Articulatory motivation of velar softening

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ABSTRACT

The present paper presents some evidence in support of the notion that velar softening, i.e., the change of front velars into palatal or alveolar affricates, may have an articulatory basis. Electropalatographic data for Majorcan Catalan show that the voiceless palatal stop [c] (an allophone of /k/ in this Catalan dialect) may exhibit a postpalatal, mediopalatal and/or alveolopalatal closure depending on speaker, position and vowel context. Burst spectra reveal that the front-cavity dependent peak for these articulatory realizations increases gradually from about 2500 Hz to 3000-3500 Hz as closure location becomes fronter along the postpalate and mediopalate, and stays at that frequency range with variations in closure location along the prepalatal and alveolar zone. In contrast with recent claims in the literature, these data suggest that velar softening may be associated with alveolopalatal realizations of a front velar stop and thus, not necessarily with the spectral characteristics of a front velar stop burst.

1. INTRODUCTION

Velar softening, i.e., the change of front velar stops into alveolopalatal or alveolar affricates and fricatives (Tuscan *piaccio* "I enjoy", from Latin PLACEO; French *racine* "root", from Latin RADICINA), has been attributed to the perceptual confusion between the bursts for the input and output phonetic segments [1]. Data from the Romance languages in the literature are in support of the notion that this sound change process may have an articulatory basis instead. Indeed, they show that velar stops before front vowels and /j/ may yield palatal, alveolopalatal and alveolar realizations through an increase in mediodorsal, predorsal and laminal contact [2]. These outcoming articulatory realizations could then be identified as alveolopalatal or alveolar affricates provided that their bursts are long and intense enough.

This paper presents some support for the articulatory origin of velar softening through an analysis of tongue contact patterns for the Majorcan Catalan palatal stop [c]. In this Catalan dialect, [c] is an allophone of the velar stop phoneme /k/ occurring in different segmental contexts and word positions (e.g., before front vowels, word finally) and showing different degrees of palatalization depending on speaker and geographical location.

2. METHOD

In order to investigate this issue, electropalatographic (EPG) and acoustic data were collected simultaneously for /k/ with adjacent /i/, /a/ and /u/ in word initial, intervocalic and word final position. Seven repetitions of real Catalan words containing these #CV, VCV and VC# sequences were uttered in meaningful sentences composed of a similar number of syllables by five speakers of Majorcan Catalan (AR, BM, MJ, ND, CA). Linguopalatal contact configurations were gathered every 10 ms using artificial palates equipped with 62 electrodes (Reading EPG-3 system). Acoustic data were digitized at 10 kHz, filtered at 4,8 kHz and processed with a Kay CSL analysis system using the same temporal resolution as the EPG signal.

Closure onset and offset were determined by the presence of full electrode activation on one or more rows of the artificial palate. Whenever closure was not available, stop boundaries were defined by the onset and offset of a maximum linguopalatal constriction period for the consonant, or of a formant structure period associated with the adjacent vowels. Linguopalatal configurations were identified at two temporal points, i.e., at PMC or EPG frame showing the highest number of on-electrodes over the entire palate surface, and at closure offset, and averaged across repetitions for each sequence and for each speaker.

As shown by the EPG contact patterns in Figure 1, linguopalatal contact takes place on eight rows of electrodes. The frontmost row 1 (just behind the upper teeth) is at the top of the graphs and the backmost row 8 (just in front of the soft palate) at the bottom. The artificial palate was subdivided into four articulatory zones for data interpretation, i.e., alveolar at the four front rows (A in the figure), prepalatal at rows 5 and 6 (B), mediopalatal at row 7 (C) and postpalatal at row 8 (D). Electrodes appear in black (80-100% electrode activation across repetitions), grey (40-80% activation) and white (less than 40% activation).

In order to find out whether variations in the articulatory implementation of palatal stops conveyed significant acoustic changes that could yield a front affricate percept, closure location was related to the front-cavity dependent spectral peak at the stop burst. The expected trend in this case was that closure fronting should cause a decrease in front cavity length and therefore, a frequency increase of the spectral peak associated with it which could be perceived as a /tʃ/-like noise [3].

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In order to estimate front cavity length, we measured the distance (in mm) between row 1 and the frontmost row where full closure was produced using the two central electrodes on each row as reference Full closure was taken to occur when all electrodes on a given row had been contacted more than 80% of the time across repetitions, or else when one of the electrodes had been activated 40%-80% of the time and the remaining electrodes had been activated more than 80%. Frontmost closure location was also taken to occur at row 8 if there was a constriction at that row and its two central electrodes had been contacted less than 80% of the time.

Analogously to previous studies [4], stop spectra for the #CV, VCV and VC# sequences of interest were obtained at burst onset, i.e., usually at the first frame after closure offset during the frication noise. Autocorrelation LPC spectra were computed with a 25,6 ms full-Hamming window and 14 coefficients. Spectra for each speaker were displayed on a 0-80 db scale, and subsequently overlaid and averaged.

In the spectral configurations, amplitude maxima were found to occur most of the time between 2500 Hz and 3500 Hz in the /i/ and /a/ contexts and below this frequency range in the /u/ context. Judging from the corresponding closure locations (usually at less than 4 cm behind the teeth), those spectral maxima may be taken to be the resonance of the mouth cavity in front of closure location. Indeed, according to [3], F2, F3 and F4 for palatal stops approach each other at about 2000-3500 Hz when the front cavity is about 3-4 cm long while an increase in front cavity length for velars causes F2 to lower.

Occasionally, spectra did not exhibit a frequency peak but a plateau, i.e., an amplitude maximum extending over a given frequency range. In this case, frequency measurements were taken at the midpoint of the plateau provided that the plateau was not interrupted by a spectral valley whose amplitude exceeded 5% of the overall signal amplitude for a given speaker.

3. RESULTS

Inspection of the linguopalatal contact configurations reveals that Majorcan Catalan /k/ may differ in closure location as a function of speaker, word position and vowel context. Thus, for example, closure location may occur at the palatal zone (i.e., at the prepalate, mediopalate and/or postpalate) in intervocalic position, and extend towards the alveolar zone word initially and word finally. Speakers also differ regarding closure location and extent. Indeed, as shown by the linguopalatal contact configurations for word initial /ka/ in Figure 1, the stop consonant shows an alveoloprepalatal realization for speaker AR, a closure extending all over the palatal zone for speaker MJ, and a closure extending all over the surface of the artificial palate for speaker CA. Contact configurations for speakers AR and CA (and the fact that closures at the palatal zone were found to be discontinuous in some cases) may be interpreted in the sense that speakers prefer alveolopalatal to mediopalatal realizations of palatal stops derived from velars.

Table 1 gives frequency variations of the front-cavity dependent spectral peak for /k/ as a function of front cavity length for all speakers and sequences at PMC and at closure offset. Thus, for example, data for speaker AR reveal that /#ki/ has a spectral peak at 3574 Hz which is associated with a 7,5 mm front cavity at PMC and with a 11 mm front cavity at closure offset. Speaker CA exhibits two linguopalatal configurations for /aka/, /ak#/ and /uk#/, i.e., a posterior one (the front cavity is 39,5 mm long in this case) and a front one exhibiting full closure all over the palate surface (now the front cavity is 0-3,5 mm long at PMC and 8 mm long at closure offset).

Data in Table 1 have been plotted in Figures 2 and 3 for analysis. Data in Figure 2 correspond to sequences where the stop is flanked by non labial /i/ and /a/ (at PMC, top; at closure offset, bottom) and allow investigating the effect of closure fronting on the spectral characteristics of the stop consonant. Those in Figure 3 correspond to sequences with the labial vowel /u/ (at PMC only) and should provide information about the acoustic consequences of closure fronting and lip rounding for the oral stop in this vowel context. In the figures, front cavity length values for speakers AR, BM, MJ and CA proceed from row 1 (at 0 mm) back to row 8 (at 39,1 mm), and may be subdivided into articulatory zones as follows: alveolar zone, extending from 0 mm to 10,9 mm; prepalate, from 10,9 mm to 24,5 mm; mediopalate, between 24,5 mm and 31,4 mm; postpalate, beyond 31,4 mm. Data points at 45 mm correspond to speaker ND exclusively since this was always the distance between rows 1 and 8 for this speaker.

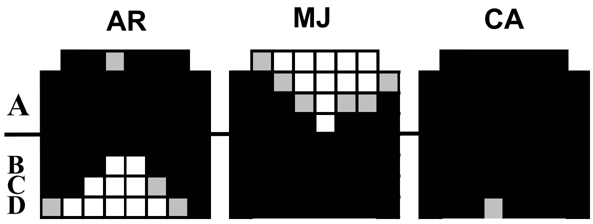

Figure 1: Contact patterns for word initial /ka/ in Majorcan Catalan (3 speakers). Articulatory divisions correspond to (A) alveolar, (B) prepalatal, (C) mediopalatal, (D) postpalatal.

Data points at PMC in Figure 2 indicate that, while closure location may occur anywhere over the palate surface, maximum closure fronting takes place most frequently at the alveolar zone (for alveolopalatal articulations) and at the medio-postpalatal zone (for medio-postpalatal or postpalatal articulations). Indeed, most data points in the figure are located within a 0-11 mm front region or within a 28,5-41,5 mm back region. Only in a few instances maximum closure fronting occurs at the prepalate, i.e., between 11 mm and 28,5 mm (for articulations extending simultaneously over the prepalate, mediopalate and postpalate).

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The regression line in the figure (r^2 = 0,6345) also reveals that the frequency of the front-cavity dependent spectral peak increases gradually from about 2500 Hz to 3000-3200 Hz as closure location is fronted along the postpalate and mediopalate. Closure fronting along the prepalatal and alveolar zone does not cause any additional frequency rise. The inflection point occurs at about 25 mm which is precisely where the mediopalate meets with the prepalate. The fact that this frequency maximum is very similar to the spectral peak for a palatoalveolar affricate (at about 3000-3500 Hz; [5]) accords with the hypothesis that [c] is prone to be perceived as /tʃ/ if articulated at the alveolopalatal zone.

Data at closure offset (Figure 2, bottom) reveal that frontmost closure location at this temporal point occurs essentially at the mediopalate and postpalate (except for speaker AR and occasionally for speaker CA for whom closure location may take place at the back alveolar zone). Differences in closure location between PMC and closure offset are due to the fact that the release of alveolopalatal consonants proceeds from front to back, i.e., central contact becomes more posterior as closure offset is approached. Analogously to the scenario at PMC, the regression line (r^2 = 0,4795) shows that, also at closure offset, the frequency of the spectral peak rises as closure location becomes fronter along the mediopalate and postpalate but not so if fronted along the prepalate and the alveolar zone.

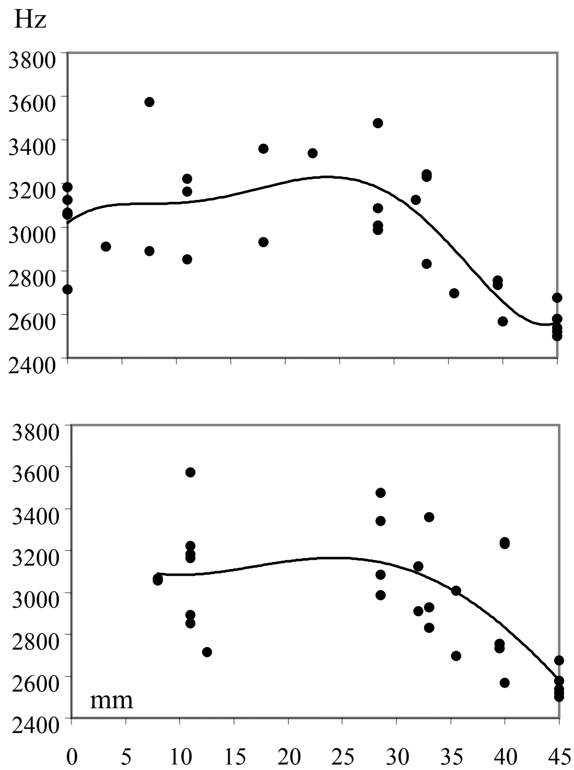

Figure 2: Frequency variations of the front-cavity dependent spectral peak as a function of front cavity length at PMC (top) and at closure offset (bottom). Data correspond to /k/ in the context of /i/ and /a/.

Data for /k/ in the context of /u/ in Figure 3 reveal that stop closure takes place at the back palate most of the time, thus rendering /k/ a medio-postpalatal or velar articulation in this vowel environment. Only in a few cases closure for /uk#/ (crosses) and /uku/ (empty circles) takes place at the front rows of the artificial palate. The frequency of the front cavity spectral peak is very different for the three sequences, i.e., it decreases in the progression /uk#/ (at 2400-3000 Hz) > /uku/ (1200-2200 Hz) > /#ku/ (about 600-1200 Hz). These spectral differences are in agreement with the prominence of anticipatory lip rounding in speech production [6].

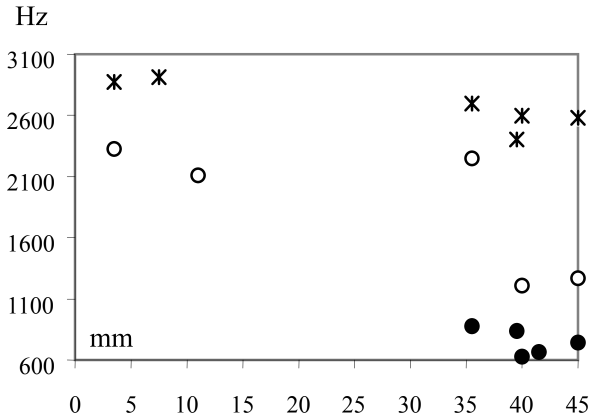

Figure 3: Frequency variations of the front-cavity dependent spectral peak as a function of front cavity length at PMC. Data correspond to /#ku/ (filled circles), /uku/ (empty circles) and /uk#/ (crosses).

4. DISCUSSION

Data reported in this paper show that palatal stop allophones of /k/ may be articulated with different degrees of closure fronting starting at the back palate all the way to the alveolar zone. At least two classes of palatal consonants may be identified, i.e., alveolopalatal and palatal proper. These data are in agreement with palatographic evidence from Romance dialects. Indeed, medio-postpalatal realizations of [c] are documented for Majorcan Catalan and Romansh in the literature ([7, 8]). On the other hand, front /k/ may also be implemented as a palatalized dentoalveolar [9] and be frequently heard as /tj/ or /t/, e.g., [tju] (CULU, "bottom") in Haute Loire, [keˈti] ('French *celui-ci*', "this one") in Provence [10, 11].

As suggested above, the large array of articulatory realizations for palatal consonants generated from a velar source through closure fronting may be sought in the difficulty involved in making a full dorsal closure at the hard palate. In agreement with this hypothesis, palatal consonants such as /ɲ/ and /ʎ/ are typically alveolopalatal in Romance [12]. Once preferred alveolopalatal productions come to exist, palatal stop releases may sound /ʃ/-like thus rendering the change /k/> [tʃ] possible. In agreement with this possibility, it was found that fronting closure location along the palatal zone causes the frequency

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of the front-cavity dependent peak at the stop burst to increase up to 3500 Hz which coincides with the strongest energy concentration for /ʃ/.

Variations in closure placement along the alveolar zone did not yield an additional frequency increase which would have accounted for the fact that velar softening may also give rise to [ts], [s]. The assumption in this case is that a front stop closure would be integrated as an alveolar affricate if produced at the alveolar zone in a similar fashion to the affrication of /tj/ (Tuscan [ˈpreddzo] from PRETIU, "price"). This negative finding may be indicative of the fact that Majorcan Catalan does not take full advantage of closure fronting while favoring palatal productions which are implemented either at the alveolopalatal or at the medio-postpalatal zone.

ACKNOWLEDGMENTS

This research was funded by projects 2001SGR425 (Generalitat de Catalunya) and BFF2000-0075-C02-01 (Ministry of Science and Technology, Spain).

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	Speaker AR		
#ki	7,5	11	3574
#ka	0	11	3184
#ku	41,5	41,5	664
iki	11	11	3223
aka	11	11	3164
uku	11	11	2109
ik#	11	11	2852
ak#	7,5	11	2891
uk#	7,5	11	2910

	Speaker BM		
#ki	22,5	28,5	3340
#ka	28,5	28,5	3477
#ku	35,5	35,5	879
iki	28,5	28,5	3086
aka	35,5	35,5	2695
uku	35,5	35,5	2246
ik#	28,5	28,5	2988
ak#	28,5	35,5	3008
uk#	35,5	35,5	2695

	Speaker MJ		
#ki	18	33	3359
#ka	18	33	2930
#ku	40	40	625
iki	33	33	2832
aka	40	40	2568
uku	40	40	1211
ik#	33	40	3242
ak#	33	40	3232
uk#	40	40	2598

	Speaker ND		
#ki	45	45	2539
#ka	45	45	2500
#ku	45	45	742
iki	45	45	2578
aka	45	45	2520
uku	45	45	1270
ik#	45	45	2578
ak#	45	45	2676
uk#	45	45	2578

	Speaker CA		
#ki	0	32	3125
#ka	0	12,5	2715
#ku	39,5	39,5	840
iki	32	32	3125
aka	39,5	39,5	2754
	0	8	3057
uku	3,5	25,5	2324
ik#	3,5	32	2910
ak#	39,5	39,5	2734
	0	8	3066
uk#	39,5	39,5	2402
	3,5	8	2871

Table 1: Front cavity length in mm at PMC (leftmost column) and at closure offset (central column), and frequency of the spectral peak at stop burst in Hz (right column). Data are given for all sequences and speakers under analysis in the present study.