio-temporal and location modifications of the complete closure of the stop consonants /t/ and /d/ but involved very variable responses from the speakers. These modifications seemed to depend on the sequences, underlining the role of the phonetic constraints in the compensatory strategies. For both speakers, the production of the voiced consonant /d/ followed by an open vowel /a/ had a tendency to become as weak as a a tap [10], in terms of spatio temporal parameters (duration of the complete closure and the number of LP contact were reduced and the area of contact shift forward). First, voiced consonant are weaker than their unvoiced counterpart and seem to be less resistant to perturbation. Secondly, the mandible was blocked in a more open position than the position required to produce the open vowal /a/, so the tongue extended toward a new constriction and needed a higher amplitude to produce the closure on the palate. We could conclude that difficulties in producing the articulatory movement under large phonetic constraints thus reducing inter-speakers varibility.

On the other hand, inter-speakers variability were conserved on all others sequences : wheareas the production of the voiceless stop /t/ was strengthened for one speaker (Y), it was weakened for the other (B). Comparing with the others studies, Arabic speakers contacted fewer sensors and English speakers contacted more sensors in bite block speech than in normal speech.[6]. Certainly, a part of these differences between subjects can be explained by dissimilitudes in implementing consonant in their native langage. But an other part of these differences is due to the existence of individual strategies for compensation depending on a set of personnal factors such as morphology, articulatory capacities, experiences, knowledge...

These results raise the questions of wether the articulatory variations resulting from the use of the bite block caused significant acoustic differences. Currently, we are making a study of the acoustic parameters of /t/and /d/ in normal and bite block speech. Spectral characteristics of the burst noise are measured in order to compare them to the articulatory parameters**.** The acoustis study should confirm that an acceptable acoustic target may be reached in different articulatory manners. Shortly we will be able to add argument to demonstrate that the variability in speech can be explained by the existence of motor equivalences that control the articulatory movements in speech [11] and this control must be adapted 'on line' with a large set of constraints of production.

5 References

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