

Contrast Dispersion and Russian Palatalization*

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Будет ей рот раздирать до ушей небывалый, невозможный звук «Ы».
Her mouth will be rent to the ears by the fantastic, impossible sound “ʔ”.

Osip Mandelshtam

Introduction

The hypothesis that phonological patterns are at least in part explained by functional phonetic considerations has a long history. Martinet (1952, 1964, 1974) advocated a view in which the sometimes conflicting needs of articulatory economy and perceptual distinctiveness both played important roles. Such notions arise again, in more explicit formulations, in the work of Liljencrants and Lindblom (1972), and Lindblom (1986, 1990). Other representative works on the functional underpinnings of phonology include Ohala (1983, 1990), Kohler (1990), and Kingston and Diehl (1994), among many others.

Yet the role that functional notions have played in the history of generative phonology can be described as indirect and peripheral, at best. Two apparent reasons for this cleft between generative phonology and functionalism will be mentioned here, though there are certainly others. First is the fact that languages differ from each other in systematic and often categorical ways. If phonology is determined by facts of the mouth and ear in some respects (to put it crudely), then why aren't all languages the same in these respects? This objection loses its force for many phonologists in the context of Optimality Theory (Prince and Smolensky 1993), since this widely adopted formal theory works precisely by deriving explicit, categorical, language particular results from a prioritization of often conflicting constraints that are considered universal. Optimality Theory has in fact paved the way for a re-emergence of functional explanations within phonological theory (Flemming 1995, Ní Chiosáin and Padgett to appear, Steriade 1995, to name just a few.)¹

Second, I would argue, is a tension between the goals of description and explanation. Though formal phonologists differ in how they practice, many consider it part of the job description to provide a characterization of a significant and sometimes intricate range of facts within a particular language that is not only theoretically revealing, but descriptively rigorous and complete. Chomsky and Halle (1968) is a paragon example of this kind of work, even though it is itself only a fragmentary description of English phonology. Yet it seems no easier to derive a complete description of even a small portion of English phonology, based on very general functional principles, than it is to derive a complete description of, say, the sea lion, based on general evolutionary principles. Those who seek the functional explanations necessarily pay a price in terms of descriptive coverage.

This article is a case in point, since it focuses on a single allophonic rule of Russian, a rule by which /i/ is said to emerge as [ɨ] after plain (non-palatalized) consonants. One goal of this paper is to argue for a significantly different understanding of the generalization. Specifically, non-palatalized *consonants* before *i* are *velarized*. At a more theoretical level, the paper advocates the goal of seeking explanations for allophonic processes, particularly non-assimilatory ones, rather than simply stating them or focusing on questions of distribution. In the case examined, and perhaps many others, the explanation depends on functional considerations, in particular the requirement that contrasts be sufficiently distinct. Most broadly, these results imply that the

terminological distinction between 'contrastive' or 'phonemic' on the one hand and 'allophonic' on the other conceals a deeper unity between the two: allophonic processes at least sometimes serve the goal of contrast preservation.

1. Russian palatalization: background

Russian has the five vowel phonemes *i, e, a, o, u*, according to most analysts. The qualification concerns a sixth vowel *ĭ* (often transcribed *y* by Slavic specialists), which will be our main focus below. The consonantal phonemes of Russian are given in (1). Most of these are 'paired', contrasting palatalized versus plain versions, notated C' versus C here, following the practice of Slavic literature. The remaining, 'unpaired', consonants are highlighted within bolded cells. The velars are palatalized before front vowels, otherwise plain; the rest are either invariably palatalized (*j* naturally falls within this group) or invariably not. (*f'*: arguably can be analyzed as *f+t'* in some dialects, as in Halle 1959).²

(1)

	labial		dental		post- alveolar	palatal	velar
stop	p b	p' b'	t d	t' d'			k/k' g/g'
fricative	f v	f' v'	s z	s' z'	ʃ (ʃ':) ʒ		x/x'
affricate			ts		tʃ'		
nasal	m n	m' n'					
lateral			l	l'			
rhotic			r	r'			
glide						j	

Some examples illustrating the palatalization contrast are given below. Contrasts as in (2)a-b are prevalent in the language, while (2)c is more limited due to assimilations and neutralizations in that context.³

(2) a. Before back vowels

<i>mat</i>	'foul language'	<i>m'at</i>	'crumpled (past part.)'
<i>rat</i>	'glad'	<i>r'at</i>	'row'
<i>vol</i>	'ox'	<i>v'ol</i>	'he led'
<i>nos</i>	'nose'	<i>n'os</i>	'he carried'
<i>nu-ka</i>	'now then!'	<i>n'uxa</i>	'scent (gen.sg.)'
<i>suda</i>	'court of law (gen.sg.)'	<i>s'uda</i>	'here, this way'

b. Word-finally

<i>mat</i>	'foul language'	<i>mat'</i>	'mother'
<i>krof</i>	'shelter'	<i>krof'</i>	'blood'
<i>ugol</i>	'corner'	<i>ugol'</i>	'(char)coal'
<i>v'es</i>	'weight'	<i>v'es'</i>	'entire'

c. Before another consonant

<i>polka</i>	'shelf'	<i>pol'ka</i>	'polka'
<i>tanka</i>	'tank (gen.sg.)'	<i>tan'ka</i>	(name)
<i>v'etka</i>	'branch'	<i>f'et'ka</i>	(name)
<i>gorka</i>	'hill'	<i>gor'ko</i>	'bitterly'

The palatalization contrast before *e* is very limited. Consonants were allophonically palatalized in this environment historically, therefore rendered 'unpaired', as shown in (3)a. However, the existence of loan words such as *tennis* and *tent*, with a plain consonant before *e*, has effectively introduced the contrast in roots, at least for certain speakers. It remains true that *suffixation* of *-e* invariably palatalizes a preceding consonant, as shown in (3)b.

(3) a. Before *e* in roots (ignoring borrowings)

<i>s'est'</i>	'to sit down'	* <i>sest'</i>	<i>n'et</i>	'no'	* <i>net</i>
<i>p'et'</i>	'to sing'	* <i>pet'</i>	<i>gd'e</i>	'where'	* <i>gde</i>
<i>v'et'er</i>	'wind'	* <i>veter</i>	<i>l'eto</i>	'summer'	* <i>leto</i>

b. Before *e* under suffixation

<i>dom</i>	<i>dom'e</i>	'house, home (nom.sg./prep.sg.)'
<i>brat</i>	<i>brat'e</i>	'brother (nom.sg./prep.sg.)'

2. Russian palatalization: i vs. ĭ

Of particular interest here is the one remaining environment: before the phoneme *i*. Paired consonants *do* contrast here; however, this contrast is normally transcribed as shown below.

(4)	<i>v'it'</i>	'to twist, weave'	<i>v#it'</i>	'to howl'
	<i>b'it'</i>	'beaten'	<i>b#it'</i>	'way of life'
	<i>t'ikat'</i>	'to tick'	<i>t#ikat'</i>	'to address in familiar form'
	<i>xod'i</i>	'walk!'	<i>xod#i</i>	'gaits'
	<i>s'ito</i>	'sieve'	<i>s#ito</i>	'sated (neut.)'

That is, after plain consonants we find not *i* but *ɨ*. The following is the nearly ubiquitous statement, abstracting across theoretical schools, e.g., Trubetzkoy (1969), Avanesov and Sidorov (1945), Halle (1959), Hamilton (1980), Sussex (1992): there is one phoneme *i*, which is realized as *ɨ* after plain (non-palatalized) consonants, so long as no pause intervenes, i.e. within something like the phonological phrase.

This allophonic rule is quite productive in Russian. In (5)a are examples of word-initial *i* varying with *ɨ*, the latter occurring in the standard pronunciation when a plain consonant precedes. This can lead to minimal pairs of the sort shown in (5)b (see Gvozdev 1949, Reformatkii 1957, Halle 1959, and references therein).

(5)	a.	<i>ivan</i>	'Ivan'	<i>k ɨvanu</i>	'to Ivan'
				<i>brat ɨvana</i>	'Ivan's brother'
		<i>ital'ija</i>	'Italy'	<i>v #al'iju</i>	'to Italy'
				<i>nad #al'ijej</i>	'above Italy'
	b.	<i>k'ir'e</i>	'Kira (dat.sg.)'	<i>k #r'e</i>	'to Ira'
		<i>v'ital'iju</i>	'Vitalij (dat.sg.)'	<i>v #al'iju</i>	'to Italy'

Indeed, *ɨ* does not occur word-initially (unless preceded in the phrase by a word-final plain consonant, as above), so that there are no words such as **ɨvan*, **ɨalija*. Nor does *ɨ* occur following a vowel in Russian, e.g., **poɨgrat'*, **poɨskat'*, cf. occurring *poigrat'* 'to play a little', *poiskat'* 'to look around for'.

We find the variation also within words, for example when a root that is otherwise *i*-initial is prefixed with a morpheme ending in a plain consonant, as shown in (6)a, or when a suffix which is otherwise *i*-initial occurs following a plain stem-final consonant, (6)b. Many morphemes display this variation within a word.⁴ It is also found in so-called stump compounds such as *p'ed#inst'itut* derived from *p'edagog'it'fesk'ij inst'itut* 'pedagogical institute'.

(6)	a.	<i>igrat'</i>	'to play (imperf.)'	<i>s'igrat'</i>	'to play (perf.)'
		<i>iskat'</i>	'to search (imperf.)'	<i>ot'iskat'</i>	'to find'
	b.	<i>ugol</i>	'corner (sg.)'	<i>uglɨ</i>	(pl.)
		<i>ugol'</i>	'(char)coal (sg.)'	<i>ugl'i</i>	(pl.)

Finally, (7) shows examples of a reduction characteristic of Russian patronymics. The sequence *ov/ev* found in patronymics is omitted in the reduced form, causing a preceding consonant to come together with a following would-be *i*. If the consonant in question is plain, then the vowel is realized as *ɨ*, as shown in (7)b (compare (7)a). Such short forms are essentially

lexicalized; the examples shown here are from *War and Peace*, where reduced forms are sometimes spelled in dialogue.

- (7) a. *al'eks'ejitʃʹ* < *al'eks'ejev'itʃʹ* b. *ivanɨʃʹ* < *ivanov'itʃʹ*
andr'ejitʃʹ < *andr'ejev'itʃʹ* *k'ir'ilɨʃʹ* < *k'ir'ilov'itʃʹ*

Throughout the large literature on Russian, this allophonic variation is discussed in a way that would be familiar to any phonology student: the complementarity of *i* and *ɨ* is pointed out, and the generalization stated above regarding their distribution is noted. Yet there are questions one might pose about it. Why, for example, should *i* become *ɨ* after plain consonants? As stated, such a requirement makes no obvious sense. Why should a *plain* consonant exert any such effect? We might also ask, is there a reason why this requirement holds of Russian in particular, and not of other languages that are abounding in plain consonants? In principle, could such a rule occur in English? Finally, why is *ɨ* limited to *only* this environment, following plain consonants within a phonological phrase?

3. Contrast shift

Another language with a palatalization contrast is Irish. Ní Chiosáin and Padgett (to appear) discuss the Irish facts, noting that the actual realization of consonants varies between palatalized, velarized, and plain, depending on the following vowel. These facts, illustrated below, hold only of consonants before long vowels. (Short vowels take their backness value from neighboring consonants.) As seen in (8)a-c, before back vowels the contrast is realized as palatalized versus plain. However, when the following vowel is front, as in (8)d-e, the contrast is realized as *plain* versus *velarized* respectively.

- (8) a. fʷu: 'worth' fu:ə 'hate'
 b. bʷo: 'alive' bo: 'cow'
 c. fʷɔ:n 'skin, flay' fɔ:n 'straying, wandering'
 d. bi: 'be (imp.)' bʷi: 'yellow'
 e. be:l 'mouth' bʷe:l/bʷi:l 'danger'

Why should the facts turn out this way? There is a relatively straightforward answer that calls on the notion of contrast dispersion: sounds in contrast should be sufficiently distinct. (See the references cited in the introduction.) To begin simply, consider the contrast between a *j*-vowel sequence and the same vowel alone, as in *ja* versus *a* and so on. Figure (9) gives a rank ordering of such contrasts, for the five common vowels, based on the movement of the second vowel formant. In the transition from *j* to *i* F2 moves very little; it moves farther in the transition from *j* to *e*, and so on. Therefore the difference between *ji* and *i* is smaller than that between *je* and *e*, etc., judging in this way. Differences in F2 are well known to roughly correlate with differences in perceived backness (as well as roundness), and the ranking shown in (9) is impressionistically clear at least for *ji-i* through *ja-a*.

(9) $ji-i < je-e < ja-a < jo-o < ju-u$

Assuming that there is a tendency for languages to favor more distinct contrasts over less distinct ones, all else being equal, then (9) makes markedness predictions. Considering again just *ji-i* through *ja-a*, for example, there should be languages that allow all three contrasts, languages that rule out specifically *ji-i*, and languages that rule out *ji-i* and *je-e*. An example of the first is English, with contrasts such as [i:st] 'east'/[ji:st] 'yeast', [e:l] 'ale'/[je:l] 'Yale', and [ɔn] 'on'/[jɔn] 'yon'. Spanish is an example of the second; it lacks the first contrast, but has pairs such as [el] 'he'/[jel] 'gall' and [a'ser] 'to do'/[ja'ser] 'to rest'. Japanese exemplifies the last kind of language, lacking the first two, but having *ja-a* (Itô and Mester 1995), e.g., [aki] 'autumn'/[jaki] 'to sear'. (All of these languages in addition allow *jo-o* and *ju-u*) On the other hand, there should *not* be languages that allow specifically *ji-i* while ruling out *je-e* and *ja-a*, or languages allowing *ji-i* and *je-e* while ruling out *ja-a*, all else being equal. This certainly seems to be the correct prediction. Putting aside these markedness implications, however, the cross-linguistic tendency to avoid *ji-i* and *je-e* is well-documented and has an evident auditory basis. (See especially Maddieson and Precoda 1992.) Similar reasoning extends to the contrasts *wu/u*, *wo/o*, and *wa/a*.

Though a contrast in palatalization is more complex, with other phonetic properties such as frication or burst potentially contributing to the distinction, we can nevertheless posit, by the same reasoning again, that the contrast *Cⁱa* versus *Ca* should be favored over *C^ee* versus *Ce*, and that both of these should do better than *Cⁱi* versus *Ci*, all else equal, where *C* is any consonant. There is a good deal of evidence that this is the case. In Northern Estonian, and in Karakatšan, the plain versus palatalized contrast is neutralized before front vowels, according to Kawasaki (1982) and Ohala and Kawasaki-Fukumori (1997). The same holds of Japanese (Itô and Mester 1995). Turning to Slavic, the contrast is also neutralized before front vowels in Bulgarian and Polabian (the latter a West Slavic language now extinct), and before *i* in Polish.⁵ Macedonian lacks a general palatalization contrast, but contrasts *ʃ* versus *l*. (The latter can be pronounced as palatalized.) This contrast is neutralized before *i* and *e*. (For an overview of the Slavic facts discussed in this paper, and references, see the papers in Comrie and Corbett 1993.) Significantly, there are no cases where a palatalization contrast is favored specifically before *front* vowels, nor to my knowledge are there languages contrasting *Cⁱi* versus *Ci*, but not *C^ee* versus *Ce*. That is, the implications for possible glide-vowel contrasts discussed earlier appear to hold for palatalization as well.

This independent evidence that the contrast plain versus palatalized is avoided before front vowels in languages bears significantly on the Irish facts. Irish can be seen as a language that takes a more assertive approach to the problem than those mentioned above. A contrast is not lost but maintained in this environment in Irish, but its realization is *shifted* from plain versus palatalized to velarized versus plain respectively. Hence it would be better to call the Irish contrast one of frontness/backness, and not simply of palatalization. This contrast shift implies that Irish requires the frontness/backness contrast to be at least as distant as *ʃi-i*, which is roughly on the order of *ja-a*, again judging by F2 transitions. In this regard Irish resembles Japanese. It is different in that it maintains all contrasts by invoking velarization before front vowels, while Japanese does not maintain the contrast before front vowels. Ní Chiosáin and Padgett (to appear) give an account of the Irish facts along these lines within Optimality Theory.

There is an alternative account for such facts well-known to phonologists, involving the Obligatory Contour Principle (OCP), a constraint prohibiting adjacent identical elements (Leben

1973, Goldsmith 1976, McCarthy 1986). For the case at hand the restriction would involve occurrences of [-back][-back], ruling out forms such as *je* and *ji*. The OCP account is significantly different from one appealing to contrast, since the latter does not specifically disfavor forms such as *ji* and *je*. Rather, it disfavors the contrasts *ji/i* and *je/e*, while leaving open the possibility that a language without these contrasts will favor either *ji* and *je*, or *i* and *e*, depending on other factors such as the requirement of an onset, or assimilation, versus articulatory or structural minimalism.⁶

There are several important disadvantages to the OCP account. First, it does not predict the markedness implications just detailed. Why is *ji/i* worse than *je/e*, since *ji* and *je* both involve sequences of [-back]? One could address this issue by assuming that the OCP not only disfavors sequences of [-back], but also checks the relevant segments for identical values for [high] and [low] (see Padgett 1995 for similar proposals), and disfavors sequences more if they have more of these features in common. Such an account acquires some of the advantage of the contrast-based approach, specifically in calling on a kind of *scale* of similarity. However, there is a divide between the formal account and the intended explanation: it remains *formally* mysterious why just these features are involved together in the prohibition. A direct appeal to the acoustic/perceptual element of F2, on the other hand, avoids this problem.

Second, since the OCP is often invoked to account for long-distance dissimilations, we would expect long-distance effects involving these glide-vowel cooccurrences, ruling out for example the cooccurrence of *i* and palatalization in *ip'a* (where *p'a* is fine). (In fact, this would not even count as long-distance within something like the feature geometric framework of Sagey 1986.) Yet no such restriction holds of any language surveyed here. In the contrast-based approach it follows immediately that such forms are acceptable, even when *p'i* versus *pi* is not, since the problem of acoustic/perceptual similarity arises precisely under adjacency of the palatalization off-glide and the vowel.

Third, though such an account predicts that *bi* and not *b'i* occurs in Irish, it does *not* explain why a language such as Irish might *require* *b'i*. It is important to ask why the presence of a palatalization contrast should *correlate* with the presence of velarization, especially bearing in mind that *b'* is articulatorily more complex than plain *b* and is considered more marked in phonology. Marshallese is another language having both palatalization and velarization (Bender 1969, Choi 1992, 1995), and so is Russian, the case we return to below. Assuming that velarization involves more articulatory effort and/or markedness than a plain consonant, we can only understand the tendency for it to accompany palatalization as a means of enhancing a contrast, as Trubetzkoy (1969:130) does.

4. Russian velarization

A tendency for the 'plain' consonants of Russian to be velarized has often been noted (Trubetzkoy 1969, Reformatskii 1958, Fant 1960, Öhman 1966, Purcell 1979, Lyovin 1997:64, many others), though the amount of velarization, and the consonants affected by it, are matters of disagreement. (See Evans-Romaine 1998 for a thorough overview of this question and references.) I argue below that the role of velarization is actually underestimated in phonological accounts of Russian, a fact that is unfortunate, since its presence bears in an important way both on phonological theory and on Russian phonology.

Considering the broader theory first, the occurrence of velarized segments in languages having contrastive palatalization points up a markedness paradox. Taking the specific example

shown in (10)a, there are languages with a contrast among plain, palatalized and velarized laterals, including Bernera Scots Gaelic, at least one dialect of Irish (see Ladefoged and Ladefoged 1997 on both of these), and Marshallese (Bender 1969, Choi 1992, 1995). There are languages contrasting palatalized and velarized laterals, including Irish and Russian (\acute{l} is the segment that is most uncontroversially velarized in Russian). Finally, there are languages having just one contrastive lateral. Though the latter is counted as 'plain' in (10)a, there can of course be variation in a sole lateral phoneme's realization.⁷ Since a plain lateral, however, is the most widespread kind across languages, markedness theories single it out as the best. It is therefore a surprise, as Lyovin (1997) notes, that Russian has no plain lateral, and the same can be said of Irish.

- (10) a. l' vs. l vs. \acute{l} Bernera Scots Gaelic
 l' vs. \acute{l} Russian, most Irish dialects
 l Many languages
- b. i vs. \acute{i} vs. u Guaraní
 i vs. u Many languages
 \acute{i} Kabardian

The situation here is closely analogous to that of (10)b. Theories of markedness developed within formal phonology are typically 'unidimensional', to use a term from Ní Chiosáin and Padgett (to appear), in the sense that they rate segments along a *single* scale of goodness. Assuming that the best segments are those found across most languages, such theories favor i and u over \acute{i} , just as they favor l over l' and \acute{l} . Yet in Kabardian, just as in Russian and Irish, the 'best' segments are *disfavored*. The facts instead support a view in which markedness is determined along more than one dimension. On the one hand, l and \acute{l} are best from the point of view of articulatory simplicity (except where coarticulatory influences dictate otherwise). On the other, when a language contrasts two segments, it can be more important that the contrast be well dispersed perceptually. This latter requirement conflicts with the first, since l' and \acute{l} make the best such pair, just as i and u do, the F2 values differing the most in each case. To the extent that other 'plain' consonants of Russian are in fact velarized, they raise the same problem for unidimensional markedness.

Turning now to a closer look at Russian, the most important reason why the existence of velarization in Russian is underestimated is that it is scarcely recognized just where it is most prevalent and systematic: on non-palatalized consonants before i . Here we have in mind \acute{l} : though described and transcribed as a central vowel in most of the literature, Russian \acute{l} is typically pronounced as a diphthong $[\acute{l}^i]$ or $[\omega^i]$, at least when stressed. This observation tends to be confined to the more phonetic literature, and occurs there only occasionally, e.g., Meillet (1951), Boyanus (1967), Jones and Ward (1969), Bondarko (1977), Derkach et al. (1983:27-8), Antonova (1988). Even in these works, the potential relevance of this fact to the presence of contrastive palatalization is not addressed. The Russian facts are strikingly similar to those of Irish, and the points raised in the previous section suggest that this is not likely to be coincidental. An alternative transcription of the Russian forms we saw in Section 2 is shown in (11).⁸

(11)	<i>vit'</i>	'to twist, weave'	<i>v^yit'</i>	'to howl'
	<i>bit</i>	'beaten'	<i>b^yit</i>	'way of life'
	<i>tikat'</i>	'to tick'	<i>t^yikat'</i>	'to address in familiar form'
	<i>xodi</i>	'walk!'	<i>xod^yi</i>	'gaits'
	<i>sito</i>	'sieve'	<i>s^yito</i>	'sated (neut.)'

As with Irish, palatalization before *i* is not transcribed. More important, Russian *ʃ* is reinterpreted as *velarization of the consonant before i*. This is a more accurate transcription in two important respects. First, in a minimal pair such as *bit* versus *b^yit*, it is the latter that phonetically bears the greater burden of the contrast. That is, the velarization in *b^yit* is much more discernable than is the palatalization in *bit*. Second, this distinguishing phonetic property is localized at the *release* of the consonant, just as we find with palatalization.

We are now in a position to address some of the questions raised earlier about the Russian allophonic rule. First, why should *i* become *ʃ* after plain consonants? The answer offered here is that there *is no ʃ* in the sense usually intended, i.e., no phonetic (let alone phonemic) category *ʃ*, nor any plain consonant. Instead there is *C^yi*. Second, why should *ʃ* be limited to occurring *only* following a 'plain' consonant within a phonological phrase? Obviously this restriction follows without comment if *ʃ* in fact represents velarization of the preceding consonant. To the question, could such a rule exist in English, or in any of the myriad languages having 'plain' consonants, the answer suggested is no: velarization before *i* in Russian is directly related to the presence of contrastive palatalization in that language, and it is just one instance of a cross-linguistic tendency to avoid contrasts such as *C^ji* versus *Ci*. The prediction is that we should not find a similar rule in a language such as English.

Let us consider (11) in more detail. First, our choice to omit palatalization in forms such as *bit* is not crucial, since the point of interest is that the velarization in *b^yit* is *more* significant from the perspective of contrast dispersion. However, people trained in transcription are not generally tempted to record palatalization in forms such as *bit*, just as they are not for Irish, and the indiscernability of palatalization (in the sense of off-glide *j*) before *i* is noted in various works on Russian, including Jones and Ward (1969) and Zubkova (1974). The facts are not so simple when we consider non-labial places of articulation. For example, coronal stops in forms such as *xodi* are typically affricated, the degree of affrication depending on the speaker and the dialect. In this sense they are more notably 'palatalized'. This point bears interestingly on the claim that contrasts such as *C^ji* versus *Ci* are deficient, since affrication is another means (besides velarization) by which the contrast dispersion of such a pair can be improved. We will return to this point later.

The more important claim of (11) is that Russian *Cʃ* should be understood as *C^yi*. In spite of discussion of velarization in other contexts (that is, not before *i*) found in the literature on Russian, and despite occasional mention of the diphthongization of *ʃ* in particular, apparently no one has suggested that *Cʃ* should be understood as *C^yi*. It is difficult to say why this is, though part of the problem may be that the extent of the diphthongization is not considered convincing enough. Most who note the diphthongization state that it ends short of Russian [i] (hence Russian "[i̯]", e.g., Jones and Ward (1969), and Lyovin (1997), who transcribe [ʉ̯i̯]). (On the other hand, Bondarko 1977, among others, is clear in stating that *ʃ* ends in Russian *i*.) The eminent Russian phonologist Shcherba (1912) explicitly argued that there is *no* diphthongization of *ʃ*, though it is difficult to reconcile this opinion with observed fact.⁹ A third consideration is that *ʃ* is in fact less

diphthongized, or not diphthongized at all (i.e., occurring as [ɨ] or something similar), in unstressed syllables. This last fact presents no serious obstacle to the claim here, however. No one would deny the existence of, e.g., *C'a* in Russian, as in *p'at* 'five', even though when not under main stress such a syllable reduces to *Ci* or *CI* as in *piti* 'five (gen.sg.)'. *Cɨ* is a plausible outcome under reduction for a syllable that is *C^yi* under stress. (One also finds reductions of this syllable to *Cə* or nearly so.)

5. Phonetic investigation

How can we further explore the claim that Russian *Cɨ* is *C^yi*? Two tests suggest themselves. First, if *Cɨ* is *C^yi*, then a comparison of Russian *Cɨ* and *Ci* should reveal that these syllables are very different at the release of the consonant, but similar at their conclusion. Second, it is worth comparing the Russian facts to those of another language that is said to have *C^yi* uncontroversially, in order to get a baseline on what a 'real' case of velarization before *i* is like. To these ends an experiment was conducted comparing Russian and Irish.

5.1 Methods

Three Russian speakers and three Irish speakers were recorded speaking the syllables *bi*, *b^yi*, *di*, *d^yi* as portions of real words. (From here on *C^yi* will be written instead of *Cɨ*, to keep the comparison between Russian and Irish forms clear.) The Russian speakers were from Moscow or nearby, were approximately in their forties or fifties, and had been living in the US for up to ten years. The Irish speakers all spoke Northern (Donegal) Irish, were in their twenties and thirties, and live in Dublin, Ireland.¹⁰ There were two women and one man in each case.

The words used for recording are shown below. Irish contrasts 'long' and 'short' vowels, though it is as much a contrast in quality as quantity. The vowels in these Irish words are 'long'. For both languages, examples with both initial *b* and initial *d* were examined because various works suggest that diphthongization in Russian *C^yi* is stronger after bilabials, with the vowel ending further forward, e.g., Meillet (1951), Boyanus (1967), Jones and Ward (1969).

(12)	The Russian words:	[rʌ'b ^y i] 'slaves'	[vʌ'd ^y i] 'water (gen.sg.)'
		[drʌ'bi] 'stamp your feet!'	[xʌ'di] 'walk!'
	The Irish words:	[b ^y i:] 'yellow'	['d ^y i:hɪ] 'to her'
		[bi:] 'be (imp.)'	[di:] 'drink (gen.sg.)'

The words were embedded in carrier sentences. There were four contexts, each intended in its own way to elicit something like a careful or hyperarticulated pronunciation (see Lindblom 1990, Moon and Lindblom 1994, and Johnson et al. 1993 on hyperarticulation). The reasoning was that *C^yi* and *Ci* stand the best chance of being similar at their endpoints under such maximally unreduced conditions. As it happens, the different contexts had no entirely systematic effect of interest on the results. Though they were treated as a factor in the statistical analyses, they are not discussed here. These carrier sentences, along with more about the materials, are shown in the Appendix.

There were three repetitions for each of the four contexts, giving twelve tokens of each word per Russian speaker. The number of tokens varied more in the case of the Irish speakers. (Some speakers did not repeat materials the requested three times in every task, so that the number of tokens went down.) Since there were four target words per language, this meant (ideally) forty eight tokens per speaker.

Analyses were performed on a Kay Elemetrics CSL 4300. The target words were digitized at 10KHz. Formants 1-3 were estimated by Linear Predictive Coding, using a 10 ms window and 10, 12, or 14 coefficients, the choice depending on the speaker. Measurements were taken at two positions: at consonantal release, and at peak F2, i.e., where F2 was highest. If F2 rose and then plateaued, then the measurement was taken at the end of the voiced portion of the vowel. These positions were determined using a waveform and spectrogram together.

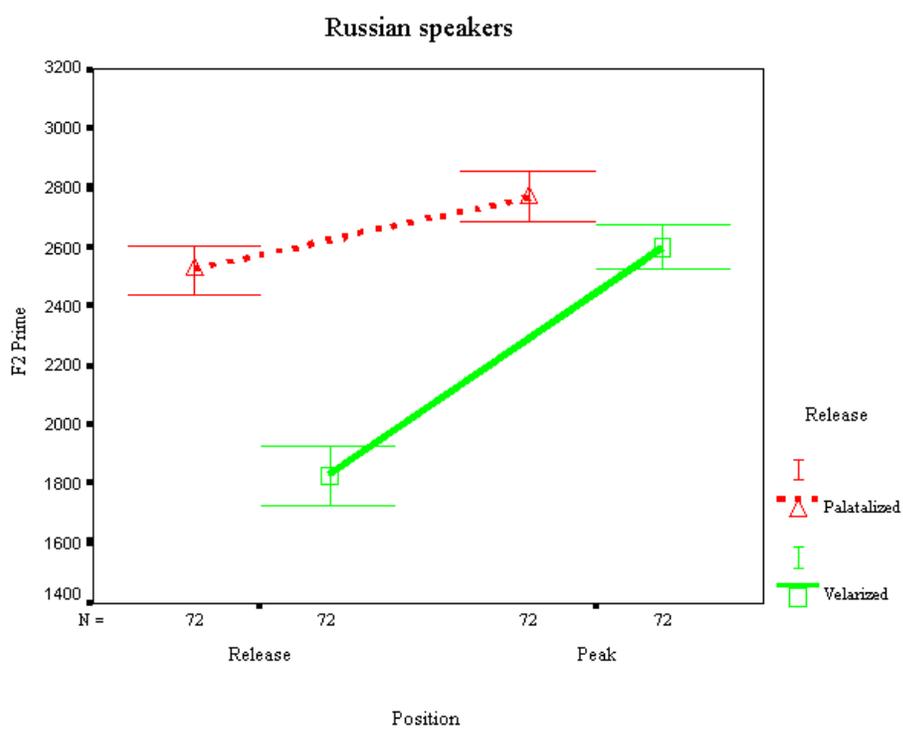
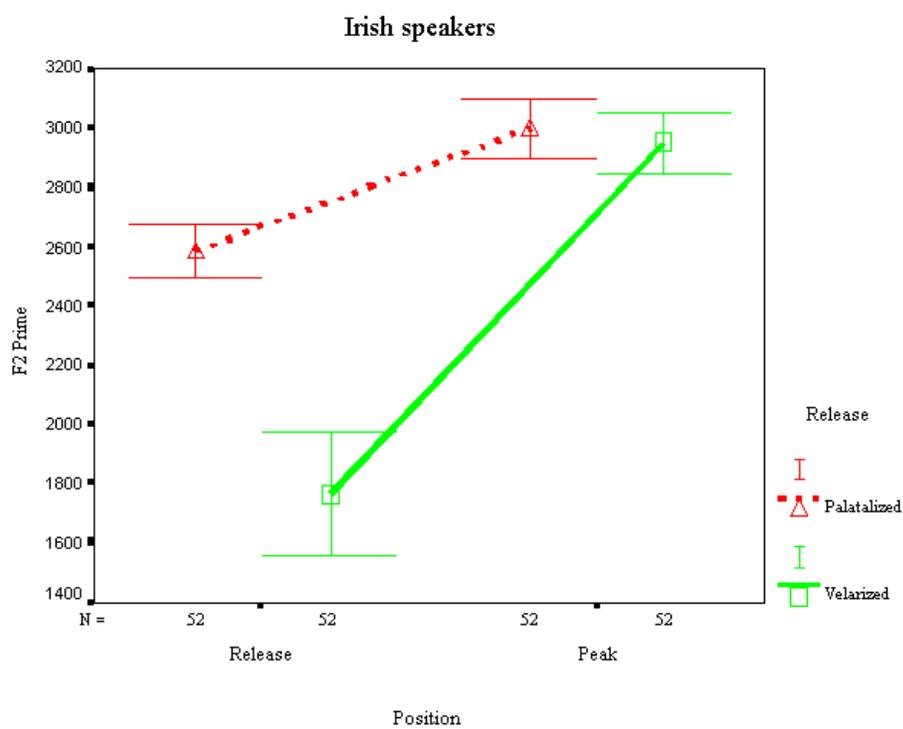
There is evidence that not only F2, but F3 figures into the perception of frontness, in particular in the case of [i], where F2 is close enough to F3 to be perceptually integrated with it (Carlson et al. 1970). Based on some of the spectrograms, in fact, it seemed that some of the perceived glide toward [i] in $C^y i$ was contributed by the upward movement of F3. It therefore seemed wise to take both F2 and F3 into account. A well known means of doing this employs the formula (due to Carlson et al.) deriving F2' ("F2 prime") shown in (13). As it turned out, F2' means at peak F2 for Ci versus $C^y i$ were more significantly different than either peak F2 or F3 means alone, for most speakers. (For one it made no significant difference, and one subject was not checked.) Thus using F2' made it more difficult to demonstrate that Ci and $C^y i$ are similar at their endpoints.¹¹

$$(13) \quad F2' = F2 + .5(F3 - F2)((F2 - F1)/(F3 - F1))$$

5.2 Results

Figure 1 shows representative spectrograms from the first Russian speaker and Irish speaker analyzed (both male). As can be seen, bi differs from $b^y i$ similarly in the two languages based on this informal inspection. In particular, the second formant of $b^y i$ in both languages begins low, and (more interestingly) ends somewhere very similar to its position for i in bi .

Figure 2: Mean F2' values, with 95% confidence intervals



There is a great deal of variation in formant values between speakers, particularly due to gender. Hence it is more informative to consider each speaker separately. For each speaker, a three-factor analysis of variance (Anova) was performed comparing the F2' means of $C^y i$ versus Ci at consonantal release, and at peak F2. The factors were palatalized versus velarized syllable (that is, Ci versus $C^y i$), consonant type (b versus d), and context (see appendix).¹² The most immediate result was that Ci is significantly different from $C^y i$ at each point for most of the speakers (five out of six). Specifically, the F2' means of $C^y i$ versus Ci were significantly different at both the point of consonantal release and at peak F2, for five speakers. For one Irish speaker they were not significantly different at peak F2.

The finding that the F2' values of $C^y i$ differ from those of Ci at consonantal release is no surprise, and would be expected whether $C^y i$ is understood as $C^y i$ or $C\acute{i}$. Indeed, the magnitude of the difference between F2' means at this point is huge in comparison to that at peak F2, for all speakers. Table (14) gives the mean F2' values at consonantal release, and the Anova results, for all consonants grouped together.

(14) Mean F2' values in Hertz and Anova results at consonantal release

Subject	Russian 1 (male)	Russian 2 (female)	Russian 3 (female)	Irish 1 (male)	Irish 2 (female)	Irish 3 (female)
Ci	2138	2833	2602	2245	3008	2519
$C^y i$	1606	2044	1832	1583	1958	1754
Difference	532	789	770	662	1050	765
Result of Anova	F(1,32) =530 p<.001	F(1,32) =2,066 p<.001	F(1,32) =310 p<.001	F(1,16) =598 p<.001	F(1,32) =435 p<.001	F(1,24) =1,039 p<.001

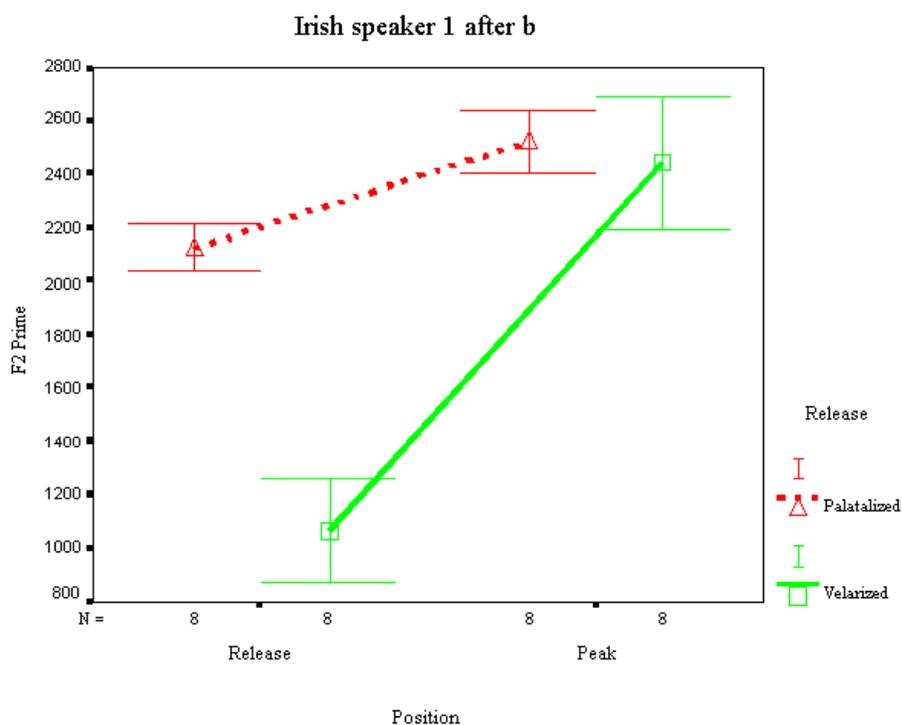
A similar table (15) reports the mean F2' values at peak F2. As the graphs of Figure 2 suggest, these differences are much smaller. However, they are statistically significant for five of the six subjects, all except Irish speaker 3.

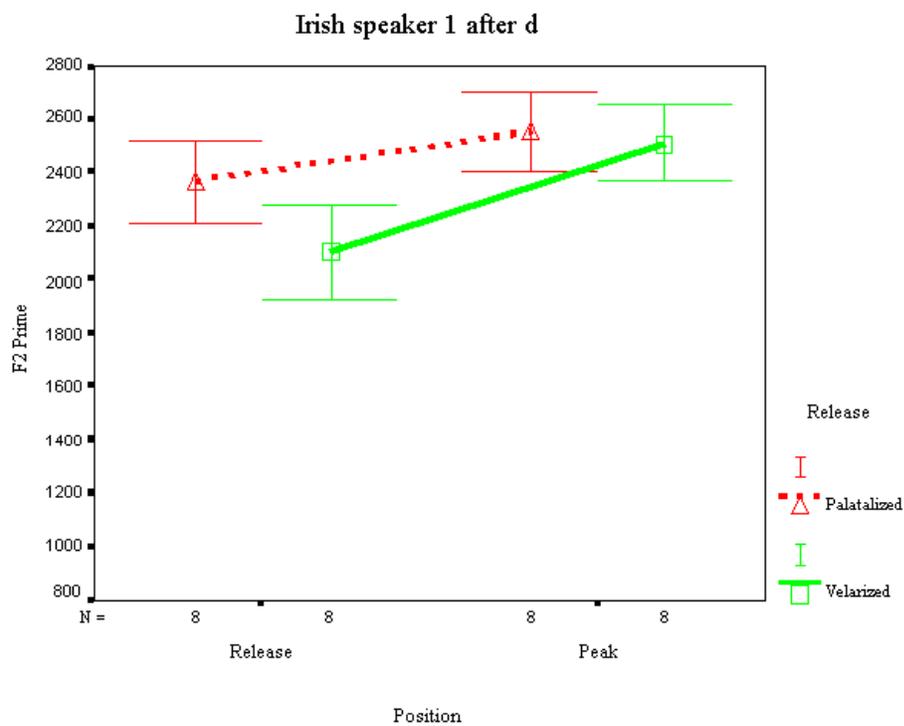
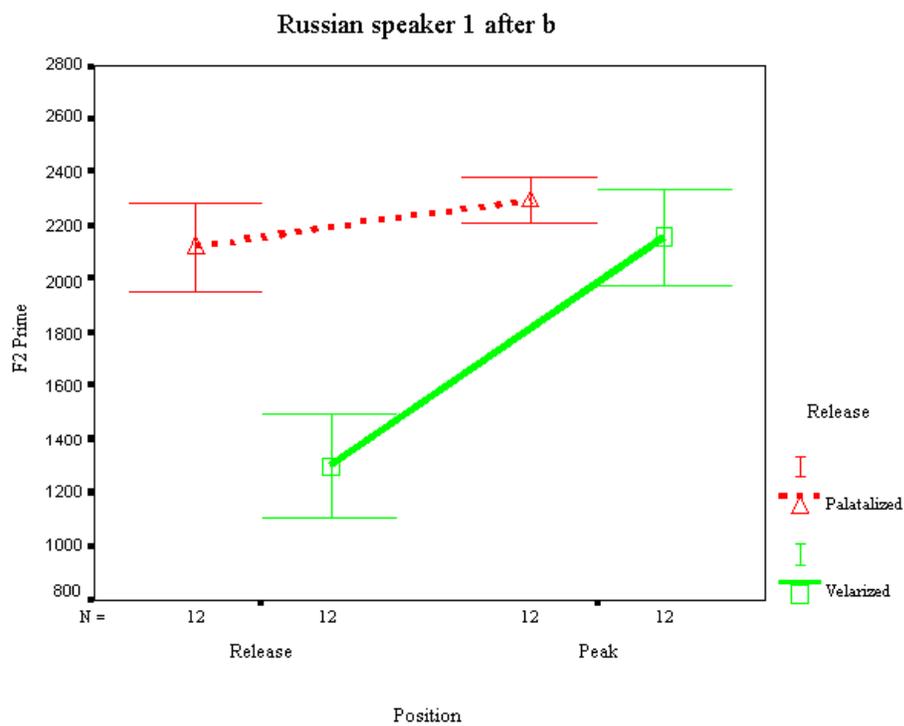
(15) Mean F2' values in Hertz and Anova results at peak F2

Subject	Russian 1	Russian 2	Russian 3	Irish 1	Irish 2	Irish 3
Ci	2283	2986	3032	2541	3452	3001
$C^y i$	2192	2869	2741	2477	3359	2998
Difference	91	117	291	64	97	3 Hz
Result of Anova	F(1,32) =29 p<.001	F(1,32) =17 p<.001	F(1,32) =75 p<.001	F(1,16) =10 p<.01	F(1,32) =5.6 p<.05	F(1,24) =0.1 n.s.

Figure 3 shows the mean F2' values for Russian speaker 1 and Irish speaker 1, broken down according to initial consonant type, *b* versus *d*. As can be seen, at the point of consonantal release, the F2' means differ much more following *b* than following *d*, for both of these speakers. In other words, the contrast between the velarized and palatalized forms is much greater following the bilabial, as judged solely by these F2' values. Note that the range shown around the means in this figure is no longer the 95% confidence interval but a larger one.¹³

Figure 3: Mean F2' values by consonant, with 2 * standard deviation





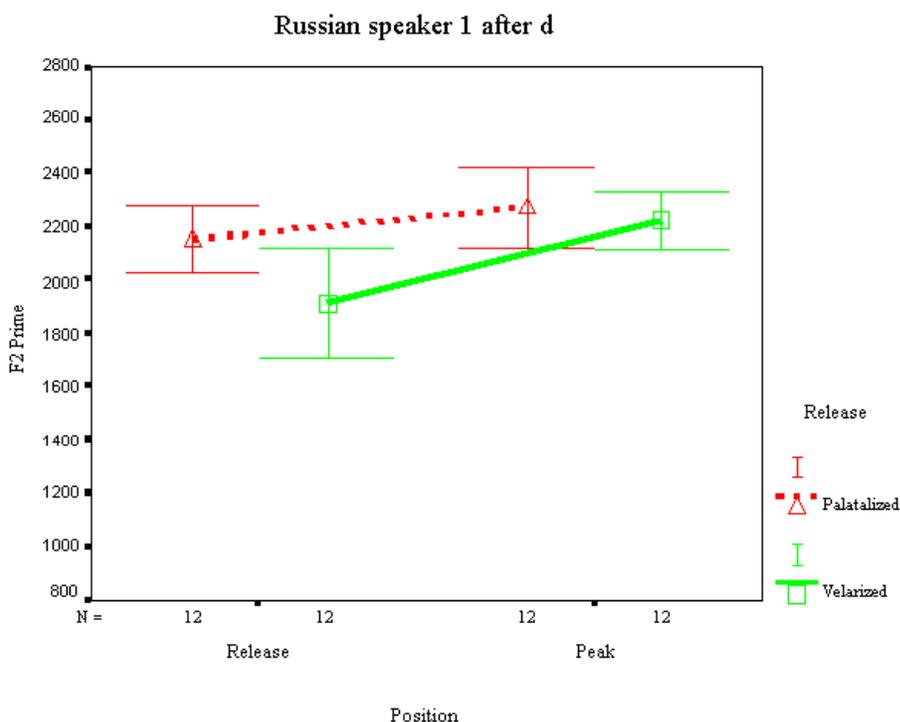


Table (16) presents the Anova results for all speakers at consonantal release. For every subject, the difference between F2' means was much larger following the bilabial consonant, an interaction (velarized/palatalized versus consonant type) that is highly significant. For Russian speakers 1 and 2 only, this difference by consonant persisted even to peak F2 position, though it was much smaller there. (Speaker 1: 134Hz versus 47Hz, $F(1,32)=6.8$, $p<.05$; speaker 2: 207Hz versus 28Hz, $F(1,32)=9.8$, $p<.01$.)

(16) Difference between mean F2' values by consonant, at release

Subject	Russian 1	Russian 2	Russian 3	Irish 1	Irish 2	Irish 3
bi vs. b ^y i	826Hz	1189Hz	1009Hz	1061Hz	1842Hz	1395Hz
di vs. d ^y i	238Hz	390Hz	532Hz	263Hz	257Hz	136Hz
Results of Anova	$F(1,32)=161$ $p<.001$	$F(1,32)=529$ $p<.001$	$F(1,32)=30$ $p<.001$	$F(1,16)=218$ $p<.001$	$F(1,32)=249$ $p<.001$	$F(1,24)=694$ $p<.001$

5.3 Discussion

In spite of the statistically significant differences seen in (15), the results here support the view that Russian *Cʲi* is indeed *C^yi*. First and most obviously, these results show that the contrast between *C^yi* and *Ci* is much greater at the release of *C* than in the following vowel, indicating that *C^yi* versus *Ci* (or *C^ji*) is indeed a better representation of the facts than is *Cʲi* versus *C^ji*. In fact, the

striking similarity between the Russian and Irish facts extends to the different treatment of *b* and *d*, and this difference also points up the importance of consonantal release to the contrast, a point we turn to momentarily.

Second, there is a good deal of overlap in the F2' values for individual tokens of *C^yi* versus *Ci* at peak F2, even within the same speaker. Figure 3 shows a range of two standard deviations around the means, a range that includes roughly 95% of the data for the respective means (assuming normal distribution). Even though F2' values for *Ci* versus *C^yi* were significantly different at Peak F2 for each of these speakers, Figure 3 shows that there was quite a bit of overlap in the relevant tokens, regardless of language or consonant type. There was similar overlap in F2' values at Peak F2 for all speakers.¹⁴

Third, another perspective on the significance of these results can be had by inquiring how robust these differences in Hertz are to the human ear. A conservative estimate of the "just noticeable difference" between vowel formants in the range of F2 is 3% of the formant value, judging by the studies summarized in Kewley-Port and Watson (1994).¹⁵ For the F2' values shown in (15) this means roughly 80Hz. The actual differences found between the F2' means are roughly this amount or less in the case of Irish, implying that the difference in that language between *Ci* and *C^yi* at their endpoints is virtually inconsequential auditorily. The actual differences are larger overall in the case of Russian, but only modestly so for speakers 1 and 2.

Though the Irish F2' means are closer together in (15) in comparison to those of Russian, a difference between languages at this level of detail in the realization of a phoneme such as *i*, assuming it were to hold up across more subjects, is not at all unusual. The fact that the vowel in *C^yi* falls a bit short of that in *Ci* in either language due to preceding velarization could be modelled in one of several ways. First, *C^yi* and *Ci* might have the same phonetic target at the syllable endpoint, but this target is undershot more in the case of *C^yi* due to the contrary tug of velarization. Second, the vowel *i* might have different *targets* according to phonetic context, i.e., the target realization for this vowel after a velarized consonant is not quite so front as that of *i* in other contexts. Third, the target of *i* might be a 'window' in the sense of Keating (1990), that is, a *range* of acceptable realizations within which variation according to context is possible. This last position can be seen as a compromise between the first two. All of these possibilities reflect well known approaches to dealing with contextual realization of phonemes.

The difference found between *b* and *d* support the observation made by Meillet (1951), Boyanus (1967), Jones and Ward (1969), and others, that the diphthongization of *i*—or rather, velarization of the consonant preceding *i*—is greater when the preceding consonant is a bilabial. (Judging by the data obtained, however, this effect is not because the vowel ends further forward, as the latter two report; rather, F2' *begins* much lower after bilabials.) The question arises whether this difference is related in any interesting way to the fact of a palatalization contrast, or whether it merely reflects an inherent difference between bilabials and dentals in their effects on formant transitions, apart from considerations of palatalization. According to the latter view, these would be just the acoustic results to expect from combining one and the same palatalization gesture with a bilabial versus a dental on the one hand, and doing the same for a velarization gesture on the other.

There is indeed evidence supporting the latter view. For example, Sussman et al. (1991) carried out a study of coarticulation between consonants and following vowels, with the goal of demonstrating invariant acoustic cues for stop place of articulation. The study involved English speakers ranging over various dialects, and it showed that formant values for bilabials at release

vary to a much greater degree due to a following vowel than do those for alveolars, a result that held across English vowel types. These results are consistent with earlier findings that a much more stable F2 "locus" exists for alveolars at release compared to bilabials. This difference may be due to the relative freedom of the tongue body to assume the posture of a neighboring vowel when the stop closure is bilabial, compared to presumed constraints that a tongue blade articulation places on tongue body movement. (See Sussman et al. for references and discussion.) Purcell's (1979) study of coarticulation in Russian VCV sequences found a similar difference between non-palatalized bilabials and dentals across vowel contexts. (Not surprisingly, the F2 values of palatalized consonants at release vary much less due to vowel context.) It also revealed that a difference such as that in (16) between palatalized and non-palatalized bilabials, compared to the dentals, holds whether the following vowel is *i*, as here, or a different Russian vowel. That is, it is seen not only in *bi/bʲi* versus *di/dʲi*, but in *bʲa/ba* versus *dʲa/da*, and so on. The data observed here are consistent with this general difference between *b* and *d*. As Figure 3 shows, the *overall* variation in F2' values following *b* is much larger. Indeed, the means for *d* vary so much less that values for palatalized versus velarized *d* actually overlap for all Irish speakers, and two of the Russian speakers, in terms of the 2 * standard deviation range indicated. There is never such overlap in the case of *b*.

On the other hand, a comparison of Irish and Russian dialects suggests that there is more to the story. There is a way in which the contrast in the case of dentals is much *more* variable in comparison to bilabials. The Irish subjects analyzed here speak a northern variety of the language that is characterized by very heavy affrication of the palatalized dentals, as shown in (17).¹⁶ In comparison, the same sequences in western dialects are much less affricated. At the same time the non-palatalized dentals before *i* are velarized very little by these subjects in comparison to the norm in western dialects, so little as to sometimes give no impression of velarization at all. Standard Russian is more similar to western Irish. However, some dialects, in north and central European Russia especially, also heavily affricate the palatalized dentals (Kuznetsova 1969). In the recorded speech of one such speaker I obtained, the non-palatalized dentals before *i* are velarized surprisingly little, similarly to those of the Irish subjects.

- (17) Northern Irish: *bi* *bʲi* *dʒi* *dʲi*
 Western Irish: *bi* *bʲi* *di* *dʲi*

A more systematic study would be required in order to determine whether heavy affrication and weak velarization indeed correlate across dialects. Such a correlation would suggest an independent reason why the palatalization contrast involves more extreme F2' movements in the case of bilabials, even in Standard Russian: palatalized dentals are somewhat affricated even in Standard Russian and western Irish, providing a further acoustic cue to palatalization, while bilabials lack this possibility of affrication. Assuming that the two kinds of cue to palatalization can be traded off, it follows that a smaller F2' difference between palatalized and non-palatalized dentals could suffice for a perceptually robust contrast, in comparison to bilabials. Zubkova (1974) suggests just this explanation for the greater velarization in the case of bilabials. Seen in this light, the overlap mentioned above between F2' values for palatalized and velarized *d*, even within speakers, might not be surprising: F2' values are not solely responsible for ensuring the palatalization contrast in the case of *d*.

These differences between dentals and bilabials most likely bear on a cross-linguistic phonological pattern. Labials are more restricted than coronals in their ability to contrast in palatalization. For example, though Polish, Belorussian, and Russian all contrast palatalized and non-palatalized labials, this contrast is neutralized in favor of plain labials syllable-finally in Polish (Rothstein 1993), Belorussian (Mayo 1993), and in some Russian dialects (Kuznetsova 1969), while the contrast is retained in the case of coronals. Further, several of the Slavic languages have no contrast at all between palatalized and non-palatalized labials, but have one in the case of coronals, e.g., Czech, Slovak, and Ukrainian. There are no cases in which the contrast is preferred for labials rather than coronals. Takatori (1997) notes this markedness implication in a survey of palatalization in Slavic languages, and proposes an Optimality Theoretic account in which constraints against palatalized labials universally outrank those against palatalized coronals. This universal might well be grounded in facts of perceptual contrast dispersion once again: the more dependent a palatalization contrast is on F2 transition cues, especially upon release, the more this contrast will suffer in positions not conducive to audible release, including syllable-finally. (See Kingston 1990, Lombardi 1991[94], and Steriade 1995 on the connection between consonantal release and the maintenance of certain contrasts.) Labials are more dependent on these cues than coronals, and are disfavored accordingly. The fact that palatalized labials are dispreferred even apart from position might follow from the very fact that the number of cues to palatalization for labials is fewer than those for coronals.¹⁷

Before concluding this section it is worth making some final comments on the treatment of Russian $C\acute{i}$ as $C^y i$. This approach helps make sense of a long-standing controversy over whether Russian " \acute{i} " is a phoneme or not. In spite of the considerable evidence seen in Section 2 that \acute{i} and i are not in contrast, there has been much disagreement on this point for decades, and descriptions of Russian often include \acute{i} in the chart of vowel phonemes. One forceful, if somewhat nebulous, reason for this follows from an old notion that sub-phonemic differences are not normally something that speakers are aware of, while Russian speakers are highly aware of " \acute{i} ", an argument Gvozdev (1949) makes, for example.¹⁸ Consider this argument in light of our earlier discussion of the phonetic realization of the contrast Ci versus $C^y i$: though the former may be perceived as palatalized to some degree (especially if affricated), the velarization in $C^y i$ is most important to perceiving the contrast. If $C^y i$ is understood as 'plain' $C + \acute{i}$, then this amounts to saying that it is the *vowel* \acute{i} that is most important to perceiving the contrast. Put differently, it is impossible to perceive the 'plainness' of C apart from \acute{i} . (Zubkova 1974, among others, makes this observation.) Once we understand $C\acute{i}$ as $C^y i$ instead, however, then we identify the crucial property as one involving the *consonant* (namely, velarization), rendering this situation analogous to that of $C^i a$, in which it is likewise a property of the consonant (palatalization) that is at issue. The problem of the status of " \acute{i} " disappears.

This gain in parallelism comes at the cost of a loss of parallelism in another sense: it is no longer possible to treat Russian as having a contrast 'plain' versus palatalized regardless of environment. It is the temptation of parallelism that leads researchers to infer from the contrast 'plain' versus palatalized in back vowel environments that the contrast must be the same before i : hence palatalized C^i versus plain $C\acute{i}$ in the usual Slavic transcription. A basic claim of this paper, however, is that Russian consonants contrast in *frontness/backness*, and that the realization of this contrast is intimately tied to the phonetic environment, as we have seen. It is only this interpretation of the facts that brings some reason to the otherwise mysterious allophonic rule of Russian we began with.

6. Conclusion

Phonological descriptions are rife with allophonic rules such as "/i/ → [ɨ] after plain C". Judging by the discussion these processes generally receive, one might infer that the major reason such rules exist is to help teach students the concept of the phoneme. A basic point of this paper has been that more attention to both phonetic detail and phonetic theories might aid in understanding what such rules are really about. This focus on understanding hinges, at least in this case, on some appeal to the functional notion of perceptual dispersion of contrast. Though the idea that *assimilatory* rules might have a basis in phonetics has a long history, this idea comes up much more rarely in the case of other kinds of allophonic rule such as this Russian one. To take another example, virtually all discussions of the rule by which English voiceless consonants are aspirated at the beginnings of words and stressed syllables limit themselves to stating this fact, sometimes also using it to draw the inference that the syllable is an important unit of phonology. Yet it is possible to explain this rule in part as the result of a contrast shift much like that of Russian (see Kingston and Diehl 1994 and references therein). A contrast such as *b* versus *p* is disfavored at the beginning of words or utterances, since voicing of obstruents is difficult in that position; hence "voiced" *b* is often realized as *p*. At the same time, the plain voiceless phoneme is shifted to voiceless aspirated *p^h*. Whether or not aspiration word-initially is truly the result of maintaining a perceptually good contrast in that position, the point is that it is worthwhile to pursue these questions rather than settle for statements about phonemes and distributions of allophones. It may be that the traditional terminological dichotomy between "allophonic" and "phonemic" processes, though serving an important purpose in phonology, has been unhelpful in this regard. The idea suggested here is that "/i/ → [ɨ] after plain C" is all about maintaining a phonemic contrast.

Appendix: the carrier sentences

The Russian and Irish materials were designed to be similar. There were two different tasks, one providing two of the carrier conditions, the other two more. Subjects were given written instructions in Russian or Irish respectively. For the first task, the instructions were as follows:

"Now we will read some short dialogues together. My portion of the dialogue is in parentheses. In each dialogue, I'll ask what word you said, as though I am hard of hearing, and you will repeat the word. Please repeat the word clearly, but not loudly. We'll read each dialogue three times."

The dialogues had the following form (the target word is underlined, and was capitalized on the third line). Translations are loose.

Russian

ja skʌ'ʒu 'slovə <u>rʌ'bʲi</u> ti'p'er'	I'll say the word <u>slaves</u> now
(kʌ'koʒi 'slovə?)	(Which word?)
<u>rʌ'bʲi</u>	<u>SLAVES</u>

Irish

<u>bʲi:</u> ə 'derhə mə ə'nɪʃ	<u>yellow</u> (is what) I'll say now
(ken 'fəkəl e: ʃɪn?)	(What word is that?)
<u>bʲi:</u>	<u>YELLOW</u>

The second task had the following instructions:

"Please read the following sentences three times each. Each time, try to stretch the last word out for two seconds."

For the Russian words, the effect of these instructions was to get the stressed syllable lengthened. (Subjects of both languages were very mixed in their ability to hold words in this way.) These materials had the following form:

Russian

ja skʌ'zal ni <u>rʌ'bʲi</u> , ʌ <u>drʌ'bi</u>	I said not <u>slaves</u> , but <u>stamp your feet!</u>
---	--

Irish

ni <u>bʲi:</u> ə du:r't' mə, ax <u>bi:</u>	(It was) not <u>yellow</u> that I said, but <u>be!</u>
--	--

For the first task, materials with the target words were interspersed with materials with filler words having other vowels and consonants. Though this was true also of the second task, this

task was intended to elicit a pronunciation contrasting similar target words, so that any idea of concealing the task was moot.

Notes

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1. A question that remains open, however, even assuming that functional forces play an important role in shaping phonologies, is the extent to which they have any place in a synchronic, 'psychologically real', description. That is, are they in direct play within the grammar of a language, as functional work within Optimality Theory might be taken to imply, or is their role indirect, shaping language through patterns of language change over time? (It is certainly possible to recast functional work within Optimality Theory in this latter way, though it is not a trivial move.) Though this question is important, it is worth keeping in mind that much useful work can be done without our knowing the answer to it. This article is meant to be neutral on the subject.

2. Another phoneme sometimes reported, ʃ^{h} , occurs marginally or not at all in contemporary Standard Russian. Palatalized velars might be considered phonemes due to historically borrowed words such as *lik'or* 'liqueur', *leg'um* 'legume', etc. *k'* is in fact very marginally phonemic based on the native vocabulary, due to one (Standard) Russian verb *tkat'* 'to weave' which in some forms presents *k'* before *o*, e.g., *tk'o'* 'you weave'.

3. The transcriptions in this paper abstract away from predictable vowel quality effects due to assimilation and vowel reduction.

4. As is well known, however, there are derivational suffixes that begin with *i* and, rather than undergo this rule, remain *i* and actually palatalize the preceding otherwise plain consonant, e.g., *lis + itsa* → *lis'i'tsa* (**l'is#sa*) 'fox (fem.)', (Gvozdev 1949). The output respects the allophonic rule, but the causality seems to be reversed. Such facts invite analysis making use of some notion of lexical level (as in Kiparsky 1982, 1985), or morphologically-governed phonology.

5. The situation in Polish is actually similar to that of Irish and Russian. There is a 'palatalization' contrast before /i/; however, /i/ is realized as a 'semi-high retracted front vowel' (Rothstein 1993) after the plain consonants. See Szpyra (1995) for a recent treatment of Polish palatalization.

6. For example, Japanese consonants before *i* might be transcribed as palatalized; similarly, though Russian rules out a palatalization contrast before *e* under suffixation and in native roots, a consonant before *e* is palatalized, not plain. (See (3).) Similarly, under conditions of hiatus such as *a + i* and *a + u*, the realizations *aji* and *awu* respectively are common.

7. In fact, there is evidence that 'plain' laterals are inherently velarized to some degree. See Sproat and Fujimura (1993) and Walsh Dickey (1997).

8. It is worth mentioning that velarization before *e* is often overlooked as well. Though consonants are palatalized before this vowel in native words, there are many borrowings violating

this regularity, and velarization is then evident, e.g., *kaʃ^ʷe* 'coffee'. (This velarization is most evident on stressed syllables, where vowel reduction does not take place.) Also, *e* does not palatalize a preceding consonant across a word boundary in Russian, leading to frequent pronunciations such as *v^ʲetəm* for *v + etəm* 'in this'.

9. Shcherba suggests that those who hear diphthongization are observing *ʃ* before a palatalized consonant, as in *bʃ^ʲ* 'to be', in which case there is indeed an *i*-like offglide from the vowel, as there is for other vowels before a palatalized consonant. Many other descriptions note this effect. However, the diphthongization of *ʃ* has a firm reality apart from this context. See below, as well as the references cited earlier. Shcherba also allows that *ʃ* might indeed be diphthongized in dialects other than his own.

10. I am very grateful to Máire Ní Chiosáin for arranging and conducting the Irish recording sessions, and for helping me construct the Irish materials.

11. An issue that arises when seeking some measure of the 'frontness' peak is that peak F2 as seen on a spectrogram may or may not coincide in time with peak F3 (or the trough of F1). Since it isn't really possible to guess what position would give the highest F2' according to the formula, F2 peak was taken as the best measurement position.

12. Irish speaker 2 provided only one repetition of tokens in two of the four sentential contexts employed. Therefore only a 2 factor Anova was performed on that data, taking consonant type, and palatalized versus velarized syllable, as factors.

13. The error bars in figure 3 indicate a range equal to twice the standard deviation. This measure of dispersion is broader than the 95% confidence intervals used in figures 1 and 2, and was chosen in order to make it more clear where there is token overlap. See the discussion below.

14. Displays for the other 4 speakers can be viewed at <http://ling.ucsc.edu/~padgett/papers.html>, or contact the author.

15. Kewley-Port and Watson (1994) and Hawks (1994) report just noticeable differences as low as about 1.5% for this frequency range. However, these values are obtained by highly trained subjects under optimal listening conditions, and Hawks concludes that "discriminability of vowels in natural speech communication modes should be based in larger perceptual units." Previous studies mostly report values in the 3-5% range, as Kewley-Port and Watson note.

16. Jim McCloskey informs me that this heavy affrication is a feature of the speech of younger speakers in Northern Ireland in particular.

17. As José Hualde reminds me, there may also be an articulatory explanation for the preference for palatalized coronals: palatalization has its roots in coarticulation with a palatal vocoid, and such coarticulation would more directly affect lingual consonants (that is, velars and coronals) than labial ones. John Kingston, on the other hand, notes an alternative perceptual account. Given the greater F2 variation in the case of bilabials noted above, independent of palatalization, a more extreme difference between F2 values for palatalized versus non-palatalized bilabials might be required to render the contrast perceptually robust, in comparison to coronals. This could be true

apart from any consideration of affrication. The discussion here is consistent with either of these possibilities, but is intended to suggest that the *number of perceptual cues* matters as well. The fact that palatalized bilabials are disfavored in syllable-final or pre-consonantal position, in particular, would not follow from either of these alternative accounts alone.

18. A contributing factor here is that Russian has a letter for "ʃ" that is separate from the letter for *i*, and the Russian name for this letter is in fact pronounced [ʃi], or perhaps [ʃʲi]. This is in part why Russians are highly aware of this sound. In our terms, this means that Russian uses a separate letter to spell velarization of a preceding consonant before *i*. Russian handles the spelling of palatalization before vowels precisely analogously: each vowel is spelled differently depending on whether the previous consonant is palatalized or not.

References

- Antonova, Dina Nikitichna. 1988. *Fonetika i intonatsiia*. Moscow: Russkii Iazyk.
- Avanesov, Ruben Ivanovich, and Vladimir Nikolaevich Sidorov. 1945. *Ocherk grammatiki russkogo literaturnaia iazyka, chast' 1. Fonetika i morfologia*. Moscow: Gosudarstvennoe uchebno-pedagogicheskaja Izdatel'stvo.
- Bender, Byron W. 1969. *Spoken Marshallese*. Honolulu: University of Hawaii Press.
- Bondarko, L. V. 1977. *Zvukovoi stroi sovremennogo russkogo iazyka*. Moscow, Prosveshchenie.
- Boyanus, S.C. 1967. *Russian pronunciation*. Cambridge, MA: Harvard University Press.
- Carlson, R., B. Granström, and Gunnar Fant. 1970. Some studies concerning perception of isolated vowels. *Speech transmission laboratory quarterly progress and status report. Royal Institute of Technology, Stockholm* 2-3:19-35.
- Choi, John. 1992. *Phonetic underspecification and target-interpolation: an acoustic study of Marshallese vowel allophony*. Ph.D. dissertation, UCLA.
- Choi, John. 1995. An acoustic-phonetic underspecification account of Marshallese vowel allophony. *Journal of phonetics* 23:323-347.
- Chomsky, Noam, and Morris Halle. 1968. *The sound pattern of English*. New York: Harper & Row.
- Comrie, Bernard, and Greville C. Corbett, eds. 1993. *The Slavonic languages*. New York: Routledge.
- Derkach, M.F., R.Ia. Gumetskii, B.M. Gura, and M.E. Chaban. 1983. *Dinamicheskie spektry rechevykh signalov*. Lvov: Vishcha Shkola.
- Evans-Romaine, Dorothy Kathleen. 1998. *Palatalization and coarticulation in Russian*. Ann Arbor: Ph.D. dissertation, University of Michigan.
- Fant, Gunnar. 1960. *Acoustic theory of speech production*. The Hague: Mouton.
- Flemming, Edward. 1995. *Auditory representations in phonology*. Doctoral Dissertation, UCLA, Los Angeles, CA.
- Goldsmith, John. 1976. *Autosegmental phonology*. PhD dissertation, MIT [published 1979, Garland: New York].
- Gvozdev, A. N. 1949. *O fonologicheskikh sredstvakh russkogo iazyka: sbornik statei*. Moscow, Izdatel'stvo akademii pedagogicheskikh nauk RSFSR.
- Halle, Morris. 1959. *The Sound Pattern of Russian*. Mouton, The Hague.
- Hamilton, William S. 1980. *Introduction to Russian phonology and word structure*. Columbus, OH: Slavica Publishers.
- Hawks, John W. 1994. Difference limens for formant patterns of vowel sounds. *Journal of the acoustical society of America* 95.2:1074-1084.
- Itô, Junko, and Armin Mester. 1995. Japanese phonology. In *Handbook of Phonological Theory*, edited by J. Goldsmith. Cambridge, MA: Blackwell, pp. 817-838.
- Johnson, Keith, Edward Flemming, and Richard Wright. 1993. The hyperspace effect: phonetic targets are hyperarticulated. *Language* 69.3:505-528.
- Jones, Daniel, and Dennis Ward. 1969. *The phonetics of Russian*. Cambridge: Cambridge University Press.
- Kawasaki, Haruko. 1982. *An acoustical basis for universal constraints on sound sequences*. Ph.D. dissertation, University of California, Berkeley.

- Keating, Patricia A. 1990. The window model of coarticulation: articulatory evidence. In *Papers in laboratory phonology I: between the grammar and physics of speech*, edited by J. Kingston and M. E. Beckman. Cambridge: Cambridge University Press, pp.451-470.
- Kewley-Port, Diane, and Charles S. Watson. 1994. Formant-frequency discrimination for isolated English vowels. *Journal of the acoustical society of America* 95.1:485-496.
- Kingston, John. 1990. Articulatory binding. In *Papers in laboratory phonology I*, edited by J. Kingston and M. E. Beckman. Cambridge: Cambridge University Press, pp.406-434
- Kingston, John, and Randy L. Diehl. 1994. Phonetic knowledge. *Language* 70.3:419-454.
- Kiparsky, P. 1982. Lexical phonology and morphology. *Linguistics in the Morning Calm*. I. S. Yang. Seoul, Hanshin. 2: 3-91.
- Kiparsky, P. 1985. "Some consequences of Lexical Phonology." *Phonology* 2: 85-138.
- Kohler, K.J. 1990. Segmental reduction in connected speech in German: phonological facts and phonetic explanations. In *Speech production and speech modelling*, edited by W. J. Hardcastle and A. Marchal. Dordrecht: Kluwer, pp.69-72.
- Kuznetsova, Adol'fina Mikhailovna. 1969. Nekotorye voprosy foneticheskoi kharakteristiki iavleniia tverdosti - miagkosti v russkikh govorakh. In *Eksperimental'no-foneticheskoe izuchenie russkikh govorov*, edited by S. S. Vysotskii. Moscow: Nauka, pp. 35-137.
- Ladefoged, Peter, and Jenny Ladefoged. 1997. Phonetic structures of Scottish Gaelic. In *UCLA Working papers in phonetics*, pp. 114-153.
- Leben, Will. 1973. *Suprasegmental phonology*. Cambridge, MA: Doctoral dissertation, MIT.
- Liljencrants, Johan, and Björn Lindblom. 1972. Numerical simulation of vowel quality systems: the role of perceptual contrast. *Language* 48.4:839-862.
- Lindblom, B. 1986. "Phonetic universals in vowel systems." In *Experimental Phonology*, edited by J. Ohala and J. Jaeger. Orlando: Academic Press, pp. 13-44.
- Lindblom, Björn. 1990. Explaining phonetic variation: a sketch of the H&H theory. In *Speech production and speech modelling*, edited by W. J. Hardcastle and A. Marchal. Dordrecht: Kluwer, pp. 403-439.
- Lombardi, Linda. 1991. *Laryngeal features and laryngeal neutralization*: PhD dissertation, University of Massachusetts, Amherst [published 1994, Garland: New York].
- Lyovin, Anatole V. 1997. *An introduction to the languages of the world*. Oxford: Oxford University Press.
- McCarthy, John J. 1986. OCP Effects: Gemination and antigemination. *Linguistic Inquiry* 17:207-263.
- Maddieson, Ian, and Kristin Precoda. 1992. Syllable structure and phonetic models. *Phonology* 9:45-60.
- Martinet, André. 1952. Function, structure, and sound change. *Word* 8.1:1-32.
- Martinet, André. 1964. *Elements of general linguistics*. Chicago: University of Chicago Press.
- Martinet, André. 1974. *Economía de los cambios fonéticos*. Madrid: Editorial Gredos [Translation into Spanish of *Économie des changements phonétiques*, 1955.].
- Mayo, Peter. 1993. Belorussian. In *The Slavonic languages*, edited by B. Comrie and G. G. Corbett. New York: Routledge, pp. 887-946.
- Meillet, Antoine. 1951. *Obshch斯拉vianskii iazyk*. Moscow: Izdatel'stvo Innostrannoi literatury [Translation into Russian of *Le Slave Commun*, 2nd edition].

- Moon, Seung Jae, and Björn Lindblom. 1994. Interaction between duration, context, and speaking style in English stressed vowels. *Journal of the Acoustical Society of America* 96.1:40-55.
- Ní Chiosáin, Máire and Jaye Padgett. To appear. "Markedness, segment realisation, and locality in spreading." In Lombardi, Linda, ed., *Segmental phonology in Optimality Theory*. Cambridge: Cambridge University Press.
- Ohala, John J. 1983. "The origin of sound patterns in vocal tract constraints." In P. MacNeilage, ed., *The production of speech*. Springer Verlag, New York, pp.189-216.
- Ohala, John J. 1990. "The phonetics and phonology of aspects of assimilation." In J. Kingston and M. Beckman, eds., *Papers in laboratory phonology, volume 1*. Cambridge: Cambridge University Press, pp. 258-275.
- Ohala, John J., and Haruko Kawasaki-Fukumori. 1997. Alternatives to the sonority hierarchy for explaining segmental sequential constraints. In *Language and its ecology: essays in memory of Einar Haugen*, edited by S. Eliasson and E. H. Jahr. Berlin: Mouton de Gruyter, pp. 343-365.
- Öhman, S.E.G. 1966. Coarticulation in VCV utterances: spectrographic measurements. *Journal of the acoustical society of america* 39:151-168.
- Padgett, Jaye. 1995. *Stricture in feature geometry*. Stanford, CA: CSLI Publications.
- Prince, Alan, and Paul Smolensky. 1993. "Optimality theory: Constraint interaction in generative grammar." Ms., Rutgers University and University of Colorado, Boulder.
- Purcell, Edward T. 1979. Formant frequency patterns in Russian VCV utterances. *Journal of the Acoustical Society of America* 66.6:1691-1702.
- Reformatskii, A.A. 1957. Fonologicheskie zametki. *Voprosy iazykoznaniiia* 6 (2):101-2.
- Reformatskii, Aleksandr Aleksandrovich. 1958. O korrelatsii "tverdykh" i "miagkikh" soglasnykh (v sovremennom russkom literaturnom iazyke). In *Mélanges linguistiques offerts à Emil Petrovici par ses amis étrangers a l'occasion de son soixantième anniversaire*. Bucarest: Editura Academiei Republicii Populare Romine, pp. 494-499.
- Rothstein, Robert A. 1993. Polish. In *The Slavonic languages*, edited by B. Comrie and G. G. Corbett. New York: Routledge, pp. 686-758.
- Sagey, Elizabeth. 1986. *The Representation of Features and Relations in Nonlinear Phonology*. Doctoral dissertation, MIT, Cambridge, MA.
- Shcherba, Lev Vladimirovich. 1912. *Russkie glasnye v kachestvennom i kolichestvennom otnoshenii*. St. Petersburg: Tipografiia IU. N. Erlikh.
- Sproat, Robert, and Osamu Fujimura. 1993. Allophonic variation in English /l/ and its implications for phonetic implementation. *Journal of Phonetics* 21:291-311.
- Steriade, Donca. 1995. Laryngeal neutralization and laryngeal features. Ms, UCLA. [Based on a paper presented at the South Western Workshop on Optimality Theory, 1995, University of Arizona, Tuscon.]
- Sussex, Roland. 1992. Russian. In *International encyclopedia of linguistics*, edited by W. Bright. New York: Oxford University Press, pp.350-358.
- Sussman, Harvey M., Helen A. McCaffrey, and Sandra A. Matthews. 1991. An investigation of locus equations as a source of relational invariance for stop place categorization. *Journal of the Acoustical Society of America* 90.3:1309-1325.
- Szpyra, Jolanta. 1995. *Three tiers in Polish and English phonology*. Lublin: Wydawnictwo Uniwersytetu Marii Curie-Sklodowskiej.

- Takatori, Yuki. 1997. *A study of constraint interaction in Slavic phonology*. New Haven: Ph.D. dissertation, Yale University.
- Trubetzkoy, Nikolai. 1969. *Principles of Phonology*. Berkeley: University of California Press.
- Walsh Dickey, Laura. 1997. *The phonology of liquids*. Doctoral dissertation, University of Massachusetts, Amherst.
- Zubkova, Liudmila Georgievna. 1974. *Foneticheskaia realizatsiia konsonantnykh protivopolozhonii v russkom iazyke*. Moscow: Universitet Druzhby Narodov.