Palatalization in Russian

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1 Overview of palatalization in Russian

In Russian, each consonant has the property of being either "soft" or "hard". Most consonants exist in both forms; in those cases, the hard form is the regular one, and the soft form is the *palatalized* version of the same consonant (denoted using a superscript *j* in IPA). However, some consonants are always hard and some are always soft. Here is the inventory of consonants in Russian:

	Bilabial	*Labiodental*	*Alveolar*	*Alveolo-palatal*	*Palatal*	*Retroflex*	*Velar*
Stops	p pʲ b bʲ		t tʲ d dʲ				k (kʲ) g (gʲ)
Nasals	m mʲ		n nʲ				
Trills						r rʲ	
Fricatives		f fʲ v vʲ	s sʲ z zʲ	ɕː		ʂ ʐ	x (xʲ) (ɣ)
Affricates			ts	tɕ			
Approximants			l lʲ		j		

Table 1. Inventory of consonants in Russian.

/ɣ/ is present in select words as pronounced by some speakers and is not of much interest here. /r/, while specified as retroflex in the table for consistency, is in reality dental[1]. Palatalized versions of /k/, /g/ and /x/ are not attested for in native Russian words, but are present (at least orthographically) in certain foreign loanwords.

The most notable phonological process related to palatalization is the way it interacts with vowels. Russian can be analyzed as a language with five vowel phonemes[2], /a/, /o/, /u/, /ɛ/ and /i/. Those vowels are expressed as [a], [o], [u], [ɛ] and [i] in the word-initial position. First four vowels are expressed in the same way after non-palatalized consonants; /i/ is expressed as [i] after palatalized consonants and as [ɨ] after non-palatalized consonants. The question of how the vowels after palatalized consonants are expressed is not widely covered in the literature on Russian, but here is an impressionistic take I can give using IPA:

[1] Ladefoged and Maddieson 1996, p. 221

[2] There are alternative ways of analyzing Russian based around six phonemes, but they do not lead to the nice consistent pairing we use. Still, we will stick to a tradition and use six vowel phonemes for broad transcription.

Phoneme	Initial	Non-palatalized context	Palatalized context
/a/	[a]	[a]	[æ]
/o/	[o]	[o]	[ø]
/u/	[u]	[u]	[y]
/ɛ/	[ɛ]	[ɛ]	[e]
/i/	[i]	[ɨ]	[i]

Table 2. Impressionistic narrow transcription of vowels in Russian.

What we observe here is that the vowels are being fronted whenever they appear after a palatalized vowel.

Examining this data suggests the following questions:

1. What phonetic process causes vowels to be fronted, or, alternatively, what causes consonants to be palatalized?
2. Why /ʂ/ and /ʐ/ are never palatalized, while /ɕː/ is always palatalized?
3. Are /k/ and /g/ actually palatalized in loanwords? Why are they never palatalized in native words?
4. Why does /tsʲ/ not exist?

2 Experimental evidence

2.1 Method

Five native speakers of Russian who live in Moscow were given a text containing words of interests. Among them were minimal pairs of words which differed by whether the final consonant was palatalized. The words were placed so that each final consonant would be followed by a pause, although for certain speakers the pause did not manifest.

Each speaker was asked to read the text three times, first time silently and next two times out loud. The last recording was analyzed, unless the word in question was obstructed by noise, in which case the first recording was used.

2.2 Vowel fronting

We measured the second formant of the vowels in palatalized and non-palatalized contexts. For vowels after palatalized consonants, second formant was measured both at the vowel onset and in the middle of the vowel. In all words the vowel measured is stressed; in case where it's not clear which vowel is measured, it is bolded.

Phoneme	Word	Average F_2 (Hz)	St. dev.
/a/	/voda/ (onset)	1386	95
	/v$^{\text{j}}$alɨj/ (onset)	1988	202
	/v$^{\text{j}}$alɨj/ (middle)	1348	45
/i/	/maʃɨna/ (onset)	1692	175
	/maʃɨna/ (middle)	1920	325
	/l̲inzɨ/ (onset)	2243	249
	/l̲inzɨ/ (middle)	2235	275
	/v̲ɨbit$^{\text{j}}$/ (onset)	1251	258
	/v̲ɨbit$^{\text{j}}$/ (middle)	1849	452
/o/	/kot/ (onset)	678	51
	/vs$^{\text{j}}$o/ (onset)	1824	55
	/vs$^{\text{j}}$o/ (middle)	1405	291
/u/	/kuxn$^{\text{j}}$a/ (onset)	583	43
	/vs$^{\text{j}}$u/ (onset)	1620	72
	/vs$^{\text{j}}$u/ (middle)	1198	196
/ɛ/	/ɛto/ (onset)	1942	268
	/z$^{\text{j}}$ɛl$^{\text{j}}$ɛn$^{\text{j}}$/ (onset)	2225	349
	/z$^{\text{j}}$ɛl$^{\text{j}}$ɛn$^{\text{j}}$/ (middle)	2266	307

Table 3. Second formants of various words in Russian.

Note that this table is not by itself very useful, since there are per-speaker variations of formant frequencies. Using paired t-test we can compare the formant frequencies of interest:

Phoneme	Position A	Position B	p-value	Difference
/a/	/voda/	/v$^{\text{j}}$alɨj/ at middle	0.3816	Not significant
	/v$^{\text{j}}$alɨj/ at onset	/v$^{\text{j}}$alɨj/ at middle	0.0013	Significant
/i/	/maʃ**i̲**na/	/l̲inzɨ/ at middle	0.0155	Significant
	/l̲inzɨ/ at onset	/l̲inzɨ/ at middle	0.9644	Indistinguishable
	/maʃ**i̲**na/ at onset	/maʃ**i̲**na/ at middle	0.1331	Not significant
	/v**i̲**bit$^{\text{j}}$/ at onset	/v**i̲**bit$^{\text{j}}$/ at middle	0.007	Significant
/o/	/kot/	/vs$^{\text{j}}$o/ at middle	0.0063	Significant
	/vs$^{\text{j}}$o/ at onset	/vs$^{\text{j}}$o/ at middle	0.0335	Significant
/u/	/kuxn$^{\text{j}}$a/	/vs$^{\text{j}}$u/ at middle	0.0041	Significant
	/vs$^{\text{j}}$u/ at onset	/vs$^{\text{j}}$u/ at middle	0.0068	Significant
/ɛ/	/ɛto/	/z$^{\text{j}}$ɛl$^{\text{j}}$ɛn$^{\text{j}}$/ at middle	0.0044	Significant
	/z$^{\text{j}}$ɛl$^{\text{j}}$ɛn$^{\text{j}}$/ at onset	/z$^{\text{j}}$ɛl$^{\text{j}}$ɛn$^{\text{j}}$/ at middle	0.1582	Not significant

Table 4. Difference between second formants in various words of Russian (paired t-test).

From tables 3 and 4, we conclude the following:

1. In general, the pure vowels have lower F_2 than F_2 at onset vowels which follow palatalized consonants.
2. In the context where the following consonant is not palatalized (/vʲalɨj/), F_2 drops to the one of its pure counterpart.
3. In the word-final context (/vsʲo/, /vsʲu/) F_2 drops, but does not reach the frequency of its pure counterpart.
4. /i/ maintains same F_2 throughout articulation even if the following consonant is not palatalized.
5. If both adjacent consonants are palatalized (/zʲɛlʲɛnʲ/), the same frequency is maintained throughout articulation.
6. [ɨ] has consistent frequency between two non-palatalized consonants, and rising frequency when the next consonant is palatalized. Unfortunately, the recording contains no stressed word-final [ɨ].[3]

2.3 Acoustic cues for palatalization

Change of F_2 is an important acoustic cue for palatalization. However, it clearly cannot be the only cue, since the palatalization of a consonant is contrastive in word-final positions, and some of palatalized consonants can be articulated without a carrier word. Hence, an analysis of palatalization would not be complete without comparing consonants in word-final positions. Note that in Russian, word-final consonants are devoiced, limiting the range of consonants we can explore in isolation.

Below, I am relying primarily on the consonant minimal pairs from word-final positions. In some cases, the context makes it hard to understand exactly the nature of difference between those pairs; for those, I have recorded myself pronouncing consonant pairs in isolation for the purpose of illustration.

2.3.1 Stops and fricatives

Stops can be distinguished by the presence of frication noise. For instance, [pʲ] is notably different from [p] by having it above 1200 Hz.

[3]The author, however, would like to note that in his own pronunciation [ɨ] does not become [i] in word-final positions.

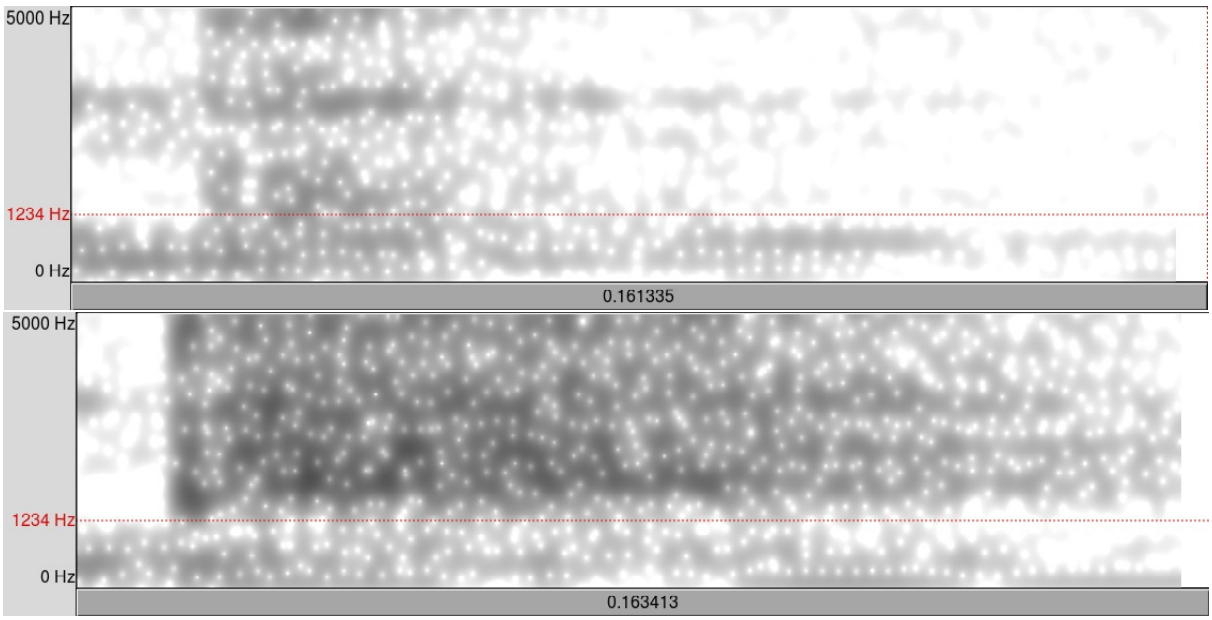

Figure 1. [p] and [p^{j}] spectrogram, from words /kop/ and /kop^{j}/.

[s^{j}] can be distinguished by presence of frication noise in 2 kHz band:

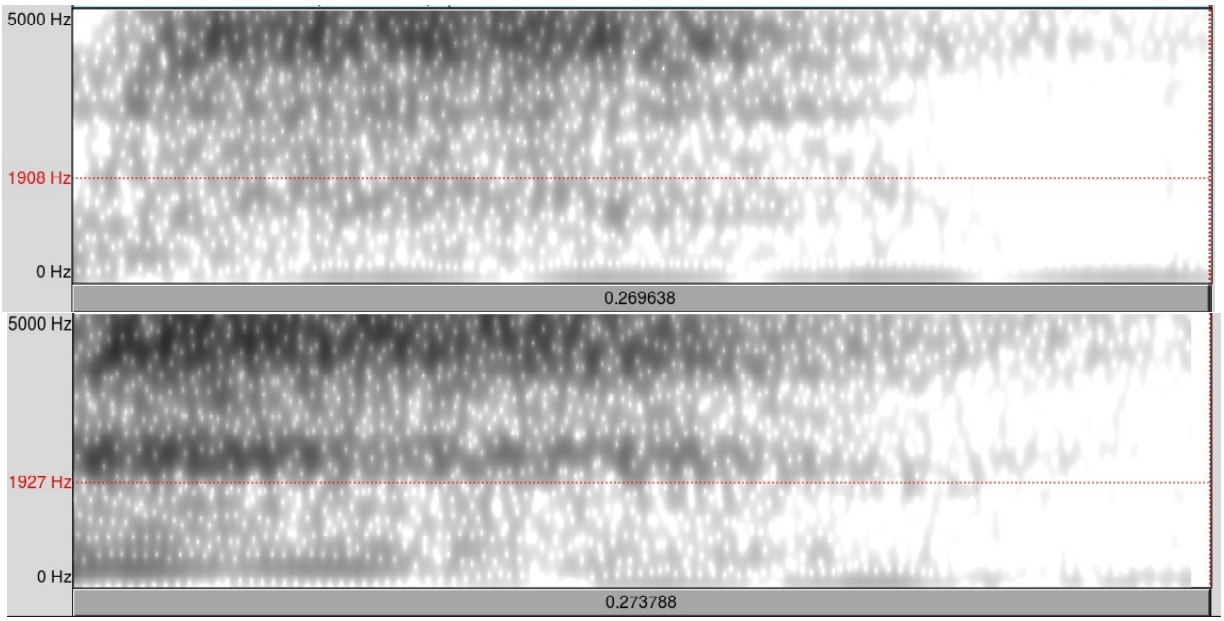

Figure 2. [s] and [s^{j}] spectrogram, from words /os/ and /os^{j}/.

[t^{j}] also has a highly distinctive frication noise:

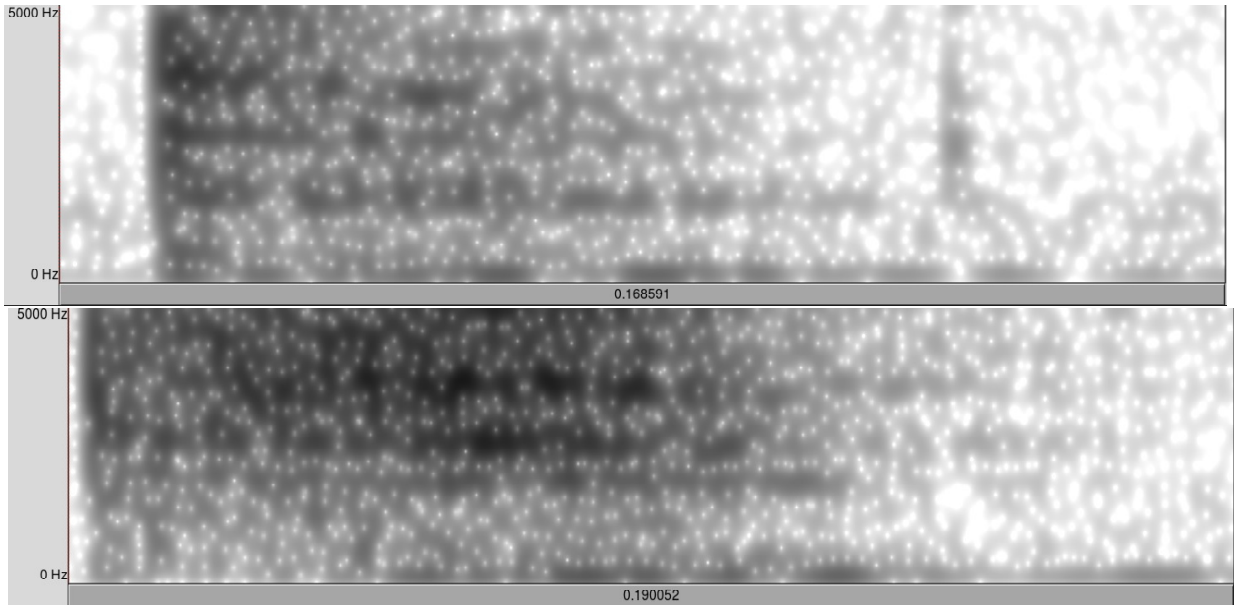

Figure 3. [t] and [tʲ] spectrogram, produced in isolated context.

[fʲ] can be also distinguished through high-pitched noise at the release:

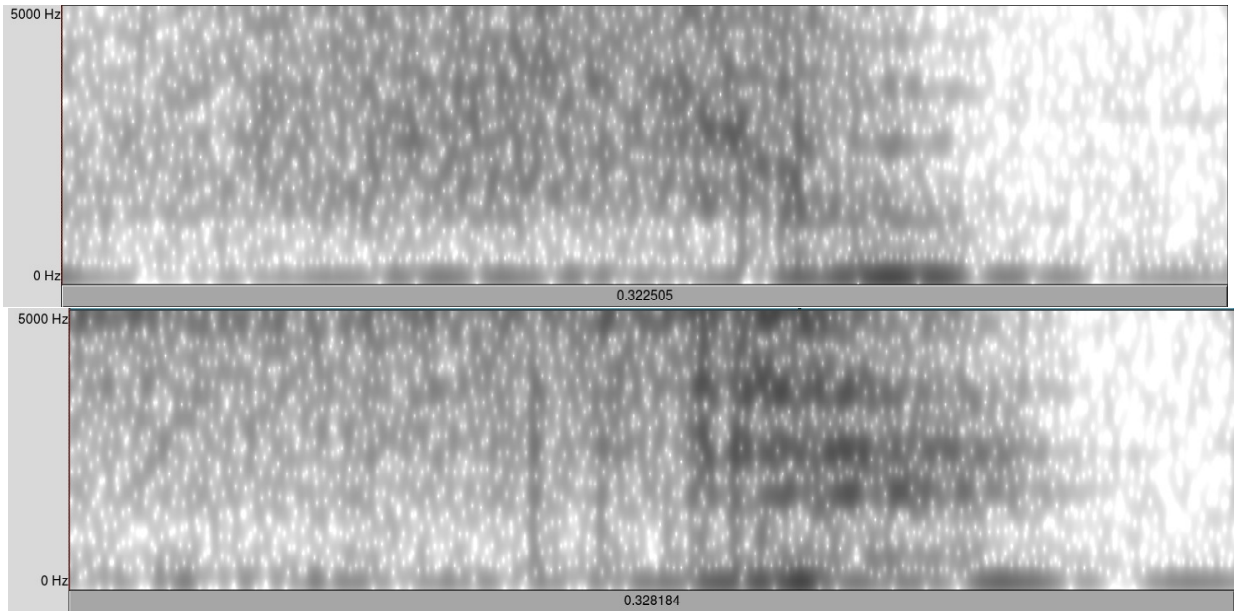

Figure 4. [f] and [fʲ] spectrogram, produced in isolation.

2.3.2 Sonorant consonants

In case of [l] and [lʲ], there is a noticeable difference in the gap between F_1 and F_2 of the lateral itself; specifically, the gap is much larger in the palatalized version:

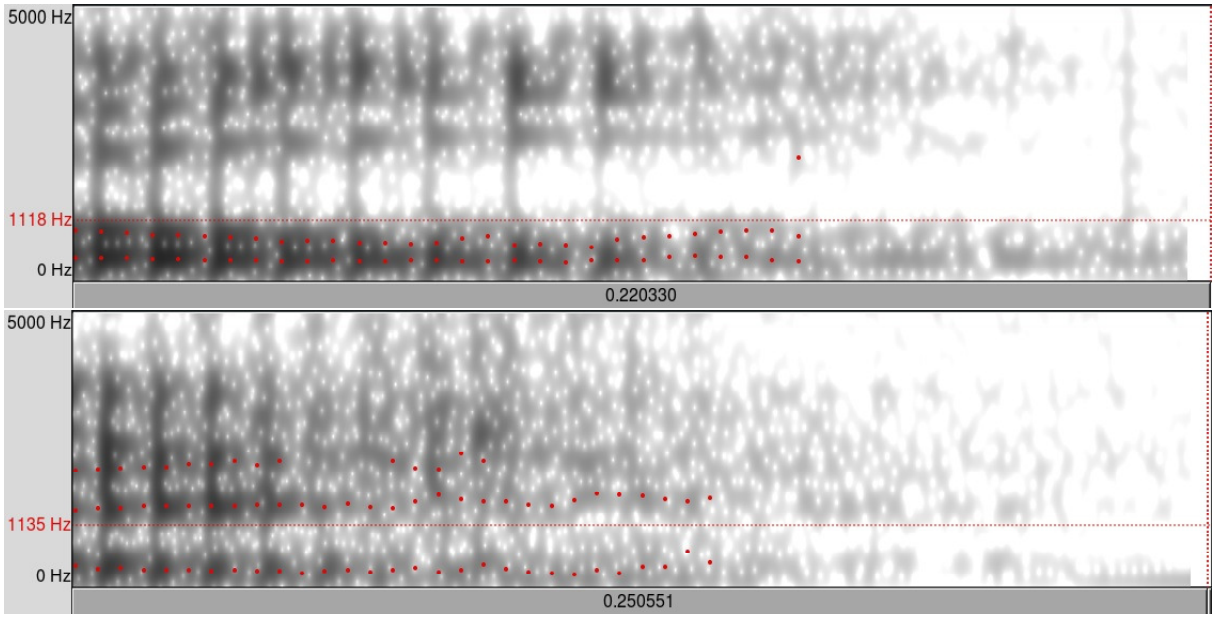

Figure 5. [l] and [l^{j}] spectrogram, from words /ugol/ and /ugol^{j}/.

Same pattern can be observed in the voiced release of [m^{j}] and [n^{j}]:

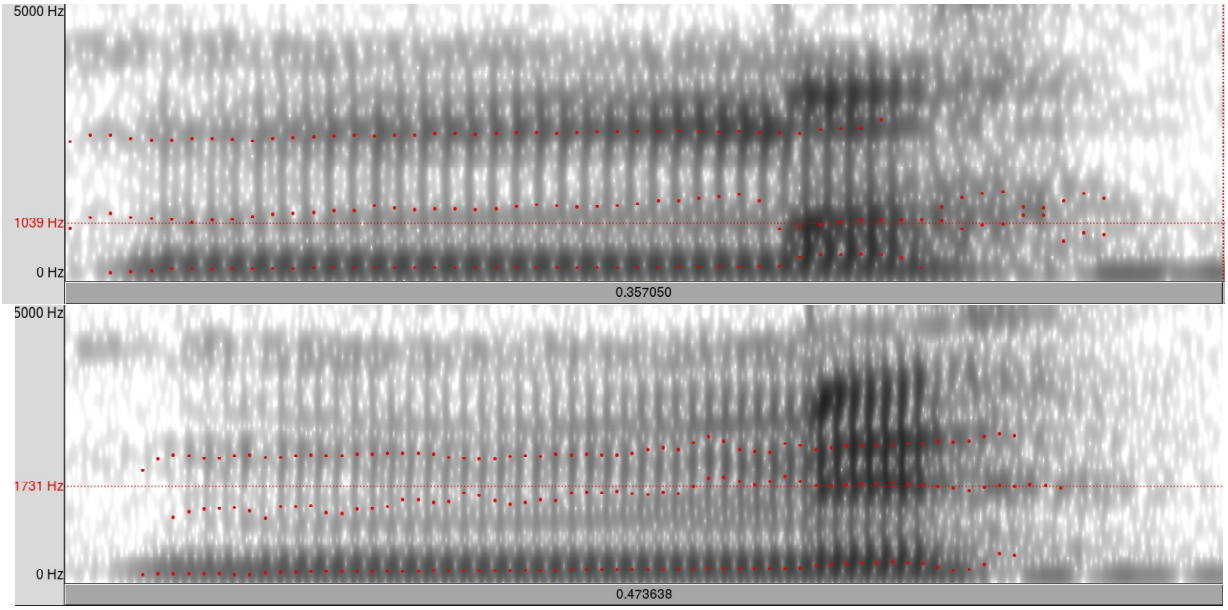

Figure 6. [m] and [m^{j}] spectrogram, produced in isolation.

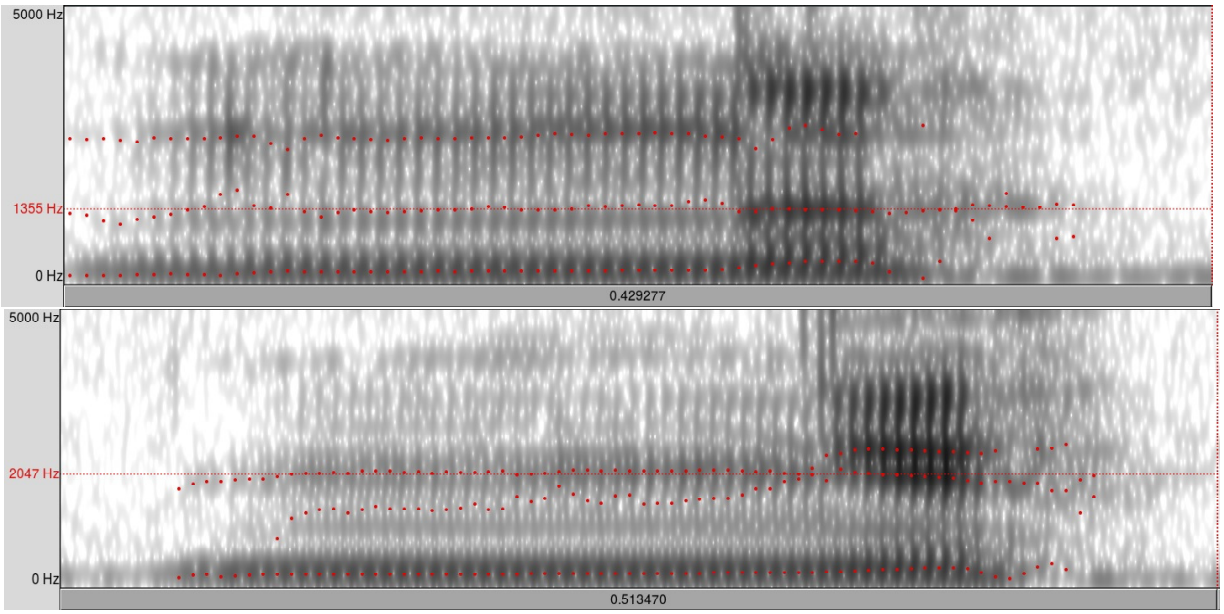

Figure 7. [n] and [nʲ] spectrogram, produced in isolation.

[j], while not having a non-palatalized version, follows the trend of F_2 being high for palatal consonants:

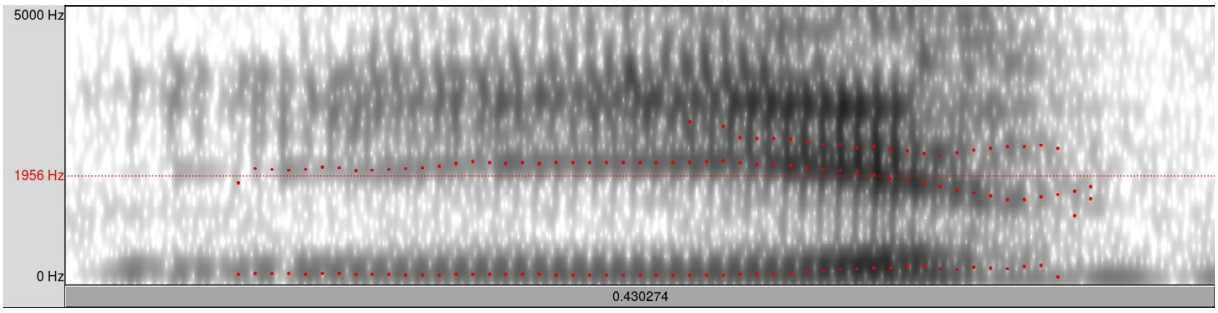

Figure 8. [j] spectrogram, produced in isolation.

2.3.3 /ʂ/ and /ɕː/

[ʂ] and [ɕː] are articulated in a sufficiently similar manner so that it is possible to transition between them continuously:

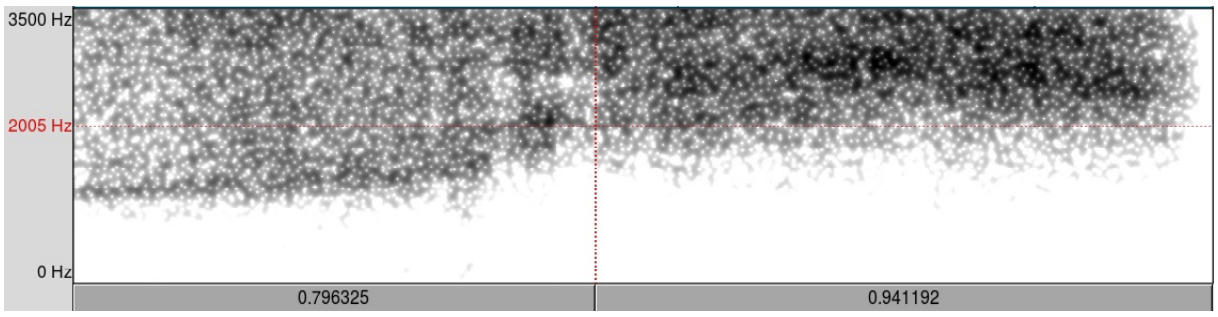

Figure 9. [ʂ] (on the left) and [ɕː] (on the right), on a lowered dynamic range spectrogram.

The difference between them is that the energy peak for [ʂ] is lower than [ɕː].

2.4 /k/

In a manner similar to table 3, we can measure whether the vowel fronting happens in the loanwords which orthographically have /kʲ/.

Phoneme	Word	Average F_2 (Hz)	St. dev.
/ko/, /kʲo/	/kot/ (onset)	678	51
	/likʲor/ (onset)	1881	141
	/likʲor/ (middle)	940	112
/ku/, /kʲu/	/kuxnʲa/ (onset)	583	43
	/barbʲɛkʲu/ (onset)	1833	334
	/barbʲɛkʲu/ (middle)	943	428

Table 5. Second formants of loanwords with /kʲ/.

Phoneme	Position A	Position B	p-value	Difference
/o/	/kot/	/likʲor/ at middle	0.0065	Significant
	/likʲor/ at onset	/likʲor/ at middle	0.0001	Significant
/u/	/kuxnʲa/	/barbʲɛkʲu/ at middle	0.1430	Not significant
	/barbʲɛkʲu/ at onset	/barbʲɛkʲu/ at middle	0.0003	Significant

Table 6. Difference between second formants in various words of Russian (paired t-test).

As we can see, the vowel fronting effect is, in fact, observed. Impressionistically, isolated [kʲ] has the "softness" effect associated with palatalization of stops in Russian, and is perceptually different from [k].

3 Analysis

3.1 Vowel fronting

In order to understand vowel fronting in Russian, we will first restrict ourselves to cases where the phoneme is non-palatalizing in its normal form, and then consider the case of /i/ expressed as [i] and [ɨ].

3.1.1 /a/, /o/, /ɛ/, /u/

The experiment confirms that the vowels in question are indeed fronted whenever they occur before a palatalized consonant. However, an important observation here is that if the vowel is not followed by another palatalized consonant, it will drop F_2 significantly over time (see table 4 and analysis of it).

While the drop before a non-palatalized consonant is an expected coarticulation, F_2 decrease at the end of the word needs to be explained.

One possible explanation is that while Russian can auditorily contain [æ], [ø], [e] and [y], from the perspective of a Russian speaker, only [a], [o], [ɛ] and [u] are the sounds they use; any possibly perceived fronted vowels are merely an effect of coarticulation. The key evidence in favor of that explanation is the word-final F_2 drop: the F_2 at the end is the real F_2 of the vowel, since it does not have an adjacent consonant influencing it; the F_2 at the onset is the result of coarticulation.

An alternative view, and the one we side with, is that all eight phones discussed above are distinct sounds of the language[4]. The evidence for that argument is that even despite the decrease in F_2, it is still far from F_2 of the vowel in non-palatalized context. In this model, F_2 decrease can be explained by assuming that the middle F_2 is the "true" F_2 of the vowel, and that the higher F_2 at the vowel onset is an effect of coarticulation *in addition* to the effect of the entire vowel being fronted. For example, the word /vsʲu/ can be explain as the following two-step process:

1. A phonological rule of vowel fronting is invoked. It results in UR /vsʲu/ turn into SR [fʲsʲy], where [y] is a consonant with F_2 of roughly 1200 Hz.
2. The speaker pronounces [fʲsʲy]. At the end of [sʲ], the tongue is at the palatal constriction position, which is not normally preferred[5]; thus, it moves it from the front, where it has frequency of 1600 Hz, to the natural position of [y], resulting in F_2 decreasing back to 1200 Hz.

This theory nicely accounts for the experiment results.

3.1.2 /i/: [i] and [ɨ]

/i/ maintains the same adjacency behavior as other vowels: the natural form does not change mid-vowel, while the alternative form shows clear coarticulation with adjacent vowels (consider /vɨbit/ in table 4). Unfortunately, we do not have good recordings for stressed word-final [ɨ] in order to perform a proper statistical test, but judging by the author's careful listening to himself and other speakers, [ɨ] does not typically rise at the end of the word. This makes the five-phone coarticulation-only model mentioned in the previous section even less capable of consistently describing the language.

3.2 Hard–soft pairing

Russian language assigns softness status to each consonant in the language. From the articulatory perspective, the criterion determining whether the vowel is soft is simple: if it can be followed by a fronted vowel, it is palatalized, otherwise it's not. From auditory perspective the situation is more interesting, but still can be described using two of the following principles:

[4]Here, we define different phones to mean that they are a different *articulatory target* the speaker aims to produce.

[5]One may make many arguments of why this is the case, from simple articulatory argument that most constrictions are inherently uncomfortable, to observing that non-palatalized consonants are much more common across languages than palatalized ones.

1. For fricatives and stops, a high-pitched frication noise, normally around 2 kHz band is a palatalization cue.

2. For sonorant consonants, the increased F_2 is a palatalization cue.

Those are relatively simple principles, and all the pairless consonants to some extent follow them too. /ʂ/ can be distinguished from /ɕː/ by how the power peak is lower for the first one. /ts/ and /tɕ/ sound hard and soft because their fricative component itself either sounds hard and soft correspondingly. /j/ has the same high F_2 other soft sonorant consonants have.

3.3 Pairing gaps

Finally, now that we understand the acoustic nature of palatalization, we are better equipped to discuss potential reasons for certain phonemes missing its hard or soft counterpart.

3.3.1 /ʂ/ and /ɕː/

In order to explain why /ʂ/ and /ɕː/ have no palatalization compliments, we first have to address the question of whether they are the complements of each other. If they were, we would expect a vowel like /i/ to cause ʂ become ɕ when appended; but instead, whenever such concatenation happens /i/ becomes [ɨ]. The reason for this is that /ɕː/ has a special elongated quality about it (often referred to as "explosive" in impressionistic descriptions) which /ʂ/ does not. Because of that quality, /ɕː/ is almost never matched with [ɕ] in loanwords from other languages, and it makes sense for it to not be a part of palatalization pairing because of that as well.

Of course, this does not yet explain why each of those sounds cannot have its own individual palatalized counterpart. The articulatory explanation is that /ʂ/ is retroflex, meaning that the tongue has to be rolled back, while palatalization implies bending it upwards. This combination of tongue positions is impossible, meaning that retroflex consonants cannot be palatalized. Similarly, articulating [ɕː] involves tongue being bent upwards in order to form a cavity necessary to produce the frication noise, meaning that it is effectively always palatalized.

Acoustically, the palatalization of voiceless consonants is associated with a high-pitched frication noise. [ʂ] and [ɕː] are both sibilants, but they are distinguished by the peak frequency. This implies that they by definition have or lack the feature which characterizes palatalized consonants.

3.3.2 /k/, /g/ and /x/

As we have shown in our recording analysis, /kʲu/ and /kʲo/ do exist in loanwords and are articulated as expected. /kʲɛ/ and /kʲa/ also exists in loanwords.

With /kʲi/, the interesting aspect is that the non-palatalized version is not attested. That rule is actually phonological: Russian plural suffix manifests itself as [ɨ] before most consonants, but as [i] before /k/. I have no hypothesis about why the rule is still active in the language, but its origins can be traced to the processes in East Slavic which are discussed in Padgett 2003.

3.3.3 /ts/, /tɕ/, /ʐ/

It is not clear immediately why there is no soft version of /ts/ and no hard version of /tɕ/, given that both [t̪s̪] and [tsʲ] successfully exist in Mandarin. [ʐ] is known to exist in Japanese, and is actually attested in some words of Russian (most famously /doʐdʲ/ ⟶ [doʐː] in St. Petersburg accent), but is not a phoneme. The best theory I can propose is that they did not evolve to gain phonemic status because that would decrease contrast between already existing 9 sibilant phonemes in Russian.

4 Conclusion

Russian can be characterized as a language where consonants can have palatalization as a contrastive feature, and the five vowel phonemes it has can be expressed as ten vowel phones (not counting ones involved in vowel reduction) as a result of phonological processes. Vowels in Russian can be partially or fully fronted depending on the context they are in.

Almost all consonants in Russian come in both palatalized and non-palatalized versions. Those can be identified by the formant transitions of adjacent vowels, as well as by presence of either frication noise or a raised second formant in the consonant itself.

While many sources claim that /kʲ/ does not exist in Russian, there are loanwords that contain it and it is expressed in them in a manner consistent with how palatalization is expressed with other stops.

There are still many unanswered questions. Does /x/ behave itself with respect to palatalization with the same way as /k/? What can a perception experiment say about the nature of palatalization? Those are all exciting questions for future research.

References

[1] Peter Ladefoged and Ian Maddieson. *The Sounds of the World's Languages*. Blackwell, 1996. ISBN: 0-631-19814-8.

[2] Jaye Padgett. "Contrast and post-velar fronting in Russian". In: *Natural Language & Linguistic Theory* 21.1 (2003), pp. 39–87.