EFFECTS OF CONTRASTIVE FOCAL ACCENT ON LINGUOPALATAL ARTICULATION AND COARTICULATION IN THE FRENCH [kskl] CLUSTER

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ABSTRACT

This paper investigates the effects of contrastive focal accent placement on lingual articulation and coarticulation of French [kskl] clusters in word-medial position. The EPG results show that (i) this type of accent does not systematically increase the amplitude, but the duration of linguopalatal constrictions (particularly their release); (ii) it directly lengthens the temporal interval between the articulatory hold phases of two contiguous consonants; (iii) no matter what the accent position is, it can affect the whole cluster; (iv) the gestural co-ordination of biconsonant sequences seemed to vary with the focal accent more according to articulatory than syllable boundary rhytmic constraints.

1. INTRODUCTION

While several recent works have shown that prosodic structure affects the lingual articulation and the lingual coarticulation of vowels in CV production [1; 2], few studies have looked at its influence on the lingual articulation of consonants and the lingual coarticulation in CC production.

The latter mostly concerned the effects of word, phrase or sentence boundaries. It was found that lingual stops have larger linguopalatal contact in word-initial than medial or final position [3; 4]. In initial position of a prosodic constituent, the duration and area of linguopalatal contact increased with constituent height in the prososdic hierarchy [5]. Moreover, a lingual consonant sequence in word-initial position [4] or separated by a sentence boundary [6] has less articulatory overlap. In contrast, only few studies analysed the influence of a prominence on lingual consonant articulation. [7] found that /t/ has a larger front linguopalatal contact in lexically stressed syllables than in unstressed one. [8] reported higher midsagittal tongue position for alveolar consonants produced in nuclear accent context than non-nuclear one. Finally, up to now no systematic investigations have been carried out on the effects of prominence on coarticulation in consonant sequences.

For this reason, in this study we analysed effects of contrastive focal accent (CFA) on the lingual articulation and coarticulation of a four-consonant cluster [kskl] uttered in word-medial position. We mainly focused our attention on four questions: Does CFA strengthen lingual consonant articulation? Does CFA reduce the temporal coproduction of adjacent lingual consonants in the cluster? Does the accent position distinctively affect the cluster, and to what extent? Can the extent of the CFA effects on the consonant articulation and coarticulation be used to determine syllable boundary position within this cluster?

2. METHOD

2.1. Speech material and speakers

The corpus was composed of a four-consonant cluster [kskl] produced in a vocalic [ɛ_a] context in the middle of a disyllabic word ("exclame" [ɛksklam], meaning "exclaim"). This word was embedded in a carrier sentence read at normal speaking rate by two French speakers (B and Y). Stress was alternatively induced on three different portions of the sentence as an answer to a question from the experimenter simulating a misunderstanding about a specific part of the target sentence. The [kskl] cluster was therefore either in unaccented (UA), left-accented (LA) or right-accented (RA) position: UA = "J'ai DIT: "Pam e*xcl*ame même sa peine"", as an answer to "Tu as PENSÉ: "Pam exclame même sa peine"?" (10 repetitions); LA = "J'ai dit: "Pam E*xcl*ame même sa peine"", as an answer to "Tu as dit: "Pam DÉclame même sa peine"?" (20 repetitions); RA = "J'ai dit: "Pam e*xCL*AME même sa peine"", as an answer to "Tu as dit: "Pam EXPRIME même sa peine"?" (20 repetitions).

We also checked that the CFA's were produced at the expected position. Since contrastive prominence is generally cued by a peak accent in French, an analysis of variance carried out on the maximum F0 value of [ɛ] and [a] showed that it was significantly higher in the accented context than in the unaccented one for both speakers and vowels ($p < .0001$).

2.2. EPG acquisition and analysis

Points of contact of the tongue with the hard palate were sampled every 5 ms by means of a 62-electrode electropalatographic equipment (EPG Reading System). The EPG signal enables to account for timing, localisation and amplitude of linguopalatal constrictions. Our EPG data analysis and reduction was based on Byrd's empirical region definition [9] which was used to determine an EPG articulatory zone specific for each lingual consonant. Specifically, we defined for each speaker a tight posterior

zone (related to [k]) and a tight anterior zone (related to [s] and [l]). The spatio-temporal evolution of the different linguopalatal constrictions involved in the production of [kskl] were thereafter estimated by simultaneously calculating the percentage of contacted electrodes relative to the total number of electrodes in each zone.

2.3. EPG measurements

All measurements were based on the temporal and spatial values of four basic events of a lingual consonant articulation. The beginning *(ON)* and the end (*OF*) of a constriction were respectively defined by the first and the last EPG frame with at least one linguopalatal contact in the EPG zone of the consonant. The beginning (*bHP*) and the end (*eHP*) of the articulatory hold phase were respectively defined by the first and the last EPG frame of a quasi stable plateau of maximum contacts (see Figure 1).

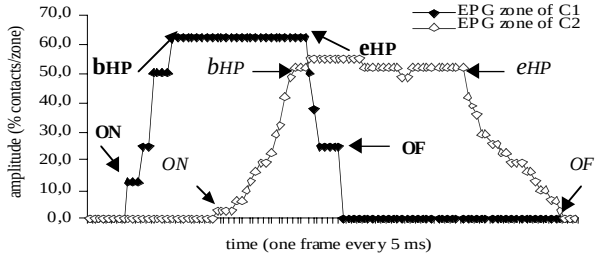

Figure 1: Curves of spatio-temporal evolution of EPG contacts of a [ks] sequence

Temporal measurements The durations of four consonant phases were considered: the linguopalatal constriction (*durSQ = OF – ON*); its approach (*durON = bHP – ON*); its articulatory hold phase (*durHP = eHP – bHP*) and its release (*durOF = OF – eHP*). The durations of four interconsonant phases were also considered: the articulatory overlap of two contiguous constrictions (*overlap C_1C_2 = OF C_1 – ON C_2*; occurred for all items but one), the inter-hold-phase interval (*interHP C_1C_2 = bHP C_2 – eHP C_1*), the part of the consonant which was not overlapped by the preceding one (*nov1 C_n = durSQ C_n - overlap $C_{n-1}C_n$*), or by the following one (*nov2 C_n = durSQ C_n - overlap C_nC_{n+1}*).

Amplitude measurements In order to estimate the linguopalatal constriction magnitude of each consonant and each consonant phase, the average percentage of contacted electrodes in the corresponding EPG zone was calculated (*mct = number of contacted electrodes in an EPG zone / number of electrodes of the zone*).

Velocity measurements For each consonant, the approach and release velocities of the linguopalatal constriction were calculated (*velON = [bHP amplitude – ON amplitude] / durON; velOF = [eHP amplitude – OF amplitude] / durOF*).

2.4. Statistical analysis

We analysed the data by means of Fischer's PLSD post hoc tests at 5% significant level (Table 1) and linear correlations estimated by means of the R^2 coefficient of linear regressions (Table 2).

3. RESULTS

3.1. Effects on contact amplitude

Concerning the effects of a CFA on the amplitude of the linguopalatal contact, the speakers showed two opposite articulatory behaviours (see Table 1). B had a smaller linguopalatal contact in the accented context than in the unaccented one. This decrease of amplitude concerned all consonants (especially the anterior ones), except [k_1]. Conversely, Y's amplitude of linguopalatal constrictions were larger in accented contexts, excepted for [l]. Nevertheless, both speakers' approach and hold phases of linguopalatal constrictions were more sensitive to the CFA than their releases.

3.2. Effects on duration and timing

Table 1 shows that for B and Y the durations of all sequences (excepted [kl] for Y) increased significantly in the accented contexts as a consequence of the lengthening of [k_1], [s] and [k_2]. For [l], the presence of CFA produced shortening, especially in the RA context. This opposite behaviour could be explained by a larger, earlier and/or faster lowering of the jaw in an open vowel context affecting particularly apical closing gestures [1; 8]. Moreover, the variation of duration was not uniform among the consonant phases. Only the release duration was significantly and systematically affected by CFA while the approach and the hold phase remained fairly constant.

Regarding the interconsonant phases, the duration of both the non-overlapped parts of the consonants (excepted [k_2] and [l] for Y) and the overlap regions were increased (excepted for [kl]) in CFA contexts. The durations of these two interconsonant phases were nevertheless positively correlated with the durations of the consonants or the biconsonant sequences (see Table 2). The variations of these phase durations seemed not to be completely and directly due to the presence of an accent, but partly due to the modification of the consonant duration in accented conditions. Furthermore, the proportion of these phases (related to the consonant or sequence duration) was not correlated with the duration of the consonant or sequence. The lengthening or shortening of a consonant due to CFA may thereby have a proportional repercussion on the duration of its non-overlapped and overlapped parts.

In contrast, the duration of the inter-hold-phase interval and its proportion relative to the sequence duration were not correlated with the duration of the biconsonant sequence (see Table 2) and were significantly lengthened in the accented contexts for [sk] and [kl] (see Table 1). Hence, for certain types of biconsonant sequences, the presence of CFA at an edge of the cluster influenced directly the co-ordination of the two contiguous consonants by involving a longer temporal interval between their articulatory hold phases.

3.3. Effects on velocity

For both speakers, like for the phase durations, the approach velocities were mostly independent of CFA while release velocities varied with it. This could suggest that gesture onsets are more invariant than their offsets.

Only [k_2] showed a modification of the velocity of its release and its approach in the accented contexts for both speakers. The release velocity of [l] was especially increased in CFA condition. This was likely due to the interaction of a lower, earlier and/or faster opening of the jaw induced by the following accented [a].

3.4. Extent of the CFA effects

Here we consider only the phases directly and systematically affected by an accent (see Table 1).

Concerning the effects of the position of CFA (LA *vs* RA) on the consonants, the approach and the hold phase amplitude of the linguopalatal constrictions did not vary with accent position. The influence of accent position on duration was homogeneous between consonants and their release but not between speakers. The consonant and release durations indicated that the articulatory effects of CFA in LA position extended up to [l] for B and Y, but that its predominant influence relatively to the RA position stopped at [l] for B and [k_2] for Y. CFA in the RA position affected the cluster up to [k_1] for B and up to [s] for Y, but its superior influence relatively to the LA-position influence stopped at [s] for B and [l] for Y.

The only result shared by Y and B was the predominant influence of the accent in the RA position on the duration of [l] and its release. For B, the more important effect of the LA context on [l] duration is misleading. In RA context, [l] could be subject to two conflicting influences: a shortening due to the opening of the jaw due to the following accented [a], and a lengthening due to the accented context (as for the other consonants). While for Y the first influence was more important, for B there was a conflict between them in RA context. This conflict could have lead B to an articulatory compromise, neutralising the distinctive effect of the RA condition (ms averaged duration: UA = 97; LA = 78; RA = 93). An examination of the duration and the velocity of its release confirms this point of view. For the second half of the cluster, i.e. for [k_2] and [l], both speakers' velocities depended only on the right-position CFA. For the first half of the cluster, i.e. for [k_1] and [s], only Y's velocity depended exclusively on the left-position CFA.

About the extent of CFA effect within the cluster, two main points can be raised about the duration and the temporal interval between the hold phase of each biconsonant sequence. First, while Y did not show any significant difference between left- and right-accented condition, B was almost only influenced by the CFA in the RA position for [kl] to [sk]. Secondly, for both speakers the inter-hold-phase interval of [ks] was not affected by an accent, while its duration was indistinctly influenced by both accent contexts.

4. DISCUSSION

4.1. Articulatory correlates of the CFA

The clear opposition between the speakers, regarding CFA influence on the magnitude of the linguopalatal constrictions (see [3]), confirms that several active strategies may exist to the purpose of strengthening supraglottal consonant gestures in accented syllables: realising a larger linguopalatal constriction of the approach and the hold phase and/or a longer release of the linguopalatal constriction. The latter combined with the lengthening of the entire consonant could protect the hold phase of a consonant from being too encroached by the following one. This is corroborated by the fact that a CFA imposes directly a longer gap between the linguopalatal hold phases of two contiguous consonants, although it does not involve the expected temporal reduction of the articulatory coproduction of two linguopalatal consonant gestures (on the contrary).

So, CFA seems to influence the co-ordination of two linguopalatal consonants only by emphasising their articulatory hold phases (with a likely perceptual aim) and not necessarily reducing coproduction.

4.2. Articulatory marking of the syllable boundary

The type of consonant cluster studied here is most interesting with regard to its syllabification. A phonetic approach based on the sonority hierarchy cannot predict a syllable boundary in the word-medial [kskl] cluster (because of the position of [s], which is more sonorous than [k]). Conversely, the biconsonant phonotactic distribution and its morphological structure based on the Latin etymology predict that the syllable parsing should be /ks.kl/.

We can accordingly expect that CFA would strengthen the articulatory marking of the syllable in two different ways. (1) It would affect more the segments belonging to the accented syllable than the other ones. The limit of the extent of its influence may thereby correspond to the syllable boundary. (2) It would reduce the articulatory cohesion for the pair of consonants straddling the syllable boundary (i.e. /s.k/) by reducing the overlap duration and by increasing the inter-hold phase interval, and it would increase (or not affect) the articulatory cohesion between tautosyllabic consonants (i.e. /ks/ and /kl/).

The results do not validate the first hypothesis. Though the effects of the CFA depended on its position in several cases, it appears that whatever its position, the CFA was able to influence the articulation of the whole cluster. No obvious articulatory limits emerged for two reasons. Firstly, the articulation of each speaker was modified in a different way by the CFA. Secondly, the results show an important overlap between the limit of the extent of the influence of the CFA at the left edge of the cluster and the CFA at its right edge. The articulatory influence of a CFA did not only affect the accented syllable but also the preceding or following one.

The second hypothesis is not confirmed by the results either. In fact, [ks]' articulatory cohesion was not significantly increased by an accent. And if [sk]'s was reduced by both CFA contexts, it was identical for [kl]. Hence, CFA may influence the articulatory co-ordination between two consonants more according to intrinsic articulatory / aerodynamic constraints than rhythmic ones induced by the syllable boundary. This account is especially supported by the opposite behaviours of the inter-hold phase intervals of [ks] and [sk] when CFA is produced. In contrast with [ks], an essential aerodynamic requirement for [sk] could constraint the articulatory co-ordination between [s]' and [k]'s hold phases: the beginning of [k]'s cannot occur too early because it could truncate [s]' fricative noise. This constraint could explain why the temporal interval between each articulatory hold phase is especially increased in an accented context for [sk] and not for [ks]. For [ks], no real or obvious articulatory constraints could be specified, so the biconsonant does not need to be especially emphasised in a CFA context. This hypothesis is supported by a significant shorter overlap in [sk] compared to [ks] (ms average duration for the undifferentiated speakers and CFA conditions: [ks] = 97, [sk] = 79; $p < .0001$).

5. REFERENCES

1. Kent, R., and Netsell, R. «Effects of stress on certain articulatory parameters», *Phonetica* 24: 23-44, 1971.
2. Jong de, K., et al. «The interplay between prosodic structure and coarticulation», *Lang. & Sp.* 36: 197–212, 1993.
3. Keating, P. «Effects of prosodic position on /t,d/ tongue/palate contact», *13th ICPhS, Vol. 3, 1995, p. 432–435. Stockholm.*
4. Byrd, D. «Influences on articulatory timing in consonant sequences», *J. Phon.* 24: 209–244, 1996.
5. Fougeron, C., and Keating, P. «Articulatory strengthening at edges of prosodic domains», *J. Ac. Soc. Am.* 101: 3726–3740, 1997.
6. Hardcastle, W. «Some phonetic and syntactic constraints on lingual coarticulation during /kl/ sequences», *Sp. Com.* 4: 247–263, 1985.
7. Farnetani, E., and Vayra, M. «The role of prosody in the shaping of articulation in Italian CV syllables», *1st ESCA Tutor. and Res. Work. on Sp. Prod. Model., 1996, p. 9–12. Autrans.*
8. Jong de, K. «The supraglottal articulation of prominence in English: linguistic stress as localized hyperarticulation», *J. Ac. Soc. Am.* 97: 491–504, 1995.
9. Byrd, D., et al. «Using regions and indices in EPG data reduction», *J. Sp. & Hear. Res.* 38: 821–827, 1995.

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Mea.	Phase	Spk	k_1	s	k_2	l	ks	sk	kl
Amplitude	*mctON*	**B**	-	**3**	**3**	**3**			
		Y	-	3	3	**2 ***			
	mctHP	**B**	-	**1**	-	**3**			
		Y	3	3	3	-			
	mctOF	**B**	-	-	-	**1 ***			
		Y	-	1*	3	-			
	mctSQ	**B**	-	**3**	-	**3**			
		Y	1*	3	3	-			
Temporal	*durON*	**B**	-	-	-	2			
		Y	-	-	-	-			
	durHP	**B**	-	-	2*	-			
		Y	-	3	-	-			
	durOF	**B**	3	2>1	2	**2 > 1**			
		Y	1*	3	1*	**2***			
	durSQ	**B**	3	2>1	2	**1**	3	2	2
		Y	1*	3	1*	**2 > 1**	3	3	-
	nov1	**B**		3	1*	-			
		Y		3	**3**	**2**			
	nov2	**B**	1	2*	3				
		Y	-	3	3				
	overlap	**B**					2	3	**1***
		Y					-	3	**3**
	interHP	**B**					-	2	2>1
		Y					-	3	3
Velocity	*velON*	**B**	-	-	2*	-			
		Y	1*	-	3	-			
	velOF	**B**	2*	-	**2**	2			
		Y	1*	**1**	2*	2			

Table 1: Effects of the CFA relative to its position on amplitude, duration and velocity of the phases of the consonants/sequences for each speaker. Only the accents modifying significantly an articulatory phase relative to UA are indicated ($p < .05$; decreasing effect in bold). "1" = LA; "2" = RA; "3" = LA and RA undifferentiated; ">" = the CFA written on the left has a significant stronger effect; "*" = the indicated CFA has a significant effect relative to UA, but not to the other accented context; "-" = no significant difference between UA, LA and RA contexts

durSQ*	**nov1/2**		**overlap**		**interHP**	
consonant	.53	.00	.49	.00		
sequence			.47	.10	.00	.01

Table 2: Coefficient R^2 of linear regression between the interconsonant phase durations and the consonant / sequences ones. Each duration was measured either in ms (at the left) or relatively to the corresponding consonant / sequence duration (at the right). All consonants, sequences and speakers were pooled