



ARTICULATORY AND ACOUSTIC PROPERTIES OF DIFFERENT ALLOPHONES OF /l/ IN AMERICAN ENGLISH, CATALAN AND ITALIAN

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ABSTRACT

This paper attempts to investigate whether velarization is a scalar articulatory feature and if an increase in degree of velarization conveys an increment in the degree of constraint upon tongue dorsum activity. Electropalatographic and acoustical data for [l] in different languages and contextual conditions allow isolating three degrees of velarization in the consonant. Precise articulatory and acoustic correlates are given for each velarization group. Moreover V-to-C coarticulatory effects in dorsopalatal contact were found to decrease with degree of velarization for [l] thus suggesting that changes in degree of velarization convey modifications in degree of articulatory constraint.

I. INTRODUCTION

The velarization of [l] is associated with the formation of a secondary constriction at the velopharyngeal region with the postdorsum and some lowering of the predorsum. Acoustic studies [3] have shown that those articulatory modifications cause a F1 increase and a F2 decrease with respect to non velarized allophones of the consonant. Moreover it has been acknowledged that [l] may be produced with different degrees of velarization depending on different factors: language - e.g., the consonant is velarized in Russian but slightly palatalized in Irish English [2]; position within the syllable - e.g., British English Received Pronunciation has a 'clear' allophone in syllable initial position and a 'dark' allophone in syllable final position [1]; vowel context - e.g., the degree of velarization increases with adjacent back vs front vowels. The main goal of this paper is to establish those variations in the articulatory and acoustic correlates of velarization which may occur as a function of those three factors.

The paper also investigates the hypothesis that vowel-dependent coarticulatory effects on [l] decrease as the degree of velarization for the consonant increases. This hypothesis is based on the assumption that velarization involves a high degree of constraint on tongue dorsum activity. A similar trend has been observed for syllable-final vs syllable-initial [l] in British English RP [1], and for intervocalic 'dark' vs 'clear' [l] in Catalan and Spanish or Italian, respectively [4][5].

II. METHOD

Electropalatographic (EPG) and acoustical data were recorded for syllable-initial and syllable-final [l] with adjacent [i], [a] and [u]. Syllable-initial [l] occurred in absolute initial position and in symmetrical intervocalic sequences; syllable-final [l] occurred in preconsonantal position and in absolute final position. The speech material consisted of meaningful sentences of English, Catalan and Italian. The sentences were read nine times by one male speaker of American English (New York City dialect), one male Catalan speaker (Eastern Catalan dialect) and one female speaker of Italian (Northern variety of Standard Italian). Those language dialects were chosen since [l] has been reported to be non velarized in Italian and velarized in American English and Catalan in the phonetics literature.

The Rion Model DP-01 was used for electropalatographic recording and analysis. Electrodes on the surface of the artificial palate have been arranged in seven horizontal rows for data analysis and interpretation, as shown in Figure 1. The four front rows correspond to the alveolar zone and the four back rows to the palatal zone. LPC spectral analysis was performed using ILS (Interactive Laboratory System). Both articulatory and acoustic data points were sampled every 15.6 ms. Measurements were taken at the midpoint of the [l] closure as determined on the EPG display. Data reported in this paper represent averages across repetitions (all nine repetitions in the case of the palatographic data, and a subset of five repetitions in the case of the acoustic data).

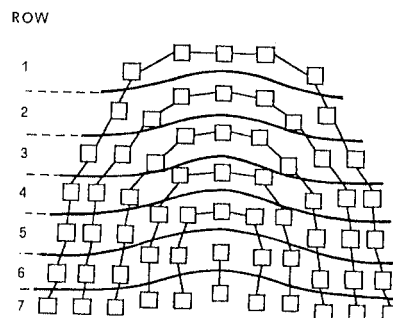


Figure 1. Electropalate. Electrodes on the surface of the artificial palate have been arranged in seven horizontal rows.

III. RESULTS

3.1 Articulation.

3.1.1 Degree of velarization.

The EPG data on Figure 2 have been plotted as a function of language (left, mid and right columns of graphs), syllabic position (upper, mid upper, mid lower and lower rows of graphs) and vocalic context (continuous, dashed and dotted lines on each graph). Each of the 12 graphic displays in the figure shows the percent frequency of electrode activation (vertical axis) on each row of electrodes (horizontal axis). Linguopalatal fronting on each graph progresses from left to right.

Alveolar contact is more extended and retracted (and thus presumably more laminal) in Italian than in Catalan and in American English, and less extended in syllable-final than in syllable-initial position in these two latter languages. Preconsonantal [l] was produced by means of a vowel-like gesture and no alveolar closure in American English.

The amount of dorsopalatal contact for [l] in Italian generally exceeds that for the consonant in the other two languages, consistently so when the adjacent vowel is [i]. This contrast is crucial to establish cross-linguistic differences in degree of velarization. The expected trend is for [i] to cause less dorsopalatal contact as [l] becomes more velarized, the reason being that [i] and velarized [l] are produced by means of antagonistic gestures while [i] and non-velarized [l] are not. On these grounds it can be claimed that [l] is less velarized in Italian than in Catalan and American English since the percent frequency of electrode activation for the consonant when adjacent to [i] is always higher for the former (between 40 and 60) than for the latter (below 40).

The extent of dorsopalatal contact is also higher in syllable-initial vs syllable-final position in Catalan and American English. Accordingly, percent frequency of electrode activation for [l] when adjacent to [i] is found between 20 and 40 in the former context, and below 20 in the latter. A similar trend is observed when the consonant is adjacent to [a] and [u].

In summary, velarization conveys a decrease in degree of linguopalatal contact both at the palatal zone and at the postalveolar zone. The consonant is more velarized in Catalan and American English than in Italian, and in syllable-final vs syllable-initial position in the two former languages. Therefore we can differentiate between three degrees of velarization in the consonant, namely, for Italian [l] in all syllabic positions (minimal degree), for syllable-initial [l] in Catalan and American English (intermediate degree), and for syllable-final [l] in these two languages (maximum degree).

3.1.2 V-to-C coarticulation.

The degree of V-to-C coarticulation at the palatal zone was inferred from a calculation of the coarticulation index (CI) at that articulatory location. CI was obtained by summing up the differences in linguopalatal contact between pairs of contextual vowels, and averaging those differences over the four back rows.

Results show that syllable-initial CI is about two times larger in Italian (25 to 40) than in Catalan and American English (10 to 20). Linguopalatal contact varies according to fronting and height in the adjacent vowel (mostly in the progression [i]>[u]>[a]) in Italian, to vowel fronting in Catalan and to vowel height in American English. The cross-language contrast in CI values is even larger in syllable-final position due to the absence of vowel-dependent

effects in Catalan and American English (CI value= 2 to 7) vs the presence of effects in Italian (CI value= 25 to 40). Again, the degree of dorsopalatal contact for [l] changes as a function of vowel height and fronting in Italian.

It can be concluded that the CI value decreases as the extent of dorsopalatal contact for the consonant decreases. Moreover the degree of V-to-C coarticulation appears to be inversely related to the degree of velarization in the consonant.

3.2 Acoustics.

Several ANOVAs were performed with F1 and F2 of [l] independently for each language. The effects of the following parameters were investigated: syllable position (syllable-initial vs syllable-final), contextual vowel ([i] vs [a] vs [u]), status of the phonetic segment opposite to the contextual vowel (presence vs absence of a preceding vowel in open syllables, and of a following consonant in closed syllables). ANOVAs for American English were only carried out in symmetrical VCV sequences due to limitations associated with the diphthongal nature of syllable-final [l] in that language. The level of significance was set at 95 %.

Articulatory-acoustic concomitances are also specified. The vowel [u] is not taken into consideration since its F2 is not only related to tongue movement but to lip rounding as well. It should be emphasized that while the EPG data only provide information about linguopalatal contact, the acoustic data are conditioned by articulatory changes taking place along the entire vocal tract.

F1 was found to vary significantly as a function of syllable position in Italian and Catalan, and vowel context in American English, Italian and Catalan. F1 of [l] is higher with low vs high vowels in the two syllable positions, more so in Catalan and American English than in Italian. More vowel-dependent acoustic variability in the two former languages than in the latter language is not consistent with the EPG data and may be associated with changes in jaw opening activity and/or tongue body configuration. F1 is higher in syllable-final than in syllable-initial position, quite more so in Catalan than in Italian. Considering F1 is inversely correlated with dorsopalatal contact size [6] these acoustic data suggest the existence of a higher degree of velarization in syllable-final vs syllable-initial position (at least in Catalan) which is consistent with the EPG data.

F2 is affected significantly by vowel context in Italian, American English and Catalan, and syllable position in Catalan. F2 of [l] decreases in the progression [i]>[a]>[u]. Consistently with the EPG data, vowel-dependent coarticulatory effects for [i] vs [a] in Catalan occur in syllable-initial position but not in syllable-final position; in Italian however they take place in intervocalic position only, which is in partial disagreement with the EPG data. Catalan shows higher formant values in syllable-initial position than in syllable-final position. Considering F2 is directly related to dorsopalatal contact size and tongue body fronting [6] these acoustical data allow assuming (in agreement with the EPG data) that syllable-final [l] is more velarized than syllable-initial [l] in Catalan. Results from the statistical analyses also reveal a significant contribution of the status of the opposite vowel in Italian (formant values of [l] in absolute initial [la] and [lu] are higher than those in intervocalic [ala] and [ulu]).

F2 frequency is quite higher for non-velarized [l] in Italian than for velarized [l] in Catalan and American English;

thus, for example, F2 of intervocalic [l] with adjacent [a] is at 1630 Hz in Italian, and at 1020 Hz in Catalan and at 720 Hz in American English. Such a notorious contrast in F2 height between the two groups of languages cannot be attributed to sex-related differences between speakers but to differences in degree of velarization in the consonant. In accordance with acoustic differences in degree of velarization, the EPG data reported in section 3.1 show more considerable dorsopalatal contact in Italian than in the other two languages.

Acoustic data reported in this section are in overall agreement with the EPG data in confirming the existence of three degrees of velarization for [l]. The articulatory-acoustic correspondence is more accurate for those allophones which are related to syllable position than for vowel-dependent allophones. This finding suggests that variations in other articulatory parameters besides linguopalatal contact size occur for different contextual vowels.

3.3 Articulatory-acoustic correlations.

To gain a better understanding of the acoustic correlates of velarization (especially concerning changes in degree of velarization caused by different vowels) articulatory-acoustic relationships were assessed for Catalan and Italian by means of a series of correlation analyses between the mean values for different parameters. Changes in EPG contact for [l] across syllabic positions were correlated with F1, F2 and F2-F1. Separate correlations were obtained for contextual [i], contextual [a] and cross-vocalic CI. The vowel [u] was excluded for reasons pointed out in section 3.2. Only the highest correlation values will be given.

Italian shows a direct correlation between changes in EPG contact and F2-F1 ($r = .98$) and F2 ($r = .96$) when the consonant is adjacent to [i], and a direct correlation between changes in EPG contact and F2 ($r = .99$) when the consonant is adjacent to [a]. As for the relationship between CI and formant frequencies, the highest r value (.90) was observed between CI and the difference between context [i] and context [a] in the F2-F1 interval $[(F2-F1)_{[i]} - (F2-F1)_{[a]}]$.

In the case of adjacent [i] in Catalan, changes in EPG contact correlate directly with F2 ($r = .96$) and inversely with F1 ($r = -.93$). An inverse correlation holds between changes in EPG contact and F1 ($r = -.95$) when the contextual vowel is [a]. Finally, analogously to Italian, the best correlation value for CI was obtained with the difference between context [i] and context [a] in the F2-F1 interval ($r = .97$).

These data show that in most cases velarization is not correlated with a single formant but is specified by the joint contribution of F1 and F2. In particular an increase in degree of velarization causes a F1 increase and a F2 decrease (see Introduction section). This was found to be a good acoustic correlate of CI as well.

IV. DISCUSSION AND CONCLUSIONS

The data reported in this paper reveal that an increase in the degree of velarization conveys some fronting at the primary place of alveolar articulation, lowering and retraction of the tongue dorsum, and jaw lowering. Moreover, it conveys presumably an increment in the degree of constraint upon tongue dorsum activity, as revealed by a decrease in

sensitivity to coarticulatory effects associated with adjacent vowels (especially with vowels involving tongue body raising and fronting).

Articulatory and acoustic data on production constraints and coarticulatory effects suggest that velarization is an articulatory continuum. Three degrees of velarization have been found. For the subset of languages chosen in this study, the distinction between the minimal and intermediate degrees appears to be language-dependent, while that between the maximum and the intermediate degrees takes place within the same language and depends on position within the syllable. These data suggest that languages may choose one or more allophones along the velarization continuum. The role of phonology is to point out the number and the phonetic nature of possible degrees of velarization for a given language (namely, two or even more than two) and also, should a given language present several degrees of velarization, whether or not such degrees must be successive in the velarization continuum (as in Catalan).

In future research we will analyze the temporal evolution of the articulatory and acoustic trajectories along complete [IV] and [VI] sequences. Preliminary data indicate that the presence vs absence of velarization in the consonant contributes to a reorganization of the spatiotemporal strategies used by speakers during the production of long stretches of speech (also [7]).

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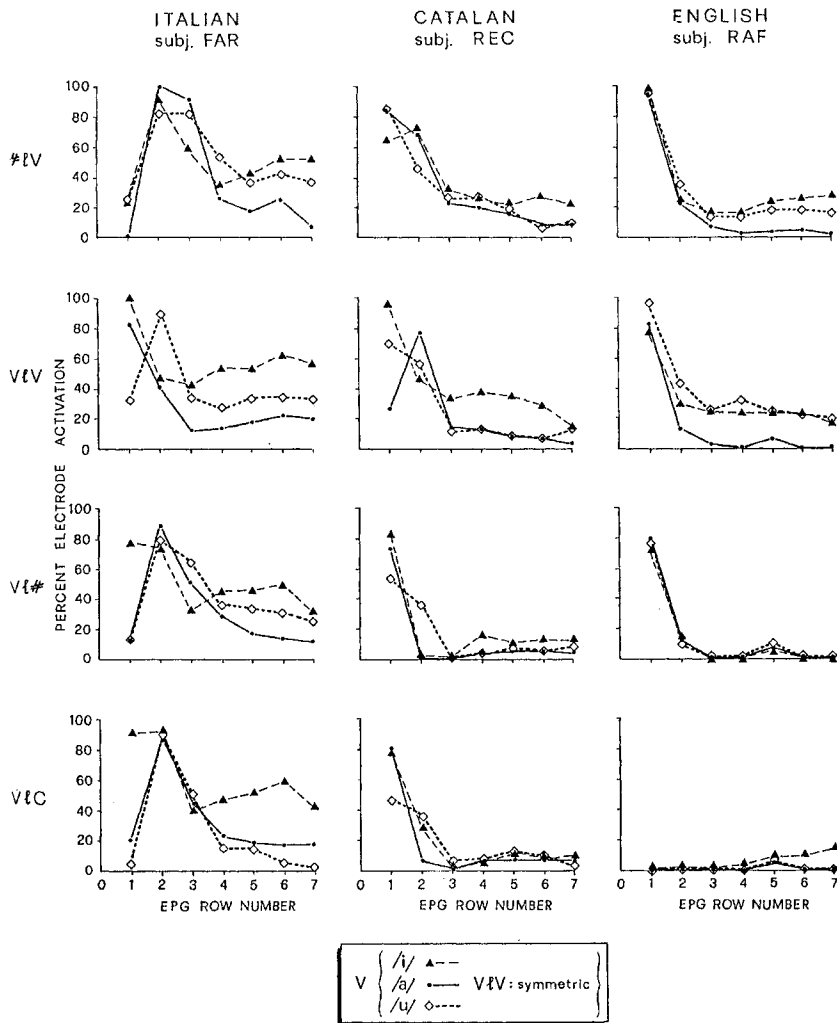


Figure 2. EPG data on linguopalatal contact for [l] as a function of language (left column: Italian; mid column: Catalan; right column: American English), syllabic position (upper row: absolute initial; mid upper row: intervocalic; mid lower row: absolute final; lower row: preconsonantal) and vocalic context (continuous line: [a]; dashed line: [i]; dotted line: [u]). Each of the 12 graphs show the percent frequency of electrode activation (vertical axis) on each row of electrodes (horizontal axis). Linguopalatal fronting on each graph progresses from left to right.