COARTICULATION IN /kl/ SEQUENCES IN FRENCH : A MULTISENSOR INVESTIGATION OF THE TIMING OF LINGUAL GESTURES

Alain Marchal* & Yohann Meynadier°

* DR19, CNRS
°Laboratoire Parole et Langage, CNRS URA 261

ABSTRACT - The timing of lingual gestures in the production of /kl/ clusters in read French sentences is reported in this poster. Our data indicates that the body and tip of the tongue do not behave as independent articulators. In fact, there is a strong resistance to coarticulation from /k/ to /l/.

INTRODUCTION

This study deals with lingual coarticulation in /kl/ consonant clusters in French. It was hypothesized that the tongue is a pluridimensional articulator, i.e. that its apex and dorsum can function as two separate articulators.

To demonstrate the independence of these two parts of the tongue, we examined the timing of articulatory gestures in the production of /k/ and /l/. Overlap is considered to exist if the onset of the occlusion of the /l/ occurs before the release of the /k/. This was measured here by the so-called Overlap Index (OI), which accounts for the timing of the different phases contributing to the articulation of this cluster.

The present analysis is a supplement to Gibbon et al.'s (1993) recent work on a related question in several European languages. They found no clear evidence of free coarticulation of the tongue's apex and dorsum in /kl/, whether in French or in the other languages studied (Swedish, Italian, German, English, and Catalan). The linguistic material used in their studies consisted solely of nonsense words and isolated real words (the results for the two types of items were pooled). Their corpus thus provided a favorable context for hyperarticulation.

The question raised here is whether the same results would be found in a continuous speech context. To shed light on this issue, the present study concentrated on the coarticulation of the /kl/ cluster in sentences.

EXPERIMENTAL PROCEDURE

Subjects and Corpus

The corpus consisted of ten repetitions of the same sentence pronounced by three native French speakers : a man, GC (1), and two women, AD and GM. The subjects were the same as the ones who had produced the nonsense words and isolated real words in the Gibbon et al. (1993) study. There were two occurrences of the /kl/ sequence in the embedding sentence, which was:

[sɛ mɛ̃tənɑ̃ kə la smala le zaklam]

For the first occurrence, the coarticulation of /kl/ can only exist if the /ə/ not pronounced. This is a direct consequence of the speech rate. For the second occurrence, the link is mandatory because the phonemes /k/ and /l/ are adjacent. It should be noted that the two occurrences differ in pitch accent : the first is in a unstressed position and the second is in a stressed position.

Data Acquisition and Recording Conditions

The multisensor, multichannel system developed in Reading (Hardcastle et al., 1989; Gibbon et al., 1993) was used to capture and record the laryngographic, electropalatographic, oral and nasal airflow and acoustic data. The sound signal was sampled at 20 kHz using a Sennheiser MKH40 P48 microphone with simultaneous recording on a Sony DAT DTC-1000ES. For this study, only the data supplied by the audio, electropalatographic, and oral airflow channels was processed. A signal editor was used to simultaneously and synchronously display the various acoustic, articulatory, and aerodynamic parameters and segment the speech signal (Nicolaidis et al., 1993; Marchal et al., 1995).

Segmentation and Labelling

The speech signal was segmented on the basis of the electropalatographic data (Figure 1), using the same set of labels as in the Gibbon et al. (1993) study.

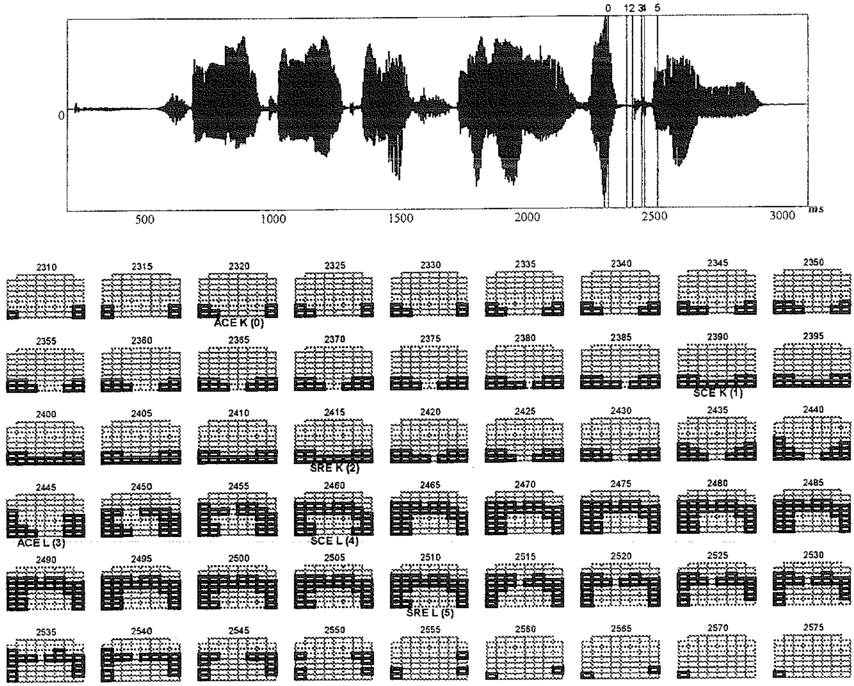

Figure 1. Oscillogram of the embedding sentence (upper), and electropalatograms illustrating the segmentation and labelling method (lower), for a realization of the sequence /akla/. The palatographic images are separated by a 5-ms interval. The top of the palatogram shows the alveolar area of the hard palate, and the bottom, the beginning of the soft palate. The tongue's contact points on the palate are shown as highlighted rectangles.

ACE identifies the *A*pproach to the *C*losure measured from the *E*lectropalatographic data. This label indicates the approach of the articulatory target (the occlusion). It is placed at the moment when the first electrodes or groups of electrodes start coming together from each side at various places on the palatogram in order to achieve the occlusion, in the middle (for /l/) and at the back (for /k/).

SCE pinpoints the exact moment when the *S*top *C*losure measured from the *E*lectropalatographic data is achieved. This label is placed on the first palatographic image where the occlusion is complete. Complete occlusion appears as a horizontal, solid bar of electrodes, at the back for /k/ and in the middle for /l/.

SRE marks the Stop *R*elease of the closure measured from the *E*lectropalatographic data. This label is placed on the last electropalatographic image with a complete occlusion.

The labelling method used here differed slightly from the Gibbon et al. (1993) study, where /k/ segmentation was based on variations in the oral airflow curve and /l/ segmentation was based on the electropalatographic images. We preferred to use the same articulatory criteria for /k/ and /l/, and to only rely on the oral airflow curve when the occlusion was incomplete in either case (Figure 2), i.e. whenever one or more electrodes were missing relative to a complete occlusion, probably due to an electropalatographic data acquisition problem (such as a /k/ occlusion articulated too far back).

SCO or the *S*top *C*losure measured from the *O*ral airflow data is used to mark the beginning of the air closure, which corresponds to the beginning of the occlusion. This label locates the absolute oral airflow minimum and is situated at the end of a substantial drop in the curve preceding a stable section. It generally coincides with an SCE.

SRO marks the point where the air is released. It is the *S*top *R*elease of the closure measured from the *O*ral airflow data, and is located at the point where the stable section of the curve ends (the closure part of the occlusion) and the air flow begins (which shows up as a significant rise in the curve). It generally coincides with an SRE.

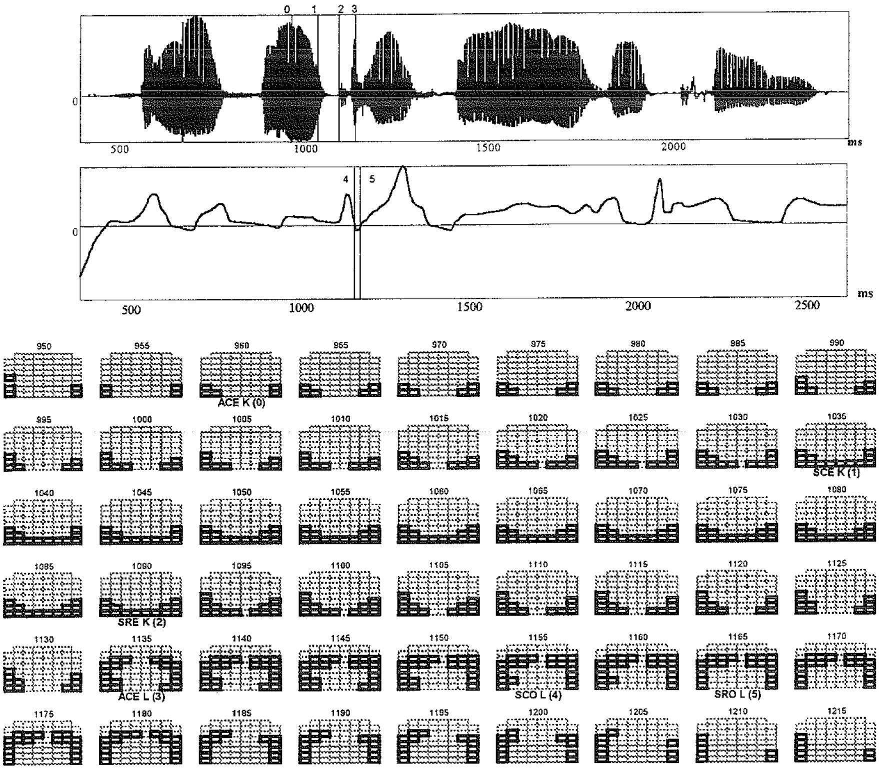

Figure 2. Oscillogram of the embedding sentence with EPG segmentation (upper), oral airflow curve with two labels marking the incomplete occlusion of /l/ (middle), and EPG sequence (lower), for a realization of /ɑ̃kla/.

Calculating the Overlap Index

The Overlap Index (OI) was calculated from the temporal values of the labels, using the following formula:

$$OI = \frac{/k/\,ACE - /l/\,ACE}{/k/\,ACE - /k/\,SRE} \times 100$$

If OI = 100, then /k/ SRE and /l/ ACE coincide : there is no overlap. If OI > 100, then /k/ SRE is located before /l/ ACE : the articulation of the /l/ follows the articulation of the /k/, i.e. it occurs after the /k/ is produced and there is no /l/ anticipation. If OI < 100, then /l/ ACE precedes /k/ SRE : overlap occurs and there is /l/ anticipation before the end of the /k/. In this case, the articulation of the /kl/ sequence is no longer linear, but multilinear.

Temporal Organization

For each repetition, the duration of the three phases of the /kl/ sequence was measured as follows:

1. /k/ = /k/ SRE - /k/ ACE
2. Intergesture Interval (ii) = /l/ ACE - /k/ SRE
3. /l/ = /l/ SRE - /l/ ACE

From these measures, it is possible to determine whether a given production mode has a marked effect on the duration of the /kl/ sequence. This temporal data also tells us something about the relative duration of each gesture and about a potential reorganization between production in words (nonsense/isolated real words) and in sentences.

RESULTS AND INTERPRETATION

Duration of /kl/ Phases

The results indicated that in-sentence production led to quite a large reduction (17.5%) in the overall duration (in ms) of the consonant cluster /kl/ (Table 1).

	Word		**Sentence**		**Word/sentence differences**
	mean	**s.d.**	**mean**	**s.d.**	**(in % of phase duration)**
/k/	117	41	116	17	**- 0.90**
ii	73	35	27	16	**- 63.00**
/l/	56	25	62	18	**+ 10.70**
/kl/	246	?	203	20	**- 17.50**

Table 1. Mean duration of /kl/ phases and entire /kl/ sequence (in ms), and difference between the two production modes expressed as a percentage.

The speech rate did not have the same effect on all phases in the sequence. The /k/ was hardly affected compared to the /l/, whose duration increased. More pronounced, however, was the effect on the intergesture interval (the transition between the two phases), which underwent the greatest change brought about by speech rate.

Expressing the phases as proportions of the whole sequence tells us more about the influence of speech rate and its variable effect across phases. As Figure 3 clearly shows, it is indeed the intergesture interval that was affected the most, even in terms of proportions.

Figure 3. Phases depicted as proportions of the whole /kl/ sequence, pronounced in a nonsense/isolated real word, and in a sentence.

Careful examination of Table 2 gives us a better picture of the changes in the proportions of the different phases of the /kl/ sequence articulated in a sentence or in a word. While the intergesture interval decreased considerably (by more than a half), the share occupied by /k/ and /l/, proportionately speaking, increased substantially (by 1/5 to 1/3) between the word and sentence production contexts. Thus, one cannot really speak of /k/ and /l/ shortening in the /kl/ sequence produced in a sentence. From a temporal standpoint, the essential difference between production in nonsense/isolated real words, and production in sentences, lies in the transition phase (ii).

	Word	Sentence	Word/sentence difference (in % of phase proportions)
/k/	47	57	+ 21.30
ii	30	13	- 56.70
/l/	23	30	+ 30.40
/kl/	**100**	**100**	

Table 2. /kl/ phase proportions, and difference between the two production modes.

Overlap Index

Did the sharp decrease in the /k/-to-/l/ transition, which took less time in the sentence, also show up in the OI values?

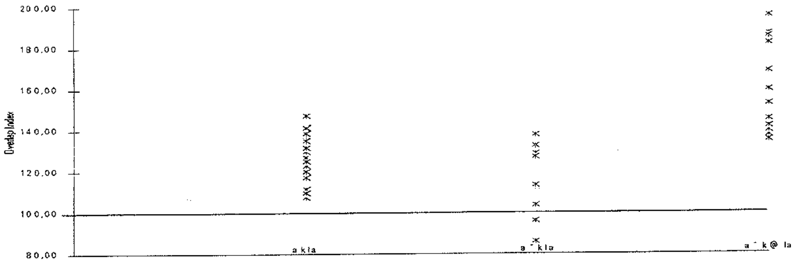

Figure 4. OI value obtained for each realization of the consonant cluster /kl/, in each phonotactic context.

We can see from Figure 4 that there were actually only two cases of overlap in our corpus. Both these are realised in unstressed position.

Table 3 shows how the amount of overlap changed between production in a sentence and production in a nonsense word or isolated real word. Note that these figures do not include cases where the sequence /ãkla/ was pronounced /ãkəla/ (52% of the realizations), or cases where the occlusion of the /k/ was incomplete and for which no oral airflow curve was available (20% of the realizations).

	AD	GC	GM	mean
Sentence	116.41	132.09	130.53	**123.61**
s.d.	15.20	7.77	5.08	14.26
Word	112.20	163.40	130.80	**135.47**

Table 3. Mean Overlap Index, by subject and production mode.

These results indicate that the tendency to overlap was not very strong in the sentence context either, although the intergesture interval was much shorter in this production mode. However, the mean Overlap Index did decrease sharply between the two production modes.

CONCLUSION

The inherent constraints of /l/ articulation appear to prevent overlap in the consonant cluster /kl/, whether produced in a nonsense word, in a word real, or in a sentence. The speech rate does not seem to lead to a true modification in phase timing. Lingual gesture timing remains linear, with the different phases articulated in succession.

In line with the results obtained by Gibbon et al. (1993), we cannot speak of free coarticulation for this consonant cluster; the dorsum and the apex of the tongue do not appear to be independent. Consequently, as a preliminary answer to the question raised above, we can say that for the consonant cluster /kl/, these two parts of the tongue do not behave as independent articulators.

However, the corpus analyzed here was read. It would be worthwhile to determine whether, in a spontaneous speech context, the decrease in the Overlap Index (word : 135.47; sentence : 123.61) between production in a nonsense/isolated real word and production in a sentence, lead to the fusion of the articulatory gestures of the two consonants /k/ and /l/, including a particular focus on stress effects on coarticulation in this cluster.

The alternative account, which we propose to verify in a future study, hypothesizes that aerodynamic constraints limit the occurrence of coproduction phenomena.

(1) For GM, there were only five repetitions and oral airflow was not recorded.

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