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Articulatory Characteristics of Secondary Palatalization in Romanian Fricatives

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Abstract: The production of fricatives involves the complex interaction of articulatory constraints resulting from the formation of the appropriate oral constriction, the control of airflow through the constriction so as to achieve frication and, in the case of voiced fricatives, the maintenance of glottal oscillation by attending to transglottal pressure. To better understand this mechanism in a relatively understudied language, we explore the articulatory characteristics of five pairs of plain and palatalized Romanian fricatives produced by 10 native speakers using ultrasound imaging. Our analysis includes an assessment of the robustness of the plain-palatalized contrast at different places of articulation, a comparison of secondary palatalization with other relevant word-final [Ci] structures, and the identification of individual variation patterns. Since our study is the first to document the articulatory properties of secondary palatalization in Romanian, our findings are of descriptive interest.

Keywords: secondary palatalization; high vowels; morphological palatalization; articulatory properties

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Citation: Spinu, Laura, Alexei Kochetov, and Maida Percival. 2024. Articulatory Characteristics of Secondary Palatalization in Romanian Fricatives. *Languages* 9: 201. https://doi.org/10.3390/languages9060201

Academic Editor: John Hajek

Received: 5 November 2023
Revised: 14 April 2024
Accepted: 16 April 2024
Published: 31 May 2024

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1. Introduction

Romance languages often exhibit a process of full palatalization, also known as coronalization (Bateman 2007; Hume 1994) whereby a consonant's primary place of articulation changes to palatal or postalveolar (e.g., k → ʧ), often across morphological boundaries. Like other Romance languages, Romanian exhibits full palatalization (e.g., [zik] 'I say', [ziʧe] 's/he says'). Romanian, however, is unique among Romance languages in also exhibiting word-final secondary palatalization (e.g., [lupʲ] 'wolves'), and it is possible for a segment to undergo both full and secondary palatalization when certain morpho–phonological conditions are met, e.g., [fak] 'I do', [faʧʲ] 'you do'. Secondary palatalization (henceforth SP) has been extensively documented in Slavic (Fant 1970; Kochetov 2002), Celtic e.g., Irish (Bennett et al. 2018; Ní Chiosáin 1994) and Scottish Gaelic (Kirkham and Nance 2022; Nance and Kirkham 2022; Sung et al. 2015) and Finno-Ugric languages, e.g., Estonian (Malmi 2022) in a series of acoustic, perceptual, and articulatory studies. Among others, SP is also present in Mongolian, Carib, Zoque, and Isthmus Mixe (Bateman 2007; Bhat 1978). While several studies (Spinu et al. 2018; Spinu and Lilley 2016) have addressed the acoustic—and to a lesser extent perceptual—characteristics of the plain-palatalized contrast in Romanian consonants, articulatory studies have not yet been conducted. In this study[1], we examine the articulatory characteristics of SP in Romanian fricatives at four different places of articulation and for five consonants including postalveolars which, according to cross-linguistic studies, do not typically contrast plain and palatalized forms (Bateman 2007). Our work fills this gap in the literature and provides a comprehensive picture of this phenomenon in a relatively understudied language. The examination of additional but related word-final

C+i structures (which we elaborate on in the following sections) is particularly noteworthy, as it enables us to clearly establish the properties of Romanian SP.

1.1. General Properties of SP

This section provides an overview of the most important findings regarding SP in other languages, with a particular focus on its articulation, given the focus of the current paper. In terms of phonological status, SP can be distinctive, as in Russian, where consonants with secondary palatal articulations are part of the phonemic inventory, contrasting with plain ones, e.g., /krov/ 'shelter' vs /krovʲ/ 'blood' (Yanushevskaya and Bunčić 2015). In other languages, such as Koromfe (a language of the Gur family), the addition of an SP gesture to the primary place gesture is considered allophonic: /gɛbam/ → [gʲɛbam] 'please' (Bateman 2007). Romanian, as we will see, does not fully conform to either of these patterns.

Articulatorily, SP is characterized by the presence of a secondary palatal gesture timed with respect to the primary place gesture of a consonant (Ladefoged and Maddieson 1996). Languages vary in the phonetic realization of plain and palatalized segments at a given place of articulation (Kochetov 2002). For instance, while in the case of labial stops, the most frequent realization of the contrast is the simple absence/presence of the secondary palatal gesture, there are also cases (e.g., Irish) where the plain labial (in a plain-palatalized contrasting pair) can be velarized or labialized (Bennett et al. 2018). For the phonologically palatalized coronal stop, all realizations involve raising and fronting of the tongue body to the hard palate, usually with a laminal shape to the tongue front. Differences in realizations involve the location of the primary constriction (upper teeth/alveolar ridge, post-alveolar region, pre-palatal region, or hard palate) as well as the burst release duration. Palatalized coronals are thus less restricted than palatalized labials in their realizations.

Regarding specific investigations, an electromagnetic articulography (EMA) study of the articulatory characteristics of Russian palatalized stops based on data from 3 speakers (Kochetov 2002) reported that palatalized coronal stops showed a raising and fronting (although fronting was not contrastive) of the tongue body beginning before primary closure, and coinciding with closure. The same study also reported on the acoustic properties of SP. Palatalized coronals were found to be longer than plain ones with a noisier strident-like release which is attributed to the laminal contact. More generally, palatalized consonants (compared to plain consonants) cause lowering of F1 and raising of F2 on neighboring vowels (Fant 1970; Kochetov 2002).

Comparing different places of articulation, it was found that in palatalized labial stops, raising and fronting are greater compared to coronals, as in the former the tongue body is not constrained by the primary articulator. Kochetov observed a raising and fronting of the tongue body beginning less than 30 ms before primary closure and coinciding with the release of the primary articulator. He noted that the peaks of the fronting and raising were not always simultaneous and confirmed earlier reports that Russian plain consonants are velarized. Furthermore, the timing of the primary (the lips) and secondary (the tongue body) articulations, as well as tongue raising and tongue fronting, were found to vary by speaker and by syllabic position. In coda position, the achievement of the secondary target was found to be earlier than in onset position (Kochetov 2006).

Postalveolar place is also of interest, given that it is a host of SP in Romanian and we have included it in our study as mentioned above. Kochetov (2002) observed that postalveolar segments usually pattern with either plain or palatalized consonants but not both. Some exceptions were reported: Livonian contrasts /ʃ/ and /ʃʲ/ (Campbell 1974), and morphological palatalization affects all consonants in Isthmus Mixe, including the postalveolar fricative (Dieterman 2008). An acoustic analysis found distinctions between the plain and palatalized postalveolar forms in duration, spectral peak, and formant transitions, with higher F2 and F3 for the palatalized consonants (Dieterman 2008). While according to some analyses Russian does not directly contrast plain and palatalized postalveolar fricatives, it is one of the few languages with a 4-way contrast involving palatalized sibilant fricatives, specifically: palatalized dental/alveolar /sʲ/, palatalized post-alveolar (prepalatal) /ʃʲ/, non-palatalized dental/ alveolar /s/ and retroflex (apical post-alveolar) /ʂ/ (Spinu et al. 2018; Timberlake 2004). In an articulatory study of Russian palatalized consonants, Biteeva Lecocq (2021) noted that the tongue is more fronted for /ʃʲ/ compared to /ʃ/ and its shape more resistant to the vocalic context. Furthermore, the tongue shape for /ʃʲ/ was not affected by either stress or syllabic position.

Few studies to date have addressed the articulatory properties of SP using ultrasound, with some notable exceptions for Russian (Biteeva Lecocq 2021; Cavar and Lulich 2021; Matsui and Kochetov 2018), Scottish Gaelic (Kirkham and Nance 2022; Nance and Kirkham 2022; Sung et al. 2015) and Connemara Irish (Bennett et al. 2018).

1.2. SP in Romanian

Turning to Romanian, SP is only found in word-final position, being commonly associated with (but not restricted to) the presence of two affixes: the plural of certain nouns and adjectives (e.g., [pom] 'tree' vs. [pomʲ] 'trees', spelled *pomi* in Romanian orthography) and the second person singular in the present indicative of verbs (e.g., [sar] 'I jump' vs. [sarʲ] 'you jump', spelled *sari*). Regarding the distribution of the surface forms, it should be noted that the plural form is realized as SP after a single consonant, but as a full [i] after certain consonant clusters, as in [sokru] – [sokri] 'father(s)-in-law'.

From a phonological perspective, a common view is that for the SP forms the word-final /-i/ triggers palatalization on the preceding consonant and is subsequently deleted (Spinu et al. 2012), resulting in a *surface* contrast between plain and palatalized consonants. Thus, SP in Romanian is not considered phonemic as it is in Russian.

1.2.1. Morphological Conditioning

As mentioned above, secondarily palatalized consonants tend to contrast on the surface with plain consonants forming plain-palatalized minimal pairs (e.g., 1a-b for the plural-singular alternation, and 2a-b for the second person-first person alternation) but this morphological requirement is not mandatory, as morphologically unrelated words can also form a minimal pair (e.g., 3a-b). In these examples, the orthographic spelling is shown in italics.

(1)	a.	*pantofi*	[pantofʲ]	'shoes'	b.	*pantof*	[pantof]	'shoe'
(2)	a.	*lucrezi*	[lukrezʲ]	'you work'	b.	*lucrez*	[lukrez]	'I work'
(3)	a.	*unghi*	[ungʲ]	'angle'	b.	*ung*	[ung]	'I lubricate'

Such pairs led Petrovici to posit palatalized consonants as phonemic in Romanian (Petrovici 1956), a view unanimously opposed by contemporary linguists (Chitoran 2002). Not only is the occurrence of these consonants restricted to word-final position, but it is also generally morphologically predictable, as they are frequently associated with the two inflectional suffixes shown above. In the presence of these affixes, root-final consonants sometimes undergo further changes in their primary place and/or manner of articulation in addition to secondary palatalization (4), more precisely they exhibit assibilation (4a-b), change in primary place of articulation (4c-d) or the first type of palatalization described in the introduction, that is, coronalization (4e-f). As (4) shows, anterior coronal obstruents [t, d, s, z] and velars [k, g] are all affected by such processes.

(4)	a.	[pot]	'I can'	[potsʲ]	'you can'
	b.	[kad]	'I fall'	[kazʲ]	'you fall'
	c.	[pas]	'step'	[paʃʲ]	'steps'
	d.	[treaz]	'awake'	[treʒʲ]	'awake-pl'
	e.	[rak]	'crawfish'	[ratʃʲ]	'crawfish-pl'
	f.	[rog]	'I beg'	[rodʒʲ]	'you beg'

In the few cases where word-final palatalized consonants are not conditioned by the presence of these suffixes, they are still phonologically predictable. A small number of monomorphemic items exhibit final SP in the absence of the usual morphemes, as shown in (5)—note that this list is not comprehensive. Historically these structures resulted from the application of a process of syncope and palatalization of the CL cluster as in (5a): Latin *oculus* [okulus] > Romanian [ok^j].

(5)	a.	[ok^j]	'eye/eyes'	h.	[aitʃ^j]	'here'
	b.	[ʒung^j]	'pang'	i.	[ɨm^j]	'to me'
	c.	[unk^j]	'uncle/uncles'	j.	[jer^j]	'yesterday
	d.	[kurek^j]	'cabbage'	k.	[barem^j]	'at least'
	e.	[puʃt^j]	'kid/kids'	l.	[nimen^j]	'nobody'
	f.	[totuʃ^j]	'however	m.	[mjerkur^j]	'Wednesday'
	g.	[az^j]	'today'	n.	[viner^j]	'Friday'

1.2.2. Acoustic and Perceptual Properties

A number of studies have revealed higher perceptual salience of SP for coronals as compared to labials in Russian (Kavitskaya 2006; Kochetov 2002; Ní Chiosáin and Padgett 2012). Spinu et al. (2012), however, found the reverse pattern in Romanian. In their detailed account of the acoustic and perceptual properties of SP in Romanian fricatives, greater acoustic separation and higher perceptual discrimination of plain and palatalized consonants were found at the labial and dorsal places of articulation compared to the dental and postalveolar places. Given listeners' very low perceptual sensitivity to SP in postalveolars, the question arose whether it is realized at all on these consonants in Romanian. In a subsequent acoustic study, Spinu (2018) found evidence suggesting the contrast was produced by 27 out of 31 speakers tested. This was consistent with previous intuitions and reports obtained directly from native speakers (Suteu 1961). Spinu's main findings were that: (a) the plain vs. palatalized form can be distinguished reliably based on cepstral measurements (though not to the same extent as with other places of articulation), and (b) the SP contrast was acoustically realized at this place by the overwhelming majority (87.1%) of the speakers.

Nevertheless, the SP contrast with postalveolars conformed to typological predictions of being acoustically and perceptually weaker compared to other places. From a phonological perspective, the fact that to date this contrast does not appear to have been neutralized (possibly due to high functional load) or enhanced (like other places within the same paradigm in Romanian) is a good example of the lack of 1-to-1 correspondence between the phonetic factors triggering neutralization and actual neutralization patterns attested in individual languages (Kochetov 2002). It is thus unclear whether SP in Romanian postalveolars is robustly implemented in articulation but at the same time obscured acoustically by the presence of the primary place of articulation, or whether it is an articulatorily weak contrast and/or variable across speakers (which may indicate a certain degree of neutralization).

1.2.3. Articulatory Properties

The articulatory properties of Romanian secondary palatalization have not, to our knowledge, been investigated to date using imaging technology. Our study therefore is intended to shed light on how the plain-palatalized contrast is realized articulatorily, and whether similarities exist between articulatory patterns and previously explored acoustic and perceptual patterns (Spinu 2018; Spinu and Lilley 2016; Spinu et al. 2012).

It is worth noting that, while not addressed in the literature, it has anecdotally been suggested to the first author at various conferences in the field that a possible description for the phenomenon generally referred to as SP in Romanian would be that of devoiced vowels (with or without accompanying aspiration) as in Japanese (Iwasaki et al. 2022). This was based purely on perceptual grounds, but it raises the question of what the best description might be for the phenomenon that is the focus of the current paper. It is difficult to make predictions in the absence of any studies directly comparing secondary palatalization and devoiced vowels, but we can tentatively expect that devoiced vowels would have the same lingual configuration as voiced vowels, without the greater anterior tongue raising and posterior tongue fronting generally observed with SP.

While acoustically similar, there are several arguments against this view, the most important of which being that devoiced vowels typically occur in voiceless environments (e.g., in between, preceding, or following voiceless obstruents). Romanian SP is encountered with voiced consonants as well as voiceless ones. Out of 11 voiced consonants (excluding glides) in the Romanian inventory, 10[2] have a secondarily palatalized counterpart. Moreover, the additional phonological processes triggered by the presence of the final /i/ suffix, e.g., assibilation and coronalization, as shown in (4), have long been associated with palatalization, both phonologically and at the phonetic level. It should however be noted that Spinu and Lilley (2016) found that in the /f-v/ pair (in a corpus including equal numbers of both plain and palatalized consonants), the voice distinction is mostly realized at the beginning of the fricative, consistent with the possibility that Romanian fricatives tend to devoice towards the end of the segment. This devoicing may affect SP as well. Furthermore, the possibility arises that aspiration of word-final consonants may serve as an enhancing cue to their palatalized (plural) status. There is thus a need for a more precise description of the realization of Romanian SP and how it interacts with factors such as consonant voicing, place, and manner of articulation. Since our study is not directly concerned with these differences but rather with tongue position as visualized with ultrasound technology, we will only be able to provide a partial answer at this time.

1.2.4. Related Structures

Because surface SP in Romanian is associated with a word-final underlying /i/, the question arises to what extent this realization is similar to other structures involving post-consonantal word-final /i/. Such structures include

- the plural+definite article sequence for masculine nouns and adjectives—a sequence of two underlying /i/[3], i.e., /ii/ that has traditionally been transcribed phonetically with a word-final [i] as in (6a)
- root-final unstressed /i/ (6b)
- the stressed verbal suffix /i/ associated with the infinitive form of a subset of Romanian verbs (6c)

(6) a. *pantofii* /pantof + i + i/, root + pl. + def. art., [pan.ˈto.fi], 'the shoes'
b. *Sofi*, proper name, [ˈso.fi], 'Sofi' (short form of Sofia)
c. *a istovi* /istov + i/, root + infinitive marker, [is.to.ˈvi], 'to exhaust'

In all the cases in (6) the assumption has been that they end in a full-fledged word-final [i][4] (with the definite article merging with the plural marker into a surface high vowel [i] in (6a) (Chitoran 2002)) and they are typically transcribed as such in studies of Romanian (Chitoran 2002; Renwick 2012), but to our knowledge their acoustic or articulatory properties have not been investigated experimentally. It is thus not clear if there are differences in tongue position for plural structures (a single underlying /i/ realized as SP on a preceding consonant) compared to plural definite structures (two underlying /ii/word-finally, assumed to be realized as a post-consonantal full-fledged [i]). The effects of stress (6b versus 6c) have also not been investigated to date.

To address this and other related questions, the current study explores the articulatory characteristics of secondary palatalization in Romanian fricatives. As such, it contributes new data from a relatively understudied language and adds to the body of work on the realization and neutralization of the SP contrast as well as on fricative properties.

2. Current Study

The production of fricatives involves the complex interaction of articulatory constraints resulting from the formation of the appropriate oral constriction, the control of airflow through the constriction so as to achieve frication and, in the case of voiced fricatives, the maintenance of glottal oscillation by attending to transglottal pressure (Proctor et al. 2010). We selected fricatives as the optimal segments for our study for several reasons. First, we aimed to make our work comparable with earlier acoustic studies of Romanian SP (Spinu 2018; Spinu and Lilley 2016; Spinu et al. 2012). Second, the Romanian fricative inventory enables the investigation of a higher number of places of articulation (i.e., four different places) compared to all other consonant categories. Lastly, among the inventory of plain and palatalized consonants in Romanian, fewer changes appear to affect the primary place in fricative plain and palatalized pairs of sounds compared to stops, for which coronalization or affrication of the consonant are common in the presence of SP—see example (4). Our experiment was designed to address the following research questions:

1. Does the articulatory behavior of the plain-palatalized contrast reflect the acoustic and perceptual findings of earlier studies? Specifically, is the separation between plain and palatalized forms largest with labials and dorsals, and weakest with postalveolars, with dentals falling in between?
2. Is there evidence of neutralization of the perceptually weak SP contrast at the postalveolar place of articulation? Specifically, do plain and palatalized postalveolars differ only minimally, and/or is there more variability in the realization of this contrast, including speakers who do not realize it?
3. Is Romanian SP characterized by features distinguishing it from the high vowel [i]? Specifically, are there differences in tongue position during the articulation of palatalized consonants versus consonants followed by a syllabic high front vowel ([i]), either stressed or unstressed?

While not directly connected to SP, our experiment also enables a comparison between stressed and unstressed vowels in word-final position. The expectation is that there might be an effect of stress, manifested as a more extreme articulation in stressed syllables. It is possible however we do not find such an effect: Biteeva Lecocq (2021) reports that in Russian the tongue shape for /ʃʲ/ is not affected by stress. We are also interested in whether differences exist between the plural definite forms which underlyingly end in a sequence of two /i/ suffixes, e.g., /lupii/, lup + i + i (root + plural suffix + definite article suffix) and words ending in a single underlying /i/, whether unstressed, e.g., proper noun *Jovi*, /ˈʤo.vi/, or stressed, e.g., infinitive form of a certain category of verbs, e.g., *a lovi*, 'to hit', /lo.ˈvi/.

To study patterns of Romanian palatalization, we use ultrasound tongue imaging, a method that has been used extensively in phonetic research to study differences in lingual articulations, including secondary articulations such as palatalization and velarization (Bennett et al. 2018; Kirkham and Nance 2022; Proctor 2011; Roon and Whalen 2019). Numerous ultrasound studies use the Smoothing Spline ANOVA (SS-ANOVA); (Davidson 2006; Mielke et al. 2011, 2017) method to determine if tongue shapes for two or more articulations differ from each other in any specific region of the tongue. One limitation of this method is that separate SS-ANOVAs need to be performed for each speaker, given the inherent individual differences in the vocal tract size and shape, as well as the placement of the probe. Another limitation is that, while indicating significant differences, an SS-ANOVA model does not tell us how big the difference is—over the entire tongue shape or for a specific region. This makes it difficult to use the method when the research requires comparisons for multiple articulations or phonetic contexts, as well as for multiple speakers. One alternative approach to analyzing ultrasound data is to measure the distance between the origin of the probe and a point or multiple points on the tongue surface. Such distance measures can be calculated for each token and combined for multiple speakers in traditional quantitative analyses such as linear mixed effects models. For example, in their study of the velar fricative in Iskarous et al. (Iskarous et al. 2011) measured the distance from the probe to the point of the posterior tongue surface showing the maximum displacement (raising and retraction) towards the target. Similarly, Hussain and Mielke (2020) used the measures of tongue retraction and blade anteriority (as distances from the probe to the most posterior and more anterior points on the tongue surface) to study differences between rhotic and non-rhotic vowels in Kalasha. In their analysis of tongue shapes for multiple coronal consonant and vowel articulations in Recasens and Rodriguez (2016, 2017, 2018) took this approach a step further to calculate average distances from the probe to specific regions of the tongue surface (pharyngeal, velar, palatal, and alveolar). A similar approach for two regions—posterior and anterior—was adopted in the analyses of multiple coronal articulations in Arrernte by Tabain and Beare (2018) and of dental and retroflex consonants in Kannada by Kochetov et al. (2018). In the current paper we adopt the latter approach as an appropriate way to quantify tongue shape differences between plain and palatalized consonants. This is because palatalized consonants are typically distinguished from their plain counterparts by the fronting of the posterior portion of the tongue and the raising of the anterior portion e.g., Kochetov (2002) and Biteeva Lecocq (2021). We would therefore expect posterior distance differences to be smaller and anterior distances to be greater for Romanian palatalized fricatives compared to their plain counterparts. We may also expect Romanian fricatives to differ in the palatalization effect, with labials in particular showing greater plain-palatalized differences than the postalveolar /ʃ/.

2.1. Participants, Materials and Methods

2.1.1. Participants

The participants were 10 native speakers of Romanian, 5 females and 5 males. All the speakers lived in Canada except for one, who resided in Romania and was visiting for a few weeks, and all used Romanian regularly with members of their families. The mean age was 42 (range 29–51). They all spoke English, having left Romania in their adulthood. Except for the one speaker visiting from Romania, the rest of the participants had lived in Canada for a minimum of 6 years and a maximum of 16 years. None of the participants reported any speech or hearing problems.

2.1.2. Stimuli

Following the methodology employed in earlier studies (Spinu 2018; Spinu and Lilley 2016; Spinu et al. 2012), the stimuli consisted of 5 root-final fricatives, specifically /f, v, z, ʃ, h/, each embedded in 4 different target words. It should be noted that the latter consonant was found to be realized as a velar fricative 86.7% of the time when plain, and palatal fricative 99.7% of the time when palatalized, (Spinu and Lilley 2016). Each consonant was part of a series of (real) words ending in one of three forms:

1. plain consonant (singular), e.g., *cireş* [ʧi.ˈreʃ] ‘cherry tree’
2. palatalized consonant (plural indefinite), e.g., *cireşi* [ʧi.ˈreʃʲ] ‘cherry trees’
3. the vowel /i/, (plural definite), e.g., *cireşii* [ʧi.ˈre.ʃi] ‘the cherry trees’

Other than being real words of Romanian, the root words were also disyllabic, with final stress, and for each of them the consonant of interest was root-final. These requirements imposed limitations on the selection of the targets, and thus the vowels preceding the target fricatives could not be strictly controlled for. The only requirement for vowels was that they not be high front, as these are typical SP triggers across languages and we sought to avoid coarticulatory effects on the targets. The preceding vowels were /e/, /a/, /o/, /u/ but their distribution was not balanced across consonants.

We further added two other constructions: nonce names, consisting of proper names of the form [CVˈ.Ci], where the final /i/ is unstressed, and nonce verbs (with one exception), presented in their infinitive form, ending in a stressed /i/: [CV.Ciˈ]. The total number of target forms for each consonant was thus 14 (4 words × 3 forms, plus 1 nonce name + 1 nonce verb). Table 1 shows all the constructions we elicited. For the full set of stimuli, please consult Appendix A.

Table 1. Full set of forms elicited for each target consonant. We are only showing the set for /f/ here, and only one of 4 target words (i.e., cartof 'potato'). Three additional words were elicited in the singular, plural indefinite and plural definite forms.

Morphology	Realization (Word-Final)	IPA	Example (Orthography)
Singular	plain consonant	-C#	*cartof*
Plural Indefinite	palatalized C	-Cʲ#	*cartofi*
Plural Definite	high V, unstressed	-Ci#	*cartofii*
Nonce Name	high V, unstressed	-Ci#	*Lofi*
Nonce Verb	high V, stressed	-ˈCi#	*a lofi*

2.1.3. Instrumentation and Procedure

Midsagittal ultrasound data were collected using the Telemed Echo Blaster 128 CEXT-1Z system with an Articulate Instruments pulse-stretch unit (Wrench and Scobbie 2011). The frame rate was 38 frames per second, the probe field of view and depth were 82 degrees and 180 mm. The probe was stabilized using an Articulate Instruments stabilization headset (Scobbie et al. 2008). Audio recordings were done using an AT831b lavalier microphone and a Sound Devices USBPre2 pre-amp. The audio, collected at a sampling rate of 22,050 Hz, was synchronized with the ultrasound video using the *Articulate Assistant Advanced* software (AAA (Articulate Instruments Ltd. 2012)). The data were collected in the Phonetics Lab at the University of Toronto.

The list of stimuli was randomized and presented to the participants in standard Romanian orthography using a laptop computer. Each word was read three times in a row in the carrier phrase *Zic _ când pot.* [zik _ kɨnd pot] 'I say _ when I can'. The word list was read through twice for a total of six repetitions per word (giving 420 tokens per speaker, or 4200 tokens in total). Given occasional technical issues with the video-audio synchronization, most speakers were asked to produce additional repetitions of selected stimuli. As the synchronization issues were later resolved, this resulted in 204 additional tokens, giving in total 4404 tokens.

2.1.4. Articulatory Analysis

All target fricatives were annotated using AAA (Articulate Instruments Ltd. 2012), with the onset and offset of each segment corresponding to the onset and offset of frication. Tongue tracings for the fricatives were performed at the frame of maximum displacement within the annotated interval. This typically corresponded to the midpoint or the second half of the fricative. The tracings were performed by a paid undergraduate assistant under the supervision of the third author. Occasional ambiguous cases were discussed with the second author. A total of 49 tokens (or 1% of the data) were excluded due to poor imaging. The remaining 4355 tokens were annotated and used for the analysis: 1239 for singular, 1236 for plural indefinite, 1254 for plural definite, 309 for nonce names, and 317 for nonce verbs.

For each token, contours were extracted as series of Cartesian X and Y coordinates, converted to polar coordinates (Mielke 2015), and rotated with respect to the occlusal plane using a script. Figure 1 shows sample tracings in the polar coordinate space before and after the rotation, with the origin of the probe indicated as 0.

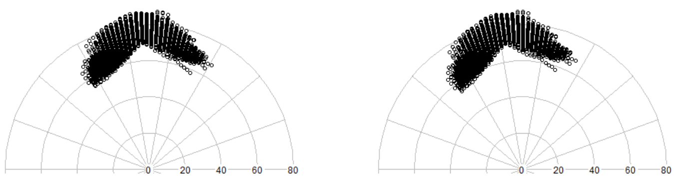

Figure 1. Raw tracings for all tokens produced by speaker RM4 before (**left**) and after the rotation (**right**); the 0 point corresponds to point of origin (the probe); the tongue front is on the right.

Note that a contour in AAA consists maximally of 42 points, from point 1 at the front (the tongue blade) to point 42 at the back (the root). For most speakers, however, tracings consisted of fewer points, given only partial imaging of the tongue due to the shadows of the hyoid bone and mandible. Further, not all of these points were shared across all plain and palatalized consonants for a given speaker. For the purpose of the quantitative analysis (see below), we selected only the points shared across all consonants. On average, there were 25 such points per speaker (range 20–29).

To distinguish between plain and palatalized consonants, we followed Tabain and Beare (2018) and Kochetov et al. (2018) in dividing tongue contours into two areas—the anterior and posterior portions, roughly corresponding to the blade/front and the body/root of the tongue, respectively. The boundary between these regions was determined individually for each speaker as the point at which average contours for the plain and palatalized /f/ intersected. As shown in Figure 2 for one of the speakers, the tongue root/back was more posterior and the tongue body/blade was lower for plain [f] than its palatalized counterpart [fʲ], so that their tongue contours crossed each other around the middle of the tongue. This pattern was consistent for all speakers. Considering speaker RF2 in Figure 2, her tongue contours consisted of 25 points (from point 12 at the front to point 36 at the back of the tongue) shared by all consonants. The speaker's average plain and palatalized versions of /f/ intersected at point 23, and thus the anterior region for the speaker was chosen to include points 12 to 22, and the posterior region was chosen to include points 24 to 36, as shown in the figure.

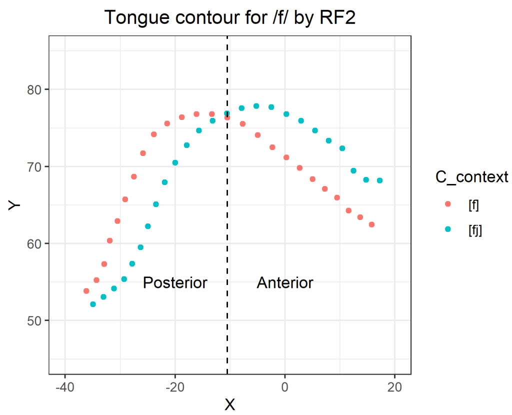

Figure 2. Average tongue contours for RF2's plain and palatalized variants of /f/ based on the selected 25 points, divided into the anterior and posterior regions as indicated by the vertical line.

Each tongue contour point was associated with a radius value—the distance (in mm) from the surface of the tongue (at that point) to the origin of the ultrasound probe. Higher radius values correspond to the tongue surface being further away from the probe. Radius values were averaged across anterior and posterior regions for each token, resulting in a total of 8710 datapoints, 4355 for each region.

These radius distance values were submitted to Linear Mixed Effects Models, separately for each region, as well as separately for two datasets, with the first one comparing plain and palatalized consonants (singular and plural indefinite forms) and the second comparing palatalized consonants (plural indefinite forms) with plain consonants before /i/ (plural definite forms, nonce names, and nonce verbs). In these models, Type (2 levels for the first set: singular, plural indefinite; 4 levels for the second set: plural indefinite, plural definite, nonce name, nonce verb), Consonant (/f/, /v/, /z/, /ʃ/, /h/), and gender (female, male) were fixed effects. Of these, we examined the interaction between Consonant and Type. Speaker (RF1-5, RM1-5), Preceding Vowel (/a/, /o/, /e/, /u/), and Word were random effects (random intercepts).[5] The intercept was set to the plain [f] in the first set and for the palatalized [fʲ] in the second set. The models were run using the lme4 package (Bates et al. 2017) for R (R Core Team 2013). P-values were obtained using the chi-square test implemented in the Anova() function of the lmerTest package (Kuznetsova et al. 2017). For each analysis, likelihood ratio tests were used to compare the full model to a nested model excluding the factor of interest, employing the Anova() function of the lmerTest package (Kuznetsova et al. 2017). Pairwise comparisons and posthoc tests (with a Bonferroni correction for multiple comparisons) were performed using the phia package (De Rosario-Martinez et al. 2015). Further details of the analysis are presented in each subsection. To provide an overview of contour patterns by Type we created plots of individual averages in ggplot2 using the smooth() function and the method gam (formula y ∼ s(x, bs = "cs")).

3. Results

3.1. Plain C (Singular) vs. Palatalized C^j (Plural Indefinite)

3.1.1. Overview

We begin with an overview of differences between plain and palatalized consonants in the first data set (singular and plural indefinite forms). Figure 3 presents gam-generated tongue contours for five consonants in the singular forms (plain) and plural indefinite forms (palatalized), separately by speaker. We can see that palatalized consonants in general (shown in blue) are produced with a raised anterior portion of the tongue and a fronted posterior portion of the tongue, compared to their plain counterparts (shown in red). This holds consistently for the labial /f/ and /v/, and the dorsal /h/. Similar differences, albeit smaller in magnitude, can be observed for /z/, with the exception of speakers RF2 and RF3. The plain-palatalized differences for /ʃ/, in contrast, are most limited: they can be observed visually only for speakers RF1, RM1, RM2, and RM3.

In the subsequent two sections we will examine differences between tongue shapes using the measure of radius distance calculated separately for the anterior and posterior portions of the tongue. Recall that we expect palatalized consonants to have a more raised anterior portion and a more fronted posterior portion of the tongue. This should correspond to higher anterior and lower posterior radius distances. We may also expect to see some radius distance differences among plain consonants, as these differ primarily in presence or absence of active lingual gestures (coronals and dorsals vs. labials).

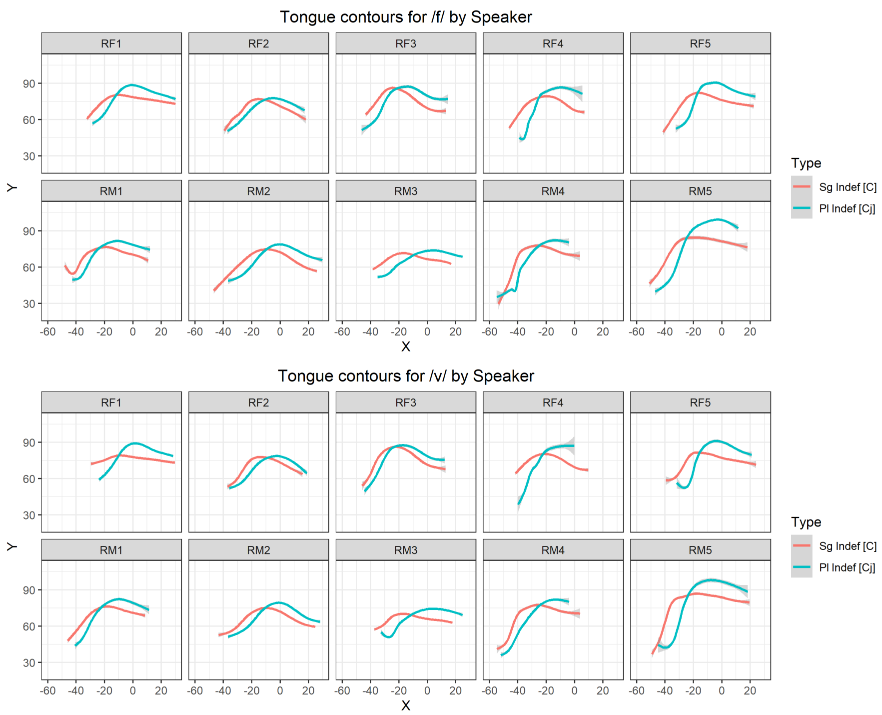

Figure 3. *Cont.*

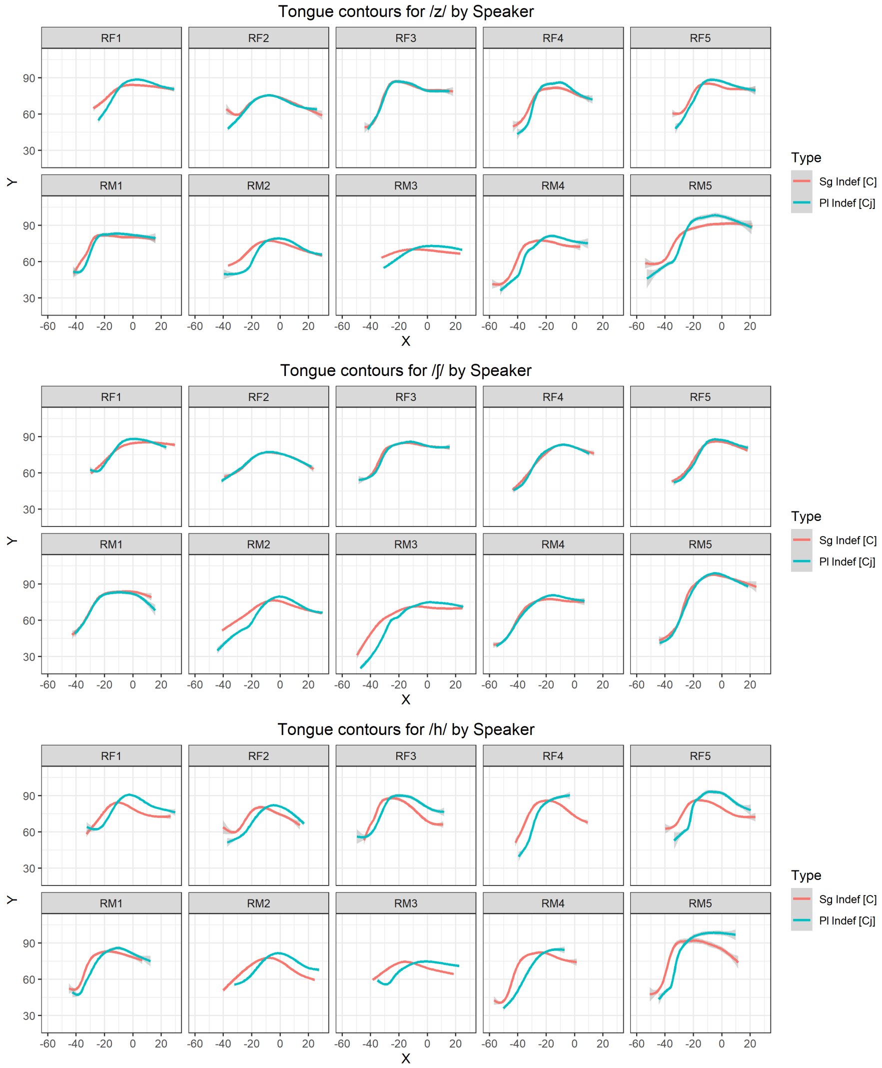

Figure 3. Tongue contours for 5 consonants by Type (singular vs. plural indefinite, i.e., C vs. C^j) separately by speaker (females RF1-5, males RM1-5); the tongue front is on the right; plots generated using the ggplot2 geom_smooth() function using the method gam and formula y ∼ s(x, bs = "cs").

3.1.2. Anterior Tongue

Results of a linear mixed effect model for the anterior portion of the tongue, summarized in Table 2, produced significant effects of Type ($\chi^2(1) = 2243.07$, $p < 0.0001$) and Consonant ($\chi^2(4) = 428.19$, $p < 0.0001$) but not gender. There was also a significant interaction of Type and Consonant ($\chi^2(4) = 644.67$, $p < 0.0001$). Differences between the five consonants can be observed in Figure 4.

Posthoc tests revealed that radius distance was significantly higher for plural indefinite forms than singular forms, regardless of the consonant ($p < 0.0001$ for all). This means that palatalized consonants in plural indefinite forms, as a class, were produced with a greater raising of the anterior portion of the tongue. It should be noted (and can be seen in Figure 4) that the magnitude of the radius distance differences between plain and palatalized variants was much greater for the labial /f/ and /v/ (on average 8.5 mm and 8.0 mm), followed by the dorsal /h/ (on average 6.8 mm), and then the coronals /z/ and /ʃ/ (on average 2.8 mm and 1.2 mm). Note in particular the very small (yet significant; $\chi^2(1) = -1.16$, $p < 0.0001$) difference between the plain and palatalized versions of /ʃ/, seemingly indicative of the inter-speaker variation noted above. For a more detailed overview, Appendix C shows the mean radius distance values (r, in mm) for the anterior and posterior portions of the tongue by utterance type and consonant.

Table 2. Model comparisons for radius distance (r, distance from the probe origin and the tongue surface) in the Anterior tongue region (Analysis of Deviance Table, Type II Wald χ^2 tests) in the set comparing two form Types (singular and plural indefinite, i.e., C vs. C^j), five consonant types (/f/, /v/, /z/, /ʃ/, /h/), and two genders (female, male); significance codes: 0 '***' 0.001 or less, an output of Anova() based on the model lmer (r ~ Type * C + Gender + (1 | Speaker) + (1 | Preceding.V) + (1 | Word), Set1_anterior).

Effects & Interactions	χ^2	df	Pr(>χ^2)	
Type	2243.07	1	<0.0001	***
C	428.19	4	<0.0001	***
Gender	0.123	1	0.7264	
Type:C	644.67	4	<0.0001	***

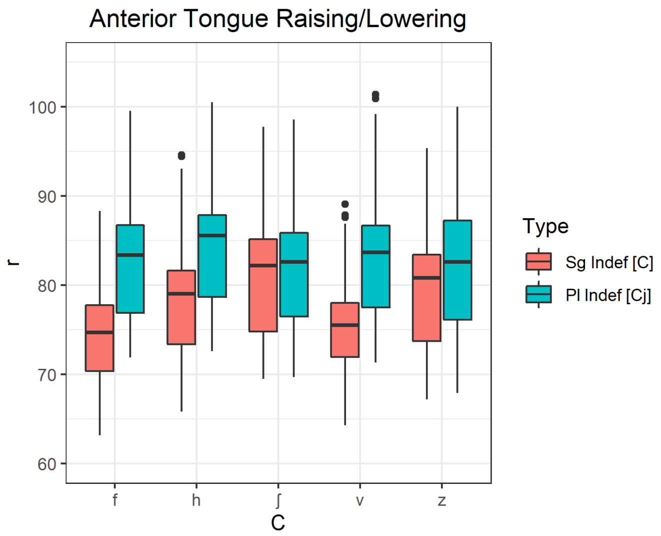

Figure 4. Radius distance (r, in mm) for the anterior portion of the tongue in the set comparing two form Types (singular and plural indefinite, i.e., C vs. C^j), presented by Consonant (/f/, /v/, /z/, /ʃ/, /h/); higher values indicate greater raising of the tongue.

Unlike for Type, significant Consonant differences were limited to a subset of pairs. Specifically, radius distances in the singular forms were higher for plain [ʃ] than for all the other plain variants, [f], [v], [h], and [z] ($p < 0.0001$; by on average 1.80 to 6.74 mm) and higher for the plain [z] and [h] than for [f] and [v] ($p < 0.0001$; by 1.31 to 4.93 mm). In other words, the anterior portion of the tongue was raised higher for the plain alveolar [z], dorsal [h] (we remind the reader that in an earlier study (Spinu and Lilley 2016) this segment was found to be realized as a velar fricative 86.7% of the time when plain, and palatal fricative 99.7% of the time when palatalized), and especially the postalveolar [ʃ]. In the plural indefinite forms, radius distance was higher for the palatalized [h^j] than most other palatalized consonants: [$ʃ^j$], [z^j], and [v^j] ($p < 0.0001$; by 1.79 to 2.50 mm). That is, the palatalized variant of /h/ (realized as palatal) was produced with a greater anterior tongue raising than for most other palatalized variants of consonants.

3.1.3. Posterior Tongue

Results of a linear mixed effect model for the posterior portion of the tongue, summarized in Table 3, produced significant effects of Type ($\chi^2(1) = 520.67$, $p < 0.0001$) and Consonant ($\chi^2(4) = 55.40$, $p < 0.0001$) but not gender. There was, however, a significant interaction of Type and Consonant ($\chi^2(4) = 84.55$, $p < 0.0001$). Differences between the two types for each consonant can be observed in Figure 5.

Table 3. Model comparisons for radius distance (r, distance from the probe origin and the tongue surface) in the Posterior tongue region (Analysis of Deviance Table, Type II Wald χ^2 tests) in the set comparing two form types (singular and plural indefinite, i.e., C vs. C^j), five consonant types (/f/, /v/, /z/, /ʃ/, /h/), and two genders (female, male); significance codes: 0 '***' 0.001 or less, an output of Anova() based on the model lmer (r ∼ Type * C + Gender + (1 | Speaker) + (1 | Preceding.V) + (1 | Word), Set1_posterior).

Effects & Interactions	χ^2	df	Pr(>χ^2)	
Type	520.67	1	<0.0001	***
C	455.40	4	<0.0001	***
Gender	3.34	1	0.0678	
Type:C	84.55	4	<0.0001	***

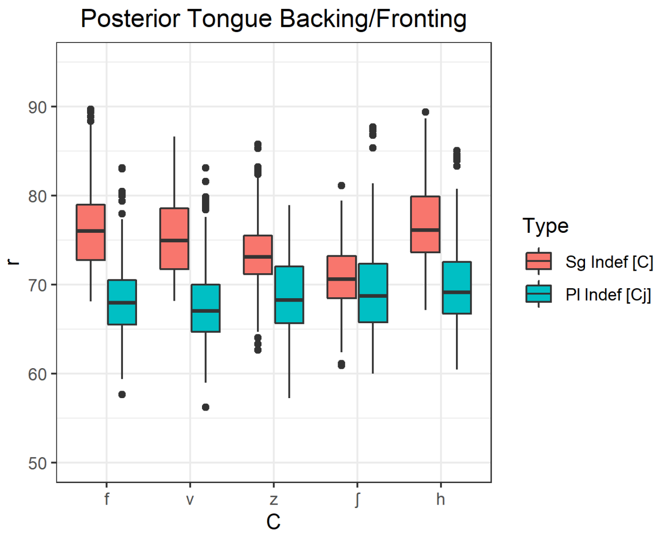

Figure 5. Radius distance (r, in mm) for the posterior portion of the tongue in the set comparing two form Types (singular and plural indefinite, i.e., C vs. C^j), presented by Consonant (/f/, /v/, /z/, /ʃ/, /h/); higher values indicate lesser fronting of the tongue.

Posthoc tests revealed that radius distance was significantly lower for plural indefinite forms than singular forms, regardless of the consonant ($p < 0.0001$ for /f/, /v/, /h/, /z/; $p < 0.05$ for /ʃ/). In other words, palatalized consonants in plural indefinite forms were produced with a greater fronting of the posterior portion of the tongue. As can be seen in Figure 4, however, the magnitude of the fronting difference between plain and palatalized consonants was much greater for the labial /f/ and /v/ (on average 7.81 mm for both), followed by the dorsal /h/ (on average 6.8 mm), and then the coronal /z/ (on average 4.8 mm). The difference was the smallest for /ʃ/ (on average 1.7 mm).

Significant Consonant differences were, as before, limited to a subset of pairs. For the singular forms, radius distances were lower for [ʃ] than for all the other consonants ([f], [v], [h], [z]; $p < 0.0001$; by 2.71–5.86 mm) and lower for [z] than for [f] ($p < 0.05$; 2.15 mm) and [h] ($p < 0.0001$; 3.14 mm). In other words, the posterior portion of the tongue was more fronted for the plain coronals [ʃ] and [z] than for plain variants of other consonants. For the plural indefinite forms, radius distance was higher for plain [h] than [f] ($p < 0.05$; 2.04 mm) and [v] ($p < 0.001$; 2.1 mm). That is, the palatalized ^{j} (likely realized as palatal) was produced with a greater posterior tongue fronting than the palatalized labials.

In sum, the comparison of plain (singular) and palatalized (plural indefinite) consonants revealed that the two types were clearly different in terms of the position of the anterior and posterior portions of the tongue (see Appendix C). Specifically, palatalized consonants were produced with the raising of the anterior tongue and fronting of the posterior tongue. These differences were the greatest for labials /f/ and /v/, and the smallest for coronals /z/ and, especially, /ʃ/. The dorsal /h/ showed intermediate differences. The results also revealed some differences within plain and palatalized realizations. These differences were largely limited to plain consonants and primarily reflected the presence or absence of the lingual gesture ([ʃ, z, h] vs. [f, v]). Among palatalized consonants, only [hʲ] showed significant differences from the other consonants, seemingly reflecting the distinction between the primary palatal place and secondary palatal articulation.

To follow up on the finding of minimal difference for /ʃ/, we have informally examined individual differences and noted that these were clearly exhibited by 4 speakers (RF1, RM2, RM3, and RM4) for the anterior portion and by 3 speakers (RF3, RM2, and RM3) for the posterior portion. For other speakers, the distribution of plain and palatalized values was very similar, even if mean values were slightly higher for the palatalized variants. See Appendix B for the individual results for /ʃ/.

3.2. Palatalized Cʲ (Plural Indefinite) vs. Ci (Plural Definite, Nonce Names, and Nonce Verbs)

We now turn to the comparison of phonologically (morphologically) palatalized consonants (plural indefinite) to those phonetically palatalized, that is, consonants occurring before /i/ in plural definite, nonce name and nonce verb forms. Both types of palatalized consonants are expected to show some anterior tongue raising and posterior tongue fronting; yet one may expect the magnitude to be greater for the phonologically palatalized consonants. Further, if such differences exist, they may be manifested to a greater extent in some consonant phonemes than others.

3.2.1. Overview

Figure 6 presents gam-generated tongue contours for five consonants in the palatalized plural indefinite forms and three C+i forms (plural definite, nonce names, and nonce verbs), separately by speaker. We can see that shapes for the palatalized consonants (shown in red) are overall rather similar to the same consonants before /i/– either in the anterior or posterior portion of the tongue. Whether there are any significant quantitative differences among the types or among the consonants, is examined in the subsequent two sections.

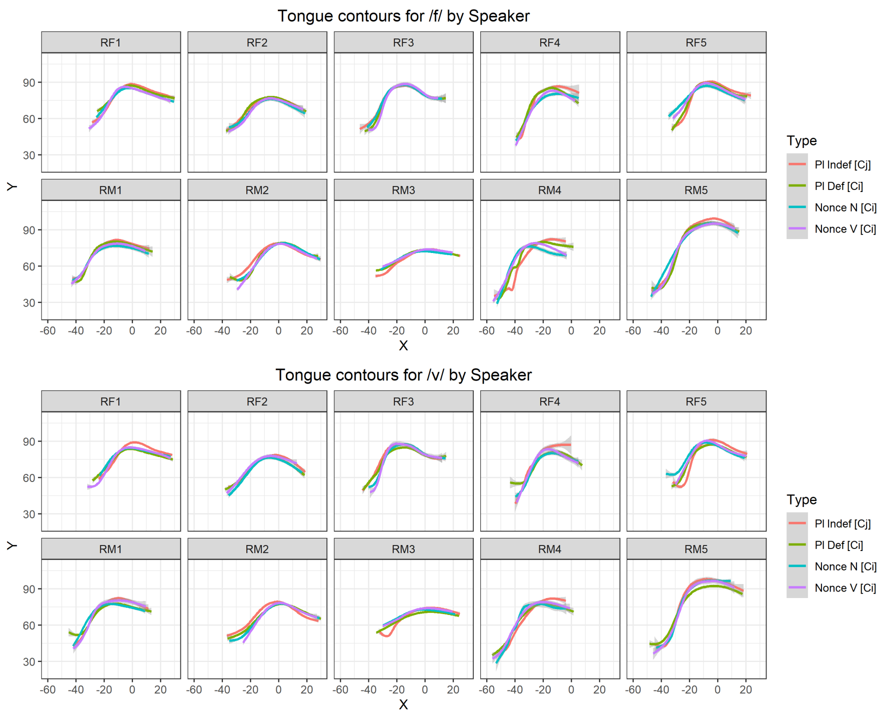

Figure 6. *Cont.*

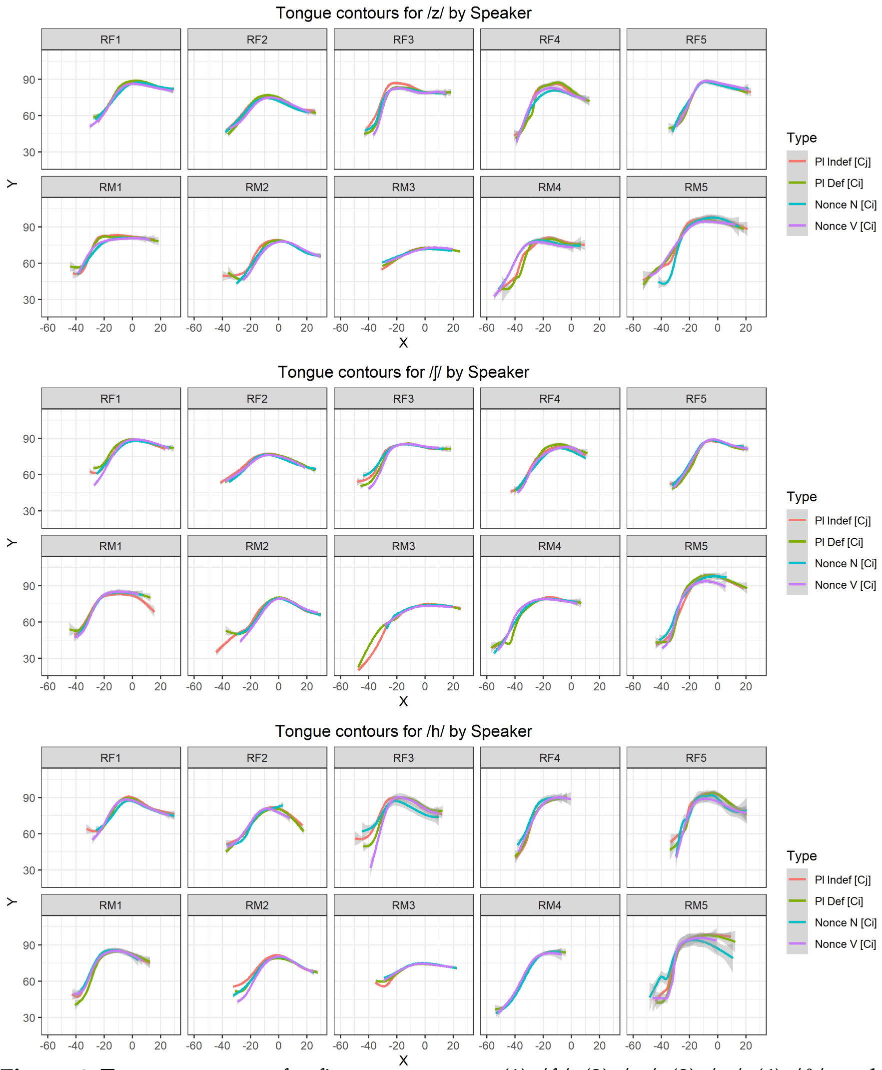

Figure 6. Tongue contours for five consonants – (1) /f/, (2) /v/, (3) /z/, (4) /ʃ/, and (5) /h/ by Type (C+i nonce names, nonce verbs and plural definite, and C^j plural indefinite) separately by speaker (females RF1-5 and males FR1-5); the tongue front is on the right; the plots are generated using the ggplot2 geom_smooth() function using the method gam and formula y ∼ s(x, bs = "cs").

3.2.2. Anterior Tongue

Results of a linear mixed effect model for the anterior portion of the tongue, summarized in Table 4, produced significant effects of type ($\chi^2(1) = 38.80$, $p < 0.0001$) and consonant ($\chi^2(4) = 163.53$, $p < 0.0001$) but not gender. There was, however, a significant interaction of Type and Consonant ($\chi^2(4) = 55.88$, $p < 0.0001$). The distribution of radius distance values among the four form types and five consonants can be observed in Figure 7.

Posthoc tests revealed that radius distance was significantly higher for plural indefinite forms (C^j) than nonce name forms (C+i) with the labials /f/ and /v/ (both $p < 0.0001$; by 3.12–3.35 mm). It was also higher for plural definite forms than nonce name forms (both C+i) with /f/ ($p < 0.05$; by 2.43 mm). There were no other significant Type differences. This means that palatalized consonants in plural indefinite forms were produced with a similar raising of the anterior portion of the tongue than in C+i sequences, except for those in nonce names. As the latter consonants were also different from C+i sequences in plural definite forms, the effects are likely due to some differences among the types in preceding vowel contexts or due to the speakers' producing nonce names with lesser vowel coarticulation.

Table 4. Model comparisons for radius distance (r, distance from the probe origin and the tongue surface) in the Anterior tongue region (Analysis of Deviance Table, Type II Wald χ^2 tests) in the set comparing four form Types (plural indefinite, plural definite, nonce names, and nonce verbs; i.e., C^j vs. C+i), five consonants (C; /f/, /v/, /z/, /ʃ/, /h/), and two genders (female, male); significance codes: 0 '***' 0.001 or less, an output of Anova() based on the model lmer (r ∼ Type * C + Gender + (1 | Speaker) + (1 | Preceding.V) + (1 | Word), Set2_anterior).

Effects & Interactions	χ^2	df	Pr(>χ^2)	
Type	38.80	3	<0.0001	***
C	163.53	4	<0.0001	***
Gender	0.14	1	0.7045	
Type:C	55.88	12	<0.0001	***

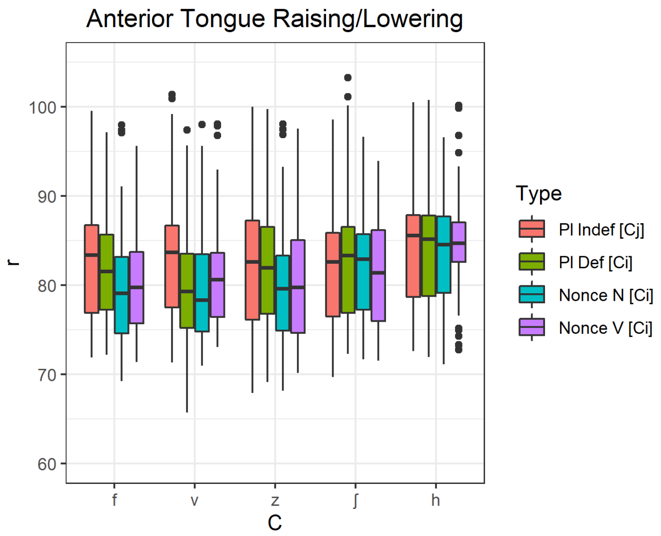

Figure 7. Radius distance (r, in mm) for the anterior portion of the tongue in the set comparing four form Types (plural indefinite, plural definite, nonce names, and nonce verbs; i.e., C^j vs. C+i), presented by Consonant (/f/, /v/, /z/, /ʃ/, /h/); higher values indicate greater raising of the tongue.

Significant Consonant differences involved only /h/ and at least some of the other consonants. Specifically, the palatalized variants of /h/ were produced with a higher anterior portion of the tongue than all the other consonants in plural indefinite forms (with p values ranging from < 0.01 to < 0.0001, depending on the pairwise comparison; by on average 1.76 to 2.49 mm) and plural definite forms (with p values ranging from < 0.01 to < 0.0001; by on average 1.99 to 5.10 mm). Similar significant differences between /h/ and some of the other consonants were observed for nonce names (/h/ vs. /f/, /v/, /z/; with p values ranging from < 0.01 to < 0.0001; by on average 3.37 to 4.44 mm) and nonce verbs (/h/ vs. /f/ and /z/; $p < 0.01$; by on average 3.46 to 3.51 mm). These differences can be attributed to the likely realization of both phonologically and phonetically palatalized variants of /h/ as true palatals (and thus involving the most extensive raising of the anterior portion of the tongue towards the palate). In addition, posthoc tests showed that /v/ in plural definite forms was produced with a lower anterior portion of the tongue than for the other consonants of the same condition ($p < 0.001$; by on average 2.29 to 3.17 mm). This can be possibly attributed to the effect of the preceding vowel, which was consistently /a/ for /v/ (in contrast to /a/, /o/, and /u/ for /f/, /a/ and /o/ for /h/, /e/ and /u/ for /z/, and /a/, /e/, /o/, and /u/ for /ʃ/). We refer the reader to Appendix C for the mean radius distance values for the anterior and posterior portions of the tongue by utterance type and consonant.

3.2.3. Posterior Tongue

Results of a linear mixed effect model for the posterior portion of the tongue are summarized in Table 5. None of the effects—type, consonant, and gender—or the interaction were significant. This means that the posterior portion of the tongue did not vary across the types and consonants. The lack of clear differences can be observed in Figure 8.

Table 5. Model comparisons for radius distance (r, distance from the probe origin and the tongue surface) in the Posterior tongue region (Analysis of Deviance Table, Type II Wald χ^2 tests) in the set comparing four form Types (plural indefinite, plural definite, nonce names, and nonce verbs; i.e., C^j vs. C+i), five consonants (C; /f/, /v/, /z/, /ʃ/, /h/), and two genders (female, male), based on the model lmer (r ∼ Type * C + Gender + (1 | Speaker) + (1 | Preceding.V) + (1 | Word), Set2_posterior).

Effects & Interactions	χ^2	df	Pr(>χ^2)
Type	6.20	3	0.1025
C	6.50	4	0.1647
Gender	2.22	1	0.1361
Type:C	14.51	12	0.2691

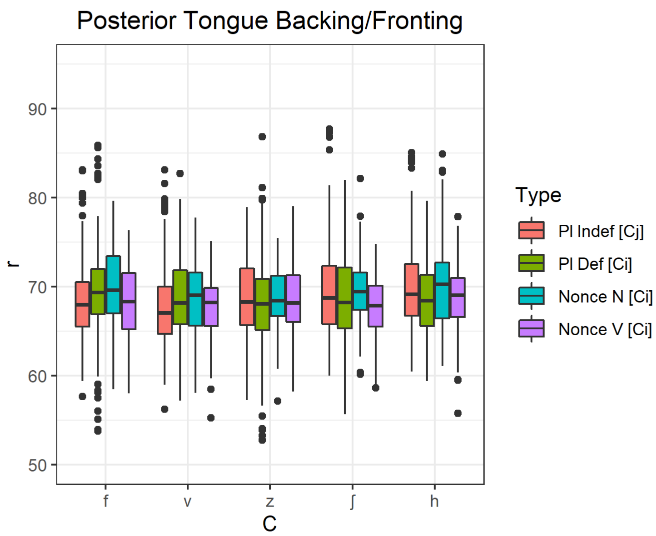

Figure 8. Radius distance (r, in mm) for the posterior portion of the tongue in the set comparing four form Types (plural indefinite, plural definite, nonce names, and nonce verbs; i.e., C^j vs. C+i), presented by Consonant (/f/, /v/, /z/, /ʃ/, /h/); higher values indicate lesser fronting of the tongue.

In sum, the comparison of palatalized consonants (plural indefinite) and consonants before /i/ (plural definite, nonce names, and nonce verbs) revealed that the two were produced very similarly both in terms of the anterior tongue raising and posterior tongue fronting. The only C^j vs. C+i differences involved nonce names in the anterior tongue fronting—with the difference being specific to the nonce name Type. Among consonants, there were anterior tongue differences involving the dorsal /h/ and the other consonants, likely reflecting the palatal realization of the former in both palatalized and /i/ contexts. Leaving this aside, we can conclude that the results revealed essentially no tongue shape/position differences between phonologically and phonetically palatalized consonants.

4. Discussion

In the previous section, we compared tongue shapes for plain and palatalized consonants, as well as for palatalized consonants and three different types of word-final consonant-/i/ sequences in Romanian. With respect to the first comparison, we have found differences between plain and palatalized forms for both the anterior and posterior portions of the tongue (at the point of maximum displacement during the articulation of the consonant). Compared to plain consonants, the production of palatalized consonants involved raising of the anterior part of the tongue and fronting of the posterior part of the tongue. Our first research question was whether the articulatory findings with the plain-palatalized contrast will match the results of earlier studies (Spinu 2018; Spinu and Lilley 2016; Spinu et al. 2012). In these studies, the acoustic separation and perceptual distinctiveness of the plain and palatalized consonants was highest with dorsals and labials and lowest with postalveolars, with dentals falling in between. We have indeed found the greatest articulatory differences for labials /f/ and /v/, followed by dorsal /h/, and the smallest for /ʃ/, with the dental values in between. However, while an earlier study reported that in Romanian the secondary palatalization contrast is most acoustically distinct and most perceptually salient at the dorsal place of articulation (Spinu et al. 2012), we have found that articulatorily the difference between plain and palatalized dorsals was smaller than for labials. More specifically, the difference in tongue raising was 6.8 mm on average for dorsal /h/ compared to, on average, 8.5 mm for voiceless labials and 8.0 mm for voiced labials. The same pattern was noted for tongue fronting, with the magnitude of the difference being greater for labial /f/ and /v/ (on average 7.81 mm for both) compared to dorsal /h/ (on average 6.8 mm). These findings suggest that additional cues to SP may be available in the case of dorsal fricatives, perhaps having to do with the overall tongue shape and the fact that the primary place of articulation was found to be different for plain dorsals, the majority of which were realized as velar fricatives, compared to palatalized dorsals, which were realized as palatal fricatives (Spinu 2018). It is also possible that additional cues are present in the preceding vocalic portion (but note that only the frication portion was analyzed acoustically in the earlier study). Lastly, as pointed out by one of our reviewers, the magnitudes of difference across these places of articulation may not be on the same scale regarding a comparison to acoustics and perception. A relatively small articulatory difference at one place could lead to a larger perceptual difference compared to a similar difference at a different place, which may explain our results with labials and dorsals. And while the articulatory findings with postalveolars match the earlier acoustic and perceptual results, it may still be the case that the articulatory separation is comparable with that of other places (but we just have not captured it using our current methodology).

Our second research question was concerned with the status of the SP contrast in postalveolars. We have found that for the most part the differences in tongue shape between plain and palatalized forms were very small (on average 1.2 mm for anterior tongue, and 1.7 mm for posterior tongue), if at all present. Only 4 out of 10 speakers (40%) realized the contrast at this place based on our measurements, which is a marked decrease compared to 27 out of 31 (87%) in a study reporting on data collected 15 years ago (Spinu 2018) and native speakers self-reports from 1961 (Suteu 1961), according to which 94.4% of the informants produced the contrast at this place of articulation. While the 1961 findings relied on native speaker intuitions and may not reflect the phonetic reality, the 2018 study (reporting on productions collected in 2008) was based on acoustic measurements and thus reliable. It is worth noting that the four speakers who produced the contrast in the current study were the oldest of the group (mean age 49.75, range 49–51), while the remaining six speakers' ages ranged from 29 to 45, with a mean of 37.3. This might suggest that the neutralization we observed regarding the SP contrast in postalveolars reflects a relatively recent change in the language. It is also plausible, however, that this may be due to some degree of language attrition (considering that all but one speaker had lived abroad for a minimum of 6 years) or to the relatively small sample size. Another possibility is that the expected differences were produced by the speakers but the spatial resolution of our ultrasound measurements was not sufficiently high to detect them. It is worth nothing that a high degree of speaker-specific variability has also been found with SP in [t, s, n, l] in Scottish Gaelic (Sung et al. 2015). None of speakers examined in this study (n = 26) exhibited similar articulatory patterns for SP.

Moving on to our third research question, that is, whether Romanian SP is characterized by features that distinguish it from the high vowel /i/ in three word-final contexts (which we refer to collectively as C+i), i.e., plural definite (/Cii/), nonce names (/Ci/, unstressed vowel), and nonce verbs (/Ci/, stressed vowel), we have found that the two were produced very similarly both in terms of the anterior tongue raising and posterior tongue fronting. The only significant differences we observed between C^j vs. C+i involved nonce names in the anterior tongue fronting—with the difference being specific to the latter Type. There were also anterior tongue differences involving the dorsal /h/ and the other consonants, likely reflecting the palatal realization of the former in both palatalized and /i/ contexts. To sum up, palatalized consonants in plural indefinite forms were produced with a similar raising of the anterior portion of the tongue compared to C +i sequences, except for those in nonce names. As nonce names were also different from C+i sequences in plural definite forms, the possibility arises that the effects were due to differences in preceding vowel contexts among the types, or due to the fact that speakers produced nonce names with lesser vowel coarticulation. Since we found the front part of the tongue to be higher in palatalized consonants (plural indefinites) as well as consonants followed by two /ii/ sequences (plural definites), we should also consider the possibility that plural definites are realized with some degree of palatalization. In other words, the plural morpheme may surface as a palatal gesture, i.e., [ʲi] or [iʲ]. Our findings to this effect are however limited (only with labial /f/ and dorsal /h/) and therefore this topic warrants additional investigation. Because of the similarities in the articulation of SP and C+i sequences in Romanian, we cannot exclude the possibility that SP may be realized as a non-syllabic (devoiced) vowel, supporting the anecdotal reports mentioned in Section 1.2.3. In order to establish this with more certainty (and rule out the possibility of partial final devoicing of voiceless obstruents, an examination of how SP is realized with voiced segments such as sonorants is warranted.

Lastly, we have found no effects of stress on the realization of consonants at any place of articulation. Our findings are thus similar to Lecocq's (Biteeva Lecocq 2021) who also reported that stress did not affect tongue shape for /ʃʲ/ in Russian. Lecocq discusses the possibility that in Russian, as stated by Kniazev and Pozharitskaja (2012) stress is more likely to affect the vocalic nucleus, with stressed vowels being longer than unstressed ones, but otherwise subject to a reduction of the magnitude of the lingual gesture, that is, undershoot. This may be the case in Romanian as well. We have not collected duration data for the word-final stressed (nonce verbs) and unstressed (nonce names) vowels but we recommend this comparison for future studies.

Given the inherently dynamic nature of SP, which is not always timed synchronously with a consonant's primary gesture, another direction for future work would be to examine differences at multiple time points, as our current set-up may be missing some relevant differences occurring beyond the consonant midpoint. Nevertheless, we found certain differences between Romanian and other languages with SP, most notably Russian. These include greater differences between plain and palatalized forms at the labial place of articulation, or the possible discrepancy between the SP contrast's high perceptual salience (supported by acoustic differences) and smaller articulatory differences at the dorsal place compared to labials. We have also found higher inter-speaker variability with postalveolars, but also that some of the speakers continue to maintain the SP contrast at this place despite its low perceptual salience. Typologically, Romanian does not conform to the previously proposed place of articulation markedness scale, according to which coronals are better hosts for the palatalization contrast than labials (Kavitskaya 2006; Kochetov 2002). These differences may be explained by a complex interaction of factors such as language-specific phonetic realization, the role played by manner of articulation (since previous studies of SP in other languages tended to focus on stop consonants or rhotics), the impacts of morphological conditioning and functional load (given the fact that in Romanian SP is associated with the plural and second person morphemes), and the possibility of phonetic enhancement. Our findings thus add to the body of work on broader issues such as the typology of SP and markedness.

5. Conclusions

Our study is the first to document SP in Romanian using ultrasound for tongue body imaging. We have found differences in tongue shape between plain and palatalized consonants. The palatalization effects were stronger in labials and dorsals compared to coronals, and in dentals compared to postalveolars. We also observed a higher degree of neutralization with the latter. Our results mirror earlier findings regarding the strength of the SP contrast at different places of articulation. The sole exception was that dorsals did not show the largest differences in tongue shape between plain and palatalized forms, while the SP contrast was previously found to have the largest acoustic separation and highest perceptual distinctiveness at this place. We have also found limited evidence that definite plurals (spelled in Romanian as word-final 'ii') may differ from either stressed or unstressed word-final 'i' in exhibiting more raising of the anterior part of the tongue. Lastly, we did not observe an effect of stress on word-final consonants.

Author Contributions: Conceptualization, L.S.; methodology—data collection and annotation—M.P., methodology—data analysis, A.K.; writing—original draft preparation, L.S. and A.K.; writing—review and editing—all authors. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partly funded by the Social Sciences and Humanities Research Council of Canada, grant number 435-2015-2013 to A.K.

Institutional Review Board Statement: The study was approved by the Social Science, Humanities and Education Research Ethics Board of the University of Toronto (protocol code 31791, 06-20-2015).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Available upon request.

Acknowledgments: We thank our editors and two anonymous reviewers for their helpful comments and suggestions. We would like to thank Luke Zhou for assistance with the data post-processing, Weijia Wang for data annotation, and the audiences of Interspeech 2019 and the 2019 Annual Meeting on Phonology for their feedback on preliminary results. An earlier report on this study, based on a subset of the data (plain and palatalized /f/, z/, and /ʃ/) was published earlier (Spinu et al. 2019).

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviation

The following abbreviations are used in this manuscript:

SP Secondary Palatalization

Appendix A

The full set of target stimuli is shown in the table below. Note that the words are shown in Romanian orthography.

Table A1. Experimental stimuli used in this study. All words are shown in Romanian orthography. * According to (Spinu and Lilley 2016), /h/ is mostly realized as dorsal [x] in the singular indefinite environment and as [ç] in the plural indefinite environment. ** The verb /a lovi/ is not nonce, it means ‘to hit’. The forms in the Nonce N (Ci) column are all intended to be treated as proper nouns, therefore they start with capital letters.

C	Meaning	Sg Indef [C]	Pl Indef [C^j]	Pl Def [Ci] Possibly [Ci^j]	Nonce N [Ci] Unstressed	Nonce V ** [Ci] Stressed
/f/	potato	*cartof*	*cartofi*	*cartofii*	*Lofi*	*a lofi*
	shoe	*pantof*	*pantofi*	*pantofii*		
	bailiff	*vătaf*	*vătafi*	*vătafii*		
	curl	*zuluf*	*zulufi*	*zulufii*		
/v/	sick	*bolnav*	*bolnavi*	*bolnavii*	*Lovi*	*a lovi*
	great	*grozav*	*grozavi*	*grozavii*		‘to hit ’
	feeble	*firav*	*firavi*	*firavii*		
	house painter	*zugrav*	*zugravi*	*zugravii*		
/z/	Chinese	*chinez*	*chinezi*	*chinezii*	*Lozi*	*a lozi*
	grumpy	*mofluz*	*mofluzi*	*mofluzii*		
	obese	*obez*	*obezi*	*obezii*		
	morose	*ursuz*	*ursuzi*	*ursuzii*		
/ʃ/	cherry tree	*cireş*	*cireşi*	*cireşii*	*Loşi*	*a loşi*
	rooster	*cocoş*	*cocoşi*	*cocoşii*		
	playful	*ghiduş*	*ghiduşi*	*ghiduşii*		
	slacker	*codaş*	*codaşi*	*codaşii*		
	Cossack	*cazah*	*cazahi*	*cazahii*	*Lohi*	*a lohi*
/h/ *	monk	*monah*	*monahi*	*monahii*		
	vicar	*paroh*	*parohi*	*parohii*		
	Wallachian	*valah*	*valahi*	*valahii*		

Appendix B

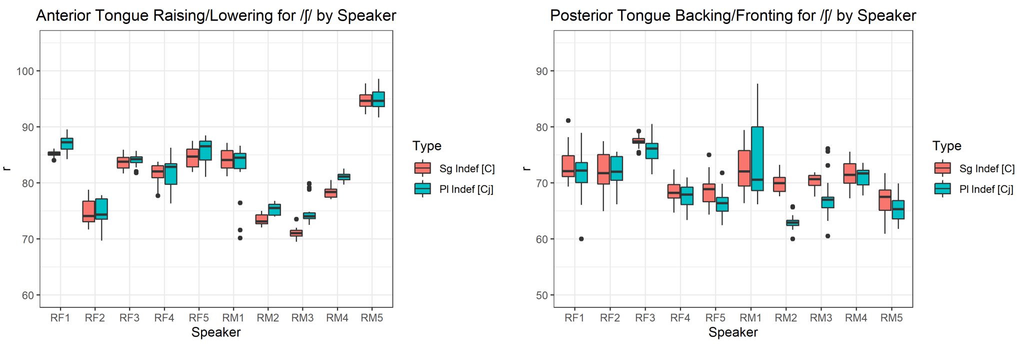

Figure A1. Result plots for individual speakers’ production of the plain and palatalized variants of [ʃ].

Appendix C

Table A2. Mean radius distance values (r, in mm) for the anterior and posterior portions of the tongue by utterance type and consonant.

Radius Distance	Type	C				
		f	**v**	**z**	**ʃ**	**h**
Anterior	Sg indef [C]	74.2	75.1	79.4	81.1	77.9
	Pl indef [C^j]	83.1	83.1	82.6	82.1	84.8
	Pl def [Ci]	82.0	79.6	82.0	83.1	84.5
	Nonce N [Ci]	79.6	79.8	80.5	82.2	83.9
	Nonce V [Ci]	80.7	81.2	80.2	81.7	84.2

Table A2. *Cont.*

Radius Distance	Type	C				
		f	**v**	**z**	**ʃ**	**h**
Posterior	Sg indef [C]	76.3	75.6	73.6	71.1	76.8
	Pl indef [C^j]	68.4	67.8	68.8	69.4	70.1
	Pl def [Ci]	69.2	68.7	67.9	68.3	68.5
	Nonce N [Ci]	70.0	68.7	68.3	69.3	70.7
	Nonce V [Ci]	68.2	67.9	68.4	67.2	68.5

Notes

1 Preliminary findings with a subset of our target consonants were reported in an earlier paper (Spinu et al. 2019).

2 The only voiced consonant that is never encountered with SP in Romanian is /d/, which always undergoes spirantization in the presence of the plural or second person singular affixes, e.g., *cad* [kad] 'I fall', *cazi* [kaz^j] 'you fall'.

3 Note that in Romanian it is also possible to have a word-final sequence of three /i/, where the first /i/ is part of the root, as in the word *copiii* "the children". While no studies have investigated the surface form of this word, preliminary visual inspection based on the productions on three native speakers suggests the output might be [iji]. While the formants remain steady throughout the vocalic portion, a reduction and subsequent increase in amplitude about halfway through the vocalic portion might indicate the presence of a glide.

4 If the plural morpheme surfaces as palatalization regardless of the preceding segment, the possibility also arises that underlying plural marker-definite article /ii/ sequences are realized as [i^j].

5 Random slopes by Type and Consonant were attempted for Speaker and Preceding Vowels, but resulted in model non-convergence.

References

Articulate Instruments Ltd. 2012. *Articulate Assistant Advanced User Guide: Version 2.16*. Edinburgh: Articulate Instruments Ltd.

Bateman, Nicoleta. 2007. A Crosslinguistic Investigation of Palatalization. Ph.D. dissertation, University of California San Diego, San Diego, CA, USA.

Bates, Douglas, Martin Maechler, Ben Bolker, Steven Walker, Rune Haubo Bojesen Christensen, Henrik Singmann, Bin Dai, Fabian Scheipl, Gabor Grothendieck, Peter Green, and et al. 2017. lme4 Package (Version 1.1–13). Computer Software: An R Package/Online Resource. Available online: https://cran.r-project.org/web/packages/lme4/index.html (accessed on 21 October 2023).

Bennett, Ryan, Máire Ní Chiosáin, Jaye Padgett, and Grant McGuire. 2018. An ultrasound study of Connemara Irish palatalization and velarization. *Journal of the International Phonetic Association* 48: 261–304. [CrossRef]

Bhat, Darbhe N. S. 1978. A general study of palatalization. In *Universals of Human Language. Phonology*. Edited by Joseph H. Greenberg, Charles A. Ferguson and Edith A. Moravcsik. Stanford: Stanford University Press, vol. 2, pp. 47–92.

Biteeva Lecocq, Ekaterina. 2021. Complexité et contrôle du geste linguo-palatal sous l'éclairage de sa variabilité. Le cas de la palatalisation en russe. Aspects phonétiques et phonologiques. Ph.D. dissertation, Université Grenoble Alpes, Grenoble, France.

Campbell, Lyle. 1974. Phonological features: Problems and proposals. *Language* 50: 52–65. [CrossRef]

Cavar, Małgorzata E., and Steven M. Lulich. 2021. Variation in the articulation of Russian stressed vowels and the mechanics of palatalization in consonants. *Phonological Data and Analysis* 3: 1–44. [CrossRef]

Chitoran, Ioana. 2002. *The Phonology of Romanian: A Constraint-Based Approach*. Berlin and New York: Mouton de Gruyter.

Davidson, Lisa. 2006. Comparing tongue shapes from ultrasound imaging using smoothing spline analysis of variance. *The Journal of the Acoustical Society of America* 120: 407–15. [CrossRef] [PubMed]

De Rosario-Martinez, Helios, John Fox, R Core Team, and Chalmers Phil. 2015. Package 'phia'. CRAN Repos. Available online: https://cran.r-project.org/web/packages/phia/index.html (accessed on 31 January 2023).

Dieterman, Julia Irene. 2008. *Secondary Palatalization in Isthmus Mixe: A Phonetic and Phonological Account*. SIL e-Books, 11. Dallas: Summer Institute of Linguistics.

Fant, Gunnar. 1970. *Acoustic Theory of Speech Production: With Calculations Based on X-ray Studies of Russian Articulations*, 2nd ed. The Hague: Mouton.

Hume, Elizabeth V. 1994. *Front Vowels, Coronal Consonants and Their Interaction in Nonlinear Phonology*. New York: Garland Publishing, Inc.

Hussain, Qandeel, and Jeff Mielke. 2020. An acoustic and articulatory study of laryngeal and place contrasts of Kalasha (Indo-Aryan, Dardic). *The Journal of the Acoustical Society of America* 147: 2873–90. [CrossRef] [PubMed]

Iskarous, Khalil, Christine H. Shadle, and Michael I. Proctor. 2011. Articulatory–acoustic kinematics: The production of American English /s/. *The Journal of the Acoustical Society of America* 129: 944–54. [CrossRef]

Iwasaki, Rion, Kevin Roon, Jason A. Shaw, Mark Tiede, and D. H. Whalen. 2022. Dynamic evidence for the vowel gesture retention of devoiced high vowels in Tokyo Japanese. In *Proceedings of Meetings on Acoustics*. New York: AIP Publishing, vol. 46, p. 060004.

Kavitskaya, Darya. 2006. Perceptual salience and palatalization in Russian. In *Laboratory Phonology 8*. Edited by Louis Goldstein, Douglas Harry Whalen and Catherine T. Best. Berlin and New York: Mouton de Gruyter, pp. 589–610.

Kirkham, Sam, and Claire Nance. 2022. Diachronic phonological asymmetries and the variable stability of synchronic contrast. *Journal of Phonetics* 94: 101176. [CrossRef]

Kniazev, Sergey V., and Sofya K. Požarickaya. 2012. *Sovremennyj Russkij Literaturnyj Jazyk. Fonetika, Orfoepija, Grafika, Orfografija*. Moscow: Gaudeamus.

Kochetov, Alexei. 2002. *Production, Perception, and Emergent Phonotactic Patterns: A Case of Contrastive Palatalization*. New York: Routledge.

Kochetov, Alexei. 2006. Syllable position effects and gestural organization: Articulatory evidence from Russian. In *Laboratory Phonology 8*. Edited by Louis Goldstein, Douglas Harry Whalen and Catherine T. Best. Berlin and New York: Mouton de Gruyter, pp. 565–88.

Kochetov, Alexei, Marija Tabain, N. Sreedevi, and Richard Beare. 2018. Manner and place differences in Kannada coronal consonants: Articulatory and acoustic results. *The Journal of the Acoustical Society of America* 144: 3221–35. [CrossRef] [PubMed]

Kuznetsova, Alexandra, Per B. Brockhoff, and Rune Haubo Bojesen Christensen. 2017. lmerTest package: Tests in linear mixed effects models. *Journal of Statistical Software* 82: 1–26. [CrossRef]

Ladefoged, Peter, and Ian Maddieson. 1996. *The Sounds of the World's Languages*. Oxford and Cambridge: Blackwell.

Malmi, Anton. 2022. The production of Estonian Palatalization by Estonian and Russian Speakers. Ph.D. dissertation, University of Tartu, Tartu, Estonia.

Matsui, Mayuki, and Alexei Kochetov. 2018. Tongue root positioning for voicing vs. contrastive palatalization: An ultrasound study of Russian word-initial coronal stops. *Journal of the Phonetic Society of Japan* 22: 81–94.

Mielke, Jeff. 2015. An ultrasound study of Canadian French rhotic vowels with polar smoothing spline comparisons. *The Journal of the Acoustical Society of America* 137: 2858–69. [CrossRef] [PubMed]

Mielke, Jeff, Christopher Carignan, and Erik R. Thomas. 2017. The articulatory dynamics of pre- velar and pre-nasal /æ/-raising in English: An ultrasound study. *The Journal of the Acoustical Society of America* 142: 332–49. [CrossRef] [PubMed]

Mielke, Jeff, Kenneth S. Olson, Adam Baker, and Diana Archangeli. 2011. Articulation of the Kagayanen interdental approximant: An ultrasound study. *Journal of Phonetics* 39: 403–12. [CrossRef]

Nance, Claire, and Sam Kirkham. 2022. Phonetic typology and articulatory constraints: The realization of secondary articulations in Scottish Gaelic rhotics. *Language* 98: 419–60. [CrossRef]

Ní Chiosáin, Maire. 1994. Irish palatalisation and the representation of place features. *Phonology* 11: 89–106. [CrossRef]

Ní Chiosáin, Maire, and Jaye Padgett. 2012. An acoustic and perceptual study of Connemara Irish palatalization. *Journal of the International Phonetic Association* 42: 171–91. [CrossRef]

Petrovici, Emil. 1956. Sistemul fonematic al limbii române. *Studii si cercetari lingvistice* 7: 7–14.

Proctor, Michael. 2011. Towards a gestural characterization of liquids: Evidence from Spanish and Russian. *Laboratory Phonology* 2: 451–85. [CrossRef]

Proctor, Michael I., Christine H. Shadle, and Khalil Iskarous. 2010. Pharyngeal articulation in the production of voiced and voiceless fricatives. *The Journal of the Acoustical Society of America* 127: 1507–18.

Recasens, Daniel, and Clara Rodríguez. 2016. A study on coarticulatory resistance and aggressiveness for front lingual consonants and vowels using ultrasound. *Journal of Phonetics* 59: 58–75. [CrossRef]

Recasens, Daniel, and Clara Rodríguez. 2017. Lingual articulation and coarticulation for Catalan consonants and vowels: An ultrasound study. *Phonetica* 74: 125–56. [CrossRef] [PubMed]

Recasens, Daniel, and Clara Rodríguez. 2018. Contextual and syllabic effects in heterosyllabic consonant sequences. An ultrasound study. *Speech Communication* 96: 150–67. [CrossRef]

Renwick, Margaret Elspeth. 2012. Vowels of Romanian: Historical, Phonological and Phonetic Studies. Ph.D. dissertation, Cornell University, Ithaca, NY, USA.

R Core Team. 2013. *R: A Language and Environment for Statistical Computing*. Version 4.3.1. Vienna: R Foundation for Statistical Computing. Available online: https://urldefense.com/v3/__http://www.R-project.org/__;!!GekbXoL5ynDpFgM!S2ttokrGWzwNkj1ScPS3wvZHHaPteKxFRIZ3Js6ggOdZscyUqDNCDMOtrrXniOZT2tlKOHI87fHjNIJwky3Vkg$ (accessed on 21 October 2023).

Roon, Kevin D., and Douglas H. Whalen. 2019. Velarization of Russian labial consonants. Paper presented at the 19th International Congress of Phonetic Sciences, Melbourne, Australia, 5–9 August 2019. Edited by Sasha Calhoun, Paola Escudero, Marija Tabain and Paul Warren. Canberra: Australasian Speech Science and Technology Association Inc., pp. 3488–92.

Scobbie, James M., Alan A. Wrench, and Marietta van der Linden. 2008. Head-probe stabilization in ultrasound tongue imaging using a headset to permit natural head movement. Paper presented at the Eighth International Seminar on Speech Production, Strasbourg, France, 8–12 December 2008, pp. 373–76.

Spinu, Laura. 2018. Investigating the status of a rare cross-linguistic contrast: The case of Romanian palatalized postalveolars. *The Journal of the Acoustical Society of America* 143: 1235–51. [CrossRef] [PubMed]

Spinu, Laura, Alexei Kochetov, and Jason Lilley. 2018. Acoustic classification of Russian plain and palatalized sibilant fricatives: Spectral vs. cepstral measures. *Speech Communication* 100: 41–45. [CrossRef]

Spinu, Laura, and Jason Lilley. 2016. A comparison of cepstral coefficients and spectral moments in the classification of Romanian fricatives. *Journal of Phonetics* 57: 40–58. [CrossRef]

Spinu, Laura, Irene Vogel, and H. Timothy Bunnell. 2012. Palatalization in Romanian: Acoustic properties and perception. *Journal of Phonetics* 40: 54–66. [CrossRef]

Spinu, Laura, Maida Percival, and Alexei Kochetov. 2019. Articulatory Characteristics of Secondary Palatalization in Romanian Fricatives. Paper presented at the 20th Annual Conference of the International Speech Communication Association (Interspeech 2019), Graz, Austria, 15–19 September 2019, pp. 3307–11.

Sung, Jae-Hyun, Diana Archangeli, Samuel Johnston, Ian Clayton, and Andrew Carnie. 2015. The articulation of mutated consonants: Palatalization in Scottish Gaelic. In *Proceedings of the 18th International Congress of Phonetic Sciences*. Edited by The Scottish Consortium for ICPhS 2015. Glasgow: The University of Glasgow.

Şuteu, Valeriu. 1961. Observaţii asupra pronunţării limbii române. *Studii şi Cercetări Lingvistice* 12: 293–304.

Tabain, Marija, and Richard Beare. 2018. An ultrasound study of coronal places of articulation in Central Arrernte: Apicals, laminals and rhotics. *Journal of Phonetics* 66: 63–81. [CrossRef]

Timberlake, Alan. 2004. *A Reference Grammar of Russian*. New York: Cambridge University Press.

Wrench, Alan A., and James M. Scobbie. 2011. Very high frame rate ultrasound tongue imaging. Paper presented at the ninth International Seminar on Speech Production, Montreal, QC, Canada, 20–23 June 2011, pp. 155–62.

Yanushevskaya, Irena, and Daniel Bunčić. 2015. Russian. *Journal of the International Phonetic Association* 45: 221–28. [CrossRef]

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