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Lithuanian and Latvian laterals: Comparison of acoustic properties[1]

Lietuviešu un latviešu valodas laterālie spraudzeņi: akustisko īpašību salīdzinājums

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The aim of the paper is to examine how acoustic contrast manifests itself between /l/ and /ʎ/ in Latvian, as well as /l/ and /lʲ/ in Lithuanian. For the study, speech recordings of 6 adult informants (3 Lithuanian and 3 Latvian male speakers) have been analysed. Initial and final laterals in closed symmetric [l]V[l] sequences and intervocalic syllable-initial laterals in V[l]V sequences have been examined. During the analysis, the focus is placed mainly on locus equations, as well as changes in formant structure (especially F1 and F2) triggered by position and vocalic context.

Acoustic data demonstrates differences in coarticulation effects between Latvian palatal /ʎ/ and Lithuanian palatalized /lʲ/. The formant structure of /ʎ/ and /lʲ/, unlike the corresponding non-palatal laterals, is more stable and less dependent on the quality of adjacent vowels. Vowel context affects the degree of palatalization, e. g. palatalized [lʲ] next to [ɪ], [iː] and [eː] is pronounced "softer" than next to [ɔ̨], [ɔː], [ʊ̨], and [ʊ̨ː].

Latvian /ʎ/ is characterized by a more stable vowel F2 locus, which indicates higher degree of coarticulatory resistance to vowel effects; the quality of /lʲ/, on the contrary, depends more on vowel context. The same is true (although to lesser degree) for the Lithuanian /l/. The assumption about the similarity of Latvian non-palatal /l/ and Lithuanian palatalized /lʲ/ is only partly supported by the recent data. In terms of the degree of coarticulation (indicated by slope values of locus equations), Latvian /l/ is closer to Lithuanian /lʲ/, while its formant structure, especially low F2, brings it closer to Lithuanian /l/.

Keywords: Lithuanian language; Latvian language; laterals; acoustic features; palatalization; formants; locus equations.

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Introduction

Since language is constantly changing and in the third millennium its spoken form ceases to be the main form of communication, it is very important to capture the sound system of the contemporary Baltic languages of the beginning of the 21st century, and to analyse experimentally various relevant phenomena and processes of sounds and sound systems. Both Lithuanian and Latvian have several common characteristics, such as phonological distinction between short and long vowels, pitch accent, etc. Still, there are quite a few substantial differences between the two Baltic languages, one of them being phonological contrast between palatalized and non-palatalized consonants in Lithuanian and the lack thereof in Latvian, which instead has developed large subsystem of palatal consonants (Laua 1997; Girdenis 2014; Urbanavičienė, Indričāne, Jaroslavienė, Grigorjevs 2019).

The present study focuses on the acoustic properties of Lithuanian and Latvian laterals. The study is a part of the research project "The Sound System in the Contemporary Baltic Languages at the Beginning of the 21st Century: Comparative Acoustic and Perceptive Research of Sonorants" (*BaltSon*; funded by the Research Council of Lithuania, No. S-LIP-21-7) that has been carried out at the Institute of the Lithuanian Language, Vilnius in 2021–2022. The previous research project "Spectral characteristics of the sounds of the contemporary Baltic languages (experimental study)" (funded by the Lithuanian Research Council, Program of Research teams projects, contract No. MIP-081/2013) helped to evaluate objectively and to compare the main distinctive acoustic features of the vowels and consonants of Baltic languages produced in isolation (the results of the project are published in Jaroslavienė, Urbanavičienė, Grigorjevs, Indričāne 2019; Urbanavičienė, Indričāne, Jaroslavienė, Grigorjevs 2019). Now it is important to ensure consistent research on other aspects of phonetics and phonology: changes caused by different positions, phonetic contexts, speech rate and style, etc. The goal of the *BaltSon* project is to explore, describe and compare the acoustic and auditory features of sonorants of the contemporary Baltic languages using unified methodology. The aim of this paper is to examine how acoustic contrast manifests itself between /l/ and /ʎ/ in Latvian and /l/ and /lʲ/ in Lithuanian in different positions and vowel contexts. Another topic of interest is whether there are any differences in palatal and palatalized consonant coarticulation patterns. The comparison of sonorants in terms of palatalization can be beneficial for identifying distinctive acoustic and articulatory features of palatal consonants.

1. Classification and pronunciation of laterals in the contemporary Baltic languages

By the place of articulation Lithuanian /l/ is considered dental (during its production the tip of the tongue touches upper front teeth, see Mikalauskaitė 1975, 52); meanwhile, in Latvian /l/ traditionally is classified as alveolar (it is articulated by touching the alveolar ridge with the body of the tongue, see Laua 1997, 45).

Although it should be noted that in more recent EPG studies dental articulation of /l/ was recorded (Grigorjevs 2012a, 275; Nītiņa, Grigorjevs 2013, 70). Latvian /ʎ/ is considerably softer than Lithuanian /lʲ/ – it is a palatal consonant. When pronouncing Latvian /ʎ/, the body of the tongue is pressed against the hard palate. When articulating the Lithuanian palatalized /lʲ/, the body of the tongue only rises upwards, but it does not touch the palate (Kabelka 1987, 69) (Table 1).

Place of articulation		
dental	alveolar	palatal
Lith. /l/	Lat. /l/ Lith. /lj/	Lat. /ʎ/

Table 1. Classification of the Lithuanian (Lith.) and Latvian (Lat.) laterals

The Lithuanian laterals [l] and [lʲ] form an opposition not only according to palatalization, but also according to the place of articulation: [l] is dental, [lʲ] is alveolar (see Table 1). However, not all Lithuanian speakers are able to pronounce laterals correctly (for animated images of language implements pronouncing Lithuanian sounds, see http://tartis.vdu.lt/fonetika-ir-tartis/igudziu-tobulinimas/garsu-ypatybes/), especially the dental [l], for example: in the case of [l] the anterior part of the tongue is not attached to the anterior teeth, but only the lip is raised, therefore [ʊ] is pronounced instead of [l] (Mikalauskaitė 1975, 52). When articulating the alveolar [lʲ], the middle part of the tongue touches hard palate, and there is no posterior focal point of articulation.

Even if speakers are able to produce the unpalatalized [l] and the palatalized [lʲ], due to foreign language influence in borrowed words laterals may be pronounced incorrectly, e. g., instead of a palatalized consonant, a non-palatalized consonant can be produced ([bu[1]ˈɣaˑlʲtɛrʲis] – [bu[1]ˈɣaˑltɛrʲis]), or instead of a non-palatalized, a palatalized one can be produced ([[1]ˈpaˑltɐs] – [[1]ˈpaˑlʲtɐs]) (Pakerys 2003, 141).

Although in Standard Lithuanian only non-palatalized consonants can appear in final position, word-final palatalized lateral sonorants can be produced due to dialect or foreign language influence, for example, *daũgel* [[2]ˈdɐuˑgʲɛlʲ], *gál* [[1]gaˑlʲ] (Kazlauskienė 2018, 67).

In case of Latvian, dialects can affect the pronunciation of the palatal lateral [ʎ]. As Laua (1997, 130–131) observes, speakers of High Latvian might need special training to produce [ʎ] as well as other palatals, since these phonemes are not present in the consonantal system of their dialect.

2. Primary and secondary palatalization in the contemporary Baltic languages

The palatalization of consonants is considered one of the key distinctive features of contemporary Baltic languages (Urbanavičienė, Indričāne, Jaroslavienė, Grigorjevs

2019, 222). In Latvian, the palatal consonants /ɟ c ɟ ʎ ɲ/ are produced by raising the blade of the tongue to the hard palate (see Laua 1997, 49–55) – this is considered primary palatalization. For Lithuanian consonants, secondary (*i*-type) palatalization is typical when raising the tongue to the hard palate accompanies primary articulation. The feature that distinguishes palatal and palatalized consonants is the absence of non-palatal counterparts of palatals; their articulation towards the hard palate is stable, whereas palatalized consonants have non-palatalized counterparts and raising of the body of the tongue towards the hard palate is an additional property of articulation. Palatalized consonants also can be characterized by other articulatory nuances, e.g., /pʲ bʲ mʲ/ are usually pronounced with stronger labial articulation than their non-palatalized counterparts /p b m/, palatalized velars /kʲ gʲ xʲ ɣʲ/ are more advanced than non-palatalized /k g x ɣ/. Compared to the corresponding palatalized sounds, non-palatalized consonants /l ʃ ʒ/ are velarized (the posterior part of the tongue is raised to soft palate), and non-palatalized /ʃ ʒ/ are labialized (Ambrazas et al., 2005, 27). The articulation of the non-palatalized /l/ also differs considerably from that of /lʲ/, cf. *Lukas* [ˈlʊkɐs] (name) and *liukas* [ˈlʲʊkɐs] ‘hatch’, *planas* [²ˈplɑːnɐs] ‘plan’ and *plynas* [¹ˈpʲlʲiːnɐs] ‘bare; smooth; open’. The non-palatalized /l/ can have a strongly velarized articulation (Ambrazevičius, Leskauskaitė 2014, 165), when the back part of the tongue is raised towards the soft palate and the tongue blade creates dental contact (Pakerys 2003, 75; Girdenis 2006, 36). The palatalized /lʲ/ is articulated with the front part of the tongue touching alveolar ridge.

The experimental research of the Baltic sonorants enables us to study both primary and secondary palatalization by analysing the sounds of the same articulation classes, cf. the class of lateral sonorants includes non-palatalized Lith. and Lat. /l/, palatalized Lith. /lʲ/ and palatal Lat. /ʎ/; the class of nasal sonorants includes non-palatalized Lith. and Lat. /n/, palatalized Lith. /nʲ/ and palatal Lat. /ɲ/.

3. Phonological interpretation of Lithuanian and Latvian lateral sonorants

In Lithuanian, palatalized and non-palatalized consonant phonemes contrast before back vowels, e.g., *galu* [gɐˈlʊ] ‘end’ (Instr. Sg.) *: galiu* [gɐˈlʲʊ] ‘(I) can’. This position is relevant for all the palatalized vs. non-palatalized consonant pairs. In other positions contrast between palatalized and non-palatalized consonants is neutralized (Table 2):

1) palatalized consonants are used before front vowels (e.g., *tylėti* [tʲiː¹ˈlʲeːtʲɪ]² ‘be silent’) and before other palatalized consonants or the palatalized /j/, e.g., *balti* [bɐlʲˈtʲɪ] ‘white’ (NOM PL M), *balsius* [bɐlʲˈsʲʊs] ‘vowels’ (ACC PL M);

[2] The number 1 before a stressed syllable signals the acute accent; the number 2 marks the circumflex accent. Short syllables do not have pitch accents and are therefore not numbered.

2) non-palatalized consonants are used before other non-palatalized consonants (e.g., *anksčiau* [ɐŋʲkʃʲˀˈʧʃɛʊˑ] ‘earlier’) and at the end of a word, e.g., *kels* [ˀˈkʲɛlˑs] ‘(s/he, it, they) will raise, lift’.

Consonants	Positions					Interpretation
	[–V^{u}]	[–V^{i}]	[–C]	[–C^{j}]	[–#]	
[l]	+		+		+	/l/
[lʲ]	+	+		+		/lʲ/

Table 2. Phonological interpretation of non-palatalized [l] and palatalized [lʲ] in Standard Lithuanian (according Girdenis 2014, 153)

Latvian consonants are not divided into palatalized and non-palatalized. Consonants are not affected by the following vowel, they are pronounced identically both with front and back vowels (Kabelka 1987, 68). There are no palatalized consonants in Latvian, but there are palatal consonants [ɟ c ɟ ʎ ɲ], which, according to the phonological interpretation (Table 3), are considered to independent phonemes.

Consonants	Positions					Interpretation
	[–V^{u}]	[–V^{i}]	[–C]	[–C^{j}]	[–#]	
[l]	+	+	+		+	/l/
[ʎ]	+	+		+	+	/ʎ/

Table 3. Phonological interpretation of non-palatal [l] and palatal [ʎ] in Standard Latvian

4. Acoustic properties of laterals

During the production of laterals, the tongue is placed so that the air escapes around one or both its sides (Ladefoged, Maddieson 2002, 182; Crystal 2008, 296). In the world’s languages, lateral place of articulation may vary from dental to velar. Languages with phonological contrast of two laterals are most common (Ladefoged, Maddieson 2002, 185–186). As mentioned before, there are two laterals in Latvian: alveolar (according to Laua (1997)) or dental (according to Grigorjevs (2012a)) [l] and palatal [ʎ]. In Lithuanian there are two laterals as well: dental non-palatalized [l] and alveolar palatalized [lʲ]. Laterals have well-defined formant structure similar to one of vowels with relatively high intensity (compared to obstruents) and pronounced formant structure.

According to Ladefoged and Maddieson (2002, 193–197), the most significant acoustic features of laterals are as follows (see also Figure 1):

1) when adjacent to vowel, laterals are characterized by abrupt formant transitions, especially apical ones (laminal and dorsal laterals usually have slower transitions);
2) low F1 frequency (usually below 400 Hz);

3) F2 may vary within a rather wide range depending of the place of articulation and tongue profile;
4) F3 with rather strong amplitude and high frequency (it was observed that apical laterals are characterized by greater F2–F3 interval than laminal laterals); there may also occur several additional closely spaced formants above F3.

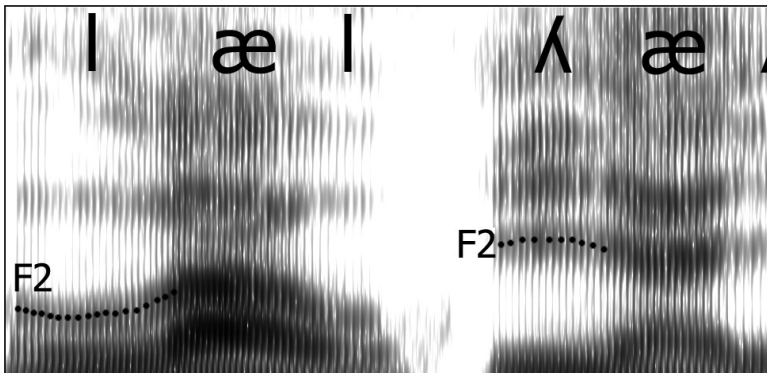

Figure 1. Dynamic spectrogram of [læl] un [ʎæʎ] produced by a native Latvian speaker. The dotted lines indicate F2 centre

F1 frequency correlates with the volume of pharynx cavity: the smaller pharynx cavity volume, the higher F1 frequency (Bladon 1979, 502). It is usually affected by the quality of adjacent vowel (increases in the context of open vowels and decreases in the context of close vowels), as well is associated with the degree of velarization (velarization results in F1 increase) (Ibid.; Recasens, Farnetani 1990, 963; Ladefoged, Maddieson 2002, 194). Palatalized and palatal laterals usually have lower F1 than dental and alveolar non-palatalized laterals.

F2 frequency is inversely proportional to the volume of oral and pharyngeal resonator behind the constriction (Bladon 1979, 502; Ladefoged, Maddieson 2002, 196) and directly proportional to the amount of dorsopalatal contact (Bladon 1979, 502). The highest F2 frequency is typically observed in [ʎ], medium – in dental [l̪], the lowest – in alveolar [l]. Velarization causes the decrease of F2 frequency (Recasens, Farnetani 1990, 963), it is the lowest for [ɬ] due to narrowing in velar and pharyngeal region (Bladon 1979, 502).

5. Sound recording material and methods

For the study, speech recordings from 6 adult informants (3 Lithuanian and 3 Latvian male speakers, 21–42 years of age) without any speech disorders or notable dialectal traces in their pronunciation have been analysed. The material for research was recorded with a digital high resolution audio recorder *Tascam DR-100MK II* and a head-set microphone *AKG C 520*. The signal was sampled at a rate of 44,1 kHz (16-bit quantization). Initial and final laterals in closed symmetric [l]V[l] sequences

and intervocalic syllable-initial laterals in V[l]V sequences have been examined (V – one of the Lithuanian vowels [ɪ, iː, eː, ɛ, æː, ɐ, ɑː, ɔ, ǫ, oː, ǫ̇ː, ʊ, ʊ̨, uː ʊ̨ː] or one of the Latvian vowels [i(ː); e(ː); æ(ː); ɑ(ː); ɔ(ː); u(ː)]. Each sequence produced three times by every speaker), thus about 730 items were analysed in total.

During the analysis, the focus is put mainly on locus equations, as well as changes in formant structure (especially F1 and F2 frequencies) depending both on position and vocalic context of the consonants. Locus equation indices (derived from the F2 of adjacent vowels) provide information on the degree of coarticulation between vowel and consonant: high slope indicates variable consonantal locus and high degree of coarticulation between the vowel and the consonant (V-to-C effects); low slope indicates stable locus and low degree of coarticulation between the vowel and the consonant (vowel scarcely affects the consonant).

The analysis of the sounds of both Baltic languages was performed using *Praat* (5.3.63 and its later versions, developed by Paul Boersma and David Weenink). The obtained data were further processed using *MS Excel*.

6. Results

6.1. Formant structure

Changes in the structure of four first formants (F1–F4) were analysed in the following positions: non-palatal laterals of both languages were compared in the initial prevocalic, intervocalic, and postvocalic positions (Figures 2–4), Lithuanian palatalized and Latvian palatal laterals were compared in the initial prevocalic and intervocalic positions (Figures 5–6). In postvocalic position there is no contrast between Lithuanian palatalized [lʲ] and non-palatalized [l] since only non-palatalized consonants can appear in this position: *vėlei* [ˀˈvʲeːlʲɛɪ] – *vėl* [ˀˈvʲeːl], *eiki* [ˀˈɛɪˑkʲɪ]ˑ– *eik* [ˀˈɛɪˑk].

For Lithuanian and Latvian sonorant [l], no significant difference was found in F1 and F2 formant frequencies in initial position (Figure 2). In intervocalic and postvocalic positions, the values F1 and F2 of the Latvian lateral are higher (Figures 3–4). Considerably higher F1 frequency of the Latvian [l] suggests its higher degree of velarization in comparison with the corresponding Lithuanian consonant, but higher F2 values of the Latvian lateral presupposes stronger palatal articulation, so no reliable results have been obtained so far comparing the first two formants of Latvian and Lithuanian [l]. The frequencies of F3 and F4 are determined more by the articulation of the adjacent vowels rather than by the place of articulation of the consonant itself, so their values were compared in the environment of different vowels (see below). In general, the most significant difference between the Lithuanian and Latvian [l] was observed in intervocalic position (Figure 2, B).

The formant structure of Lithuanian palatalized [lʲ] and Latvian palatal [ʎ] in initial and intervocalic positions is shown in Figure 3. It is natural that the degree of palatalization in Latvian **[ʎ]** is higher than the one in Lithuanian [lʲ] – F2 frequency of [ʎ] in both positions is higher than that of [lʲ], although the difference is not significant.

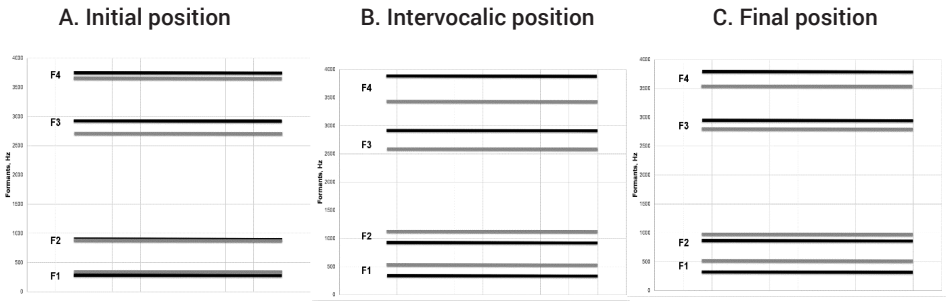

Figure 2. F1–F4 formant structure of Lithuanian and Latvian [l]: mean values of the first four formant frequencies (black – Lithuanian data, grey – Latvian data)

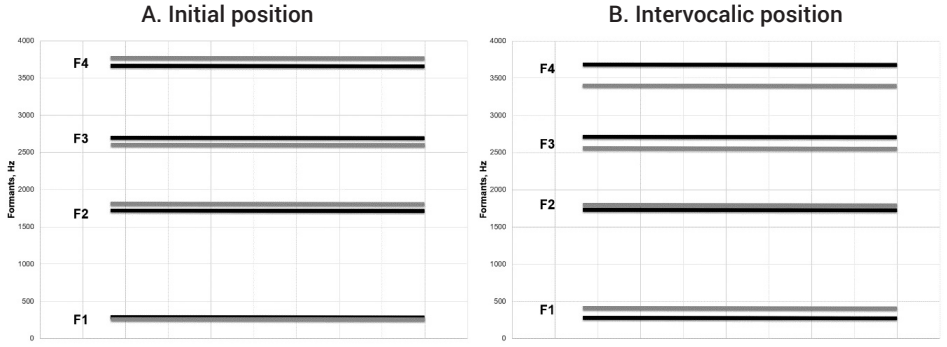

Figure 3. F1–F4 formant structure of Lithuanian /lʲ/ and Latvian /ʎ/: mean values of the first four formant frequencies (black – Lithuanian data, grey – Latvian data)

Decreased F1 frequency, which is associated with palatalization as well, is ambiguous: in prevocalic position, slightly lower F1 frequency was observed for the Latvian [ʎ], while in intervocalic position the result is opposite – F1 is considerably lower for the Lithuanian [lʲ] (Figure 3). No regularities were observed in the data for other formants, except the more pronounced difference in F1–F4 frequencies in intervocalic position (as in the case of non-palatalized sonorants). Consequently, coarticulation processes in Lithuanian and Latvian have a different effect on lateral sonant, so it is expedient to compare formant values in the context of different vowels (Figures 4–6).

Further on, we will discuss separately the results of Latvian plain and palatal laterals and Lithuanian non-palatalized and palatalized laterals. When comparing F1 values of Latvian non-palatal [l] and palatal [ʎ], they are influenced by the quality of adjacent vowels, i. e. vertical tongue movement: Lateral's F1 value increases near open vowels and decreases near close vowels (Figure 4). F2 value correlates with the degree of frontness of adjacent vowels, i. e. with horizontal tongue movement: consonant's F2 frequency decreases near back vowels and increases in the context of front vowels (Figure 4, A). It should be noted that in comparison with [l] the formant structure of the Latvian [ʎ] is more stable and less dependent on the quality of adjacent

vowels. The reason for that is the fact that palatals are articulated in the area of hard palate, they typically have very precise position of the tongue, so their articulation is minimally affected by coarticulation processes. For the non-palatal Latvian [l], in its turn, the values of the first two formants are affected more by the neighbouring sounds.

The formant values of the Latvian non-palatal [l] and palatal [ʎ] change differently in different positions (*<l>Vl*, *V<l>V* and *lV<l>*, Figure 5). F1 remains the most stable, and its value is higher for [l] than for [ʎ] in all positions. F2 changes are the most pronounced: in all positions F2 values of [ʎ] is much higher than those of [l]. F2 value of [l] decreases significantly near [ɔ (:)] and [u (:)] and increases near [i (:)] and [e (:)]. The dynamics of F3 and F4 do not have any relevance in distinguishing between plain and palatal sonorant, although they demonstrate some coarticulatory effects, i. e. their values are decreased in the context of rounded vowels [ɔ (:)] and [u (:)].

When comparing F1–F4 of the Lithuanian lateral sonorants, F1 value of [l] is higher than that of [lʲ], and this is related to the velarization of [l] (Figure 6). F2 values of different sonorants differ significantly in terms of palatalization: F2 value of [lʲ] is significantly higher than its non-palatalized counterpart. In addition, its dynamics indicates a different degree of palatalization: it is more palatalized near the front

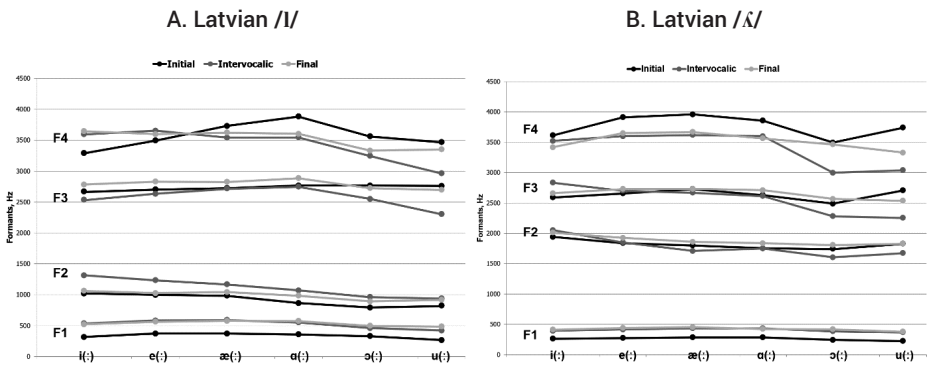

Figure 4. Mean values of F1–F4 formants in the context of different vowels: Latvian /l/ and /ʎ/ in initial, intervocalic and final positions

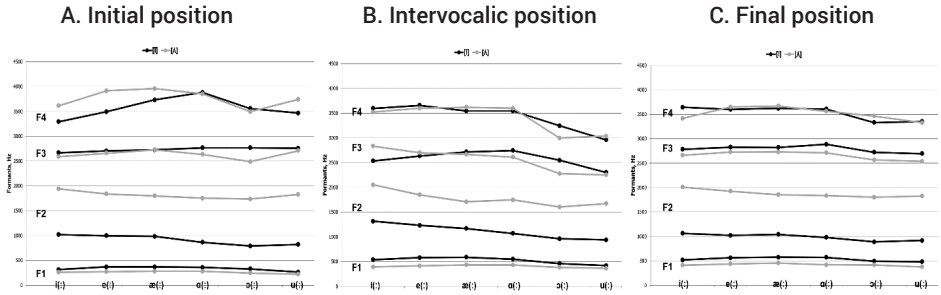

Figure 5. F1–F4 formant structure of Latvian non-palatal /l/ and palatal /ʎ/: coarticulation on adjacent vowels in initial, intervocalic and final positions

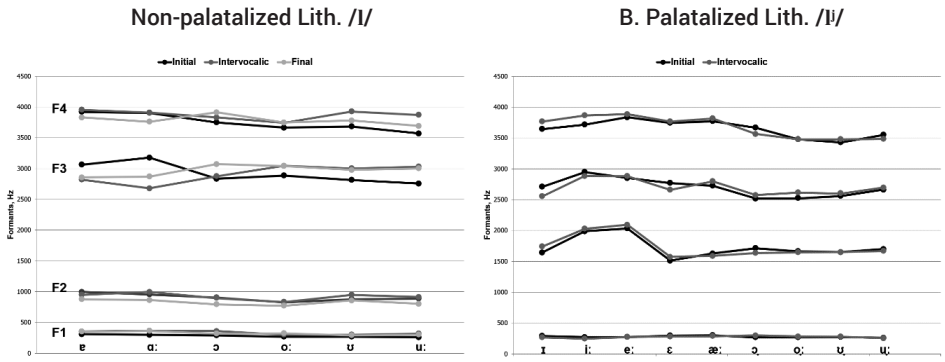

Figure 6. Mean values of F1–F4 formants in the context of different vowels: non-palatalized Lith. /l/ and palatalized Lith. /lʲ/ in initial, intervocalic, and final positions

vowels [ɪ], [i:] and [e:], and less palatalized next to rounded [ɔ̣], [o̤:], [ʊ̣] and [ṳ:] (Figure 6, B). In case of palatalized [lʲ], all four formants are more stable and vary less than in case of [l]. The formant structure of [l], especially F3 and F4, is highly dependent on position (see Figure 6, A).

After examining and comparing the formant structure of laterals in the Baltic languages, it can be concluded that:

1) the degree of palatalization increases in the following order:

Lith., Lat. [l] < Lith. [lʲ] < Lat. [ʎ].

F1–F4 values of the Lithuanian palatalized [lʲ] and Latvian palatal [ʎ] are more stable, their articulation varies less than that of [l], which is affected more by adjacent sounds;

2) the differences in the formant structure of Lithuanian and Latvian laterals are most pronounced in intervocalic position, when the investigated sonorant is between vowels of different quality (cf. transcription, cf.: Lith. [ɪ] – Lat. [i], Lith. [ɛ] – Lat. [e], more about contemporary research on vowel system of Lithuanian and Latvian languages: Jaroslavienė, Grigorjevs, Urbanavičienė, Indričāne 2019).

3) adjacent vowels have the greatest influence on the F2 values of the Lithuanian palatalized [lʲ] and Latvian palatal [ʎ]: F2 frequency increases next to the front vowels [ɪ] / [i], [i:] and [e:] and decreases next to the back vowels [ɔ (:)] and [u (:)], as well as [ɔ̣] , [o̤:], [ʊ̣] and [ṳ:].

6.2. Locus equations

Locus equation data could be important for further investigation of the distinctive features of lateral sonorant in Baltics when data on the spectral properties of consonants are obtained based on the phonetic context of adjacent vowels.

F2 frequency is negatively related to the length of the oral cavity, which in case of consonants is associated primarily with tongue position. Thus, fronting tongue body

gesture induces the increase of the F2 frequency, while retracting tongue body results in generally low F2 (Iskarous et al., 2010, 2024).

Locus equations are linear regressions of the frequency of the second formant transition sampled at its onset ($F2_{onset}$) on the frequency of the second formant sampled in the middle of the following vowel ($F2_{middle}$):

$$\mathbf{F2_{onset} = k \cdot F2_{middle} + c}$$

Björn Lindblom (1963) discovered that the slopes of regression lines for the consonants in CVC syllables with different vowels varied systematically along with place of articulation, and thus could be used for distinguishing between consonants. In accordance with this approach, the F2 locus can be defined as "the frequency of the formant at the first pulse of the vowel after consonant release" (Krull 1987, 44), which varies systematically under the influence of contextual vowels, therefore the so termed locus equations enable one to calculate an ideal locus pattern for each consonant using data on formant transitions before several different vowels (Ladefoged 2003, 163).

Later it was also argued that the slope of a regression line is associated primarily with the degree of coarticulation between the vowel and the consonant (Krull 1987; 1989; Fowler 1994):

1) high slope indicates variable consonantal locus and high degree of coarticulation between the vowel and the consonant (i. e., the vowel markedly affects the consonant);
2) low slope indicates stable locus and low degree of coarticulation between the vowel and the consonant (i. e., the vowel scarcely affects the consonant).

Locus equations are obtained for a single consonant coarticulated with a range of vowels. Slope (*k*) and y-intercept (*c*) values derived from locus equations vary systematically along with the place of articulation across different manner classes (Sussman, Shore 1996).

The results of the two constants of the Lithuanian and Latvian lateral sonant locus equations – slope (k) and y-intercept (c) – are presented in Table 4: the highlighted

Informants	Latvian		Lithuanian	
	k	***c***	***k***	***c***
/l/	**0.33**	**707**	**0.33**	**658**
M1	0.21	801	0.30	736
M2	0.35	740	0.29	666
M3	0.37	643	0.39	564
/ʎ/ / /lʲ/	**0.23**	**1454**	**0.35**	**1252**
M1	0.23	1551	0.33	1377
M2	0.15	1471	0.28	1265
M3	0.26	1403	0.40	1184

Table 4. Locus equations of Lithuanian and Latvian laterals: data of Lith. M1-M3 and Lat. M1-M3 informants (*k* – slope, *c* – y-intercept)

row shows mean data, the other rows show the results of individual informants (M1, M2 and M3).

According to the data presented in Table 4, the slope of the current non-palatalized / non-palatal lateral sonant in the Baltic languages is higher (Lith. [l] k = 0.43; Lat. [l] k = 0.33) than the corresponding Lith. palatalized [lʲ] (*k* = 0.39) and Lat. palatal [ʎ] (k = 0.23). Thus, the slope increases in the following order:

Lat. [ʎ] < Lat. [l] < Lith. [lʲ] < Lith. [l]

The other index of the locus equations – the point where the regression line of the locus equation intersects the y-axis, or y-intercept (*c*) – changes in reverse: its larger values are characteristic of the Lithuanian palatalized [lʲ] (*c* = 1076 Hz) and Latvian palatal [ʎ] (*c* = 1454 Hz), lower for the Lithuanian [l] (*c* = 546 Hz) and Latvian [l] (*c* = 707 Hz). According to the decreasing values of y-intercept, the lateral consonants of Lithuanian and Latvian are arranged in almost the same order as according to the increasing slope:

Lat. [ʎ] > Lith. [lʲ] > Lat. [l] > Lith. [l]

The Latvian [ʎ] has the lowest slope and the highest value of y-intercept, while the Lithuanian [l] has diametrically opposite values. The indices of locus equations make it possible to distinguish between Lithuanian and Latvian lateral sonorants by both palatality/palatalization and the place of articulation. Visually, the differences in laterals can be seen by depicting slope and y-intercept values in the coordinate plane: slope on the x-axis and y-intercept on the y-axis (Figures 7–8; mean data are indicated by larger symbols, individual data are indicated by smaller symbols).

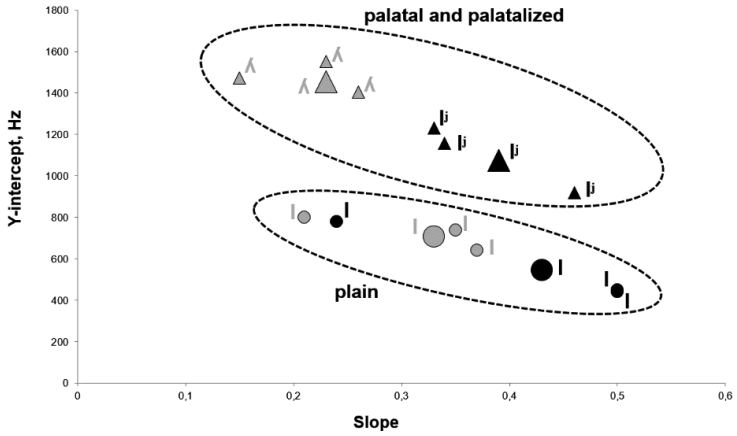

Figure 7. F2 loci of Lithuanian (black) and Latvian (grey) laterals with highlighted zones of plain and palatal/palatalized consonants. F2 loci for /l/ are marked with circles, F2 loci for /ʎ/ and /lʲ/ are marked with triangles. Larger symbols indicate mean data, smaller symbols indicate individual data

In the coordinate plane, Latvian palatal [ʎ] and Lithuanian palatalized [lʲ] occupy higher position than the Lithuanian and Latvian [l] (Figure 7). Palatal and palatalized lateral sonorants have high y-intercept values and lower slopes, which indicates greater resistance to adjacent vowels than non-palatal consonants. The higher coarticulatory resistance of palatal/palatalized sonant to coarticulation is due to two factors (Recasens 1985):

1) they require high articulatory control over relatively large region of vocal tract (i. e., wide pharyngeal passage) with a large degree of dorsopalatal contact, which results in high F2 frequency at the onset of an adjacent vowel;
2) palatal articulation involves highly constrained gestures that override conflicting vocalic gestures (such as those needed to produce low back vowels). This results in relatively stable F2 onset frequency that is scarcely affected by vowel quality.

Latvian [ʎ] and Lithuanian [lʲ] have more stable locus than their unpalatalized equivalents (Figure 7), which is also related to more precise position of the tongue and other articulators during articulation. However, in the contemporary Baltic languages, according to the indices of locus equations Latvian [ʎ] occupies the extreme position (has the highest y-intercept and the lowest slope values) and differs from the Lithuanian [lʲ], for which palatalization – the lifting of the middle part of the tongue towards the hard palate – is only secondary articulation (cf. Pakerys 2003, 74).

The calculated values of slope and y-intercept also allow to distinguish between the Baltic laterals according to the place of articulation (Figure 8).

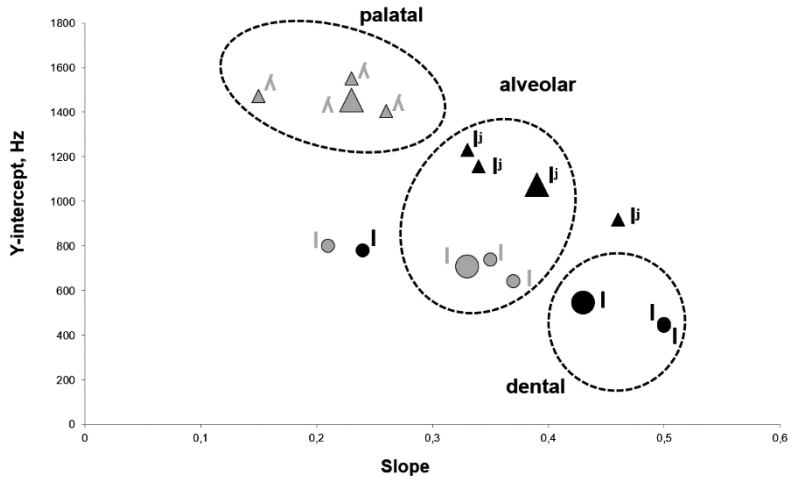

Figure 8. F2 loci of Lithuanian (black) and Latvian (grey) laterals with highlighted zones of palatal, alveolar and dental consonants. F2 loci for /l/ are marked with circles, F2 loci for /ʎ/ and /lʲ/ are marked with triangles. Larger symbols indicate mean data, smaller symbols indicate individual data

According to the increasing values of the slope and the decreasing values of the y-intercept, the articulation classes of Lithuanian and Latvian lateral sonorants are arranged, as follows:

palatal Lat. [ʎ] < alveolar Lat. [l] / alveolar palatalized Lith. [lʲ] < dental Lith. [l]

The obtained results agree with the classification of contemporary Baltic sonorants in Table 1. As it can be observed in Figure 8, Lithuanian [lʲ] and [l], as well as Latvian [ʎ] and [l] can be distinguished both by slope and y-intercept values. When comparing Lithuanian and Latvian data, it can be observed that both indices interfere heavily in case of the Latvian [l] and Lithuanian [lʲ]. Higher slope values and lower y-intercept values of the Lithuanian [lʲ] in comparison with the Latvian [ʎ] suggest less coarticulatory resistance to vowel effects.

The values of slope and y-intercept for both Lithuanian and Latvian alveolar and dental laterals vary greatly, and individual data may not fit into one articulation zone. This agrees with previous studies on Latvian sonorants, which allow the lateral sonant [l] to be classified as both dental and alveolar consonant (Grigorjevs 2012b; Taperte 2014, 94–95).

Locus equation indices also demonstrate, on the one hand, lower coarticulatory resistance of non-palatal lateral sonorant (compared to palatal) and, on the other hand, uneven degree of coarticulation non-palatal lateral sonorant and adjacent vowels (depending on different degree of velarization, individual differences, etc.).

Conclusions

The analysis of the formant structure and locus equation indices of Latvian and Lithuanian laterals showed that these consonants can be distinguished efficiently using these parameters. The study was performed considering different positions of the consonants on CVC syllables (prevocalic, intervocalic, and postvocalic), as well as the quality of the adjacent vowels:

1. In terms of the degree of palatalization, Lithuanian and Latvian laterals can be arranged in the following order:

   non-palatal Lith., Lat. [l] < palatalized Lith. [lʲ] < palatal Lat. [ʎ]

   The formant structure of Latvian [ʎ] and Lithuanian [lʲ], unlike the corresponding non-palatal laterals, is more stable and less dependent on the quality of adjacent vowels.
2. Vowel context effects the degree of palatalization, e.g., palatalized [lʲ] next to front vowels [ɪ], [iː], and [eː] is pronounced "softer" than next to back advanced vowels [ɐ̟], [ɒ̟ː], [ʊ̟], and [ʉ̟ː].
3. The most significant differences in the Latvian and Lithuanian [l] formant structure are recorded in the intervocalic position, when the sonorants are between vowels that differ in both languages (cf. Lith. [ɪ] – Lat. [i], Lith. [ɛ] – Lat. [e]).
4. Acoustic data demonstrates differences in coarticulation effects between Latvian palatal /ʎ/ and Lithuanian palatalized /lʲ/. Latvian /ʎ/ is characterized

with more stable vowel F2 locus, which indicates higher degree of coarticulatory resistance to vowel effects. Lithuanian /lʲ/, on the contrary, is more variable depending on vowel context. The same is true (although, to a lesser degree) for the Lithuanian and Latvian /l/.

5. According locus equation indices (the increasing values of slope and decreasing values of y-intersept), the following articulation classes of Lithuanian and Latvian lateral sonorants can be distinguished:

palatal Lat. [ʎ] < alveolar Lat. [l] / palatalized alveolar Lith. [lʲ] < dental Lith. [l]

The assumption on the similarity of Latvian non-palatal /l/ to Lithuanian palatalized /lʲ/ (as both are traditionally classified as alveolar consonants) is only partly supported by the recent data. In terms of the degree of coarticulation indicated by slope values of locus equations, Latvian /l/ is closer to Lithuanian /lʲ/, while its formant structure, especially the low F2 values, brings it closer to Lithuanian /l/ and in some cases suggests even greater degree of velarization than the latter. Further research on the variability of formant structure and locus equations as affected by syllable or phrasal position, stress, speaking style and other aspects should be carried out to evaluate their effect on Lithuanian and Latvian laterals. Parallel study of articulation and perception would be beneficial to link acoustic data with articulation and auditory processes.

Abbreviations

ACC	accusative
C	consonant
C^j	palatalized consonant
C	y-intercept
F	formants
$F2_{onset}$	second formant frequency measured at onset
$F2_{middle}$	second formant frequency measured at middle
Hz	hertz
K	slope
M	masculine
NOM	nominative
PL	plural
SD	standard deviation
V	vowel
V^u	back vowel
V^i	front vowel
–#	position before pause

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Kopsavilkums

Rakstā tiek aplūkotas latviešu un lietuviešu standartvalodas laterālo spraudzeņu akustiskās īpašības. Raksta mērķis ir izpētīt, kādā veidā izpaužas akustiskais kontrasts starp alveolāro / dentālo /l/ un palatālo /ʎ/ latviešu valodā un starp dentālo /l/ un palatalizēto alveolāro /lʲ/ lietuviešu valodā. Rakstā analizēti sešu vīriešu (trīs lietuviešu un trīs latviešu) runas ieraksti. Tika aplūkoti sākuma un beigu līdzskaņi [l]V[l] zilbēs, kā arī intervokāli līdzskaņi mākslīgos V[l]V tipa vārdos.

Rakstā tiek analizētas laterālo spraudzeņu formantu struktūras (it sevišķi pirmā un otrā formanta) izmaiņas atkarībā no līdzskaņa pozīcijas un blakus esoša patskaņa kvalitātes, kā arī līdzskaņu lokusa vienādojumu indeksi. Akustiskie dati liecina par līdzartikulācijas procesu atšķirībām starp latviešu palatālo /ʎ/ un lietuviešu palatalizēto /lʲ/. Latviešu [ʎ] un lietuviešu [lʲ] formantu struktūra atšķirībā no atbilstošajiem nepalatalizētajiem līdzskaņiem ir stabilāka un ir mazāk atkarīga no blakus esošu patskaņu kvalitātes. Fonētiskais konteksts ietekmē palatalizācijas apjomu, piem., palatalizētais [lʲ] blakus [ɪ], [iː] un [eː] tiek izrunāts "mīkstāk" nekā [ɔ̨], [ɔ̨ː], [ʊ̨] un [ʊ̨ː] fonētiskajā apkaimē. Vislielākās atšķirības latviešu un lietuviešu [l] formantu struktūrā ir konstatētas intervokālā pozīcijā. Latviešu laterālajam spraudzenim /ʎ/ ir raksturīgs visstabilākais F2 lokuss, kas liecina par lielāku artikulārās pretestības pakāpi starp līdzskani un blakus esošo patskani. Turpretī lietuviešu /lʲ/ F2 lokuss ir mainīgāks un vairāk atkarīgs no fonētiskās apkaimes. Tas pats attiecas arī uz lietuviešu /l/.

Atslēgvārdi: lietuviešu valoda; latviešu valoda; laterālie spraudzeņi; akustiskās pazīmes; palatalizācija; formants; lokusa vienādojumi.