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Articulatory characteristics of secondary palatalization in Romanian fricatives

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Abstract

This study explores the articulatory characteristics of plain and palatalized fricatives in Romanian. Based on earlier acoustic findings, we hypothesize that there are differences in tongue raising and fronting depending on the primary place of articulation, with more subtle gestures produced in the vicinity of the palatal area. We also predict more individual variation in the realization of secondary palatalization in postalveolars, based on general cross-linguistic patterns.

Ten native speakers participated in an ultrasound experiment. The stimuli included real words containing labial, dental, and postalveolar fricatives. The fricatives at all three places were either plain or palatalized word-finally (the only position available for secondary palatalization in this language). Tongue contours at the consonant midpoint were compared using Smoothing Spline ANOVAs individually with radius distance from the ultrasound probe.

The findings indicate differences in tongue shape between plain and palatalized consonants, with stronger palatalization effects in labials compared to coronals, as well as in dentals compared to postalveolars. The latter also revealed higher individual variation. Our findings thus suggest that tongue configurations for secondary palatalization in Romanian differ by place of articulation. The contrast is also overall less robust in postalveolars, confirming previous reports and explaining its rarity cross-linguistically.

Index Terms: articulation, secondary palatalization, fricatives, Romanian

1. Introduction

Romanian is unique among Romance languages in exhibiting a phenomenon of secondary palatalization, in addition to other palatalization phenomena commonly found in the Romance family, such as full palatalization or coronalization [1, 2]. A survey of a random sample of 117 languages [1], revealed the presence of secondary palatalization in 27% of them, indicating it is not a rare phenomenon typologically. Languages from diverse families exhibit secondary palatalization, e.g. Hungarian, Mongolian, Scottish Gaelic, and Isthmus Mixe [1, 3]. The acoustic, perceptual, and articulatory properties of secondary palatalization have been described in detail for Russian [4, 5, 6], as well as for Irish [7, 8], but remain understudied in many other languages. In particular, articulatory studies have not yet been conducted with Romanian.

While a number of studies have revealed higher perceptual salience of secondary palatalization for coronals as compared to labials in Russian [9, 6], Spinu et al. [10] did not replicate this finding for Romanian. In their detailed account of the acoustic and perceptual properties of secondary palatalization in Romanian fricatives, the labial and velar places of articulation exhibited more salient effects of secondary palatalization compared to the dental and postalveolar places. Given listeners' very low sensitivity to secondary palatalization in postalveolars, the question arose whether it is realized at all in this language. In subsequent work, Spinu [11] found evidence suggesting the contrast is produced by the majority of the speakers tested. This was consistent with previous reports of native speakers [12]. Nevertheless, the secondary palatalization contrast with postalveolars conformed to typological predictions of being acoustically and perceptually weaker compared to other places. It is thus unclear whether secondary palatalization 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).

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

2. Background

In terms of phonological status, secondary palatalization 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 /krov^j/ *blood*. In other languages, such as Korean, the addition of a secondary palatalization gesture to the primary place gesture is considered allophonic: /put-i/ –> [put^{j}i] *please* [13]. Romanian, as we will see, does not fully conform to either of these patterns.

Acoustically, palatalized consonants across languages cause lowering of F1 and raising of F2 on neighboring vowels compared to plain consonants. In terms of articulation, electromagnetic articulography studies show secondarily palatalized consonants are characterized by fronting and raising of the tongue body towards the hard palate, timed with respect to the primary articulation. The timing of the primary and secondary gestures was found to vary with speaker and syllabic position [14]. Very few studies to date have addressed the articulatory properties of secondary palatalization using ultrasound. A notable exception is Bennett et al. [8], providing an extensive examination of secondary palatalization in Connemara Irish.

While true palatalized palatals have not been attested [15] and are considered impossible from a phonological and articulatory perspective ([16]; see [17], for a differing view), the situation with postalveolars is less clearcut. Cross-linguistically, postalveolar segments tend to pattern with either plain or palatalized consonants, but not both [6]. However, some loanwords in Polish show palatalization of (retroflex) postalveolar fricatives before the high front vowel /i/ to palatalized laminal

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postalveolar fricatives, contrasting acoustically with alveolo-palatal fricatives [18]. In Isthmus Mixe, morphological palatalization affects all consonants, including the postalveolar fricative [19]. Russian is one of the few languages with a four-way contrast involving palatalized sibilant fricatives as follows: palatalized dental/alveolar /sʲ/, palatalized postalveolar (prepalatal) /ʃʲ/, non-palatalized dental/alveolar /s/, and retroflex (apical postalveolar) /s̺/ [20, 21]. Given the cross-linguistic rarity of this contrast, understanding the details of its articulatory implementation in languages in which it is present – Romanian being one of them – may help us gain insights into the mechanics of contrast realization and maintenance over time.

Turning to the specific case of Romanian, secondary palatalization is only found in word-final position, being commonly associated with (but not restricted to) the presence of two affixes thought to be an underlying /-i/: the plural of certain nouns and adjectives (e.g. [domn] *gentleman* vs. [domnʲ] *gentlemen*, UR: /domn + i/) and the second person singular in the present indicative of verbs (e.g. [sar] *I jump* vs. [sarʲ] *you jump*, UR: /sar + i/). Regarding the phonological status of secondary palatalization in this language, the widespread view is that the underlying word-final /-i/ triggers palatalization on the preceding consonant and is then deleted [22], resulting in a *surface* contrast between plain and palatalized consonants. Thus, secondary palatalization in Romanian is not considered phonemic as it is in Russian.

Regarding postalveolar fricatives in Romanian, Spinu's [11] 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 secondary palatalization contrast is acoustically realized at this place by 27 out of 31 speakers.

In what follows, we examine the articulatory characteristics of secondary palatalization in Romanian fricatives at three different places of articulation, including the postalveolar place, filling a gap in the literature and providing a comprehensive picture of this phenomenon in a relatively understudied language.

3. Experiment

3.1. Hypotheses

Our predictions are primarily based on previous acoustic and perceptual results with secondary palatalization in Romanian [10, 11]:

Hypothesis 1 There are differences between plain and palatalized fricatives in tongue raising and fronting depending on the primary place of articulation, with more subtle gestures produced in the vicinity of the palatal area.

Hypothesis 2 There is more individual variation in the realization of secondary palatalization in postalveolars.

3.2. Stimuli

The stimuli analyzed for this study are a subset of a larger corpus collected to investigate several aspects of the Romanian inventory. Following the methodology in earlier studies [10, 11, 23], the stimuli read by the participants consisted of 5 root-final fricatives, specifically [f, v, z, ʃ, x], each embedded in 4 different target words. Each word was presented in one of two forms: plain (singular), e.g. 'cireş' [ʧireʃ] *cherry tree* and palatalized (plural indefinite), e.g. 'cireşi' [ʧireʃʲ] *cherry trees*. All words were bisyllabic, with the stress falling on the final syllable. Other constructions, not relevant here, were also included.

For the current study, we have selected word-final plain and palatalized labials, dentals, and postalveolars, e.g. [pantof]-[pantofʲ] (*shoe - shoes*), [kinez]-[kinezʲ] (*Chinese-sg. - Chinese-pl.*), [ʧireʃ]-[ʧireʃʲ] (*cherry tree - cherry trees*). The total for analysis was thus 3 fricatives × 4 words × 2 forms × 6 repetitions × 10 speakers = 1,440 tokens.

3.3. Participants

The participants were 10 native speakers of Romanian, 5 females and 5 males. All the speakers but one resided in Canada. They were 29-51 years old (mean age 42). The participants reported no speech or hearing problems. All participants were bilingual, having left Romania in their adulthood, and lived in Canada for a minimum of 6 years and a maximum of 16 years (except for one subject who was visiting from Romania and had only been in Canada for a few weeks).

3.4. Instrumentation and procedure

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 _ kind pot] *I say _ when I can*. The word list was read through twice for a total of six repetitions.

Midsagittal ultrasound data were collected using the *Telemed Echo Blaster 128 CEXT-1Z* system with an *Articulate Instruments* pulse-stretch unit [24]. 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 [25]. 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* [26]). The data were collected in a quiet lab space.

3.5. Analyses

Tongue tracings for target consonants were performed at the frame of maximum displacement, which typically corresponded to the midpoint of the fricative. This was done using *AAA* [26]. For each token, contours were extracted as series of x and y coordinates and rotated with respect to the occlusal plane [27]. 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 (on average 33), given only partial imaging of the tongue. Figure 1 shows sample tracings before and after the rotation, with the origin of the probe indicated as 0.

We further converted Cartesian (x, y) coordinates to polar coordinates (cf. [28]), and used a measure of radius distance (in mm) from the origin of the probe to the tongue surface (cf. [29]). That is, each tongue contour point was associated with a radius value, with higher values corresponding to the tongue surface being further away from the probe.

Radius values were averaged across two regions – the front and the back of the tongue. The boundary between these regions was determined individually for each speaker – as the point at which the contours for the plain and palatalized [f] intersected (with both having approximately the same radius values). Note that, for all speakers, the tongue root/back was more

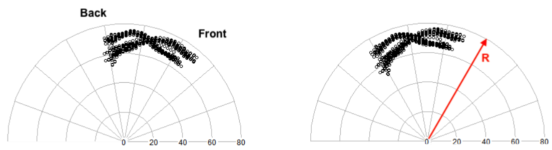

Figure 1: *Raw tracings for all tokens produced by speaker R06 before (left) and after the rotation (right); the 0 point corresponds to point of origin (the probe). The arrow indicates radius distance.*

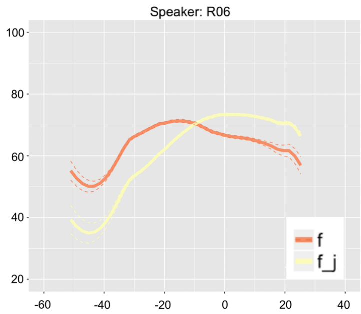

Figure 2: *A sample SS-ANOVA for the [f] vs. [fʲ] target sequences produced by speaker R06. Note: [fʲ] = f_j).*

posterior and the tongue body/blade was lower for plain [f] than its palatalized counterpart, so that their tongue contours crossed each other around the middle of the tongue (see Figure 2).

The data, averaged across words per speaker, were submitted to Linear Mixed Effects (LME) models with radius R as a dependent variable, Consonant (f, z, ʃ) and Palatalization (plain, palatalized) as fixed effects, and Speaker (R01-R10) and Utterance (3 per target sequence) as random effects. The intercept was set to plain [f]. The models were run separately for the front and back portions of the tongue, using the *lme4* package [30] for R [31]. P-values were obtained using the Chi-square test implemented in the *Anova()* function of the *lmerTest* package [32]. Pairwise comparisons were Bonferroni-corrected.

To further investigate differences within individual productions of specific contrasts, *Smoothing Spline Analyses of Variance* (SS-ANOVAs [33]) were performed using the *gss* package in R [34]. A sample SS-ANOVA for the plain and palatalized [f] for R06 is shown in Figure 2. Due to space considerations, the results of SS-ANOVA analyses will be discussed only briefly in the rest of the paper.

3.6. Results

The LME model for the front part of the tongue revealed significant effects of Consonant, Palatalization, and a significant interaction of the two, as shown in Table 1a. Given the interaction, separate analyses were performed within the Consonant and Palatalization conditions. As shown in Table 1b, the effect of Palatalization was significant for each consonant, with palatalized consonants having higher radius values (i.e. greater tongue body/blade raising) than their plain counterparts. However, as seen in Figure 3, the consonants differed in the magnitude of this effect: [f] had the highest palatalization difference, while [ʃ] had the lowest difference. As shown in Table 1c, the effect of Consonant was significant for plain consonants, but not for palatalized consonants. In other words, plain consonants differed in the amount of raising of the tongue body/front, while the palatalized ones did not. A post-hoc test for plain consonants showed that all three were highly significantly different ($p < 0.0001$) from each other, with the radius values increasing from [f] to [z] and then to [ʃ] (see Figure 3).

Table 1: *Results of linear mixed effects models for the front portion of the tongue: (a) for the full set of data, (b) separately by consonant, and (c) separately for plain and palatalized consonants (***<0.001, **<0.01, *<0.05). Con = consonant; Pal = palatalization.*

	Effect	Chisq	Df	Pr (>Chisq)
a.	Con	19.791	2	<0.0001 ***
	Pal	91.986	1	<0.0001 ***
	Con: Pal	70.925	2	<0.0001 ***
b.	Con [f]: Pal	92.703	1	<0.0001 ***
	Con [z]: Pal	19.461	1	<0.0001 ***
	Con [ʃ]: Pal	7.1855	1	0.0074 **
c.	Plain: Con(f–z–ʃ)	52.579	2	<0.0001 ***
	Palatalized: Con (f–z–ʃ)	1.1269	2	0.5692 ns

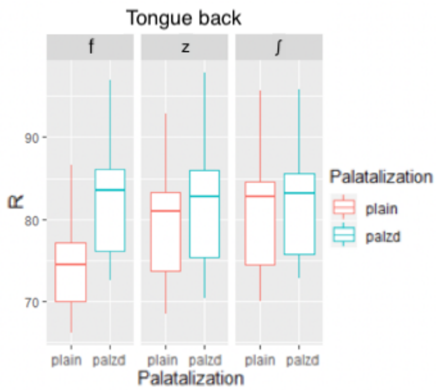

Figure 3: *Radius distance (in mm) for the front portion of the tongue by consonant and palatalization.*

The LME model for the back part of the tongue revealed a significant effect of Palatalization, but not Consonant. However, there was a significant interaction of the two, as shown in Table 2a. Given this interaction, separate analyses were performed within the Consonant and Palatalization conditions. Like with the front tongue portion, the effect of Palatalization was significant for each consonant (see Table 2b). Palatalized consonants had significantly lower radius values (i.e. greater tongue root/body fronting) than their plain counterparts. Again, however, this effect differed considerably in magnitude by consonant, with [f] showing the maximum front-back difference, and [ʃ] showing the lowest difference (see Figure 4). Table 2c shows that the effect of Consonant was significant for plain consonants, but not for palatalized consonants, as was seen earlier for the front portion of the tongue. That is, palatalized consonants showed essentially the same amount of fronting, while plain consonants showed some differences in the tongue position. A post-hoc test for plain consonants showed that the radius distance for [f] was significantly lower (i.e. more back) than for [z] ($p < 0.05$) and [ʃ] ($p < 0.0001$); the latter two were not significantly different from each other (while showing marginally lower values – that is more fronting – for [ʃ] than [z]; $p < 0.1$).

Table 2: *Results of linear mixed effects models for the back portion of the tongue: (a) for the full set of data, (b) separately by consonant, and (c) separately for plain and palatalized consonants (***<0.001, **<0.01, *<0.05). Con = consonant; Pal = palatalization.*

	Effect	Chisq	Df	Pr (>Chisq)
a.	Con	2.0211	2	0.364 ns
	Pal	63.5406	1	<0.0001 ***
	Con: Pal	21.3095	2	<0.0001 ***
b.	Con [f]: Pal	67.683	1	<0.0001 ***
	Con [z]: Pal	26.408	1	<0.0001 ***
	Con [ʃ]: Pal	8.0457	1	0.0046 **
c.	Plain: Con(f–z–ʃ)	16.104	2	0.0003 ***
	Palatalized: Con (f–z–ʃ)	0.6518	2	0.7219 ns

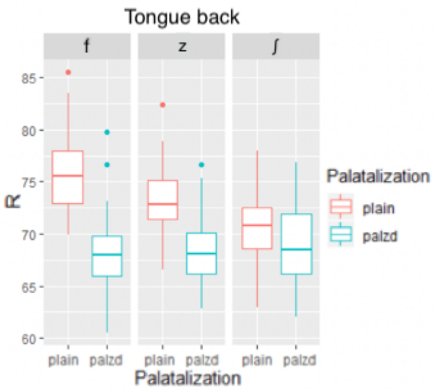

Figure 4: *Radius distance (in mm) for the back portion of the tongue by consonant and palatalization.*

These differences can be seen in Figure 4.

As far as individual behavior is concerned, an examination of SS-ANOVA results showed that only 3 speakers clearly distinguished palatalization in postalveolars. The others either showed relatively small differences (5 speakers) or no differences at all (2 speakers). In contrast, 8 out of 10 speakers showed clear palatalization differences in dentals, with only one speaker apparently neutralizing the contrast. All speakers produced clear differences between plain and palatalized labials.

To sum up, the results revealed that the secondary palatalization contrast was produced at all places, but the magnitude was rather small for postalveolars, with more than half the participants showing a near-merger of the contrast at this place.

4. Discussion

Both hypotheses formulated in Section 3.1 were supported. As predicted by Hypothesis 1, we found that plain and palatalized targets differ significantly in both tongue regions (front and back), but the magnitude of this difference was not the same: [f]-[f^j] > [z]-[z^j] > [ʃ]-[ʃ^j]. The latter contrast also shows more variation, in support of Hypothesis 2, and appears to have been completely neutralized by 2 of the 10 speakers. This is consistent with the findings in [11] which indicated that 13% of native speakers had neutralized this contrast, based solely on acoustics.

Other types of variability in the realization of secondary palatalization at this place may be present, such as coarticulatory effects with the preceding vowel. Secondary palatalization is inherently dynamic and may not be synchronously timed with the primary gesture. There are likely some other differences (including during the preceding vowel) that our current analysis is missing, as it was limited to a single frame during the fricative.

While most apparent with postalveolars in Romanian, interspeaker variability is not surprising, and may be related to the observed neutralization of the secondary palatalization contrast at this place [11]. As found by Kochetov [14], the timing of the primary and secondary gestures may vary by speaker, particularly when the targets for the two gestures are very close to each other. A high degree of speaker-specific variability was also found with secondary palatalization in [t, s, n, l] in Scottish Gaelic [35]. According to the authors, none of 26 speakers shared similar articulatory patterns for secondary palatalization, exhibiting highly individualized patterns instead.

Lastly, the fact that no significant differences at consonant midpoint were found between palatalized forms at all three places raises the question of potential invariance in feature realization [36, 37, 38], which may be more robustly manifested at the production level compared to the acoustic level [39, 40]. In this respect, our findings are similar to those for Connemara Irish [8], which revealed high consistency in the realization of the secondary palatalization contrast across place, manner, and vowel contexts. By contrast, native speakers of Scottish Gaelic, while preserving the contrast between plain and palatalized consonants in their production, were found not to do so in a systematic way that would correspond to a “palatal gesture” [35], as discussed in the previous paragraph. These conflicting results may be reconciled in the future by taking a closer look at language-specific use of articulatory space, and how phenomena in addition to the presence of contrastive palatalization might influence it [41]. It is also conceivable that differences in the phonemic status of secondary palatalization in these languages (i.e. contrastive in Irish, surface contrast in Romanian, and lexicalized consonant mutation in Scottish Gaelic) might have an effect on its realization.

5. Conclusion

Secondary palatalization in Romanian has never been documented before in articulatory studies. Our findings are thus of descriptive interest, indicating differences in tongue shape between plain and palatalized consonants. The palatalization effects were stronger in labials compared to coronals, and in dentals compared to postalveolars. The latter consonants also revealed higher individual variation. Our results thus support the claim that tongue configurations for the secondary palatalization contrast in Romanian differ by place of articulation. We also found that the contrast was overall less robust in postalveolars, confirming previous reports and explaining its cross-linguistic rarity. Differences from other languages were also found, raising questions about featural invariance, the role of phonemic status, and language-specific use of articulatory space, which must be left for future studies to elucidate.

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