/l/ VELARISATION AS A CONTINUUM IN EUROPEAN PORTUGUESE

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ABSTRACT

There are contradictory positions in the literature about the allophonic variation of the lateral /l/ when produced in different syllable positions. The validity of the velarisation gradual hypothesis is supported by several authors that, having studied different languages, observed various degrees of /l/ velarisation for particular dialects (with light /l/ and dark /l/), regardless of syllable position.

In the present paper, analysis of adjustments in tongue shape and constriction place, and therefore the degree of /l/ velarisation, have been inferred from European Portuguese acoustic data, to contribute novel knowledge on the controversial question about /l/ velarisation.

The main study's contributions are that /l/ velarisation occurs in all syllable positions, but it is possible to define a velarisation continuum of /l/: There is an increased degree of velarisation from coda to complex onset syllable positions.

Keywords: Lateral /l/, velarisation, continuum, European Portuguese

1. INTRODUCTION

The articulatory and acoustic properties of /l/ have been well studied for many languages [1–7]. In the last decades, several studies about articulatory and/or acoustic characteristics present an allophonic perspective about the production of /l/, assuming the existence of a binary distinction between clear (or light) and dark /l/ [1, 8–11]. However, other studies' results suggest the that there are languages with different degrees of darkness in /l/ [2, 4, 5, 12–15].

For European Portuguese (EP), it has been argued that /l/ is categorically associated with a non-velarised (light or clear) allophone in syllable onset and a velarised (dark) allophone in coda position [16, 17]. However, this point of view is not consensual and there are contradictory positions in the literature about it. The data collected from articulatory and acoustic EP studies, suggests that /l/ is consistently dark/velarised even in the onset position and that the light versus dark syllabic position distinction is hard to observe and can be influenced by factors such as speaker, vowel context and word position [12, 18–21].

The measures most frequently used to differentiate these allophones are based on formant frequency values. It is known that the tongue body retraction lowers the frequency of the second formant (F_2), that the first formant frequency (F_1) is correlated with tongue height [5], the third formant frequency (F_3) is front-cavity dependent and can be conditioned by lip rounding [5, 22, 23]. Recasens [4] reported formant frequency data for /l/ in 23 languages/dialects, including EP. The range of mean values was 240-550 Hz for F_1, 750-2000 Hz for F_2 (F_2 is higher than 1500 Hz for clear /l/ and has values around 1000 Hz for dark /l/) and 2300-3000 Hz for F_3 (F_3 values were not reported for EP).

In agreement with empirical descriptions of EP lateral /l/, based on acoustic data previously presented by Andrade [12] , Recasens and Espinosa [5] concluded that EP belongs to a group of sound systems where /l/ essentially shows the same dark realisation in onset and coda position.

In the current study, measurements of F_1, F_2, F_3, and the slope of F_2 transitions were carried out. Analysis of formant frequencies are sensitive to modifications in tongue shape and constriction place, and therefore the degree of /l/ velarisation can be inferred from the acoustic data. Furthermore, the slope of the F_2 transition provides dynamic information that also reflects the adjustments in vocal tract shape during speech sound production [11].

The purpose of this paper is to contribute novel knowledge on the acoustic properties of /l/ in order to shed a new light on the controversial question about /l/ velarisation.

2. METHOD

2.1. Participants

Five adult female and five adult male speakers, whose ages ranged from 20 to 40 years, were recruited. They were all monolingual speakers of EP, south variant, and none had history of speech and/or language disorders. All speakers were informally assessed by a speech and language therapist as having normal speech and normal orofacial structures. They were also assessed by an audiologist as having normal hearing. None of the speakers knew the nature of the study, nor had any prior phonetic training.

2.2. Data collection

The set of real words selected for data collection had the following characteristics: Trisyllabic words; paroxytone stress pattern; the lateral consonant occupied the middle of the word in onset, complex onset and coda positions; the vowel context varied between seven oral vowels /i, e, ɛ, u, o, ɔ, a/, (e.g., <baliza> ([bɐˈlizɐ])). In complex onset and coda positions, /l/ was preceded or followed by a stop consonant, (e.g., <complica> ([kõˈplikɐ]), <cobalto> ([kuˈbaltu])).

The speakers produced 100 utterances (5 random repetitions of 20 different words). Each word was produced within the frame sentence <Diga a palavra… por favor> [ˈdigapɐˈlavrɐ… puɾfɐˈvoɾ]. Speakers were instructed to read the utterances at a natural rhythm.

Data was recorded at the University of Algarve in Faro, Portugal, in a sound proof booth, using a DPA 4006-TL microphone located 30cm in front of the speaker's lips, connected to an audio interface (TASCAM US-800) and a desktop computer located outside the cabin. The acoustic signal was recorded at 16 bits and a sampling frequency of 44100 Hz, using Audacity 2.0.

2.3. Corpus annotation

The segmentation and annotation of the acoustic signal was performed using Praat 5.3.40 [24] and according to criteria proposed by several authors [7, 8, 25–30]. The waveforms and spectrograms of all the corpus words were manually analysed to detect:

- The start of preceding vowel (onset and coda) or stop consonant (complex onset) – phone 1;
- The start of transition into /l/ (TL) (decrease in amplitude and the end of steady state in the vowel) – transitions tier (beginning of TL interval);
- The end of transition into /l/ (the start of steady state in the lateral) – phone 2 (phones and transitions tiers);
- The start of transition out of /l/ (TS) (increase in amplitude and the end of steady state in the lateral) – phones and transitions tiers (beginning of phone 3 and TS interval);
- The end of transition out of /l/ (the start of steady state in vowel) – transition tier;
- The end of following vowel (onset or complex onset) or stop consonant (coda) – phone 3 (phone tier).

The main cues to identify the lateral /l/ were low amplitude, identifiable formant structures, spectral continuity, and a period of steady state formant patterns, combined with formant shifting to and from adjacent speech sounds.

2.4. Data analysis

Formant data was extracted using the following Praat 5.3.40 function: To Formant (burg)... 0.01 5 5500 0.025 50; [Time step(s), Max. number of formants, Maximum formant (Hz), Window length(s), Pre-emphasis from (Hz)] – split Levinson algorithm.

Matlab R2007b was used for post-processing the data initially extracted using Praat 5.3.40, with the following formant frequency threshold values: $200\ \text{Hz} < F_1 < 900\ \text{Hz}$; $700\ \text{Hz} < F_2 < 2600\ \text{Hz}$; $1600\ \text{Hz} < F_3 < 3900\ \text{Hz}$; $2800\ \text{Hz} < F_4 < 5000\ \text{Hz}$. These limits were defined based on the literature [9, 12, 13, 18, 20, 31–33] in order to eliminate eventual outliers resulting from errors introduced by the automatic extraction. All productions that were not within limits were excluded from the analysis.

The following parameters at specific instances and time intervals were considered for analysis:

- F_1, F_2 and F_3 formant frequencies at the middle of phone 1 (t1FF), phone 2 (t2FF) and phone 3 (t3FF);
- F_2 formant frequencies at the beginning of the transition into the lateral (t4FF);
- F_2 formant frequencies at the end of the transition into the lateral (t5FF);
- F_2 formant frequencies at the beginning of the transition out of the lateral (t6FF);
- F_2 formant frequencies at the end of the transition out of the lateral (t7FF);
- Absolute values (Hz/ms) of F_2 slopes from the nuclear vowel into (coda) and out (onset and complex onset) of the laterals: (t5FF-t4FF)/dur2 and (t7FF-t6FF)/dur4, respectively.

All data was exported to a SPSS 17.0 (SPSS Inc., Chicago, USA) database for statistical analysis, which included 645 /l/ realisations: 220 in onset; 217 in complex onset; 208 in coda.

A 3-factor Analysis of Variance (ANOVA) was performed. The factors were vowel context, syllable position and participants. To further explore the effects of these factors other analyses of variance (ANOVAs) were carried out afterwards. Two-way ANOVAs were used to study the effects of the independent variable (factor) vowel context ([i, e, ɛ], [u, o, ɔ] and [a]) on each of the dependent variables F_1 frequency, F_2 frequency, F_3 frequency and the slope of the F_2 transition. The ANOVAs were performed separately for each syllable position (onset, complex onset and coda). The second factor considered in the analysis relates to the participants which naturally interfere with the results and must be accounted for. However, since the natural differences between the participants is not the focus of the present study we will not report the corresponding p-values of the ANOVAs.

The same statistical procedure was applied to study the effects of independent variable (factor) syllable position (onset, complex onset and coda) on each of the dependent variable F_1 frequency, F_2 frequency, F_3 frequency and the slope of the F_2 transition. Similarly, the analysis was performed separately for each vowel context ([i, e, ɛ], [u, o, ɔ] and [a]).

Post-hoc multi-comparison tests were performed using Sheffé's correction. The level of significance was set at 5%.

3. RESULTS

3.1. First formant (F_1) frequency values

Three-factor ANOVA results showed a significant effect for vowel context, syllable position, participants ($p< 0.001$) and for all interactions between factors ($p< 0.05$).

A two-way ANOVA showed significant effect of the factor vowel context on F_1 frequency values (onset [F(2; 190)= 22.907; p< 0.001]; complex onset [F(2; 188)= 9.658; p< 0.001; coda [F(2; 180)= 26.250; p< 0.001]). A post-hoc Scheffé test showed that F_1 frequency values are significantly higher in [a] vowel context for all syllable positions.

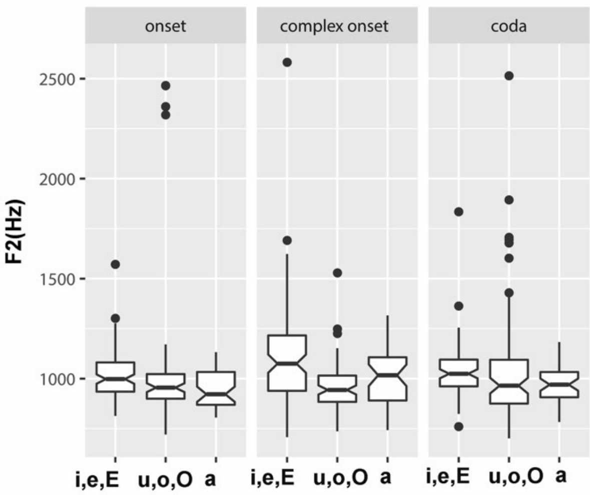
There was a significant effect of the factor syllable position on F_2 frequency values for all vowel contexts ([i, e, ɛ] [F(2; 247)= 11.128; p< 0.001]; [u, o, ɔ] [F(2; 240)= 24.466; p< 0.001]; [a] [F(2; 100)= 52.764]; p< 0.001]). A post-hoc Sheffé test showed that F_1 frequency values are significantly higher in coda than in onset and complex onset positions for [u, o, ɔ] and [a] contexts. For front vowel contexts, F_1 frequency values are significantly higher in complex onset and coda positions than in onset position. However, F_1 frequency values are higher in coda for all vowel contexts which reflects a strong pharyngeal coupling in coda [33].

3.2. Second formant (F_2) frequency values

Three-factor ANOVA results indicated a significant effect for vowel context, participants and vowel context ($p< 0.05$), but no significant variation between syllable positions and other factors interactions.

Two-way ANOVA results showed a significant effect of the factor vowel context on F_2 frequency values for onset and complex onset position (onset [F(2; 190)= 3.103; p=0.047]; complex onset [F(2; 188)= 18.207; p< 0.001]; coda [F(2; 180)= 1.397; p= 0.250]). The Scheffé post-hoc test helped to isolate the specific sources for these differences and showed that for complex onset position the lateral's F_2 frequency (see Figure 1) decreases in the contextual progression: [i, e, ɛ] > [u, o, ɔ] = [a]; no significant differences were found for onset position.

Figure 1: F_2 frequency values for [i, e, ɛ], [u, o, ɔ] and [a]contexts in all syllable positions.



There was a significant effect of the factor syllable position on F_2 frequency values for [i, e, ɛ] and [a] contexts ([i, e, ɛ] [F(2; 247)= 11.873; p< 0.001]; [u, o, ɔ] [F(2; 240)= 0.750; p=0.473]; [a] [F(2; 100)= 10.633; p< 0.001]). A post-hoc Scheffé test showed that for [i, e, ɛ] and [a] contexts the lateral's F_2 decreases in the following syllable position progression: complex onset > coda = onset.

3.3. Third formant (F_3) frequency values

Three-factor ANOVA results indicated a significant effect for vowel context [F(2; 558)= 28.108; p< 0.001], syllable position [F(2; 558)= 21.949; p< 0.001], participants [F(9; 558)= 75.991; p< 0.001] and for all interactions between factors ($p< 0.001$), except for vowel context and syllable position interaction [F(4; 558)= 1.695; p= 0.150].

A two-way ANOVA showed a significant effect of the factor vowel context on F_3 frequency values (onset [F(2; 190)= 12.162; p< 0.001]; complex onset [F(2; 188)= 7.719; p=0.001]; coda [F(2; 180)= 12.254; p< 0.001]. A post-hoc Scheffé test showed that F_3 frequency values are significantly higher in back vowel context ([u, o, ɔ]) for all syllable positions.

There was a significant effect of the factor syllable position on F_3 frequency values for all vowel contexts ([i, e, ɛ] [F(2; 247)= 3.694; p=0.026]; [u, o, ɔ] [F(2; 240)= 9.968; p=0.000]; [a] [F(2; 100)= 9.487; p< 0.001]. A post-hoc Sheffé test revealed that F_3

frequency values were significantly higher in coda for all vowel contexts.

3.4. The slope of the F_2 transition

Three-factor ANOVA results showed a significant effect for vowel context, syllable position, vowel context and participants and syllable position and vowel context interactions ($p< 0.05$) but no significant differences between participants and remaining interactions between factors ($p> 0.05$).

Two-way ANOVA results showed a significant effect of the factor vowel context on the slope of the F_2 transition (onset [$F(2; 190)= 246.035$; $p< 0.001$]; complex onset [$F(2; 188)= 93.230$; $p< 0.001$]; coda [$F(2; 180)= 44.968$; $p< 0.001$]). A post-hoc Scheffé test revealed that the slope of the F_2 transition is higher in front vowel contexts for all syllable positions.

There was a significant effect of the factor syllable position on F_2 slope values for [i, e, ɛ] and [a] contexts ([i, e, ɛ] [$F(2; 247)= 7.298$; $p=0.001$]; [u, o, ɔ] [$F(2; 240)= 0.048$; $p=0.953$]; [a] [$F(2; 100)= 50.602$; $p< 0.001$]).

The small number of participants could have influenced some of the null effects. In the future, a more powerful database could result in positive findings.

4. DISCUSSION

For F_1 frequency values, the results are in agreement with acoustic data for other languages with dark realisation of /l/ in all syllable positions [9, 15, 33, 34]. Considering the relationship between F_1 and back cavity volume [22], and a clear link between this acoustic data and the velarisation degree identified by several authors [4, 5, 14, 15, 33, 34], our data suggests the existence of a higher degree of velarisation in coda position, for all vowel contexts.

In agreement with data reported in previous studies for EP [12, 18–20], F_2 frequency values (around 1000 Hz) indicate a velarised /l/ in all syllabic positions, despite a tendency to higher F_2 frequency values in front vowel context.

Second formant frequency results show that /l/ in complex onset is less resistant to coarticulation effects than /l/ in onset and coda positions. Previous studies show vowel coarticulatory resistance for /l/ is dependent on the degree of velarisation. The dark /l/ offers more coarticulatory resistance than clear /l/ [5, 14, 15]. Thus, according to our results, /l/ in complex onset, has a lower velarisation degree than other syllable positions.

The results obtained for F_3 frequency values follow the general trend that rounding lowers all formant frequencies, especially F_3 [23], because statistical analysis showed that F_3 frequency values are significantly higher in back rounded vowel contexts, for all syllable positions. The effect of vowel context on F_3 frequency values may raise interesting and difficult questions, such as: Is it possible that there is an articulatory “similarity” between back vowels and velarised /l/ that “overrides” the lip rounding effect? or Is lip rounding responsible for the higher /l/ velarisation degree? To clarify these issues in the future, it is important to combine acoustic and articulatory data.

Evidence from earlier studies [4, 5, 7] about dark versus clear dialects has shown that F_3 frequencies values are higher for dark /l/ than for clear /l/ varieties. From this we can infer that the EP lateral /l/ is more velarised in coda position than in other syllable positions.

The higher slope of F_2 transitions in front vowel context for all syllable positions is indicative of the greater articulatory distance between /l/ and front vowels. The data collected about the slope of the F_2 transition and F_2 frequency values show that there are no significant differences between syllable positions for back vowel contexts. These results reinforce the view that the velarisation degree is similar for [u, o, ɔ] contexts, for all syllable positions, possibly as a consequence of the very short “articulatory distance” between the lateral /l/ and back rounded vowel contexts.

5. CONCLUSIONS

The results show that lateral velarisation occurs in all syllable positions (onset, complex onset and coda). However, it is possible to observe the following progression of velarisation degree according to syllable position: complex onset → onset → coda.

Results show that not only syllable position, but also vowel contexts play an important role in /l/ production and should be considered when studying /l/ velarisation. The lateral /l/ in EP is velarised in all syllable positions, but the “more velarized” /l/ is more resistant to vowel effects (onset and coda positions) than the “less velarized” /l/ realisations (complex onset position).

The velarisation degree is similar for all syllabic positions (onset, complex onset and coda) when the vowel context is [u, o, ɔ].

It is therefore important to consider acoustic measures such as F_1, F_3 and the slope of the F_2 transition to better understand /l/ velarisation.

We are currently considering the following as future work: More speakers from different dialects; synchronously acquiring acoustic and articulatory data for the EP lateral /l/, to clarify and to assist with the interpretation of the acoustic results.

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7. REFERENCES

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