Postalveolar Fricatives in Slavic Languages as Retroflexes*

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The present study poses the question on what phonetic and phonological grounds postalveolar fricatives in Polish can be analyzed as retroflex and whether postalveolar fricatives in other Slavic languages are retroflex as well. Velarization and incompatibility with front vowels are introduced as articulatory criteria for retroflexion, based on cross-linguistic data. According to these criteria, Polish and Russian have retroflex fricatives, whereas Bulgarian and Czech do not. In a phonological representation of these Slavic retroflexes, the necessity of perceptual features is shown. Lastly, it is illustrated that palatalization of retroflex fricatives both in Slavic languages and more generally causes a phonetic and phonological change to a non-retroflex sound.

1 Introduction

The postalveolar series of fricatives in Polish is traditionally described as apical postalveolar and referred to with the symbols /š/ and /ž/ (e.g. Rubach 1984 or Wierzchowska 1980). Spencer (1986) and Dogil (1990), among others, use the IPA symbols /ʃ/ and /ʒ/ for these respective sounds. Nevertheless, these sounds differ significantly from those usually designated with /ʃ/ and /ʒ/, for example in English, as the latter are clearly laminal, whereas the Polish phonemes seem to have the apex involved in their articulation (Biedrzycki 1974, Catford 1988). Furthermore, the Polish sounds yield a different perceptual impression than English postalveolars (Hume 1994). These facts lead Ladefoged & Maddieson (1996) and others to claim that the postalveolar fricatives in Polish are *retroflex*, though their articulation does not involve the characteristic bending backwards of the tongue tip found for example in Dravidian retroflex fricatives. A phonological argument that Polish fricatives are retroflex was made by Hall (1997a). Apart from Polish, Keating (1991: 35) classifies only Russian and Serbian as Slavic languages with retroflex fricatives, but merely on phonetic grounds.

The present article proposes a retroflex analysis for the postalveolar fricatives in Polish and Russian. Furthermore it tackles the question whether only this subgroup of the Slavic languages or additional ones, too, has retroflex fricatives. In order to do so, phonetic and phonological characteristics for retroflex sounds in general and retroflex fricatives in particular from typologically diverse language groups such as Scandinavian, Indo-Aryan, Dravidian and Australian are presented in section 2. Section 3 compares these characteristics with the postalveolars in Polish, Russian, Bulgarian, and Czech to test the retroflex nature of these sounds. In line with former proposals, it will be argued that Polish and Russian have a retroflex fricative. Bulgarian and Czech will be shown to have a laminal postalveolar phonetically and phonologically. Section 3 furthermore seeks an answer to the question why certain Slavic languages developed a retroflex from a palatoalveolar fricative whereas others kept the original Proto-Slavic sound. Section 4 deals with the phonological representation of retroflexes and shows that the use of the perceptual features [low F2], [high F2] and [low F3] is necessary to account for their phonological behavior found in

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Slavic and other languages. Connected with the question of defining retroflex in Slavic languages, section 5 illustrates that palatalization of retroflex fricatives in these languages does not simply involve an addition of a secondary articulation, but yields a change in primary articulation to palatalized palatoalveolar. Phonetic evidence and a phonological treatment for this will be given. Section 6 concludes.

2 Retroflex Sounds in Non-Slavic Languages

The phonetic and phonological classification of retroflex sounds in general is problematic as these sounds make up a category with large articulatory variation. Problems in finding a unifying phonetic property were pointed out by Bhat (1973) and Hamann (1999). Phonologically, the differing proposals for their representations, which include Lin (1989), Hamilton (1993) and Gnanadesikan (1994), indicate the problematic nature of classifying retroflexes. This section assembles cross-linguistic data on the articulation, acoustics and phonological behavior of retroflexion.

2.1 Articulatory Definition

Retroflexes are often defined as sounds articulated with the tongue tip bent backwards towards the postalveolar region (e.g. Trask 1996: 308). However, this class of sounds shows considerable articulatory variation. Two figures of retroflex plosives, one from Hindi, cf. (1a), and one from Tamil, cf. (1b) (both based on x-ray tracings in Ladefoged & Maddieson 1996: 27), exemplify this variation:[1]

(1) a. Hindi retroflex stop /ɖ/ b. Tamil retroflex stop /ɖ/

Hindi retroflex stops (cf. 1a) are articulated with the tongue tip against the region behind the alveolar ridge, whereas Tamil retroflex stops (cf. 1b) involve a placement of the underside of the tongue tip against the postalveolar region. These two types of retroflexion can be understood as two extremes on a spectrum of possible articulations.[2]

[1] In this and the following descriptions of x-ray tracings it should be kept in mind that the shape of the tongue and the placement of its tip depends very much on the vocal tract anatomy of the speaker, and that there is large variability in anatomy from speaker to speaker.

[2] Ladefoged & Maddieson (1996: 15) introduce two different symbols for these two types of retroflex stops. The Hindi-type of articulation involving just the tongue tip (mostly found in Indo-Aryan languages) is transcribed with a subscript dot beneath the symbol for the alveolar stop, whereas the articulation with the underside of the tongue as in Tamil and other Dravidian languages receives the traditional IPA symbol for a retroflex stop. Švarný & Zvelebil (1955) distinguish 'retroflex' from 'cacuminal', where the former involves the use of the underside of the tongue, whereas the latter involves the tongue tip only. In this article, only one term, 'retroflex', and one symbol, the traditional IPA symbol for retroflex /ʈ/, are used for both kinds of articulation.

The problematic nature of defining retroflexes is reflected in the IPA symbol chart, where 'retroflex' is used along with terms referring to the place of articulation such as 'dental', 'alveolar' etc., though 'retroflex' does not describe a place but rather a gesture of articulation.[3]

Variation in the articulation of retroflexes occurs not only across languages; we also find considerable speaker to speaker variation within one language, see for instance Dixit's (1990) description of Hindi retroflex stops.[4]

A unifying articulatory criterion for all retroflex stops is their sub-lingual cavity, visible in both articulations in (1), caused by the raised and somewhat retracted tongue tip. All sounds articulated with the tongue tip or blade at or behind the alveolar ridge evince a cavity beneath the tongue. But as Keating (1991: 43) points out, this cavity is larger for retroflex sounds than for palatoalveolars, and increases from apical to sub-apical retroflex.

Furthermore, retroflex stops show a retraction of the tongue body towards the velum, i.e. velarization. According to Bhat (1974), all articulations involving the tongue tip co-occur with this retraction of the tongue body. Velarization of apical sounds can be articulatory explained. The tongue, in order to be able to move its tip upwards, stretches, which results in a flattening and retraction of the tongue body.

For the present study on Slavic fricatives, it is of interest whether retroflex fricatives are articulated at the same place and with the same gesture as retroflex stops. Languages with a large fricative inventory such as Toda have a retroflex fricative that involves a raising of the tongue tip towards the post-alveolar region, cf. the x-ray tracings in (2a) (Ladefoged & Maddieson 1996: 160). This sound resembles the retroflex stops of Indo-Aryan languages and is (what is traditionally described as) retroflex. Cross-linguistically far more common are retroflex fricatives articulated like the Tamil sound in (2b) (Ladefoged & Maddieson 1996: 156). Here the tongue tip does not seem to be involved in articulation at all, and the place of constriction is far wider than that of the Toda fricative.[5]

(2) a. Toda retroflex fricative /ʂ/ b. Tamil retroflex fricative /ʂ/

It is interesting to note that the two different articulations for retroflex fricatives occur within the same language family (Dravidian). The difference might be due to the fact that Toda has a fricative system with four coronals, whereas Tamil has only three coronal fricatives. This question is further discussed in Hamann (in prep.).

A retroflex fricative with a curling backwards of the tongue tip, comparable to the Tamil stop in (1b), does not seem to occur in any language. From this we can conclude that retroflex fricatives

[3] The literature disagrees on whether retroflexion is a gesture or a place of articulation. Ladefoged (1975) and Maddieson (1984) e.g. use 'retroflex' as a value for the feature 'articulatory place', Catford (1977), M. Ohala (1983), and Laver (1994), on the other hand, apply this term to an articulatory gesture. Hamann (in prep.) argues for an analysis of it as a gesture rather than a place of articulation.

[4] Context-dependent differences such as the change in location of the articulator depending on the adjacent vowel are ignored here. See e.g. Dixit & Flege (1991) on the phonetic influence of vowel context, rate and loudness on the articulation of retroflex stops.

[5] Again, Ladefoged & Maddieson (1996: 156) introduce two different symbols for the two retroflex articulations. Whereas the Tamil-type of fricative receives an underlined alveolar symbol, the fricative found in Toda is transcribed with the traditional IPA symbol for retroflex fricatives.

do not involve the same backwards bending of the tongue tip as retroflex stops.[6] Nevertheless, they share the sublingual cavity with retroflex stops, and also show a velarization of the tongue body. The difference in articulation between retroflex fricatives and stops suggests that stops and fricatives have different requirements. Whereas stops allow some degree of sloppiness in their articulation, fricatives and especially sibilants like retroflex and alveolar fricatives require very precise articulatory gestures that yield a turbulent airstream.

In order to determine whether the Slavic fricatives in question are retroflex or laminal postalveolar, we will now compare retroflex to laminal postalveolar articulations to formulate criteria that differentiate between them. The x-ray tracing in (3) illustrates an English laminal postalveolar (based on Laver 1994: 246). This type of sound will henceforth be referred to as palatoalveolar.

(3) English palatoalveolar fricative /ʃ/

In contrast to the retroflex fricatives in (2), the palatoalveolar in (3) shows a fairly long constriction in the alveolar and postalveolar region. Furthermore, the tongue has a convex tongue shape behind the constriction. For this reason the tongue shape of palatoalveolars is sometimes called "domed", for example by Ladefoged & Maddieson (1996: 148). Lass (1976) and Catford (1977) infer from this tongue shape that the palatoalveolar is palatalized. The present study follows these authors and assumes that the palatoalveolar fricative is inherently palatalized and therefore cannot undergo secondary palatalization.

The palatoalveolar differs from the retroflex in its tongue shape, it is domed instead of velarized and convex, and in its constriction length, which is far longer than the retroflex constriction.

Summing up the articulatory criteria for retroflex fricatives, they all show a sublingual cavity, are articulated with the tongue tip or blade and with a flat, velarized tongue body. Not all of these criteria are capable of distinguishing retroflexes from palatoalveolars. Using the active articulator as a unifying criterion alone is problematic, because not all retroflexes are apical, as shown above. The sublingual cavity cannot be used as a distinguishing criterion either as it is not unique to retroflex sounds; they share it with palatoalveolars. Only velarization of retroflexes, which is responsible for the flattening of the tongue body, clearly distinguishes retroflex from palatoalveolar articulation. Support for this can be found in Hamilton (1980: 21) who uses the terms velarization and retroflex interchangeably when describing the postalveolar fricative in Polish, which suggests a dependence of one on the other. The articulatory criterion for retroflex fricatives used in the following is therefore a postalveolar place of articulation combined with a velarized flat tongue.

Reference to the shape of the tongue as a defining criterion for a sound class is not new in phonetics; Ladefoged & Maddieson (1996: 29f.), for example, propose to distinguish between the four coronal stops and nasals in Australian Eastern Arrerente by referring to the articulator shape instead of the place of articulation.

When defining retroflex sounds as velarized postalveolars, the Australian language Lardil seems to pose a problem, as it is said to have phonetically and phonologically a non-velarized

[6] Other retroflex manners such as nasal, lateral, or rhotic, behave like the stop, as shown in Hamann (in prep.).

retroflex fricative (Hall 1997a, 2000, and Wilkinson 1988, both based on Stevens et al. 1986). As shown in Hamann (2002), these assumptions are phonetically incorrect and also unnecessary phonologically, since an alternative representation for the Lardil data can be given without stating that the retroflex sounds in this language are [-back], i.e. non-velarized.

2.2 Acoustics of Retroflexes

Though the acoustic criteria for retroflex fricatives presented in this section are not going to be applied to all Slavic fricatives in question, they are necessary for the phonological account of the behavior of retroflexes in section 4.

The following acoustic description is restricted to voiceless fricatives, voiced fricatives usually only differ in having lower intensity than voiceless ones. A problem in describing acoustic characteristics of fricatives are the great discrepancies among the spectra of a given fricative as spoken by different speakers (Ladefoged & Maddieson 1996: 172). The following descriptions are generalizations across the data and might not hold for every single instance of a retroflex fricative.

In general, the cavity under the tongue blade in palatoalveolars and retroflexes has a lowering effect on the acoustic resonance, as Keating (1991) points out. For the retroflex fricative the frication noise usually starts earlier than for the palatoalveolar and shows an energy maximum in the area of the second and third formant, i.e. between 1600 Hz and 2400 Hz. These values are similar to those of the low second and third formant obscured for retroflex stops, see Stevens (1998) or Hamilton (1996), and will therefore henceforth be referred to as low second and third formants.

In contrast to the spectral peak of retroflex fricatives, palatoalveolars show a more evenly spread energy till roughly 5000 Hz (Ladefoged & Maddieson 1996: 174f.), resulting in a flat, plateau-like spectrum. According to Cruttenden (1994: 164), for example, English /ʃ/ has continuous noise in the 2000 – 7000 Hz region. The formants discernable in the spectrum are higher than those of retroflexes, namely around 1800 Hz for the second and 2600 Hz for the third formant (Stevens 1998: 410).

Despite these differences, [ʃ] and [ʂ] are very similar acoustically when compared to fricatives articulated in the velar or alveolar region. An additional rounding of the postalveolar, as occurs for instance in Polish, enhances the similarity, as lip rounding enlarges the front cavity and results in lowering of the formant frequencies, especially the third (Johnson 1997: 118). As a result, [ʃʷ] and [ʂ] are perceptually hard to distinguish.

2.3 Phonological Behavior of Retroflexes

Cross-linguistically, retroflex sounds show a tendency to avoid a high or middle front vowel context.[7] This might result in a change of the vowel in retroflex context, for example the process of /e/-lowering in Norwegian. The segment /e/ has an allophone [æ] before a retroflex, exemplified in (4). The first column contains words with /ɛ/ (4a) or /eː/ (4b) followed by a dental, the second column contains an /ɛ/ followed by a retroflex, where the vowel is realized as [æ] (Kristoffersen 2000: 105f.).

(4)	a.	[vɛt]	vett	‘intelligence’	[væʈ]	vert	‘host’
		[hɛlg]	helg	‘weekend’	[hæʈj]		‘weekend’, less formal register
	b.	[heːl]	hœl	‘heel’	[hæːʈ]		‘heel’, less formal register

[7] In the following examples it is only the preceding front vowel that changes. The Slavic examples to be discussed in section 3.2, however, show an influence of retroflex segments onto the following vowel (and vice versa). Cross-linguistically, a pre-retroflex vowel is prone to changes more often than a post-retroflex one because of the more prominent acoustic cues of retroflexes in VC transitions compared to CV transitions (see Hamann in prep. for a full discussion of this point).

A similar process of front vowel avoidance can be found in Mandarin (Yip 1996). Here, the retroflex series /tʂ, tʂʰ, ʂ/ is in complementary distribution with the palatal series /tɕ, tɕʰ, ɕ/. The pairs /tʂai-*tɕai/, /tʂu-*tɕu/, /*tʂi-tɕi/, and /*tʂʏ-tɕʏ/ illustrate the incompatibility of the retroflex non-aspirated affricates with high front vowels, which leads to their replacement in this context by palatal affricates.

According to Himmelmann (1991), the Austronesian language Tolitoli spoken in Indonesia shows an alternation between an alveolar lateral approximant /l/ and a retroflex lateral flap /ɭ/. The retroflex surfaces only after back vowels, cf. (5a), the lateral /l/ occurs in all other surroundings, cf. (5b).

(5)	a.	mo[ɭ]ogo	‘wash hands’	b.	membembe[l]an	‘to tremble’
		u[ɭ]ag	‘snake’		[l]abia	‘sago’
		to[ɭ]ito[ɭ]i	‘Tolitoli’		kiki[l]o	‘firefly’

The avoidance of front vowels is not restricted to retroflexes, it can also be found with velars. In Bulgarian, for example, the velars /k, g, x/ have the allophones [c, ɟ, ç] before front vowels (Scatton 1983: 65). One can assume, then, that velar consonants (at least in Bulgarian) are inherently velarized. Apical alveolar consonants tend to avoid front vowels as well (Bhat 1974 lists several languages illustrating this point). A possible explanation for these findings is that apical consonants (both alveolar and retroflex ones) are velarized (recall the articulatory explanation for this in section 2.1), just like (the Bulgarian) velar consonants. The phonological changes occurring in front-vowel and retroflex sequences are thus phonetically motivated by the velarization of retroflexes, and support the criteria for retroflexion posed in section 2.1, namely the velarized and flat tongue position.

Retroflexion causes not only lowering of front vowels but also rounding of the front vowels, though this process occurs relatively rarely compared to vowel lowering. Flemming (2002: 90) gives the following examples from the aboriginal Australian language Wembawemba spoken in Victoria, where the vowel /i/ is rounded before retroflex consonants:

(6)	/ʈjiɳʈjiɳ/	[ʈjyɳʈjyɳ]	‘poker’
	/tiʈənaiuk/	[tyʈənaiuk]	‘new, fresh’
	/miɽkuk/	[myɽkuk]	‘egg’

This rounding does not occur with other coronals, for instance /tir/ [tir] ‘tomahawk’. Flemming (ibid.) mentions Wergaia as a further example of a language where retroflexes condition the rounding of vowels. Interestingly, the Tolitoli data in (5) show rounding before the retroflex, too.

A phonological account for the rules of vowel-lowering/centralizing and vowel-rounding in retroflex context is given in section 4, together with an account of the Slavic retroflexes.

3 Postalveolar Fricatives in Slavic Languages

The postalveolar sounds investigated in this study are illustrated with words from Polish, Russian, Bulgarian and Czech in (7) – (10). The upper row of each language illustrates the voiceless sound, the lower the voiced, in word-initial, medial and final position. In all these languages final devoicing occurs, thus the final column of the second row remains empty in each case. The palatoalveolar symbol was used throughout the phonetic transcription for the sounds in question, in order to avoid any implications for possible retroflexion.

	WORD-INITIAL		WORD-MEDIAL		WORD-FINAL	
(7)	*Polish*					
	szal	[ʃal] ‘scarf’	kasza	[ˈkaʃɑ] ‘groats’	lekarz	[lɛkaʃ] ‘physician’
	żal	[ʒal] ‘grief’	gaża	[ˈgaʒɑ] ‘fee’		
(8)	*Russian*					
	šag	[ʃak] ‘step’	pošel	[pʌˈʃol] ‘went’	naš	[naʃ] ‘our’
	žar	[ʒar] ‘heat’	xožu	[xʌˈʒu] ‘I go’		
(9)	*Bulgarian*					
	šal	[ʃal] ‘scarf’	kaša	[ˈkaʃɑ] ‘groats’	loš	[lɔʃ] ‘bad’
	žar	[ʒar] ‘heat’	lože	[ˈlɔʒe] ‘bed’		
(10)	*Czech*					
	šál	[ʃaːl] ‘scarf’	šašek	[ˈʃaʃɛk] ‘fool’	váš	[vaːʃ] ‘your’
	žal	[ʒal] ‘grief’	lože	[ˈlɔʒɛ] ‘bed’		

Slavic postalveolars are usually transcribed with the symbols /š/ and /ž/ in traditional Slavic literature (e.g. Rubach 1984 for Polish, Bola 1981 for Russian, Simeonova 1988 for Bulgarian, and Kučera 1961 for Czech). Sometimes the use of the IPA symbols /ʃ, ʒ/ can be found, for example in Spencer (1986) and Dogil (1990) for Polish, Bola (1981) and Jones & Ward (1969) for Russian, and Skalicková (1974) for Czech.

In order to determine their retroflex status, we will check in 3.1 whether the postalveolars in these languages are articulated with the tongue front and with a velarized, flat tongue body. Furthermore, some acoustic cues and perceptual judgments on the sounds in question are given. In section 3.2, the phonological behavior of the Slavic postalveolars is investigated. It will be shown that some of the languages show an incompatibility of postalveolar with high front vowels.

3.1 Phonetics

The following judgments on the articulation of the postalveolar fricatives in Polish, Russian, Bulgarian, and Czech are based on x-ray studies and phonetic descriptions from the phonetic literature. The discussion is usually restricted to the voiceless fricative, but holds for the voiced one as well.

In (11), a schematic figure of the Polish postalveolar voiceless fricative is given, based on x-ray tracings in Wierzchowska (1980: 64).

(11) Polish postalveolar

As can be observed from the tracing in (11), the Polish sound is articulated with a flat, velarized tongue and the active articulator seems to be the tongue blade. In the literature, diverging opinions on the articulator can be found. Biedrzycki (1974: 20ff.), Catford (1988: 90f), Dogil (1990), and Spencer (1986) all describe the Polish sound as apical. Ladefoged & Maddieson (1996: 154) call it laminal. Ladefoged (2001: 151) describes it as a sound articulated with a raised tongue tip, and Keating (1991) says that it varies between apical and laminal. In cases where the shape of the

tongue is described (e.g. in Keating 1991 or Ladefoged & Maddieson 1996), there is agreement on its flat, velarized nature. As a result, the phonetic criterion for retroflexion developed in section 2.1 applies to the Polish postalveolar. In addition to a flat, velarized tongue shape, the Polish sound is described as rounded (Dogil 1990, Keating 1991) or protruded (Ladefoged & Maddieson 1996).

The acoustic measurements attest the retroflex nature of the Polish sound. According to Dogil (1990) the postalveolar Polish fricative has a low start of frication noise. As far as perception is concerned, Keating (1991) cites studies showing that the Polish postalveolar fricative sounds more like retroflexes in other languages than like a palatoalveolar.

The Russian postalveolar fricative is illustrated in (12), based on x-ray tracings of the voiceless sound in Bolla (1981: plate 60).

(12) Russian postalveolar

This sound shows a flat tongue shape and distinct velarization. Phonetic descriptions on the Russian sound explicitly mention the velarization or flattened tongue, for example Bolla (1981: 90), and Jones & Ward (1969: 134). Maddieson (1984: 226) even uses special diacritics, /ʃ/ and /ʒˠ/, to indicate the velarization. Agreement also exists on the apical articulation of the Russian postalveolars. Keating (1991: 35) claims that some x-ray tracings of the postalveolar fricatives in Russian made by Oliverius (1974) show that they are actually articulated with the tongue tip bent backwards. Like Polish, the Russian postalveolar is rounded or protruded (Bolla 1981, Jones & Ward 1969). Concerning perception, the Russian sound has a 'darker' or more 'hollow' quality than the English postalveolar (Jones & Ward 1969: 134). Consequently, the Russian postalveolar is retroflex according to the previously established criteria.

A schematic figure of the Bulgarian postalveolar is given in (13), based on x-ray tracing of the voiceless sound in Bojadžiev (1982: 87).

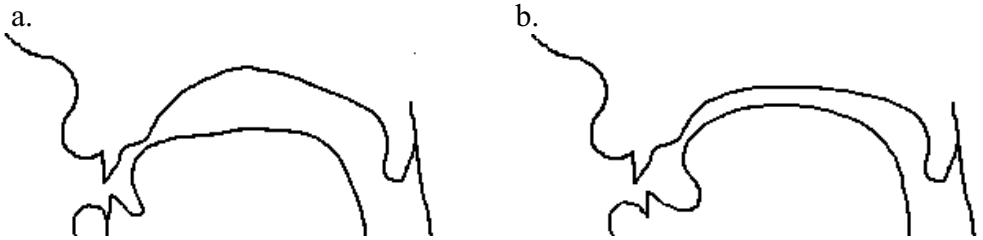
(13) Bulgarian postalveolar

The tongue shape of the postalveolar in Bulgarian differs very much from that of the corresponding Russian and Polish sounds, as it is not flat but has a raised tongue body, similar to the English palatoalveolar. The Bulgarian fricative is described in the literature as 'prepalatal' (Simeonova 1988: 174) or 'weakly palatalized alveopalatal' (Scatton 1983: 58). We can conclude from this that the Bulgarian postalveolar is not retroflex but palatoalveolar.

For the Czech postalveolar, two x-ray tracings from different sources are given, as the two show a considerable difference in articulation. Figure (14a) is based on Skaličková (1974: 104), and figure (14b) on Polland & Hála (1926: 23), both of the voiceless sound.

(14) Czech postalveolar

a. b.



The articulation of the Czech sound in figure (14a) looks similar to that of the Russian or Polish sound, as it has a flatter and more velarized tongue body than the English palatoalveolar. The articulation of the same sound in figure (14b), however, shows a domed tongue body. Judging from figure (14a) alone, the Czech sound could be classified as retroflex, as it is articulated in the same way as the Russian or Polish sounds and fulfils the criteria of retroflexion developed earlier on. Its retroflex nature is confirmed by the fact that the Czech sound is usually described as apical, as for instance by Kučera (1961: 30). Furthermore, Harkins (1953: 6) describes the Czech postalveolar as "less palatal" and as having a "deeper timbre" than the English sound. Figure (14b), however, shows a clearly domed and high tongue body, which can be compared to the articulation of the respective Bulgarian sound in figure (13).[8]

According to the criteria developed in this article, it cannot be clearly determined whether Czech has a retroflex fricative or not, as the two articulations taken as bases for judgment differ too much. Future articulatory research has to clarify this point. The Czech sound is, however, classified as a postalveolar and referred to with the symbol /ʃ/ in very recent phonetic descriptions such as Dankovičová (1997).

In sum, if one assumes postalveolar articulation combined with velarization as defining criteria for retroflexion, the articulatory analysis shows that Polish and Russian postalveolar fricatives are clearly retroflex. This was predicted by previous phonetic studies (such as Keating 1991) etc., although the grounds on which the Polish and Russian sounds were claimed to be retroflex were not all clear. The two very different possibilities for the articulation of the Czech fricative are surprising, as such a variation has not been mentioned in the literature before. No clear statement on the retroflex status of this sound can be given at this point. The palatoalveolar nature of the fricative in Bulgarian, however, is very obvious and does not come as a surprise, as no suggestion to the contrary has previously been made.

3.2 Phonological Behavior

In this subsection, phonological evidence for and against the retroflexivity of the postalveolar fricative in Polish, Russian, Czech and Bulgarian will be collected. We will consider the question whether these sounds undergo rules comparable to those involving retroflexes in other languages, as discussed in section 2.3. The phonological investigation will start with Polish, moving on to Russian, Czech, and Bulgarian.

Dogil (1990: 5) states that the alveolopalatal fricative /ɕ/ and the retroflex /ʂ/ are in complementary distribution in one context in Polish. Whereas the alveolopalatal does not occur before the centralized, high vowel /ɨ/, the retroflex /ʂ/ does. On the other hand, the retroflex does not occur before front, high /i/, where the alveolopalatal /ɕ/ does. Examples for this with the verbalizing suffix /i/ are given in (15).

[8] It has to be pointed out that Polland & Hála (1926), the source of figure (14b), is 48 years older than Skaličková (1974), the source for figure (14a). There might have been a change from palatoalveolar towards a more retroflex articulation of this sound within such a big time span.

(15)	ko**s**+**i**+ć	[ɕi]	‘mow’ inf.
	towarzy**sz**+**i**+ć	[ʂɨ]	‘accompany’ inf.

The avoidance of high, front vowel contact of the retroflex fricative in Polish is manifested in a rule of vowel retraction. This so-called Retraction Rule (Rubach 1993: 9) changes /i/ into the central vowel [ɨ] after retroflex fricatives and all other non-palatalized, ‘hard’ coronal consonants. Following Hall (1997a), the Retraction Rule in Polish will be taken as phonological evidence for the retroflex status of the postalveolar fricative in Polish.

In Russian, the postalveolar also shows an incompatibility with the front vowel /i/. Only the central vowel /ɨ/ is allowed after this sound (Hamilton 1980), cf. the occurring pronunciations in the first row of (16), with the impossible ones in the second row:

(16)	šil	[ʂɨl]*[ʂil]	‘sewed’ masc.
	žil	[ʐɨl]*[ʐil]	‘lived’ masc.

Based on these data, I assume a co-occurrence restriction for Russian that disallows sequences of retroflex fricatives and front high vowels. Hence, in Russian, there is phonological evidence for the retroflexivity of its postalveolar fricative just like in Polish. Interestingly, both the Russian and the Polish sounds have a palatalized counterpart in front vowel context (see discussion of these sounds in section 5), which further supports the non-palatal nature of these sounds.

Czech has neither a high central vowel nor a retraction rule comparable to the one in Polish. It allows sequences of high front vowels and postalveolar fricatives, as exemplified in (17).

(17)	širší	[ʃɪrʃiː]	‘wider’
	úžina	[uːʒɪna]	‘narrowness’

Kučera (1961: 26) mentions that the phonemes /ɪ, iː, e/ have slightly raised allophones in the pronunciation of most speakers when preceded by /tʲ/ /dʲ/ /nʲ/ or /j/. As the postalveolar fricative is not included in the context where vowel-raising occurs, it can be concluded that this fricative does not behave like a typical palatalized segment.[9] On the other hand, Czech has palatalized counterparts for the phonemes /d, t, n/ only (Carlton 1990: 26), the postalveolar does not have a palatalized variant, and therefore no explicit evidence for its velarized/retroflex nature is given either. Altogether, there is no phonological evidence for or against the retroflexion of the Czech sound clarifying the phonetic findings.

In Bulgarian, no process of vowel change or “incompatibility” of the postalveolar fricative with the front vowel exists. The postalveolar can occur with the front vowel [i], as the words in (18) indicate.

(18)	tišina	[tiʃina]	‘silence’
	strašilo	[straʃilo]	‘monster’

According to Scatton (1983: 54) the postalveolar even closes (or slightly raises) the front vowels /i/ and /e/, i.e. it behaves like a palatalized consonant. Furthermore, the postalveolar fricative and affricate series /ʃ, ʒ, tʃ, dʒ/ does not have any palatalized counterparts, whereas the alveodental

[9] Recall from section 2.1 that the palatoalveolar /ʃ/ is assumed to be inherently palatalized, following e.g. Lass (1976) or Hall (1997b).

series does This is a phonological argument that the sounds in question are palatoalveolars in Bulgarian.

The phonological regularities give further evidence for the phonetically attested retroflexivity of postalveolars in Polish and Russian, and for the non-retroflexivity of the palatoalveolar in Bulgarian. The Czech sound does not undergo any phonological process that could support its retroflexivity, but does not show any counter-evidential behavior either.

3.3 Emergence of Retroflexes in Slavic Languages

From the four languages examined, Polish and Russian were shown phonetically to have retroflex fricatives, as supported by phonological evidence. Bulgarian, on the other hand, has a non-retroflex, palatoalveolar fricative. The status of the Czech sound could not be clearly determined in the preceding section. Diachronically, all the postalveolar sounds (both retroflex and laminal postalveolar) in Polish, Russian, Czech and Bulgarian stem from the laminal postalveolar of Proto-Slavic. The Proto-Slavic postalveolar came into existence as a palatalized allophone of the dental fricative, cf. the first and second stages in (19) (Carlton 1990: 116). When established as a phoneme, the postalveolar caused fronting of back vowels, cf. the second and third stages in (19) (ibid.).

(19)

stage 1		stage 2		stage 3
*sʲuːtej	>	*ʃuːtiː	>	*ʃiti

The fronting of back vowels in postalveolar context is a clear indication of its palatalized, non-retroflex status. Why did this palatoalveolar sound then change into a retroflex one (see stage 3 in (19)) in some Slavic languages but not in others?

One possibility of accounting for the difference between Polish and Russian, where it did, and Bulgarian, where it didn't, can be found in the sub-classes of the Slavic language family. Polish (and Czech) belong to West Slavic, Russian to East Slavic and Bulgarian to South Slavic. The hypothesis that might be proposed here is that only the fricative in South Slavic remained palatoalveolar, whereas the same sound in East and West Slavic underwent a change to retroflex. Testing this hypothesis involves establishing the exact nature of the Czech sound and by further investigating members of all three families. If Keating's claim (1991) is right that Serbian also has a retroflex fricative (recall the introduction), this might refute the hypothesis, as Serbian is a South Slavic language and should have a palato-alveolar according to this hypothesis.[10] However, even if the change from palatoalveolar to retroflex is related to language groups, this does not explain why the change happened. A reason why such a change occurred in these languages still has to be found.

Another explanation for the different development of Russian or Polish versus Bulgarian might be the markedness of the fricative inventory in the respective languages. Hall (1997a) shows that the development of the Indo-Aryan retroflex fricative was caused by the emergence of the alveolopalatal in Indo-Iranian. He assumes the following diachronic developments, cf. (20).

(20)

Indo-European		*Indo-Iranian*		*Old-Indo-Aryan*
/s, ʃ/	→	/s, ʃ, ɕ/	→	/s, ʂ, ɕ/

According to Hall, the contrast /ʃ/ vs. /ɕ/ is cross-linguistically unattested as both sounds share the same feature specification [−anterior, +distributed, −back]. As a result, the inventory of Indo-Iranian /s, ʃ, ɕ/ is marked. This marked status causes a change to the less marked Old-Indo-Aryan inventory with a retroflex postalveolar.

[10] As T.A. Hall (p.c.) points out, the Serbian system does not refute the hypothesis if one assumes that the change from /ʃ/ to /ʂ/ is a language-specific process in Serbian that occurred independently at a later stage.

Rocho_ (2001) applies Hall's proposal to Slavic languages, and argues on perceptual grounds that the emergence of an alveolopalatal fricative triggered the change from postalveolar to retroflex in Polish. The introduction of the phoneme /ɕ/ into the Polish fricative system /s, ʃ/ therefore led to a change from the laminal palatoalveolar /ʃ/ to the retroflex postalveolar /ʂ/, cf. first row in (21) of the complete Polish fricative system.[11]

(21) Slavic coronal fricative systems (allophones are given in parentheses)

	dental/ alveolar	palatalized dental/alv.	retroflex	postalveolar	alveolo-palatal
Polish	s, z		ʂ, ʐ	(ʃ, ʒ)	ɕ, ʑ
Russian	s, z	s^j, z^j	ʂ, ʐ	ʃ, ʒ	(ɕ, ʑ)
Bulgarian	s, z			ʃ, ʒ	
Czech	s, z		ʂ, ʐ		

This reasoning might hold for the Russian fricative, too, where the alveolopalatal is introduced as palatalized allophone of the dental stop (Rochoń p.c.), cf. second column in (21). Bulgarian, represented in the third row in (21), did not undergo the change from postalveolar to retroflex, as it does not have any alveolopalatals, neither phonemically nor allophonically. The conclusion is that Bulgarian supports Rochoń's hypothesis. The hypothesis also predicts Czech to have a non-retroflex fricative. As we have seen, the status of the relevant Czech sounds has to remain unclear for the moment.

The status of the Czech sound has to be investigated and further Slavic languages included into the study in order to conclusively test this hypothesis. However, so far the results look promising.

4 Phonological Representation of Retroflexes

This section gives a formal account of the phonological behavior of retroflexes described for non-Slavic languages in section 2.3 and for Slavic languages in section 3.2. In order to do so, a traditional account with articulatorily-based features is compared to one with newly introduced perceptually-based features. It will be shown that the former has shortcomings, namely the inability to account for all vowel changing processes in retroflex contexts in a homorganic way. This deficiency can be overcome by assuming an additional perception grammar with perceptual features.

Traditional Feature Geometric approaches which employ mainly articulatorily-based features, such as for example Clements (1985) and Sagey (1986), classify both retroflex and palatoalveolar fricatives as [+strident], [+coronal] and [−anterior] (see e.g. Hume 1994).[12] The two sounds /ʂ/ and /ʃ/ differ in their value for the feature [dis(tributed)], which is defined by Chomsky & Halle (1968) in terms of length of constriction. Retroflexes, with a short constriction, are [−dis], postalveolars, with long constrictions, are [+dis]. An overview of the features specifying the place of articulation is given in (22).

[11] Polish has also a palatalized allophone [ʃ] of /ʂ/, but this segment occurs before front vowels only (cf. Rubach 1995).

[12] Major class features such as [consonantal], [sonorant], etc. are omitted here and in the following as they are not relevant for the discussion.

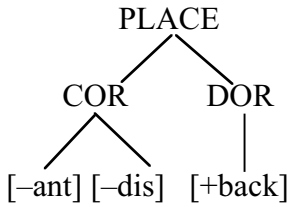
(22)

	ʂ ʐ	ʃ ʒ
CORONAL	+	+
[anterior]	−	−
[distributed]	−	+

[+dis] segments correspond to the sounds referred to as laminals, [−dis] to apicals, which lead some phonologists (e.g. Gnanadesikan 1994) to propose a replacement of the feature [dis] with the privative features [apical] and [laminal]. For the description of Slavic retroflexes it is phonetically more adequate to describe them as [−dis], because they show considerable variation in the active articulator, as illustrated in section 3.1, and thus [apical], defined as constriction of the tongue tip, would be incorrect.

In order to account for interactions with the class of vowels, coronal consonants are usually assigned an additional Dorsal node with a specification of the tongue dorsum position. As argued in section 2.1, retroflexes are generally characterized by a flat (i.e. non-high) and velarized tongue body, which can be represented under the dorsal node either as [+back] (e.g. Sagey 1986, Lin 1989, Rubach 1993) or as [+high] (e.g. Pulleyblank 1989). A featural representation of a retroflex with the dorsal feature [+back] is given in (23).

(23)



The processes described in section 2.3 and section 3.2, are repeated here in (24), listing the input vowel, the output vowel and the language in which the process occurs. The context-specification is left out, as it is always adjacency to a retroflex that triggers these processes.

(24) a. ɛ → æ Norwegian
b. front v → back v Tolitoli
c. i → y Wembawemba
d. i → ɨ Polish, Russian

A phonological representation of the vowels involved in (24) plus the vowels /ɑ, o, u/ is given in (25). The dorsal features [high], [low], and [back] are used, see for instance Sagey (1986) for a similar proposal.[13]

(25)

	i	y	ɨ	ɛ	æ	ɑ	o	u
[high]	+	+	+	−	−	−	−	+
[low]	−	−	−	−	+	+	−	−
[back]	−	−	+	−	−	+	+	+
[rounded]	−	+	−	−	−	−	+	+

With these specifications, the featural changes in the retroflexion processes in (24) can be summarized. The following list includes only those features that differ in the input and output sequences in (24), and their differing values.

[13] Centralized vowels are represented as [+back], following e.g. Sagey (1986).

(26) a. [−low] → [+low]
b. [−back] → [+back]
c. [−rounded] → [+rounded]
d. [−back] → [+back]

As can be seen from this list, there are three different features involved in all processes, but only one of them is shared with the features of retroflex segments, namely [back]. The processes in (24b) and (24d) can be explained as featural spreading of [+back] from the retroflex onto the vowel. The remaining processes (24a) and (24c) involve the features [rounded] and [low] and, assuming the featural representation of retroflexes given above in (23), cannot be explained by featural spreading. The feature [+low] could be incorporated in the representation of retroflexion and phonetically interpreted as flat tongue body. This seems to be problematic, as such a double specification of tongue body configuration is only necessary for the description of the Norwegian rule of vowel lowering, but redundant for all other processes. Furthermore, it is incompatible with former proposals. Chomsky & Halle (1968) suggest to present secondary velarization of a segment with the features [+high] and [−low]. As we assume retroflexes to be secondarily velarized, a specification [−low] cannot explain a change to [+low] in adjacent segments. Pulleyblank (1989) proposes to present retroflexes as [+high]. A specification of a segment as simultaneously [+high] and [+low] is ruled out for phonetic reasons; it is impossible to raise the tongue body from neutral position and lower it at the same time.

A further problem with the articulatory account for vowel changes in retroflex surrounding is vowel rounding in Wembawemba in (24c) and its featural change from [−rounded] to [+rounded]. There is no articulatory connection between retroflexion and rounding, thus the addition of the feature [+rounded] to a vowel in a [–ant, –dis, +back] surrounding is not explanatory. It might be argued that retroflexes can occur with simultaneous lip-rounding, represented by the feature [+rounded] under the Labial node. An indication for the validity of such a representation is given by the fact that e.g. Polish and Russian retroflex fricatives show simultaneous lip rounding or protrusion. The feature [+rounded] could then spread from the retroflex onto the adjacent vowel. Such an assumption can only be made if it is attested that the retroflexes in the languages in question are really rounded.

A solution to the problems with the representation of retroflexion requires the assumption that the cause for the vowel changing processes is perceptual and not articulatory, and that a corresponding representation with perceptual features is stated. The proposal to be made shortly does not assume a replacement of articulatory features by perceptual ones, or features that are both articulatorily and perceptually defined (such as e.g. Jakobson, Fant & Halle 1952). Instead, it assumes parallel perceptual and articulatory representations of segments, as proposed, for example, by Boersma (1998) and Flemming (2002). The need for these separate feature systems is given if one assumes separate perception and production grammars, cf. the Functional Phonology model proposed by Boersma (1998; 1999). In contrast to both Boersma and Flemming, the perceptual representations introduced here are based on abstract, binary features and set in a traditional feature-spreading account instead of an optimality-theoretic framework.

In order to introduce a perceptual account for the vowel changes, we first have to look at the acoustic properties of the vowels in question. Vowels are usually described in terms of the position of the first, second and third formant frequencies (in the following F1, F2, and F3, respectively), see for example Johnson (1997) or Stevens (1998). The specifications of vowel formants given in (27) are based on Stevens (1998: 288ff), where the values (in Hz) are for a male speaker.

(27)

	i	y	ɨ	ɛ	æ	ɑ	o	u
F1	300	300	300	500	650	700	450	300
F2	2300	1800	1800	1800	1400	1000	1000	800
F3	3000	2400	2800	2500	2400	2400	2600	2200

Using the formant values in (27), the processes in (24) can be described as changes in values as given in (28). For the process of vowel backing in Tolitoli (24b) and (28b), the change from /i/ to [u] is taken representatively.

(28)

	process	*F1*	*F2*	*F3*
a.	ɛ → æ	500 → 650	1800 → 1400	2500 → 2400
b.	i → u	300	2300 → 800	3000 → 2200
c.	i → y	300	2300→ 1800	3000 → 2400
d.	i → ɨ	300	2300 → 1800	3000 → 2800

All of these processes involve a lowering of both the second and the third formant value, though to a different degree. Retroflex segments thus cause a lowering of second and third formants in adjacent vowels.

This observation can be transferred into a featural account by the use of perceptually based binary features. For this purpose, the features [low F1], [low F2], [high F2] and [low F3] are introduced. Choosing [low F1] as the feature to indicate first formant specification is arbitrary, the use of [high F1] with opposite feature values gives the same results. The same holds for the feature [low F3].

The definition of these features is as follows. Every vowel with a F1 value below 500 Hz is [+low F1], and every vowel with a F3 value below 2500 Hz is [+lowF3]. For F2, the two features [low F2] and [high F2] are introduced, as the vowels show a large span of values from 800 to 2300 Hz for this formant, with several vowels having a medium value around 1800Hz. Thus vowels with a second formant value below 1400 Hz are classified as [+low F2, –high F2] and vowels with a second formant value over 1800 Hz are [–low F2, +high F2]. Those with a value between 1400 Hz and 1800 Hz are [–low F2, –high F2].

These features lead to the following vowel classification.

(29)

	i	y	ɨ	ɛ	æ	ɑ	o	u
[low F1]	+	+	+	–	–	–	+	+
[highF2]	+	–	–	–	–	–	–	–
[low F2]	–	–	–	–	–	+	+	+
[lowF3]	–	+	–	–	+	+	–	+

According to this feature system, the processes in (24) and their changes in formant values, cf. (28), involve the featural changes given in (30).

(30)

a. [–low F2] → [+low F2]

b. [+high F2] → [–high F2]
   [–low F2] → [+low F2]

c. [–low F2] → [+low F2]
   [+high F2] → [–high F2]
   [–low F3] → [+low F3]

d. [+high F2] → [–high F2]

Altogether, three featural changes occur in these processes, one from [−low F2] to [+low F2], one from [+high F2] to [−high F2], and one from [−low F3] to [+low F3]. Can they all be accounted for by the retroflex context? In order to answer this question, the featural specification of retroflexion needs to be formulated.

As discussed in section 2.2, retroflex fricatives are assumed to have a low second and third formant. This is formalized by the features introduced here as [+low F2], [−high F2], and [+low F3].[14] According to Jakobson et al. (1952) and Stevens & Blumstein (1975), velarization results in a lowered F3. Both specifications are given in (31).

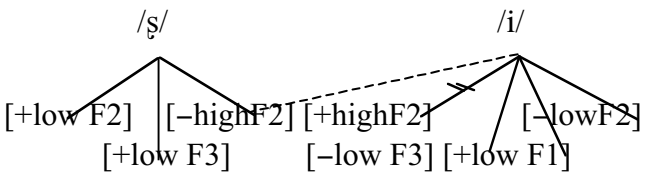
(31)

	ʂ	ɣ
[low F1]	+	
[highF2]	−	
[low F2]	+	
[lowF3]	+	+

Thus the perceptual feature value [+low F3] incorporates the retroflex articulatory criterion of velarization developed in section 2.1.

The feature specification of retroflexes in (31) can account for the phonological processes in (24) and their featural changes, cf. (30). All the resulting feature values in the vowels, namely [+low F2], [−high F2], and [+low F3], are identical to those of the adjacent retroflex. The vowel-changing processes can thus be explained as an association of retroflex perceptual features to the adjacent vowel (cf. Ohala 1993 for a discussion of perceptual misparsings like these). This 'false' association can be modeled as a 'spreading' of a perceptual feature. Contrary to articulatory features in feature geometric models, the perceptual features are not assumed to have any inherent order such as feature nodes etc. The process of re-association of perceptual features is illustrated with the example of Polish vowel centralizing from (24d). The feature [−highF2] spreads from the preceding retroflex fricative to the high front vowel and thus turns it into a front centralized vowel, cf. (32).

(32)



Summing up, the perceptual features introduced here are able to describe the phonological rules involving retroflex fricatives, where traditional articulatory features alone failed. As explained before, perceptual specifications by these features are assumed to complement the articulatory specifications, not to replace them. This brings up the question of how perceptual and articulatory features interact. Following Boersma (1998, 1999), separate production and perception grammars are assumed. Whereas the former involves the explanation of articulatory assimilation processes by articulatory features, the perception grammar describes processes such as re-association of cues with perceptual features. Thus, the two types of features have different domains.

Some of the vowel-changing processes presented in this study can be articulatorily explained, so the change of a front vowel into a back vowel is due to an incompatibility of the front vowel gesture with a retroflex gesture. Nevertheless, the similar cause and parallel change in all of these processes is not transparent in featural presentations with articulatory specifications. Vowel

[14] Other acoustic features for describing cues such as frication noise etc. are ignored here, as they are not relevant in modeling the interaction of retroflexes with vowels.

lowering, vowel centralizing, and vowel rounding in retroflex context could all be shown to involve a lowering of F2 and F3. Thus, they can be interpreted as cases of perceptual re-assimilation. This can be formalized by assuming the perceptual features [low F2], [high F2], and [low F3] in the perception grammar.

5 Palatalization of Postalveolars

Palatalization in traditional articulatory terms means a supplementary articulatory gesture superimposed upon a labial, dental, alveolar or postalveolar consonant. But as shown in Scatton (1983) for Bulgarian and Ćavar & Hamann (2002) for Polish, palatalization of dental fricatives and affricates involves a change in primary place of articulation. It will be argued in this section that palatalization of the retroflex fricative in Slavic languages causes a similar change in the major place of articulation, which has an impact on its phonological representation.

Examples of Russian and Polish palatalized postalveolar fricatives are given in (33) and (34), respectively.[15]

(33) *Russian*

šči	[ʃː$^{(j)}$i]	'cabbage soup'

(34) *Polish*

a.	masz je	[mɑʃ$^{(j)}$je]	'you have them'
b.	Shiva	[ʃ$^{(j)}$ivɑ]	'Shiva'

In Russian, the palatalized postalveolar can only occur as a geminate. In Polish, two contexts are possible for this sound. It can occur across word boundaries when the postalveolar is followed by [i] or [j] (cf. 34a), and within loanwords, cf. (34b).

In (35), x-ray tracings of the Russian retroflex fricative (solid line) and its palatalized counterpart (dashed line) are given, based on Bolla (1981: 159).

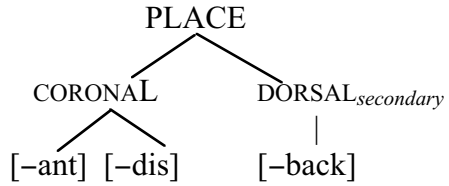
(35) Russian retroflex fricative and palatalized postalveolar fricative

As we can see from this figure, the palatalized sound does not merely have a tongue body gesture added onto its non-palatalized counterpart, but has changed its place of articulation to laminal palatoalveolar. Furthermore, the palatalized sound is articulated with a long and narrow constriction and a raised tongue body, no velarization is involved. This is not in accordance with the criteria posed for retroflexion in section 2.1, thus we must conclude that palatalization changes the primary articulation of a retroflex into a (palatalized) palatoalveolar. Hume (1994) makes a similar observation of palatalization changing a retroflex into a non-retroflex. She further notices that adding rounding to the palatalized segment repairs this effect.

[15] In the phonetic transcription the secondary palatalization is parenthesized, because according to the previously made assumption that palatoalveolar fricatives are inherently palatalized it is redundant, recall section 2.1 and footnote 9.

In articulatorily based phonological presentations, secondary palatalization can be represented with an additional place node, specifying a vowel-like gesture of the tongue body. In (36), a retroflex with secondary palatalization is represented, based on Gussenhoven & Jakobs (1998).

(36)



A structure like the one in (36) emerges in a high vowel context, when the dorsal feature [−back] spreads from the adjacent vowel to the retroflex. But as we have seen above, this structure is a segment that has no phonetic realization, because the combination of (velarized) retroflexion with palatalization seems to be articulatory impossible. Further evidence for this claim comes from Hall's (2000) study of palatalized rhotics, which shows that secondary palatalization of retroflex rhotics seems to be diachronically unstable and cross-linguistically very marked.

To present the outcome of palatalization of a retroflex fricative with articulatory features, a change from [−dis] to [+dis] must co-occur with the change from [+back] to [−back]. Thus, the retroflex, represented as [−ant, −dis, +back], must change to a palatalized palatoalveolar [−ant, +dis, −back], see the comparison of the two segments in (37).

(37)

	ʂ	ʃ
[anterior]	−	−
[distributed]	−	+
[back]	+	−

Whereas the feature [−back] is spread from the front vowel to the fricative, the change from [−dis] to [+dis] should be explained in a different way, as the trigger vowel is not specified for the feature [dis]. One could assume that the change in the feature [dis] is caused by the spreading of [−back], as the resulting segment [−ant −dis, −back] is articulatorily highly marked. Besides the awkwardness of the sequential explanation for these featural changes, the articulatorily-based account runs into a further problem with the additional rounding often found in palatalization processes mentioned by Hume (see above). These problems can again be avoided by assuming that the changes in tongue and lip position occurring in the palatalization process are perceptually motivated rather than articulatorily.

According to the acoustic description of palatoalveolar fricatives in section 2.1, these sounds have an F2 around 1800 Hz and an F3 around 2600 Hz. This translates into the features developed in section 4 as [−low F2], [−high F2] and [−low F3], cf. first row in (38). The second and third rows in (38) repeat the feature specifications of the front vowel /i/ and the retroflex fricative, respectively.

(38)

	ʃ	i	ʂ
[low F1]	+	+	+
[highF2]	–	+	–
[low F2]	–	–	+
[lowF3]	–	–	+

Palatalization of retroflexion can thus be interpreted as the featural spreading of [−low F2] and [−low F3] from the following front vowel onto the retroflex fricative, resulting in a palatoalveolar fricative.

The repair strategy of rounding introduced, for instance, in Polish when retroflex fricatives are palatalized can also be explained by featural spreading. Rounding is realized with a [+low F3], recall the difference between rounded and ungrounded front vowels in (29). Thus, a rounded palatoalveolar has a feature specification as follows:

(39)

	$ʃ^w$
[low F1]	+
[highF2]	−
[low F2]	−
[lowF3]	+

Instead of spreading the two features [−low F2] and [−low F3] from the following front vowel onto the retroflex fricative, palatalization plus rounding requires only the feature [−low F2] to spread from the vowel. The resulting segment, a fricative with the specifications [−low F2], [−high F2] and [+low F3], will be interpreted by the listener and realized by the speaker as a rounded palatoalveolar fricative.

The perceptually based features introduced here are therefore able to account for the change in primary articulation in palatalized retroflexes. Furthermore, they can explain why this palatalization process sometimes co-occurs with rounding, namely to preserve a particular perceptual quality of the retroflex.

6 Conclusion

The fricatives of Polish and Russian that are articulated in the postalveolar region were shown to be more similar to retroflex fricatives than to postalveolar fricatives for example in English. This similarity is based on articulation, in particular velarization, and on the segment's phonological incompatibility with high front vowels, which is phonetically grounded in velarization. The fricatives of Bulgarian, on the other hand, are palatoalveolar, as they show no phonetic or phonological velarization. In the present study, Czech postalveolar fricatives could be classified as neither retroflex nor palatoalveolar, as the phonetic descriptions of these sounds differ widely, and the class behaves neutral phonologically. Further research on the Czech postalveolar fricative should be carried out in order to answer the question of its status. Although two possible explanations were proposed for the difference in Slavic languages with respect to the postalveolar, neither of them fully accounted for it. Finding a plausible explanation for these differences in Slavic languages thus remains another topic for future research.

Retroflex fricatives in Slavic languages cause vowel centralizing and rounding. Furthermore, they undergo palatalization, which destroys their retroflex status, as illustrated in this paper. Traditional articulatory accounts run into problems when describing these processes, as multiple gestural changes occur that are not interrelated. It has been argued that these processes can be perceptually interpreted, namely as re-association of cues. In this way, only two changes occur, namely a lowering of F2 and F3 in the vowels. In order to capture these changes, the perceptual features [lowF1], [low F2], [high F2] and [low F3] were introduced. It has been argued that these features are part of the perception grammar, whereas articulatory features are part of the production grammar. No further reasons for the existence of two separate grammars were given here, but the interested reader is referred to Boersma (1998; 1999) for a detailed discussion of this point.

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