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AUTHOR Widdison, Kirk
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ABSTRACT

The acoustic effects of the syllable-final /l/ significantly alter the vocalic timbre of the preceding vowel in Catalan. Vowel quality is modified anticipatory to the articulatory gestures required by the /l/, resulting in a lowered second formant. Syllable-final /l/ in Catalan is heavily velarized as a result of tongue tip-tongue back coupling and presents many of the characteristics of an offglide (/w/) movement. This velarized segment is less segmentable from the vowel portion it follows, which may cause a change in the listener's perception of vowel duration. These co-articulatory effects are greatest in the case of front vowels and are of particular interest with respect to the mid-front phonemes. Historical phonology states that phonetic shifts in these vowels were generally exempted in the conditioning environment of liquid sounds. It is argued that the above-mentioned effects underlie this resistance. Evidence to support these claims is sought in the form of acoustic analysis of vowel-lateral and lateral-vowel sequences. The results favor the accepted phonological theory. (Author)

Some Consequences of Velarization on Catalan Vowels
A paper read at the AATSP conference
San Antonio - August 1989

Kirk Widdison
UC Berkeley

(Handout <i> - Abstract)

Introduction

The apicoalveolar lateral /l/ of Catalan shows varying degrees of velarization depending on the conditioning environment. The so-called "dark" impression of this [ɫ] affects the quality of adjacent vowel sounds much the same as the English equivalent in the words fell and fall. At present, this velarization effect represents a distinguishing dialectal trait of Catalan speakers of Spanish. Historically, it played an important role in the reordering of the mid front vowel series.

By way of introduction, I will examine some of the physical and acoustic properties important in the perception of the lateral and vowel sounds. Of special interest will be how these same sounds are modified as they interact in the speech chain. Next, I will report on an acoustic analysis of vowel-lateral and lateral-vowel sequences which was carried out in order to measure the positional and coarticulatory effects of these sounds. A brief summary of the results will be presented along with an interpretation of their relative significance. Finally, I will make a few remarks concerning a historical phonetic change involving vowels and laterals.

Physical and Acoustic Properties of Laterals and Vowels

Phoneticians often classify the apicoalveolar /l/ as a liquid, an auditory term for sounds sharing both vocalic and consonantal features. The constriction at the alveolar ridge impedes phonation as with all consonants, but the lateral escape of air produces periodic vibrations which are magnified at certain resonances, much the same as with vowels. Acoustically, these harmonic effects show up as moderate strength formants on a spectrogram in the low and mid frequency regions. It may be best to think of the lateral as a glide due to the intermediate speed of the oral constriction and transitions between sounds.

The acoustic properties of vowels are a result of how the glotalic pulse of the vocal cords is filtered through the resonating chamber of the mouth. The response of the vocal tract determines the frequencies of the formant patterns seen visually on a spectrogram. The necessary and sufficient cues in vowel perception are the first two formants. F_1 corresponds inversely to tongue height and F_2 roughly to frontness.

The velarization of the Catalan /l/ is produced by a retraction of the tongue back in forming a secondary constriction in the velo-pharyngeal region at the same time that the primary or alveolar squeeze is somewhat weakened. This secondary velar constriction results in a significant lowering of the frequency of F_2 due to the presence of an anti-node in this area for the second resonance. F_1 will naturally be higher because of the somewhat lower portion of the tongue.

Phonological theory states that the extent of velarization of the Catalan /l/ is determined positionally and by a number of factors. In general, the maximum degree of velarization occurs when the /l/ is realized in syllable-final position and preceded by a back vowel. The retracted position of the tongue during the production of back vowels naturally enhances the velar effect of the following [ɫ].

The theory of coarticulation as proscribed by Recasens (1985) states that the greater the articulatory constraints required in the production of a sound, the more resistent it is to the coarticulatory effects of adjacent sounds. Within this theory, the velarized [ɫ] should be less susceptible to the coarticulatory effects of a contiguous sound since the articulators are highly constrained by the tongue tip - tongue body coupling and thus resist much movement.

Vowels, on the other hand, are much freer to feel the consequences of adjacent sounds. In the case of vowel-lateral sequences we expect the velarization movement to be anticipated by the less constrained vowel formation. The corresponding acoustic effect will be a lowering of F_2 in that vowel. This effect should be greatest on front vowels since the articulatory gestures required for their production are less compatible to the following [ɫ].

(Handout <ii & iii>- Spectrograms)

-orientation <3 x 5>-

For a sequence of lateral + vowel there should be little residual effect carried over to the vowel from the preceding lateral. This is because the initial or intervocalic /l/ is much less velarized and there is no salient burst at the release of the lateral as occurs with stops. In general, the vowel segment is clearly distinguishable from the prevocalic lateral since abrupt changes in formant frequencies occur making the transition discontinuous.

The anticipatory effect of the syllable-final lateral on the preceding vowel should be greatest. Aside from the greater degree of velarization of [ɫ], the formant transitions between sounds are slower and smoother making clean segmentation difficult. This gives the vowel + velarized lateral sequence a more diphthong-like shape with a sustained lowering of F_2 over time (much more noticeable for front vowels).

This fusion of vowel and velarized [ɫ] through a slow, gliding movement may have important implications on perceived vowel length. Accepted phonological theory states that a following glide or approximant will increase vowel duration on the order of 20 ms compared with a following voiceless stop or fricative. The length of Catalan vowels is directly related to the sonority scale, that is the more open the vowel the longer the duration.

According to Recasens (1986) the average duration of vowels in Catalan increases by 10 ms for each degree of opening, but the range of each vowel's duration includes a standard deviation of 13 ms. Although length itself is not a salient cue in the

perception of Catalan vowels, when coupled with a lowered F_2 these effects may be significant, especially on vowels in relative close acoustic proximity such as occurs with the mid front pair.

Acoustic Analysis

The acoustic analysis I did was designed to measure the degree of velarization of the Catalan lateral in various positions and confirm the predictions made concerning the coarticulatory effects in vowel-lateral and lateral-vowel sequences. All seven tonic vowels were placed in combination with the apicoalveolar lateral in syllable-initial and syllable-final position. In theory the intervocalic /l/ interacts with the adjacent vowels in much the same way as initial /l/, so this sequence was not examined.

The tokens were randomized and presented twice in isolation and again embedded in a carrier phrase. The informant was a male speaker of the Eastern Catalan dialect of Barcelona. He was given a set of instructions and warm-up exercises before beginning. The recording was made onto a Sony reel to reel deck.

Measurements were obtained after the data were transmitted through a low pass filter and digitized using the HONDAS waveform program available on computer at the phonology lab at UC Berkeley. The test sounds were analyzed at their respective midpoints as calculated in milliseconds over the window of the soundwave pattern. A linear predictive coding (LPC) function was then used to display the spectral envelope of these sounds and the formant frequencies were taken as the value of the first three peaks.

(Handout <iv> - Tables 1 & 2)

The formant values of syllable-final [l] were averaged across vowels and are presented in the first line of Table 1. For purposes of comparison, figures for the English and Spanish laterals are given also. The data for English were taken from Lehiste (1964) and for Spanish from Quilis (1981).

If we look at F_2, the similarities between syllable-final laterals in Catalan and English, and their collective dissimilarity from the Spanish segment are readily apparent. The 700 Hz drop in frequency is a direct consequence of the velarization effect caused by tongue retraction.

Table 2 represents a comparison of formant frequencies for the seven tonic vowels in the near neutral context [s___k] and before velarized [ɫ]. All tokens were uttered in isolation, but in addition, the words with the lateral environment were produced within a carrier phrase. The formant values for these tokens represent an average. As was predicted, the coarticulatory effect of velarization resulted in a lowering of F_2 on the preceding vowel segment. This effect was maximal on the mid front vowels where a drop of 300-400 Hz was recorded.

(Handout <v> - Tables 3 & 4)

If we now look at Table 3, it is clear that the Catalan /l/ in syllable-initial position does not show the same degree of velarization as when it occurs word-finally. The F_2 value is much higher and well within the range of a "normal" apicoalveolar

lateral. As before, the figures for Catalan were averaged for vowels and tokens, and the English and Spanish numbers come from the sources previously mentioned.

The vowel frequency measurements in Table 4 show much less deviation from the target which may be ascribed to the residual effects of the lateral. Especially revealing is the second column where there is no lowering of F_2 so characteristic of vowels preceding velarized [ɫ]. Here the vowels in the test environment are compared with average formant values for Catalan vowels as reported in Cerdà i Massó (1972). In Cerdà's study, F_1 values for the high vowels seem very low and F_3 values are not given.

Measured, but not reported in Tables 2 and 4, were the transition frequencies between the vowel-lateral and lateral-vowel sequences. The analysis was made in the vowel segment 10 ms prior to the onset, and subsequent to the release of the lateral for the respective combinations. Figures served only to underscore the diphthongal-type drop in F_2 in the first instance and absence of the same in the second.

In a separate experiment I tested word-initial /l/ across morpheme boundaries. Lehiste's study of English consonants (1964) reveals that the lateral in an open sequence of the type free + -ly shows "normal" properties, while the lateral in a closed sequence such as meal + y is usually velarized. Combinations like real +ly consist of a lateral portion which begins velarized and releases clear.

The tokens tested in Catalan were combinations of definite article plus noun beginning with stressed vowel. In the case of the masculine article el, the [ɫ] is heavily velarized. However, in the environment tested the two words are fused and the conditioning vowel is lost. All combinations were tested including those involving the use of the feminine article la. Results showed this lateral to be much the same as the one reported in Table 3, with little or no effect on the following vowel. No acoustic difference was noted between the masculine and feminine morphemes.

Conclusions

Perception of vowels is not categorical, which means that listeners can discriminate between small differences in formant positions over a long continuum. However, if these modifications are great enough, incorrect identification may occur, especially with vowels in close proximity in their acoustic space. The prime candidates in Catalan are the mid front vowels, open /ɛ/ and closed /e/.

As we have seen, the effects of velarized [ɫ] are greatest on these vowels - greatly lowering F_2, slightly raising F_1 and increasing vowel length. In essence [e] comes out sounding like [ɛ].

Another key factor is the listener's perception and processing of the sound pattern. Normally, the experienced listener will correctly factor out these distortions as unintended disturbances brought on by the conditioning environment. If however, the listener fails to take into account the significance of the

velarized [ɬ] and instead supposes that the resulting effects on the vowel were an intended feature of that sound, then the seeds are sewn for sound change. This process is what John Ohala would call hypocorrection, and when the listener turns speaker a "mini-sound change" will occur unless corrected.

Something very much like this process probably operated during a time of important phonetic changes in the Catalan language. Diachronic studies document vowel shifts in which the mid front pair eventually flip flopped. Phonologists have set up a kind of "push chain" whereby some force (X) had a raising effect on open /e̬/. As a consequence, closed /e̬/ was pushed out of its phonemic domain and centralized to schwa where it either remained or later shifted down to replace the slot left vacant by open /e̬/.

As might be expected, closed /e̬/ was generally lowered directly to open /e̬/ in the environment of a syllable-final lateral. In addition, the original raising movement did not take place for vowels protected by this same segment. In this case, the velarized [ɬ] did not produce a vowel opening, but <u>blocked</u> a closing.

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ABSTRACT

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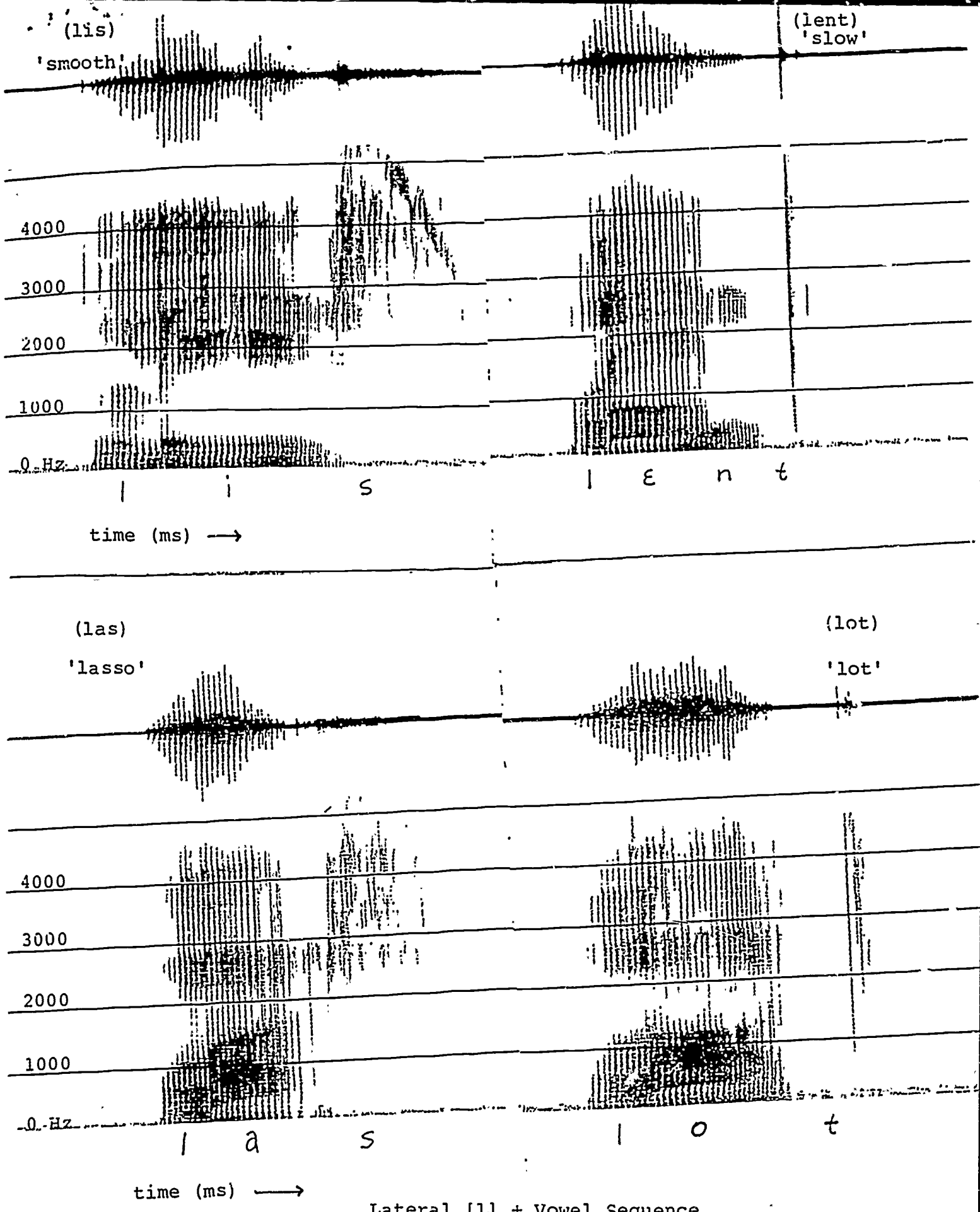
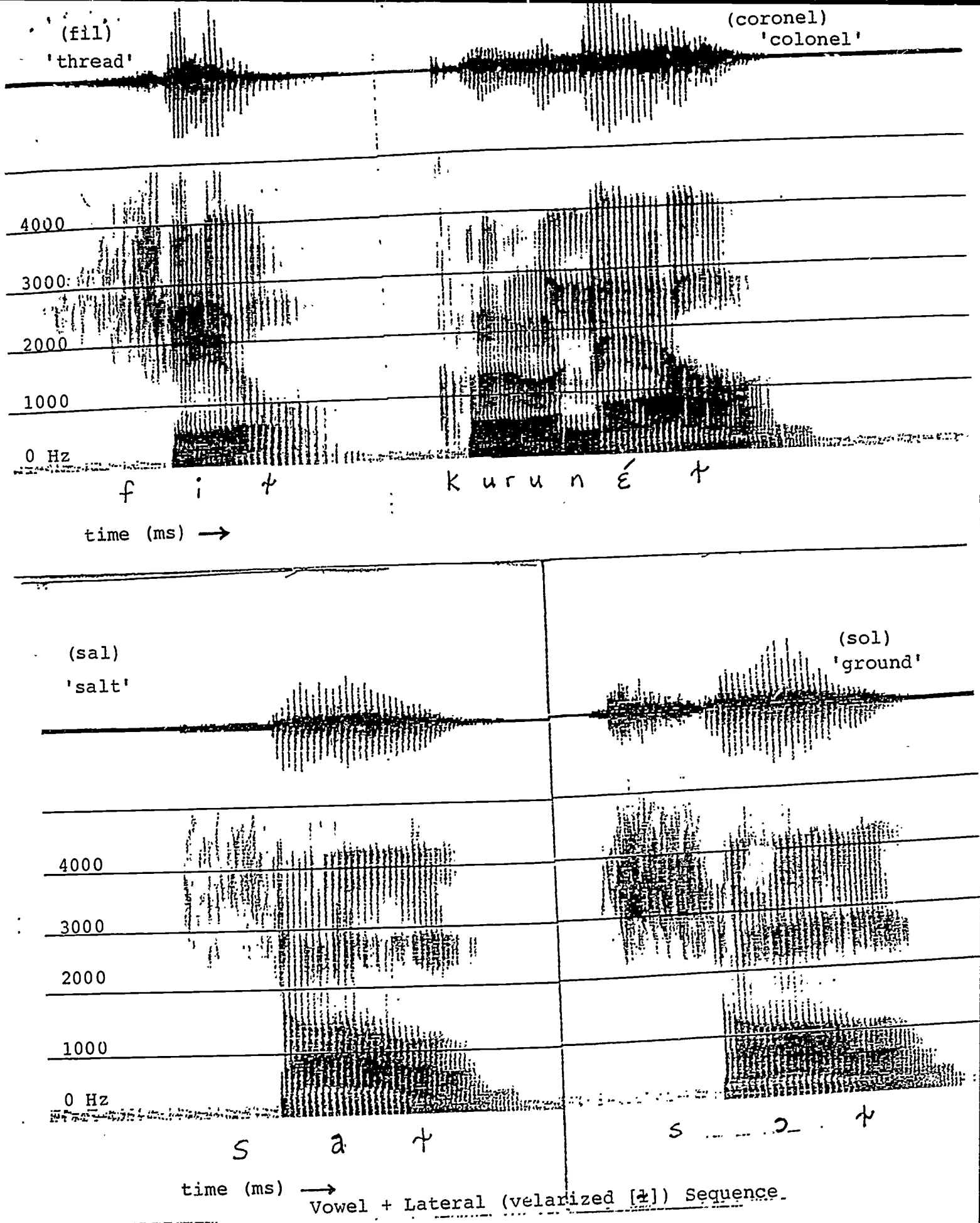
These coarticulatory effects are greatest in the case of front vowels and are of particular interest with respect to the mid front phonemes. Historical phonology states that phonetic shifts in these vowels were generally exempted in the conditioning environment of liquid sounds. It is argued that the above mentioned effects underlie this resistence.

Evidence to support these claims are sought in the form of acoustic analysis of vowel-lateral and lateral-vowel sequences. The results are in favor of the accepted phonological theory.



Lateral [l] + Vowel Sequence



Vowel + Lateral (velarized [ɬ]) Sequence

Table 1

Average Formant Value (in Hz) of Syllable-final /l/

	F_1	F_2	F_3
Catalan ([ɬ])	467	866	2584
English ([ɬ])	453	792	2589
Spanish ([l])	329	1564	2581

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Table 2

Vowel frequencies in two contexts:
[s___k] (neutral) vs. ___[ɬ] (velarized)

			F_1	F_2	F_3
[i]	sic	'sic'	300	2157	2568
	fil	'thread'	352	2003	2415
[e̞]	sec	'dry'	510	1931	2463
	coronel	'colonel'	747	1470	2377
[e̝]	cec	'blind'	568	1826	2600
	cel	'sky'	731	1508	2515
[a]	sac	'bag'	800	1400	2189
	sal	'salt'	752	1118	2586
[o̝]	sòc	'clog'	636	1068	2221
	sol	'ground'	518	904	2521
[o̞]	soc	'I am'	630	978	2315
	molt	'very'	497	747	2705
[u]	suc	'juice'	352	821	2152
	nul	'void'	357	747	2384

Table 3

Average Formant Value (in Hz) of Syllable-initial /l/

	F_1	F_2	F_3
Catalan ([l])	415	1166	2330
English ([l])	293	948	2608
Spanish ([l̪])	327	1587	2604

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Table 4

Vowel Frequencies Following Initial [l]
Compared with Averaged Frequencies

		F_1	F_2	F_3
[i]	Avg.	195	2050	----
	lis 'smooth'	250	2124	2745
[e̞]	Avg.	330	1775	----
	lent 'slow'	605	1882	2565
[e̬]	Avg.	415	1625	----
	lèxic 'lexical'	579	1871	2407
[a]	Avg.	540	1125	----
	las 'lasso'	800	1287	2588
[o̬]	Avg.	400	890	----
	lògic 'logical'	626	1194	2428
[o̞]	Avg.	300	670	----
	lot 'lot'	684	995	2580
[u]	Avg.	195	480	----
	lustre 'polish'	286	1028	2175

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