[To appear in *Natural Language and Linguistic Theory*]

Contrast and Post-Velar Fronting in Russian*

Jaye Padgett - University of California, Santa Cruz

There is a well-known rule of Russian whereby /i/ is said to be realized as [ɨ] after non-palatalized consonants. Somewhat less well-known is another allophonic rule of Russian whereby only [i], and not [ɨ], can follow velars within a morphological word. This latter rule came about due to a sound change in East Slavic called post-velar fronting here: *kɨ* > *kʲi* (and similarly for the other velars). This paper examines this sound change in depth, and argues that it can be adequately explained only by appeal to the functional notions of perceptual distinctiveness of contrast and neutralization avoidance. Further, these notions crucially require a *systemic* approach to phonology, in which the wellformedness of any form must be evaluated with reference to the larger system of contrasts it enters into. These notions are formalized in a modified version of Dispersion Theory (Flemming 1995a), a systemic theory that incorporates these functional notions into Optimality Theory (Prince and Smolensky 1993).

1. Introduction

It is well known that Russian consonants contrast in palatalization. Also well known are certain allophonic rules connected to this palatalization contrast. One such rule requires that the phoneme /i/ be realized as high central unrounded [ɨ] after non-palatalized consonants, and [i] elsewhere, e.g., *bʲitʲ* 'to beat' from /bʲitʲ/ versus *bɨtʲ* 'to be' from /bitʲ/. Another concerns velar consonants, which are more limited in their ability to contrast in palatalization: within words, velars can be followed only by [i] and not by [ɨ], e.g., *xʲitrɨj* 'clever' from /xitrij/, cf. **xɨtrɨj*. (In addition, velars before [i] are allophonically palatalized, as shown.) This latter rule arose due to a sound change in East Slavic occurring between the twelfth and fourteenth centuries. Before that time just the opposite facts held: velars could be followed only by [ɨ] and not by [i]. The vowel [ɨ] then fronted to [i] after velars, a change I will call post-velar fronting, e.g., *xɨtrɨj* > *xʲitrɨj*.

Though these allophonic processes are well described, there is a sense in which they remain poorly understood, and in this they are typical of allophonic processes. Phonologists uncover allophonic rules, infer the notion of a phoneme, and make other inferences based on allophone distributions, such as the existence of the syllable based on allophonic rules like English aspiration. Yet why do allophonic rules exist at all? Further, why does a language such as Russian have the particular allophonic rules it has, and not others? In this sense allophonic processes, especially non-assimilatory ones, remain largely mysterious.

There is an old view that sound changes, and phonological patterns, are at least in part explained by functional phonetic considerations. This view was developed notably by Martinet (1952, 1964, 1974), working especially on problems of historical sound change. Martinet took the sometimes conflicting needs of articulatory economy and perceptual distinctiveness to play an important role in explaining sound change and the resultant synchronic phonological systems. More recently, Liljencrants and Lindblom (1972), and Lindblom (1986, 1990), have applied these functional ideas in more explicit formulations in order to derive broad typological generalizations about phoneme inventories. Other work on the functional underpinnings of phonology includes Ohala (1983, 1990), Kohler (1990), and Kingston and Diehl (1994), among many others.

The main goal of this paper is to argue that such functional notions, especially the idea that phonological contrasts should be maintained and should be perceptually distinct, can be crucial to an understanding of allophonic processes, and to the sound changes that produce them. In particular, the choice of allophone can depend on the need to maintain or improve upon contrasts among phonemes.[1] This idea will be applied to the sound change of post-velar fronting outlined above, and the allophonic distribution resulting from it. The possibility that at least some allophonic processes have their origins in the needs of contrast maintenance is interesting, since allophones of a phoneme are of course defined by their inability to contrast among themselves. The results here suggest that, even if allophones do not contrast (by definition), they can have a great deal to do with contrast. One can make the same argument based on the variation between [i] and [ɨ] in Russian (Padgett 2001a,b).

A second goal of this paper is to demonstrate and motivate one means of appealing to contrast, and the perceptual goodness of contrast, within a model of phonology. The model employed is a modified version of Dispersion Theory (Flemming 1995a), itself a development of functional ideas such as those of Martinet and Lindblom, cast within Optimality Theory (Prince and Smolensky 1993).[2] Dispersion theory is crucially distinguished by its assumption that wellformedness must be evaluated with direct reference to the system of contrasts a form enters into. Inputs and candidate outputs consist not of single forms but sets of forms assumed to be in contrast. This assumption allows for a simple and direct means of formalizing the notion of neutralization avoidance. It also allows for regulation of the perceptual distinctiveness of contrast by means of constraints on the output. It will be argued here that both of these notions are indispensable for an explanation of the Russian facts.

Dispersion Theory has been taken by some to be a theory of phoneme inventories alone (Boersma 1998, for example), rather than a theory of phonology, that is, a way of deriving phonological *forms*. Here I show that this is not the case, once the model is fleshed out with the necessary assumptions. Putting these particular points about Dispersion Theory aside, however, the ideas here are influenced by those of Steriade (1997), Hayes (1999), Kirchner (1997), Boersma (1998), and others who attempt to incorporate functional explanations into phonology by exploiting the central tenet of Optimality Theory that phonologies result from the ranking and interaction of simple (and in these works phonetically grounded) constraints.

Section 2 presents the facts of Russian to be accounted for. In section 3 the basic assumptions of the model are laid out. The Russian facts are analyzed within that model in section 4. This is the heart of the paper, presenting an analysis of sound changes affecting Common Slavic and East Slavic; it is from this analysis that most of the arguments proceed. Section 5 takes up these arguments and addresses larger questions arising from the analysis. Section 6 is the conclusion.

2. The Russian facts

2.1 Background

Russian has the five vowel phonemes /i,e,a,o,u/. Its consonant inventory is shown below.

(1)

	Labial		Dental		Post-alveolar		Palatal	Velar	
Stop	p	p^j	t	t^j				k	k^j
	b	b^j	d	d^j				g	g^j
Fricative	f	f^j	s	s^j	ʃ	$ʃ^j$:		x	x^j
	v	v^j	z	z^j	ʒ				
Affricate			ts			$tʃ^j$			
Nasal	m	m^j	n	n^j					
Lateral			l	l^j					
Rhotic			r	r^j					
Glide							j		

Most consonants are 'paired', to use terminology traditional to Slavic linguistics, meaning that they contrast palatalized and non-palatalized variants. In the case of velars this contrast is limited, as we will see. The consonants /j,ts,$tʃ^j$,ʒ,ʃ,$ʃ^j$:/ are unpaired.[3]

Below are shown minimal pairs illustrating the palatalization contrast for paired consonants.[4] Palatalization is contrastive before back vowels, shown in (2)a, word-finally, (2)b, and pre-consonantally, (2)c. The contrast in the latter position is heavily restricted, due to assimilation or loss of palatalization in that environment.

(2)	a.	*mat*	'foul language'	*m^jat*	'crumpled (past part.)'
		rat	'glad'	*r^jat*	'row'
		vol	'ox'	*v^jol*	'he led'
		nos	'nose'	*n^jos*	'he carried'
		nu-ka	'now then!'	*n^juxa*	'scent (gen.sg.)'
		suda	'court of law (gen.sg.)'	*s^juda*	'here, this way'
	b.	*mat*	'checkmate'	*mat^j*	'mother'
		krof	'shelter'	*$krof^j$*	'blood'
		ugol	'corner'	*$ugol^j$*	'(char)coal'
		v^jes	'weight'	*$v^j es^j$*	'entire'
	c.	*polka*	'shelf'	*pol^jka*	'polka'
		tanka	'tank (gen.sg.)'	*tan^jka*	(name)
		v^jetka	'branch'	*$f^j et^j$ka*	(name)
		gorka	'hill'	*gor^jko*	'bitterly'

Palatalization is generally said to be non-contrastive before /e/, with paired consonants predictably palatalized there (so, 'unpaired'), as in the examples below. However, some loan words such as *tennis* and *tent* retain non-palatalized paired consonants before /e/, at least for certain speakers, raising the possibility of treating palatalization before /e/ as contrastive within roots. The rule nevertheless holds at morpheme boundaries, regularly triggering alternations, as in nominative singular *dom* 'house', *brat* 'brother' versus prepositional *dom^{j}e* and *brat^{j}e*.

(3)	*s^{j}est^j*	'to sit down'	**sest^j*	*n^{j}et*	'no'	**net*
	p^{j}et^j	'to sing'	**pet^j*	*gd^{j}e*	'where'	**gde*
	v^{j}et^{j}er	'wind'	**veter*	*k^{j}em*	'who (instr.sg.)'	**kem*

Paired consonants do contrast in palatalization before /i/, as shown below. However, the realization of /i/ depends on this palatalization contrast according to a well known allophonic rule.

(4)	*v^{j}it^j*	'to twist, weave'	*vɨt^j*	'to howl'
	b^{j}it	'beaten'	*bɨt*	'way of life'
	t^{j}ikat^j	'to tick'	*tɨkat^j*	'to address in familiar form'
	xod^{j}i	'walk!'	*xodɨ*	'gaits'
	s^{j}ito	'sieve'	*sɨto*	'sated (neut.sg.)'

According to the traditional statement of this rule, abstracting across theoretical schools, e.g., Trubetzkoy (1969), Avanesov and Sidorov (1945), Halle (1959), Hamilton (1980), Sussex (1992), the phoneme /i/ is realized as central unrounded [ɨ] after plain (non-palatalized) consonants, so long as no pause intervenes, i.e. within something like the phonological phrase. It is [i] otherwise. (The vowel [ɨ] is often transcribed as "y" in the Slavic literature.)

This allophonic rule is very regular and productive. (5)a shows examples of word-initial [i] varying with [ɨ], the latter following a plain consonant. This can lead to 'minimal pairs' (comparing words to phrases) of the sort shown in (5)b, as noted in Gvozdev (1949), Reformatskii (1957), and Halle (1959).

(5)	a.	***i**van*	'Ivan'		***k ɨ**vanu*	'to Ivan'
					*bra**t ɨ**vana*	'Ivan's brother'
		***i**tal^{j}ija*	'Italy'		***v ɨ**tal^{j}iju*	'to Italy'
					*na**d ɨ**tal^{j}ijej*	'above Italy'
	b.	***i**ra*	'Ira (name)'		***k ɨ**r^{j}e*	'to Ira'
				cf.	***k^{j}i**r^{j}e*	'Kira (dat.sg.)'
		***i**tal^{j}ija*	'Italy'		***v ɨ**tal^{j}iju*	'to Italy'
				cf.	***v^{j}i**tal^{j}iju*	'Vitalij (dat.sg.)'

As would be expected, [ɨ] does not occur word-initially (unless preceded in the phrase by a word-final plain consonant, as above): there are no words such as **ɨvan* or **ɨtalija*. Nor does [ɨ] occur following a vowel in Russian, e.g., **poɨgrat^j*, **poɨskat^j*, cf. occurring *poigrat^j* 'to play a little', *poiskatʲ* 'to look around for'. We find the variation also within words, when a morpheme that is otherwise [i]-initial follows one ending in a plain consonant, as shown in (6)a (prefix + stem) and (6)b (stem + suffix). Many morphemes display this variation within the word.[5] It is also found in so-called stump compounds such as *pʲedɨnstʲitut* derived from ***pʲed**agogʲitʃeskʲij **instʲitut*** 'pedagogical institute'.

(6)	a.	*igratʲ*	'to play (imperf.)'	*sɨgratʲ*	'to play (perf.)'
		iskatʲ	'to search (imperf.)'	*otɨskatʲ*	'to find'
	b.	*ugol*	'corner (sg.)'	*uglɨ*	(pl.)
		ugolʲ	'(char)coal (sg.)'	*uglʲi*	(pl.)

The traditional statement of this allophonic rule begs certain questions. In particular, why should /i/ become [ɨ] after a plain consonant? Could such a rule occur in English or any other language having 'plain' consonants? Farina (1991) proposes an account that addresses these questions well. She assumes that palatalization is a binary contrast, so that 'plain' consonants are actually specified [+back] in opposition to [-back] palatalized ones. The allophonic rule can then be understood as a simple example of assimilation, as shown in (7)a; [ɨ] is just the [+back] counterpart of [i]. The prediction is therefore that such a rule could not hold in English, since English consonants are genuinely 'plain', that is, lacking any [back] specification. This account also fits well with the phonetic facts, since Russian 'plain' consonants are indeed velarized, as many have noted, e.g., Trubetzkoy (1969), Reformatskii (1958), Fant (1960), Öhman (1966), Purcell (1979), Evans-Romaine (1998).

```
(7)  a.   C      i      ➜     C     ɨ           b.    Cˠ     i
          |      |            |   ⁄ ǂ                 |      |
       [+bk] [-bk]         [+bk] [-bk]             [+bk] [-bk]
```

Padgett (2001a) argues, based on a phonetic study of Russian and Irish, for a reinterpretation of this allophonic rule: the sound "ɨ" in Russian is in fact not [ɨ], but [i] preceded by a velarized consonant. In other words, sequences normally transcribed as [pɨ] are in fact [pˠi], as in (7)b. Velarization before [i], it is argued, follows from the need to keep the palatalization contrast perceptually distinct. Languages with a palatalization contrast generally avoid contrasts like [pʲi] versus [pi], that is, palatalized versus plain before [i]. While some languages neutralize the contrast in this environment, others preserve it by velarizing the 'plain' consonant. The significant implication of these ideas is that an allophonic rule such as "/ɨ/ → [i]" can be explained, rather than simply described, by appeal to functional considerations. The present paper makes a similar argument with respect to post-velar fronting.

2.2 Velars and post-velar fronting

The previous discussion constitutes background. In this section I turn to the main facts to be analyzed. The consonant chart in (1) includes consonants that are either unpaired for palatalization or significantly limited in this contrast. These can be divided into two categories.

There are those which are invariably either palatalized or not: palatalized [tʃʲ,ʃʲ:] (to which we might add palatal [j]), and non-palatalized [ts,ʃ,ʒ]. Then there are the velars, which are often said not to contrast in palatalization at all, but to vary in palatalization allophonically, with palatalized versions occurring before the front vowels [i,e] and plain versions elsewhere. (8)a illustrates velars before front vowels, (8)b before [a,o,u], and (8)c word-finally and preconsonantally. Here again we see variation triggered by suffixation, as in nominative singular *ruka* 'hand', *knʲiga* 'book', and *vzdox* 'sigh', versus prepositional case *rukʲe*, *knʲigʲe*, and *vzdoxʲe*, or nominative plural *rukʲi*, *knʲigʲi*, and *vzdoxʲi*, respectively. (As the terminology and transcriptions imply, palatalized velars differ from merely phonetically fronted velars as in English. See Keating and Lahiri 1993.)

(8)	a.	*kʲipa*	'pile'	b.	*kubʲik*	'brick'
		kʲem	'who (instr.sg.)'		*koʃka*	'cat'
					kaplʲa	'drop'
		gʲipkʲij	'flexible'		*gurt*	'herd, flock'
		gʲerp	'(coat of) arms'		*got*	'year'
					galotʃʲka	'tick'
		xʲitrostʲ	'cunning'		*xudo*	'harm, evil'
		xʲerʲes	'sherry'		*xot*	'motion'
					xam	'boor'
	c.	*sok*	'juice'			
		moskvʲe	'Moscow (dat.sg.)'			
		mʲik	'moment, instant'			
		gdʲe	'where'			
		ix	'them, their'			
		puxlʲenʲkʲij	'chubby'			

In fact, palatalization in velars is contrastive today before [a,o,u] (Gvozdev 1949:63-5, Flier 1982). First, there are a fair number of historical loans with palatalized velars in this context, e.g., *kʲurarʲe* 'curare', *lʲikʲor* 'liqueur', *lʲegʲum* 'legume', *gʲotʲe* 'Goethe', etc. There is also famously one verb in Contemporary Standard Russian, *tkatʲ* 'to weave', which displays [kʲ] before [o] in some of its conjugated forms, for example *tkʲoʃ* 'you weave' versus *tku* 'I weave'. Other verb stems ending in velars normally mutate to postalveolars under these circumstances instead, as in *pʲeku* 'I bake' versus *pʲetʃʲoʃ* 'you bake'. The word *tkatʲ* behaved this way until about a century ago, when all forms were leveled to [k]-final (Flier 1982). In non-standard dialects this leveling affects other verbs, giving for example *pʲekʲoʃ* 'you bake'. In any case, palatalization alternations triggered by other back-vowel suffixes have been extended to velars, e.g., *kiosk* 'kiosk' vs. *kioskʲor* 'kiosk attendant', *makak* 'macaque' vs. *makakʲonok* 'baby macaque'. Flier (1982) argues plausibly that velars have contrasted in palatalization before back vowels since the early eighteenth century.

On the other hand, velar palatalization remains predictable in other contexts.[6] Most relevant here, velars followed by the phoneme /i/ are always palatalized. In conjunction with the rule backing /i/ to [ɨ], this rule raises a puzzle. If velars are palatalized by front vowels, but the frontness of /i/ depends on the previous consonant, how is the outcome of underlying /ki/, /gi/, /xi/

determined? If the underlyingly plain velars were to determine the outcome, then according to the rule governing [i]/[ɨ] we would expect [kɨ], [gɨ], and [xɨ]. In fact, this is just what occurs *across* words in Russian (see (5)b again). *Within* words, we instead find only [k^ji], [g^ji], and [x^ji], as we have seen. This latter fact follows rather naturally given the rule due to Farina (1991) shown in (7). Assuming that velars are unspecified for [back] (unlike other 'plain' consonants), since they do not contrast in palatalization before /i/, this [i]-backing rule could not apply:

```
(9)   Input           p    i                k    i
                      |    |                     |
                   [+bk] [-bk]                 [-bk]

      i-backing       p    ɨ
                      |  / ǂ                N/A
                   [+bk] [-bk]

      Output          p    ɨ                k    i
                      |  /                       |
                   [+bk]                       [-bk]
```

It should be noted that this account crucially depends on assumptions about the underlying representation. Specifically, it assumes that [i], but not [ɨ], occurs underlyingly. Given the *input* /kɨ/, we would still require a means of ruling out [kɨ] at the surface. For those adopting 'richness of the base' within Optimality Theory (Prince and Smolensky 1993, see below), or for other reasons entertaining underlying /kɨ/, the problem therefore remains.

The problem is there for *everyone* when we consider this rule from a historical standpoint. The source of the rule is a sound change that affected East Slavic (the precursor to Russian) between roughly the twelfth and fourteenth centuries. Before that time, velars did not occur before front vowels at all, while they did occur before [ɨ]. Before /i/, in other words, the reverse of today's facts held: only [kɨ], [gɨ], and [xɨ] occurred, and [k^ji], [g^ji], and [x^ji] were impossible. During the period mentioned, post-velar fronting occurred: sequences like [kɨ] fronted to [k^ji], as shown below.[7,8]

(10)	a.	*kɨjev*	>	*k^jijev*	'Kiev'
		rukɨ	>	*ruk^ji*	'hands (acc.pl.)'
	b.	*$gɨb^jel^j$*	>	*$g^jib^jel^j$*	'ruin/death'
		drugɨ	>	*$drug^j$i*	'friends (acc.pl.)'
	c.	*xɨtrɨj*	>	*x^jitrɨj*	'clever'
		pastuxɨ	>	*$pastux^j$i*	'shepherds (acc.pl.)'

Why did post-velar fronting occur? Within the literature on Slavic historical phonology there is no entirely satisfactory answer to this question. Jakobson (1929), in a seminal paper arguing for the importance of viewing sound change in light of a phonological system, related the change to the emerging palatalization contrast in Russian: as we saw in section 2.1, [i] and [ɨ] are in complementary distribution, with the latter occurring after non-palatalized consonants. [i] and [ɨ] arguably had this status by the time of post-velar fronting. Jakobson suggests that there is a tendency to unify the variants of a phoneme by generalizing the 'fundamental' variant, in this case [i], after a consonant unpaired for palatalization. Velars were unpaired, because at an earlier stage of the language palatalized velars had mutated to palato-alveolars (e.g., k^j → *tʃ*). In fact, velars were the only unpaired consonants followed by [ɨ], hence (according to Jakobson) the fronting to [i] after velars (with concomitant secondary palatalization.) The notion that languages tend to unify variants of a phoneme has not received much support. However, it was a key insight of Jakobson's that the unpaired status of the velars might be important.[9]

The explanation I offer here shares with Jakobson's the view that post-velar fronting can be understood only in light of the system of contrasts of the language at the time. Post-velar fronting is particularly puzzling when viewed 'syntagmatically', that is, in terms of the local environment in the string containing the [ɨ]. Given what we know about velars and the vowels [i] and [ɨ], there is simply no compelling answer to the question why [ɨ] should have fronted after velars. It obviously cannot be viewed as any kind of assimilation, for instance. Nor is it a dissimilation: though we might consider both velars and [ɨ] to be back, it is equally true that both palatalized velars and [i] are front.

Suppose instead we view the problem from the paradigmatic perspective of the system of contrasts in the language at the time. During the period when post-velar fronting occurred, Russian had a system of contrasts that might be represented schematically as in (11)b, as opposed to the possible system (11)a. Here *p* stands in for labial and dental places of articulation, which contrasted $p^j i$ versus *pɨ*, $l^j i$ versus *lɨ*, and so on, as they do today. The velars differed importantly in lacking this contrast, due to earlier sound changes of Common Slavic, commonly known as velar palatalizations, that mutated velars to other places of articulation before front vocoids, as illustrated. The idea being pursued is that, while *pɨ* was not free to front to $p^j i$, due to a pressure to preserve contrasts, *kɨ* could front to $k^j i$ without endangering contrast, because of the 'gap' in the system of contrast left by velar mutation. Further, post-velar fronting was *motivated* by a desire to optimize the perceptual distinctiveness of contrasts. In particular, the contrast $k^j i$ versus *ku* is better than *kɨ* versus *ku*, for the same reason that the contrast *i* versus *u* is better than *ɨ* versus *u*. The fact that a velar precedes is only indirectly relevant: the former mutation process opened up a gap only where velars preceded.[10]

(11)	a.	*pi*	*pɨ*	*pu*	b.	*pi*		*pɨ*	*pu*	c.	*pi*	*pɨ*	*pu*
		ki	*kɨ*	*ku*			←	*kɨ*	*ku*		$k^j i$		*ku*
						↓					*tʃi*		
						tʃi							

The idea that fronting occurred only after velars because it would otherwise neutralize contrast was anticipated by Avanesov (1947), though few discussions of Russian historical phonology have noted this suggestion. However, it has remained unclear why the change occurred at all, and the idea that the perceptual distance of contrast motivated it has not arisen before, so far as I know. What both ideas, neutralization avoidance and perceptual goodness of contrast, have in common, I will argue, is a particularly direct appeal to the larger *system* of contrasts. In particular, I assume that the phonological evaluation of any form requires direct reference to contrasting forms. This systemic view of markedness is a clear departure from the usual practice in phonology.[11] The challenge before us is to make these ideas more explicit within the framework of Optimality Theory. This is the goal of the following section.

3. A systemic theory of contrast

3.1 Idealization in phonology

The key idea being explored here is that phonological patterns depend in part on constraints requiring that contrasts be maintained, and that they be perceptually distinct. (Compare Saussure 1959 on the first notion especially; see Anderson 1985, pp.47-9 for discussion). Taking up work of Martinet (1952, 1964, 1974) in particular, the idea is that wellformedness can be understood only with reference to a larger *system* of contrasts. More broadly, Martinet's main assumptions were, first, that the perceptual distinctiveness of contrasts should be maximized, and second, that articulatory effort should be minimized. Naturally these desires can conflict. The formal model implementing these notions here is a modified version of Dispersion Theory (Flemming 1995a), itself roughly based on ideas of Martinet, and Lindblom (1986, 1990), and cast within Optimality Theory (Prince and Smolensky 1993).

A major challenge to this kind of explanation involves formalizing the ideas of contrast preservation and perceptual distinctiveness. As a first step, consider the fact that what needs to be evaluated are not individual forms, but groups of forms in contrast, as we saw in (11). How can this be accomplished? First, following Flemming (1995a), I understand the possible inputs and candidate outputs within Optimality Theory to include not only individual forms, but also sets of forms. Flemming's analyses focus largely on sets of single segments, e.g., the set *i*, *ɨ*, *u*. In fact, Boersma (1998:361) criticizes Dispersion Theory for being a theory of phoneme inventories only. Though the discussion in Flemming (1995a) makes clear that Dispersion Theory is meant to be a full theory of phonology and not just one of inventories, it is not made clear how this is to be done. Flemming (1999) suggests that the objects of analysis are languages, and proposes that these can be made manageable if characterized by means of finite state grammars.

The proposal here is somewhat different, following Ní Chiosáin and Padgett (2001): the objects of analysis are indeed languages, but this daunting prospect is made manageable by means of extreme idealization. In particular, the overall analysis is constrained so as to severely limit the form of words that can be considered, both as inputs and as candidate outputs. Limiting the words considered for an analysis actually makes explicit what is implicit in the practice of phonology. To see this, consider a phonologist who analyzes English aspiration, to take a well known example. Suppose the analyst chooses the word *pat* in order to demonstrate the analysis, considering candidate output forms such as [pʰæt], [pæt], and [bæt]. There are obviously an indefinite number of words (and possible words) of English that are *not* explicitly treated; these might include *pit*, *cat*, and *patter*, to name just three. That is, after succeeding in deriving the form [pʰæt] from /pæt/, the analyst is not likely to show that the account also derives [pʰɪt] from /pɪt/, [pʰæɾɚ] from /pætr/, and so on, nor is a reader likely to expect this. The implicit assumption behind disregarding such forms is that *pat* is good enough because it is *representative* of what matters. That is, properties such as vowel quality, place of articulation, or length of word (apart from issues of stress or foot structure), respectively, are considered not relevant to an account of

English aspiration. In principle such assumptions may be right or wrong, of course; in making them, linguists gamble that they are concentrating on just what matters in explaining a particular phenomenon. The assumptions made also clearly vary according to the phenomenon being analyzed: word length, vowel quality, and place of articulation obviously *are* relevant to other phenomena.

Though it is not usually made explicit, the strategy described here is clearly unavoidable. Analyses differ not in the presence or absence of idealization, but in the degree of it. For the aspiration scenario above, the forms considered for the analysis (both as input and output) are in effect of the shape *Cæt*, where *C* is a bilabial stop of some voice onset time. In terms of Optimality Theory, this implicit strategy might be regarded as a kind of tactical constraint both on richness of the base (the assumption that there can be no theoretical restrictions on inputs) and on freedom of analysis (the assumption that candidates for evaluation are similarly unrestricted.). (See Prince and Smolensky 1993 and McCarthy and Prince 1993 on both these notions.) I emphasize here that the constraint is tactical, that is, an analytical strategy, and is no constraint on the theory itself, which obviously must allow for the consideration of other forms in principle. If it were to turn out that vowel quality *does* matter to an account of aspiration, for example, we would be compelled to incorporate more forms such as [p^{h}ɪt] into the idealization. Idealization in this sense is fully consistent with both richness of the base and freedom of analysis.

In order to understand candidates as idealized languages—to get control over the range of possible candidate languages, and how they are evaluated—such a strategy needs to be made explicit. In what follows, certain sound changes from Common Slavic through East Slavic will be analyzed. For the purposes of that analysis, I will be assuming the idealization shown in (12). This explicit restriction allows only the 24 words shown. A possible candidate 'language' will be regarded as any subset of these words. (In fact, many of them will never be considered, since they would be ruled out for reasons that should be clear.) To put it differently, I am assuming that only the kinds of distinctions evident in this group of forms are relevant to an analysis of the sound changes of interest. For example, it will be important to treat velars on the one hand separately from dentals and labials on the other. In this idealization, non-velars are represented by [p]. Differences among the various labials and dentals of Slavic are not relevant to the analysis. Similarly, though palatalization versus the lack of it matters to the analysis, voicing of obstruents does not. And so on for other aspects of the idealization. It will become clear as the analysis unfolds why the other properties of this idealization, such as the possible vowels, *are* relevant.

(12) Words are C$^{(j)}$V, where C ∈ {p,tʃ,k}, V ∈ {i,ɨ,u,au}

pi	pɨ	pu	pau
p^{j}i	p^{j}ɨ	p^{j}u	p^{j}au
tʃi	tʃɨ	tʃu	tʃau
tʃ^{j}i	tʃ^{j}ɨ	tʃ^{j}u	tʃ^{j}au
ki	kɨ	ku	kau
k^{j}i	k^{j}ɨ	k^{j}u	kau

3.2 Perceptual distance of contrast

Our next challenge involves formulating constraints that regulate the perceptual distinctiveness of contrast. In order to do this, we first require some means of comparing pairs of output forms within a candidate language. Here I call on the notion of correspondence of McCarthy and Prince (1995), though employing it in a new way. Consider something similar to the familiar 'minimal pair' test, applied to the pairs of English words shown in (13). Pairs like *bat* versus *back* in (13)a pass this test by virtue of having at least one pair of corresponding segments that differ sufficiently. To be clear on what 'corresponding' means for our purposes, I simply assume that the segments of a form are indexed according to their order in the string, as shown; therefore the first segments of any two words correspond, as do the second segments, and the tenth, and so on. The [t] and the [k] in (13)a therefore correspond.[12] What it means to say that the segments (in this case [t] and [k]) 'differ sufficiently', in the case of the traditional minimal pair test, is that they are perceptibly distinct in some reliable way such that substituting one for the other alters the word recognized. However, it is necessary to look at this notion of perceptual distinctiveness more closely, since the idea is to evaluate it explicitly. Putting aside this point for the moment, consider (13)b.

(13)	a.				b.		
	b_1	$æ_2$	t_3		b_1	$æ_2$	t_3
	|	|	|		|	|	|
	b_1	$æ_2$	k_3		b_1	$æ_2$	t^h_3

The forms in (13)b fail the minimal pair test (in English). In this case, there are no corresponding segments that differ sufficiently. In traditional terms, [t^h] and [t] are variants of a single phoneme, but we will once again be interested in the lack of perceptual distinctiveness that underlies such facts. (Here it is the word-final contrast in particular that is assumed to be perceptually disfavored. As is well known, the voicing contrast in English is realized as roughly plain voiceless versus voiceless aspirated in certain other contexts; see Ladefoged 1993.) With all of this in mind, let us understand the term 'potential minimal pair' to mean a pair of words having the same number of segments, and all but one of whose corresponding segments are identical, such as in (13)a-b.[13]

Returning to the idealization in (12), the segment in these forms that stands out as perhaps most marked is the vowel [ɨ]. Following Liljencrants and Lindblom (1972), Lindblom (1986), and Flemming (1995a), I assume that [ɨ] is so often disfavored, and [i] or [u] favored, for perceptual reasons. The vowel [ɨ] lies midway between [i] and [u] according to the relevant perceptual parameter (see below). Because of this, [i] versus [u] is a better contrast than is either [i] versus [ɨ] or [ɨ] versus [u]. It should be emphasized that there is no sense in which [ɨ] is *inherently* marked, compared to [i] and [u]; rather, a *contrast* between [ɨ] and either [i] or [u] is marked. In fact, [ɨ] is the least marked of these three vowels when there is no contrast among high vowels (See Flemming 1995a and Ní Chiosáin and Padgett 2001 for discussion of these facts and their consequences for phonological systems.) It is here that the notion of perceptual distinctiveness of contrast crucially enters the account of Russian sound changes.

Consider figure (14), adapted from Ní Chiosáin and Padgett (2001). (14)a shows hypothetical spacings between high vowels along a continuum of vowel *color*. This term encompasses backness and roundness in vocoids. It is well known that variations in these two articulatory parameters affect primarily the second vowel formant, with [i] having the highest second formant value, and [u] the lowest. In fact, the perceptual effect of backness and roundness variation can be modeled as a single parameter 'F2 prime', derived based on the first three formant values, apparently corresponding to a single perceptual correlate (Carlson et al. 1970). Use of the term 'color' here is intended to highlight the fact that indeed a single perceptual dimension is involved. The vowels [i] and [u] occupy the extremes (roughly) of this perceptual dimension. The scenarios shown in (14)a differ in how much of the available perceptual space is given to each segment. An idealizing assumption is made that the perceptual space is divided into equal intervals, with a segment located in the center of each.[14] Obviously the more contrasting segments, the less the perceptual space for each.[15]

(14) a. Spacing:
|...i...|...ɨ̟...|...ɨ̠...|...u...| Each segment gets 1/4 of the perceptual space
|.....i....|....ɨ....|....u.....| Each segment gets 1/3 of the perceptual space
|.......i.......|.......u.......| Each segment gets 1/2 of the perceptual space
|...............ɨ...............| Each segment gets 1/1 of the perceptual space

b. SPACE$_{\text{COLOR}} \geq 1/n$: Potential minimal pairs differing in *vowel color* differ by at least *1/n*th of the full *vowel color* range

c. SPACE$_{\text{COLOR}} \geq 1/3$ >> SPACE$_{\text{COLOR}} \geq 1/2$ >> SPACE$_{\text{COLOR}} \geq 1$

A family of SPACE constraints is assumed, (14)b, parameterized according to the dimension of contrast, here vowel color. A universal ranking holds among them, (14)c. It follows from this hierarchy that languages can vary in the amount of spacing required between contrasting segments, though all languages will prefer more spacing, all else equal. These constraints and rankings are adapted from Flemming (1995a)'s 'Minimal Distance' constraints, but are formulated after Padgett (1997) and Ní Chiosáin and Padgett (2001). The number of space constraints required in the theory depends on the dimension of contrast. In the case of vowel color, we find at most a four-way contrast in languages (Ladefoged and Maddieson 1996). This is accounted for by the assumption that SPACE≥1/4 is in Gen. (This does the work of distinctive feature theory's assumption that there are only two color features, i.e., [back] and [round] or the like.)[16] Hence only the three remaining constraints ever need be ranked in a constraint hierarchy. Most contrast dimensions will be simpler, many allowing only a binary contrast (e.g., nasality), so that SPACE≥1/2 is in Gen and only SPACE≥1 need be ranked.

Consider how SPACE constraints apply to some example candidates, as shown in (15). Recall that the only candidates we will consider here are subsets of (12), and that these are viewed as severely idealized languages. (15)a, for example, is a truly miniature language consisting of three words in all; these happen to be a minimal triplet distinguished by [i], [ɨ], and [u]. For each SPACE constraint, every possible pairing of words in a mini-language is evaluated; in (15)a there are three such pairings. Two of them, [pi] - [pɨ], and [pɨ] - [pu], violate SPACE≥1/2: [i] and [u] are separated by at least one half of the full vowel color range (see (14)a), but neither of the other pairings are. All three pairings violate SPACE≥1, since this constraint requires that any vowel have the entire color space to itself. Candidate (15)b is more harmonic for reasons that should be clear. A mini-language having only one word, such as (15)c, is even better: since there are no minimal pairs, all SPACE constraints are vacuously satisfied. Finally, (15)d violates only SPACE≥1; SPACE≥1/2 is not violated, because neither [pi] - [kɨ] nor [kɨ] - [pu] are minimal pairs. Thus SPACE constraints evaluate words (minimal pairs), and not simply individual segments, such as the vowels of these forms.

(15)

	Space≥1/3	Space≥1/2	Space≥1
a. p_1i_2 $p_1ɨ_2$ p_1u_2		**	***
b. p_1i_2 p_1u_2			*
c. $p_1ɨ_2$			
d. p_1i_2 p_1u_2 $k_1ɨ_2$			*

In the analysis to follow, SPACE≥1/3 is never violated; SPACE≥1, on the other hand, is never respected. Only SPACE≥1/2 is of particular interest, and only this constraint will be shown in tableaux.

3.3 Constraints requiring contrast

The final challenge involves addressing not the perceptual goodness of contrast, but the requirement itself that there be contrast, i.e., neutralization avoidance. As generally understood, contrast is regulated in Optimality Theory by means of faithfulness constraints requiring similarity between inputs and corresponding outputs. The account to follow employs faithfulness constraints, understood in terms of correspondence, following McCarthy and Prince (1995). One such constraint, IDENT(PALATALIZATION), is shown below.

(16) IDENT(PAL): Corresponding input and output segments have identical values for consonantal palatalization.

However, it is proposed that the notion of faithfulness be extended to include the constraint *MERGE, shown below. Along with SPACE, this constraint crucially presupposes the systemic view of contrast.

(17) *MERGE: No word of the output has multiple correspondents in the input.

*MERGE is very much like the constraint UNIFORMITY of McCarthy and Prince (1995), which prohibits the merger of independent underlying segments into one in the output. It differs in taking entire words as its arguments, rather than segments. What it prohibits, therefore, is neutralization of contrast between words in a language. To see how this works, consider the tableau below, which takes as input the mini-language /pi, pɨ, pu/. Here the subscripts tag entire words, and not individual segments as is usual in correspondence theory. (In the analyses that follow, it will always be clear which segments correspond to which, and subscripts will be understood to apply to words.) Candidate (18)a is identical to the input, but (18)b is a mini-language containing only the words [pi, pu]. The subscript notation implies that [pi] is the output correspondent of input /pɨ/ as well as /pi/, implying in turn a violation of *MERGE. In other words, this language has neutralized the contrast between [pi] and [pɨ] in favor of [pi]. Because at the same time underlying /ɨ/ of /pɨ/ has fronted to [i], one violation of IDENT(COLOR) (see below) is also recorded. As can be seen here, there is some redundancy in the use of both *MERGE and IDENT. They are both violated in this example, and this will be true of many examples to follow. In fact, a violation of *MERGE necessarily implies a violation of some conventional faithfulness constraint. However, the reverse entailment does *not* hold, and *MERGE must crucially be distinguished, as we will see.

(18)

pi_1 $pɨ_2$ pu_3	*Merge	Ident(Color)
a. pi_1 $pɨ_2$ pu_3		
b. $pi_{1,2}$ pu_3	*!	*!

It is important to be clear that what we are considering here is indeed a merger, and not 'deletion' of input /pɨ/. True 'deletion' of input /pɨ/, as opposed to /pɨ/ → [pi], would mean there is no output correspondent of this entire word at all.

Returning to the IDENT constraints, I propose also that these make reference to the very same scales of perceptual similarity that SPACE constraints do. Deviations in vowel color between input and output, for example, are penalized by constraints referencing the color dimension seen in the last section. Naturally, the further a deviation occurs along such a scale, the worse the faithfulness violation. For convenience, I will count distance by appeal to the well known features [back] and [round]. The derivation /u/ → [ɨ] seen in (19)a therefore violates IDENT(COLOR) once, for the change in roundness (as does /ɨ/ → [i], for the change in backness). The derivation /u/ → [i] violates it twice. In addition, recasting a proposal by Kirchner (1996), I assume that an IDENT constraint can be locally self-conjoined (Smolensky 1995). The conjoined IDENT constraint is violated whenever its simple counterpart is violated twice by any corresponding input-output pair. Since self-conjoined constraints are assumed to outrank their simple counterparts universally, the result is a fixed constraint hierarchy such as that shown below.

(19)

/u/	Ident(Color) & Ident(Color)	Ident(Color)
a. ɨ		*
b. i	*	**

Such a hierarchy entails that successively larger deviations in faithfulness are penalized by separately rankable constraints. Kirchner (1996) argues that this is necessary, and we will see a need for it below. The problem we will encounter involves explaining why palatalized velars mutate into palato-alveolars rather than into something else. This is not a quirk of Slavic; it is one of the most frequently observed sound changes across languages. The most promising explanation relies on research showing that [k^j] is easily confusable with [$tʃ^j$] (Guion 1998), because it has similar acoustic properties (a high second formant locus and relatively long, noisy release). Ohala (1989) and Guion (1998) hypothesize that it is this similarity that underlies the cross-linguistic frequency of velar mutations to palato-alveolars before front vocoids. In comparison, for example, palatalized labials mutate to palato-alveolars much more rarely (see discussion in Ní Chiosáin and Padgett 1993, Flemming 1995a, Zoll 1996). This idea implies a perceptual scale having (very schematically) the properties shown in (20)a. Specifically, [k^j] is more similar to [$tʃ^j$] than [p^j] or other palatalized sounds are. By the reasoning seen above, this implies a fixed hierarchy of IDENT constraints. Rather than propose a set of features to cover the perceptual properties involved (but see Flemming 1995a for some ideas), I indicate the relevant constraints by means of the change involved (/p^j/ → [$tʃ^j$] and so on), as shown in (20)b.[17]

(20) a. Spacing: |...k^j...$tʃ^j$.................p^j...|
b. Ident: IDENT(p^j→$tʃ^j$), Etc >> IDENT(k^j→$tʃ^j$)

3.4 Other constraints

A hallmark of functionally-based Dispersion Theory is its reliance on constraints having a perceptual basis on the one hand (SPACE constraints), and those having an articulatory one on the other. The articulatory markedness constraints that will play a role in the account are shown in (21). The ranking in (21)a reflects conventional markedness assumptions except in the ranking of [ɨ] as most favored. This ordering follows from the assumption that the constraints are grounded specifically in articulation: if articulatory complexity of a vowel can be measured according to deviation from the 'rest position' [ə], then [ɨ] is indeed better than [i] or [u]. This reasoning plays a crucial role in explaining why [ɨ] is in fact the vowel that occurs in languages when there is no contrast among high vowels at all (Flemming 1995a). The ranking in (21)b makes the uncontroversial assumption that palatalized segments are articulatorily more marked than their plain counterparts. The constraint in (21)c requires allophonic secondary palatalization of consonants before front vowels. (Whether allophonic palatalization is best handled this way, and whether it is grounded in articulatory as opposed to perceptual constraints, are questions worth further exploration.)

(21) a. *au >> *i, *u >> *ɨ
b. *$tʃ^j$ >> *tʃ, *p^j >> *p, *k^j >> *k
c. PAL(ATALIZE): a consonant before a front vowel is palatalized

4. Common Slavic through East Slavic

4.1 Preliminaries

The parent language of Russian and all Slavic languages is Common Slavic (or Proto-Slavic). After the first of the well-known velar mutations (see below), sound changes began affecting large portions of Common Slavic independently, and by roughly the tenth century Slavic had broken into three major branches. The East Slavic branch during the following period, from roughly the tenth to the fourteenth centuries, is also referred to as Old Russian. Our knowledge of East Slavic is based in good part on a written record. Earlier forms are either indirectly attested through Old Church Slavic, or (prior to the ninth century) based on traditional methods of reconstruction. All of the changes assumed here are relatively well established and uncontroversial. For facts and discussion of Common Slavic and East Slavic, see especially Chernykh (1962), Borkovskii and Kuznetsov (1963), Shevelov (1965), Filin (1972), Ivanov (1990), Carlton (1991), Schenker (1993), and Townsend and Janda (1996).

The charts in (22) give the consonant and vowel phonemes of Common Slavic at about the fifth century, prior to any of the velar mutations. As can be seen, Common Slavic had neither palato-alveolars, contrastive palatalization, nor the vowel /ɨ/. Velars are thought to have been allophonically palatalized before front vowels, for reasons to be seen later. The diphthongs were bimoraic, and later became long monophthongs; this sound change will also come up later. (I use [a] for a low back vowel.)

(22)	Common Slavic consonant phonemes			Common Slavic vowel phonemes[18]	
	p	t	k	i: i	u: u
	b	d	g		
		s	x		
		z		æ: æ	a: a
	m	n			
		l		(Plus æi, æu, ai, au)	
		r			

Of the forms in our idealization (see (12)), those that were possible words of Common Slavic at this stage, that is, those conforming to the phonology of Common Slavic, are shown in (23). For our purposes, (23) is simply a highly idealized Common Slavic.

(23)	pi		pu	k^ji	ku
		pau		kau	

At this stage of the language, long and short vowels were distinguished, as shown in (22). It should be noted that the history traced below of [i] and [u] is in fact the history only of originally long [i:] and [u:]. (This length distinction is soon lost in favor of a vowel quality distinction, with short [i] and [u] realized as the 'jers' [ɪ] and [ʊ] respectively.) The vowels [i] and [u] in (23) should therefore more accurately be understood as originally long, though for typographic ease this is not shown.

4.2 Common Slavic at the outset

Our next task is to consider what ranking of the above constraints would account for Common Slavic at this first stage shown in (23). The tableau below takes as input the presumed stage of Common Slavic prior to secondary velar palatalization, and considers four candidate languages derived from it, showing how velar palatalization is derived. (See the discussion of inputs just below.) The input and candidates are arranged so as to suggest their relative perceptual spacing: forms such as [pɨ] would fall between [pi] and [pu], and such forms will arise later. Derivation of secondary palatalization from this input requires the ranking PAL >> IDENT(PAL). This can be seen by comparing candidate (24)a, which is fully faithful to the input, to (24)b, the optimal candidate; the former fares worse on PAL. It is also necessary for PAL to outrank $*k^j$, as the same comparison makes clear. At this stage, only velars were palatalized; candidate (24)c is ruled out by assuming that $*p^j$ outranks PAL.[19] Finally, velar palatalization occurred only before front vowels; this follows from the account because violations of $*k^j$ must be forced by PAL.[20]

(24)

pi_1 pu_2 pau_3 ki_4 ku_5 kau_6	$*p^j$	Pal	$*k^j$	Id-Pal
a. pi_1 pu_2 pau_3 ki_4 ku_5 kau_6		**!		
b. ☞ pi_1 pu_2 pau_3 k^ji_4 ku_5 kau_6		*	*	*
c. p^ji_1 pu_2 pau_3 k^ji_4 ku_5 kau_6	*!		*	**
d. pi_1 pu_2 pau_3 k^ji_4 k^ju_5 k^jau_6		*	**!*	**!*

Before we proceed, a word about the inputs assumed here and below is required. Some works on sound change in Optimality Theory explicitly assume that the input at each historical stage is the output of the previous stage. Hutton (1996) and Holt (1997) call this the 'synchronic base hypothesis'. The synchronic base hypothesis is virtually built into any account of sound change based on ordered rules. However, it appears to flatly contradict Optimality Theory's principle of richness of the base, which requires that *no* assumptions be made about inputs. It turns out, however, that given an Optimality Theoretic model that distinguishes lexical and postlexical derivations, as in Kiparsky (1998), the *appearance* of the synchronic base hypothesis can emerge as a consequence. This is because richness of the base holds only of inputs to the *lexical* stratum; the input to the *postlexical* stratum is obviously the output of the lexical stratum. Assuming that sound change originates in the postlexical phonology, again following Kiparsky (1998), and is incorporated only later (if at all) into the lexical phonology, it follows that the postlexical stratum takes the results of some previous sound changes—those that have entered the lexical phonology—as input.

Consider the following sequence of sound changes; these are the first two sound changes of interest to us. Following Kiparsky's assumptions, a sound change first enters the postlexical phonology (stage 2.1 below); it then may enter the lexical phonology (stage 2.2). Suppose that another change now occurs, again entering the postlexical phonology (stage 3). Given the structure of the model, the relationship between this sound change and the previous one is inherently derivational. This is because stage 3's sound change takes as input not *any* phonological forms, according to richness of the base, but only those forms output by stage 3's lexical phonology. The latter, in turn, represent the results of the previous sound change.

(25)	STAGE 1			
	Output of LP	pi pu pau	ki ku kau	
	Output of PLP	pi pu pau	ki ku kau	*Prior to sound changes*
	STAGE 2.1			
	Output of LP	pi pu pau	ki ku kau	
	Output of PLP	pi pu pau	k^{j}i ku kau	*Sound change enters PLP*
	STAGE 2.2			
	Output of LP	pi pu pau	k^{j}i ku kau	*Sound change 'promoted' to*
	Output of PLP	pi pu pau	k^{j}i ku kau	*LP*
	STAGE 3			
	Output of LP	pi pu pau	k^{j}i ku kau	
	Output of PLP	pi pu pau	tʃ^{j}i ku kau	***New** change enters PLP*

Though the synchronic base hypothesis is no principle of sound change, the result of the model above is that sound change can proceed as if it were. (Given the model, it need not always: if a new sound change enters the postlexical phonology before a previous one has been 'promoted' to the lexical phonology, the interaction of the two must remain transparent.) This is important, because (as is well known) sound change can lead to the historical equivalent of opaque derivations. In order for such a thing to be possible (regardless of whether one believes such derivations have any synchronic validity), some kind of model that incorporates seriality into sound change, as above, is required. Since these issues are independent of our topic, I adopt the 'synchronic base hypothesis' as an expository convenience and do not distinguish lexical and postlexical derivations. The reader should bear in mind that this abstracts away from the sort of detail seen in (25).[21]

Returning now to Common Slavic: another possible output not shown in (24) involves /pi/ surfacing as [k^{j}i], thereby obeying PAL without violating *p^j. Such a mapping violates IDENT(PLACE), a constraint requiring input-output identity in consonantal place, as shown in (26)b below. It also violates *MERGE, since the contrast between /p/ and /k/ in this environment is neutralized. As I noted earlier, any candidate that violates *MERGE violates some faithfulness constraint (though the reverse doesn't always hold). (26)b violates *MERGE because /ki/ and /pi/ both happen to be in the input. As (26)c shows, if /pi/ surfaces with a different place of articulation, IDENT but not *MERGE penalizes the outcome. This latter candidate violates *tʃ^j also.

(26)

pi$_1$ pu$_2$ pau$_3$ ki$_4$ ku$_5$ kau$_6$	*tʃʲ	Id-Pl	*pʲ	Pal	*kʲ	*Merge	Id-Pal
a. ☞ pi$_1$ pu$_2$ pau$_3$ kʲi$_4$ ku$_5$ kau$_6$				*	*		*
b. pu$_2$ pau$_3$ kʲi$_{1,4}$ ku$_5$ kau$_6$		*!			*	*	**
c. pu$_2$ pau$_3$ kʲi$_4$ ku$_5$ kau$_6$ tʃʲi$_1$	*!	*!			*		**

Given the violations shown, we can conclude that PAL is outranked by either IDENT(PLACE) on the one hand, or both *tʃʲ and *MERGE on the other. Given the fixed input, there is seemingly no way to say anything more about the rankings. However, if the derivation being considered here is assumed to be postlexical, following a lexical derivation in Kiparsky's (1998) terms, then there is more we can say. The output of the lexical stage must rule out the palato-alveolar, which must be a possible input at that stage, given richness of the base. This means that the ranking *tʃʲ >> IDENT(PLACE), *MERGE must hold of the lexical phonology. Let us therefore assume that this ranking continues to hold at the postlexical level, since nothing requires it to change. This follows if we assume with Kiparsky that the unmarked state of affairs is for lexical and postlexical rankings to be the same. For similar reasons, *pʲ and *kʲ are assumed to outrank *MERGE.

Another candidate worth considering maps input /ki/ into [tʃʲi], since this will in fact occur in the next stage we consider. This is already ruled out, as shown below.

(27)

pi$_1$ pu$_2$ pau$_3$ ki$_4$ ku$_5$ kau$_6$	*tʃʲ	Id-Pl	*pʲ	Pal	*kʲ	*Merge	Id-Pal
a. ☞ pi$_1$ pu$_2$ pau$_3$ kʲi$_4$ ku$_5$ kau$_6$				*	*		*
b. pi$_1$ pu$_2$ pau$_3$ ku$_5$ kau$_6$ tʃʲi$_4$	*!	*		*			*

The idealization being entertained includes six consonant types; of these, only one has not been considered: plain [tʃ]. Candidate (28)b below realizes input plain (non-palatalized) /k/ as [tʃ]. Such a candidate, and one realizing plain /p/ as [tʃ] (not shown), is once again ruled out by the relevant markedness constraint, *tʃ. For convenience some markedness constraints are combined in this tableau. The analysis to come will make no use of *p and *k, which are always violated. Hence these two constraints will not be shown anymore.

(28)

pi_1 pu_2 pau_3 ki_4 ku_5 kau_6	*tʃ/ *tʃʲ	Id-Pl	*pʲ	Pal	*kʲ	*Merge	Id-Pal	*p/ *k
a. ☞ pi_1 pu_2 pau_3 k^ji_4 ku_5 kau_6				*	*		*	*** **
b. pi_1 pu_2 pau_3 k^ji_4 $tʃu_5$ $tʃau_6$	*!*	**		*	*		*	***

Turning now to the vowels, the facts to be derived (holding to the idealization) are the preservation of [i], [u], and [au], and the lack of [ɨ]. Given that [i], [u], and [au] all surface, it must be the case that *i, *u, and *au are outranked by the relevant faithfulness constraints, including *MERGE or IDENT(COLOR). Candidate (29)b violates the latter constraint four times, twice for each merger of /i/ and /u/. (29)c violates it only twice, since /a/ and /u/ are both back. This assumes that /au/ > [u] involves a coalescence, such that [u] is the output correspondent of both portions of the input diphthong. An alternative would be to assume that input /a/ simply deletes (together with compensatory lengthening, since the derived [u] was long), but nothing hinges on this choice.

(29)

pi_1 pu_2 pau_3 ki_4 ku_5 kau_6	*Merge	Id-Col	*au	*i	*u	*ɨ
a. ☞ pi_1 pu_2 pau_3 k^ji_4 ku_5 kau_6			**	**	**	
b. $pu_{1,2}$ pau_3 $ku_{4,5}$ kau_6	*!*	*!** *	**		**	
c. pi_1 $pu_{2,3}$ k^ji_4 $ku_{5,6}$	*!*	*!*		**	**	

More interesting is the treatment of [ɨ], a vowel that did not exist at this stage of Common Slavic. Given the universal ranking posited in (21) (based on purely articulatory concerns, see the references cited there), the constraint *ɨ is dominated by all of the other markedness constraints in tableau (29); it therefore cannot be due to *ɨ that this vowel fails to surface. Recall that the perceptually based constraint SPACE≥1/2 instead crucially penalizes this vowel (in a system having [i] and/or [u] as well), as seen in (15) above. Tableau (30) shows how this works again. (SPACE≥1/2 will be shown simply as SPACE in the following tableaux.) Candidate (30)b represents a kind of chain shift (very much like one to be seen below), in which /au/ has shifted to [u] and /u/

to [ɨ]. Comparison with (30)a shows that it can be ruled out assuming SPACE≥1/2 outranks *au. Candidate (30)c shifts underlying /i/ to [ɨ]; it is worth considering because it is a means of avoiding violations of PAL by vacuous satisfaction. It too is ruled out by SPACE≥1/2, assuming this constraint dominates PAL as well. Candidate (30)d likewise attempts to subvert PAL, this time by neutralizing vowel qualities, showing that IDENT(COLOR) must dominate PAL.

(30)

pi_1 pu_2 pau_3 ki_4 ku_5 kau_6	Space	Id-Col	Pal	*Merge	*au	*i	*u	*ɨ
a. ☞ pi_1 pu_2 pau_3 k^ji_4 ku_5 kau_6			*		**	**	**	
b. pi_1 $pɨ_2$ pu_3 k^ji_4 $kɨ_5$ ku_6	*!***	****	*			**	**	**
c. $pɨ_1$ pu_2 pau_3 $kɨ_4$ ku_5 kau_6	*!*	**			**		**	**
d. $pu_{1,2}$ pau_3 $ku_{4,5}$ kau_6		*!***		**	**		**	

Given the work of IDENT(COLOR) above, why rank SPACE highly? Once again the rankings assumed here make sense if (30) is a postlexical derivation. The output of the lexical derivation must ensure that even underlying /ɨ/ does not surface. Hence SPACE must dominate both *MERGE and IDENT(COLOR) in the lexical phonology, and this ranking is assumed to carry over.

One overall ranking of constraints consistent with all of the above is shown in tableau (31). This tableau presents the entire analysis of Common Slavic at this stage, at which it acquired allophonic velar palatalization. The low-ranked constraints *i, *u, and *ɨ are not shown, since they do no crucial work and will not figure interestingly in what follows. All of the candidates and attendant violations should be familiar from the previous discussion.

(31) Common Slavic: allophonic velar secondary palatalization

pi$_1$ pu$_2$ pau$_3$ ki$_4$ ku$_5$ kau$_6$	*tʃ/ *tʃ^j	Space	Id- Col	Id- Pl	*p^j	Pal	*k^j	*Merge	Id- Pal	*au
a. pi$_1$ pu$_2$ pau$_3$ ki$_4$ ku$_5$ kau$_6$						**!				**
b. ☞ pi$_1$ pu$_2$ pau$_3$ k^{j}i$_4$ ku$_5$ kau$_6$						*	*		*	**
c. p^{j}i$_1$ pu$_2$ pau$_3$ k^{j}i$_4$ ku$_5$ kau$_6$					*!		*		**	**
d. pi$_1$ pu$_2$ pau$_3$ k^{j}i$_4$ k^{j}u$_5$ k^{j}au$_6$						*	**! *		** *	**
e. pu$_2$ pau$_3$ k^{j}i$_{1,4}$ ku$_5$ kau$_6$				*!			*	*	**	**
f. pi$_1$ pu$_2$ pau$_3$ ku$_5$ kau$_6$ tʃ^{j}i$_4$	*!			*		*			*	**
g. pi$_1$ pu$_2$ pau$_3$ k^{j}i$_4$ tʃu$_5$ tʃau$_6$	*!*			**		*	*		*	**
h. pu$_{1,2}$ pau$_3$ ku$_{4,5}$ kau$_6$			*!* **					**		**
i. pɨ$_1$ pu$_2$ pau$_3$ kɨ$_4$ ku$_5$ kau$_6$		*!*	**							**

4.3 The sound changes

The first sound change of interest is commonly known as the 'first velar palatalization'. However, to save confusion, I call this change a 'mutation', since it involved more than the addition of secondary palatalization. This change fronted velars to palatalized palato-alveolars before front vocoids (vowels and the glide [j]), as illustrated in (32). (Common Slavic later experienced two other velar mutations. These can be safely ignored for our purposes here.) The voiceless velar stop resulted in an affricate, while the other two resulted in fricatives. (The forms cited are from Townsend and Janda 1996:77. Those on the right are Late Common Slavic, and have undergone other sound changes; see (35) below.) It is because of this mutation before front vocoids that velars are assumed to have been allophonically palatalized in the previous stage of the language. The result of the sound change was that velars did not occur before front vocoids. The palato-alveolars occurred *only* there; however, this stage did not last long, as the form _*dɨʃʲati_ suggests.

(32)	a. k^j > tʃ^j	E.g.,	*k^{j}ærda:	>	*tʃ^{j}erda	'herd, line'
			*k^{j}imst-	>	*tʃ^{j}ęstʊ	'frequent'
	b. g^j > ʒ^j		*g^{j}æn-	>	*ʒ^{j}ena	'woman'
			*g^{j}i:v-	>	*ʒ^{j}ivʊ	'alive'
	c. x^j > ʃ^j		*du:x^{j}æ:tæi	>	*dɨʃ^{j}ati	'breathe'
			*graix-in	>	*grěʃ^{j}ɪnʊjɪ	'sinful'

In the account seen above, [k^j] rather than [tʃ^j] occurred before front vowels due to the ranking *tʃ^j >> *k^j: compare (31)b and (31)f. (On IDENT(PLACE) see below.) With (31)b as input, the first velar mutation will therefore require that this ranking be reversed, as shown in the tableau below; compare now (33)a-b. (I omit constraints that are not of immediate relevance.) Given the universal ranking *tʃ^j >> *tʃ, I assume the latter constraint necessarily demotes as well. Candidate (33)c shows why simply promoting *k^j to the top of the constraint hierarchy would not work: this candidate can be ruled out only assuming that PAL outranks *tʃ^j.

(33) Velar mutation: *k^j >> *tʃ^j

pi$_1$ pu$_2$ pau$_3$ k^{j}i$_4$ ku$_5$ kau$_6$	*p^j	Pal	*k^j	*tʃ/ *tʃ^j	Id-Pal
a. pi$_1$ pu$_2$ pau$_3$ k^{j}i$_4$ ku$_5$ kau$_6$		*	*!		
b. ☞ pi$_1$ pu$_2$ pau$_3$ ku$_5$ kau$_6$ tʃ^{j}i$_4$		*		*	
c. pi$_1$ pu$_2$ pau$_3$ ki$_4$ ku$_5$ kau$_6$		*!*			*

Velar mutation violates not only *tʃ^j, but IDENT(PLACE) also. To demote IDENT(PLACE) below *k^j is not the answer, since this fails to explain why what occurred was specifically the change from /k^j/ to [tʃ^j]. Candidate (34)c in the tableau below, for example, better satisfies all markedness constraints than the desired winner (34)b, and does not violate *MERGE. Recall the assumption that faithfulness to the specific change, IDENT(k^j→tʃ^j), is in question; this must rank below *k^j. This is shown in the tableau; compare (34)a-b. 'IDENT(PLACE)' (shown in its original location) should now be understood as a cover for all other IDENT constraints referring to major place. It therefore rules out (34)c-f, for example. The ranking *k^j >> IDENT(k^j→tʃ^j) is consistent with all earlier tableaux, so that this does not constitute a reranking.

(34) Velar mutation: *k^j >> IDENT(k^j→tʃ^j)

pi_1 k^ji_4 pu_2 pau_3 ku_5 kau_6	Id-Pl	*p^j	Pal	*k^j	*tʃ/ *tʃ^j	Id-k^j→tʃ^j	Id-Pal
a. pi_1 k^ji_4 pu_2 pau_3 ku_5 kau_6			*	*!			
b. ☞ pi_1 tʃ^ji_4 pu_2 pau_3 ku_5 kau_6			*		*	*	
c. k^ji_4 tʃ^ji_1 pu_2 pau_3 ku_5 kau_6	*!			*	*		*
d. $pi_{1,4}$ pu_2 pau_3 ku_5 kau_6	*!		*				*
e. pi_1 tʃ^ji_4 pu_2 pau_3 $\text{tʃ}u_5$ $\text{tʃ}au_6$	*!*		*		*	*	

The vowels of East Slavic are shown in (35)a, while (35)b gives their Common Slavic sources. [ɪ] and [ʊ], derived historically from short [i] and [u], are the well known 'jers' of Slavic, commonly interpreted as high lax counterparts of [i] and [u] (the latter derived from [i:] and [au] respectively). [ĕ] is a front vowel whose precise identity is not agreed upon, though close mid [e], or [i͡e], are good candidates. Of particular interest here is the new high central unrounded vowel [ɨ], derived from [u:]. This vowel resulted from a chain shift affecting Late Common Slavic whereby the diphthongs [au] and [æu] shifted to [u], while former [u:] shifted to [ɨ]. (The relevant vowels are bolded in (35)b.)

(35) a. East Slavic vowel phonemes b. Derivation[22]

i	ɨ	u		i < i:, æj	**ɨ < u:**	**u < au, æu**
ɪ		ʊ	(Jers)	ɪ < i		ʊ < u
ĕ			(High [e] or [i͡e])	ĕ < æ:, aj		o < a
e		o		e < æ		a < a:
	a					

This chain shift occurred after the first velar mutation. Taking (34)b now as input, the tableau below shows the reranking necessary to effect this change. (Again only relevant constraints are shown.) The faithful (36)a is ruled out assuming that *au is promoted over both SPACE and IDENT(COLOR). Instead of surfacing, /au/ shifts to [u], violating IDENT(COLOR). Assuming this, Common Slavic faced two logical possibilities. First, former [u] could remain unchanged, so that the shift would lead to a neutralization of the contrast between [u] and former

[au]. This choice is represented by candidate (36)c, and is clearly prohibited by *Merge. Alternatively, contrast could be preserved by shifting former [u] to a new place, as in (36)b. In Common Slavic, it was the latter that occurred, as we saw above, and this choice violates Space. In the account here, it is the new ranking of *Merge above Ident(Color) and Space that explains this choice.[23] Therefore both *Merge and *au have been moved to undominated position. This account for a chain shift, made possible and relatively natural by virtue of the constraint *Merge, is a modern implementation of Martinet's classic view (see Martinet 1952, for example).

(36) *au* shift: *Merge, *au >> Ident(Color) >> Space

pi$_1$ pu$_2$ pau$_3$ ku$_5$ kau$_6$ tʃ^{j}i$_4$	*Merge	*au	Id-Col	Space
a. pi$_1$ pu$_2$ pau$_3$ ku$_5$ kau$_6$ tʃ^{j}i$_4$		*!*		
b. ☞ pi$_1$ pɨ$_2$ pu$_3$ kɨ$_5$ ku$_6$ tʃ^{j}i$_4$			****	***
c. pi$_1$ pu$_{2,3}$ ku$_{5,6}$ tʃ^{j}i$_4$	*!*		**	
d. pi$_1$ pɨ$_2$ pu$_3$ k^{j}i$_5$ ku$_6$ tʃ^{j}i$_4$			**** *!	**

It is worth pausing to consider the question of what restrictions there are, if any, on possible rerankings to effect sound change. Should it be troubling that more than one reranking is necessary above, in particular? In a discussion of Latin, Prince and Smolensky (1993) argue that sound changes can indeed involve multiple rerankings. Essentially, they adopt a position familiar from the work of Kiparsky (1982b) and many others, noting that sound change must be 'discontinuous' from the grammatical point of view. That is, children acquire a language by positing a ranking based on an analysis of occurring output forms, without having any access to the rankings instantiated in the grammars of older speakers. Given this fact, it is plausible to consider multiple rerankings from one stage to the next, though this question certainly deserves more study.[24]

Candidate (36)d above differs from the winner only in the fate of underlying /ku/: rather than surfacing as [kɨ], this syllable fully fronts to [k^{j}i]. (The concomitant palatalization is forced by Pal >> *k^j, Ident(Pal), as usual.) Compared to the optimal form it incurs fewer Space violations. The reason should be clear: SPACE prefers the contrast between [k^ji] and [ku] to that between [kɨ] and [ku]. In this sense (36)d is the more harmonic candidate. What makes it worse is the greater violation of IDENT(COLOR). The analysis therefore requires an additional reranking of IDENT(COLOR) over SPACE, as shown. This last candidate is of great interest, because it represents precisely the result of the next sound change, post-velar fronting.

As seen earlier, between the twelfth and fourteenth centuries, several centuries after the vowel shift just analyzed, [ɨ] fronted to [i] following velar consonants. At the same time, the velars were palatalized. The data below are repeated from section 2.

(37)	a.	*kɨjev*	>	*k^jiev*	'Kiev'
		rukɨ	>	*ruk^ji*	'hands (acc.pl.)'
	b.	*$gɨb^jel^j$*	>	*$g^jib^jel^j$*	'ruin/death'
		drugɨ	>	*$drug^j$i*	'friends (acc.pl.)'
	c.	*xɨtrɨj*	>	*x^jitrɨj*	'clever'
		pastuxɨ	>	*$pastux^j$i*	'shepherds (acc.pl.)'

It should be clear by now how this will be accounted for: it simply requires the reranking of SPACE and IDENT(COLOR), as shown below. The ranking now favors candidate (38)b. Candidate (38)c represents another chain shift, with underlying /ku/ unrounding to [kɨ] in addition to post-velar fronting. This change would not violate *MERGE since the former /kɨ/ has fronted to [k^ji]. However, it undermines the gain of post-velar fronting altogether, which was to better satisfy SPACE. Finally, (38)d considers what would happen if fronting affected not just the velars but other places of articulation. Obviously this would have led to neutralization of the contrast between [p^ji] and [pɨ] and so a violation of *MERGE, as shown.[25]

(38) Post-velar fronting: SPACE >> IDENT(COLOR)

pi$_1$ pɨ$_2$ pu$_3$ kɨ$_5$ ku$_6$ tʃʲi$_4$	*Merge	*au	Space	Id-Col
a. pi$_1$ pɨ$_2$ pu$_3$ kɨ$_5$ ku$_6$ tʃʲi$_4$			***!	
b. ☞ pi$_1$ pɨ$_2$ pu$_3$ kʲi$_5$ ku$_6$ tʃʲi$_4$			**	*
c. pi$_1$ pɨ$_2$ pu$_3$ kʲi$_5$ kɨ$_6$ tʃʲi$_4$			***!	**
d. pi$_{1,2}$ pu$_3$ kʲi$_5$ ku$_6$ tʃʲi$_4$	*!			**

5. Discussion

5.1 The importance of the systemic view

In tableau (38) we see the crucial assumptions of Dispersion Theory at work. First, post-velar fronting was motivated by the requirement of perceptual distinctiveness of contrast (represented by SPACE in the account). [kʲi] versus [ku] is a better contrast than [kɨ] versus [ku], for just the same reason that [i] versus [u] is better than [ɨ] versus [u]. In relating post-velar fronting to the goodness of an [i] - [u] contrast in general, we are grounding it in one of the best known and clearest markedness observations of phonology. There is little doubt in turn that this fact of markedness is grounded in matters of perceptual distinctiveness, as discussed earlier.

Second, it is the principle of neutralization avoidance (represented by *MERGE) that explains why fronting occurred *only* following velars, and not after other places of articulation. Notice in particular that no appeal to featural faithfulness in general can make this distinction: in any theory, the changes /pɨ/ → [pʲi] and /kɨ/ → [kʲi] obviously involve a change in the very same features; but it is only the former change that leads to neutralization. It is here that we see why *MERGE must be posited. What post-velar fronting shows, if this account is right, is that contrast preservation is about more than faithfulness to inputs.

Both of these notions, perceptual distinctiveness of contrast and contrast preservation (in the strong sense just described), require that we understand the objects to be evaluated as sets of forms in contrast, and not simply isolated forms as usual. This is essentially the argument from post-velar fronting for Dispersion Theory.

To see these points more concretely, consider the following alternative explanation for post-velar fronting, one couched within Optimality Theory as usually practiced. Suppose we wanted to pursue the idea that post-velar fronting occurs because [ɨ] is in some sense more marked than /i/. For instance, suppose that the ranking *ɨ >> *i holds. This ranking actually makes the wrong predictions about the markedness of these vowels in general (see Flemming 1995a), but let us put this aside. So long as *ɨ dominates IDENT(BACK) as well, then an input /kɨ/ will output as [k^ji], as shown below. (Secondary palatalization of the velar is assumed.)

(39)

/kɨ/	*ɨ	*i	Id-Back
a. ☞ k^ji		*	*
b. kɨ	*!		

The problem with this account, obviously, is that it will incorrectly alter input /pɨ/ to [p^ji] as well. In fact, [pɨ] contrasts with [p^ji], so *ɨ cannot outrank IDENT(BACK); instead, the reverse must be true. This problem can be avoided only by appeal to the velar versus non-velar context of the vowel, that is, by positing a constraint such as *kɨ, as shown in (40)i. This constraint would (correctly) have nothing to say about output [pɨ], allowing it to surface, as shown in (40)ii.[26]

(40) i.

/kɨ/	*kɨ	Id-Back	*ɨ	*i
a. ☞ k^ji		*		*
b. kɨ	*!		*	

ii.

/pɨ/	*kɨ	Id-Back	*ɨ	*i
a. p^ji		*!		*
b. ☞ pɨ			*	

The problem with this account is by now familiar: there is no motivation for a constraint like *kɨ. Furthermore, under this account, the fact that fronting occurred after velars only, and the fact that only velars did not *already* occur before [i], are not at all related. In fact, it would be just as straightforward to posit a constraint *pɨ that caused post-labial fronting only, even though this would be neutralizing and post-velar fronting would not.

The alternative just outlined, then, does not manage to explain why fronting occurred only after velars. A separate problem is that it also fails to explain why it was *fronting* that occurred in response to *kɨ. It would be possible to satisfy *kɨ by altering /kɨ/ to [ku], for instance. In a technical manner, this possibility can easily be excluded: so long as IDENT(ROUND) outranks

IDENT(BACK), fronting will be preferred to rounding, as shown in (41)i. As before, /pɨ/ will continue to surface as it should, (41)ii. (*i and *u are grouped together for convenience.)

(41) i.

/kɨ/	*kɨ	Id-Round	Id-Back	*ɨ	*i/*u
a. ☞ k^ji			*		*
b. kɨ	*!			*!	
c. ku		*!			*

ii.

/pɨ/	*kɨ	Id-Rd	Id-Bk	*ɨ	*i/*u
a. p^ji			*!		*
b. ☞ pɨ				*!	
c. pu		*!			*

The problem now is precisely that fronting is simply stipulated by this choice of ranking. Were we to switch the ranking of the two IDENT constraints, we would derive rounding after velars instead. (Compare (41)i-a and c.) In the account advocated here, the constraint *MERGE disprefers post-velar rounding (since /ku/ already exists), and SPACE will *prefer* fronting.

The advantages of the Dispersion Theory account described above hold with equal force against other generative approaches to phonology within or outside of Optimality Theory, and in fact against any approach that is purely 'syntagmatic' rather than systemic like the one considered here. This includes other broadly functional approaches to phonology such as Steriade (1997), Kirchner (1997), Boersma (1998), and Hayes (1999). Though Steriade (1997) and Boersma (1998) in particular emphasize the role of perceptual factors in shaping phonologies, both rely basically on syntagmatic formulations of the relevant constraints. For example, Steriade posits a family of constraints penalizing an obstruent voicing contrast in various contexts, e.g., *[voice]/#__[-son] ("a voice contrast is prohibited word-initially when an obstruent follows"). It does not follow from this argument that such syntagmatic formulations are bad or unnecessary. At the least, though, they are not enough.

Chain shifts such as that seen last section have also been argued to show a principle of neutralization avoidance at work in historical phonology (see especially Martinet 1952, 1964, 1974). The account offered in the last section (see (36)) in fact reflects in a very simple and direct way the explanatory intuition of functional historical phonologists: the chain shift occurs due to the pressure of *MERGE . Historical phonologists are not at all agreed on the need to invoke such a principle in accounting for chain shifts, however; there are alternative scenarios that can be imagined to explain many of them, including positing a 'drag chain' driven by needs of symmetry rather than a 'push chain' driven by neutralization avoidance. For example, in Common Slavic, it might be that first /u/ shifted to [ɨ], leaving no /u/ in the system; /au/ then raised to [u] due to 'pressure' to reimpose symmetry; there is no need to call on neutralization avoidance. Such a scenario is depicted in (42). (42)a shows just the high vowels of Late Common Slavic (compare (35) above). It is assumed here that short /i/ and /u/ were already distinguished in quality from long /i/ and /u/, but this is irrelevant to our concerns. When /u/ shifts to [ɨ], the system left (in (42)b) is asymmetrical: it has tense and lax (or long and short) front vowels, but only a lax (or short) back vowel. If languages tend toward symmetry, then perhaps this can explain why /au/ shifted to [u].

(42)	a.	*i*	← *u*	b.	*i*	*ɨ*	
		ɪ	*ʊ*		*ɪ*		*ʊ*

Whether push chains are real remains an important open question in historical phonology. However, the account of post-velar fronting offered here bears significantly on this general issue because it amounts to a different and more direct sort of evidence for neutralization avoidance in historical phonology. One cannot say, for example, that post-velar fronting occurred in order to restore symmetry to (43)a, because the result derived in (43)b is also not symmetrical: while the former lacks a [k]-vowel sequence that is front, the latter lacks one that is central. In other words, it cannot be 'gap filling' that motivates this change.

(43)	a.	*p^{j}i*	*pɨ*	*pu*	b.	*p^{j}i*	*pɨ*	*pu*
			← *kɨ*	*ku*		*k^{j}i*		*ku*

In our terms, of course, it is the perceptual superiority of (43)b that matters. (One might object that perhaps the asymmetry seen in (43)a is worse than that of (43)b in some sense. Were we to suppose that (43)b is better because [k^{j}i] and [ku] occupy the endpoints of the vowel color dimension, however, we would be very close indeed to adopting the proposal given here.) If we grant that this matters, then the failure to shift /pɨ/ to [p^{j}i]—a change that would also improve perceptual distinctiveness vis-a-vis [pu]—is direct evidence for neutralization avoidance.

The idea of neutralization avoidance, if understood in the wrong way, can make strange predictions. For example, consider the fact that Standard English has the words *beat* [bit], *boot* [but], and *peat* [pit], but no *poot* [put]. If [i] and [u] are unmarked because they make a perceptually good contrast, and [ɨ] is even better in the absence of such a contrast, then do we expect [pit] to become [pɨt] (since there is no [put] for [pit] to remain distinct from)? Similarly, if there were a process backing [i] to [u], would we expect that it might affect [pit] but not [bit], since only the latter would entail a neutralization (with [but])? These questions arise when we take the domain of explanation to be the set of actual lexical items in a language. But this is in fact not the practice in generative phonology. Instead theories model the set of *possible* words of a language, something argued for explicitly by Halle (1962). The string [put] is a possible word of English, whose absence from the actual lexicon (at least in some dialects) amounts to an accidental gap. It is therefore 'generated' by any theory of Standard English phonology. Similarly, it is over the domain of possible forms, not actual forms, that constraints like SPACE and *MERGE operate. Given this assumption, the questions raised above turn out to be ill-formed. To put it in the context of the Russian facts, post-velar fronting could occur because the absence of forms such as [k^ji] was a *systematic* gap, not an accidental one.[27]

Discussions of the role of neutralization avoidance in historical phonology and variation often focus only or largely on cases in which the distinction in question is a morphological one (see for example Kiparsky 1982b, Guy 1996, Labov 1994, Lass 1997), or even one between particular lexical items. A well-known example of the former involves the loss of intervocalic [s] in Classical Greek, a sound change that failed to affect future verb forms, due to pressure, some argue, to maintain the distinction between future and present forms (see Campbell 1999:288-9 for discussion). These cases are certainly relevant, but we should not lose sight of the more pervasive evidence for functional pressure on sound change that comes from the fact that change repeatedly produces languages that respect markedness tendencies, something emphasized as early as Jakobson (1929) (and more recently by Kiparsky 1995). The fact that [i] and [u] are the favored high vowels comes to mind, once again. There is little doubt that this fact has a perceptual basis, and it is a result respected repeatedly by sound change. For such reasons, the controversy around the claim that sound change respects function seems puzzling. The real questions, surely, are to what degree sound change respects function, and how functionality comes about. As a good deal of recent work makes clear (e.g., Hawkins and Gell-Mann 1992, Labov 1994, Kiparsky 1995, Guy 1996, Boersma 1998, Kirby 1999, and Nettle 1999, to name just some), a functional view of language change does not imply that language users *strive* to enhance function. (The theory of biological evolution derives functionality without intent for example; some of the works just cited attempt to model language change after biological change in certain respects.) The use here of terms like *MERGE, 'neutralization avoidance', and the like, should not be taken to imply that language change is goal-directed; however, function clearly matters on some level. The Dispersion Theory model presented here abstracts away from the complexities of variation, acquisition, competence, performance, and so on, factors which ultimately must play a role in allowing function to enter the picture.

Can Dispersion Theory, or any very functional model of phonology, be regarded as a characterization of speaker competence? Is SPACE a part of speaker competence, for example? The answer 'yes' would seem to imply goal directedness, at least in some sense. Or is perceptual distinctiveness a factor only at the level of performance? The answer 'yes' here implies that the illformedness of [kɨ] is grammaticalized by today's Russian speakers in a manner entirely independent of any functional-historical underpinnings. In fact, a rather unexplanatory constraint such as *kɨ is a possibility. Under this view, phonetic factors explain much about how sound systems get to be the way they are, even while speakers incorporate the resulting patterns into their grammar in a manner consistent with *independent* principles of language or cognition. Under this view also, the analysis given above is not a characterization of speaker competence, but once again a more abstract model of the effects of function on sound change and on phonology.

5.2 Versions of Dispersion Theory

Some differences between 'Dispersion Theory' as outlined here and Flemming's (1995a) original proposals should be noted. Some have been discussed already. For example, the use of idealization as laid out in section 4 follows Ní Chiosáin and Padgett (2001); the formulation of

SPACE constraints follows Padgett (1997), though building in an obvious way on Flemming's 'MinDist' constraints. Another significant difference involves the proposed constraint *MERGE penalizing neutralization. This constraint depends on the assumption of inputs and faithfulness. Flemming (1995a) comes to the position that Dispersion Theory can and should be practiced without assuming inputs (underlying forms). In addition, instead of input-output faithfulness constraints, he suggests there are only output constraints that require some number of contrasts directly, his 'MaintainContrast' constraints. Padgett (1997) and Ní Chiosáin and Padgett (2001) follow Flemming in this. Here I assume inputs, and faithfulness constraints, because it is impossible to even describe historical change otherwise. As noted earlier, a series of sound changes is a kind of temporal derivation, and can lead to 'derivational opacity' effects. This can be modeled only assuming the output of one stage can in some way serve as input to the next. Since it is specifically sound change that section 4 models, it could well be that the analytical assumptions there ought to differ from those relevant to any analysis of synchronic sound patterns such as previous analyses within Dispersion Theory. Alternatively, these considerations might suggest that Dispersion Theory should adopt inputs and input-output faithfulness generally, dispensing with the 'MaintainContrast' constraints (or the 'NWord' constraints of Ní Chiosáin and Padgett 2001). I leave this matter open.

5.3 Empirical extensions

The strategy adopted in this paper has been to consider one set of facts in depth in order to motivate the claims of Dispersion Theory. Of course, if the apparent relevance of perceptual distinctiveness and neutralization avoidance turned out to be a fact particular to post-velar fronting in East Slavic, this would be disappointing. This last section suggests some areas in which the ideas pursued here might find further support.

First, it is interesting to note that post-velar fronting occurred not only in Russian (and Belorussian, which is not regarded as a distinct language at this stage), but in other Slavic languages, including Ukrainian, Polish, and Upper and Lower Sorbian. (See Stieber 1968 and Schaarschmidt 1998 on Polish and Sorbian, respectively.) The conditions claimed here to motivate post-velar fronting in Russian, involving perceptual distinctivenss and contrast preservation, obtained equally in these other languages. This is because the changes affecting Common Slavic that brought about these conditions occurred before the disintegration of that language. Jakobson (1929) and Timberlake (1978), among others, assume that these different instances of post-velar fronting were independent of one another.[28]

There is a well known case of lax vowel height neutralization that affects southern dialects of American English. It occurs before nasals in words such as *pen* and *hem,* which are realized as homophonous with *pin* and *him*. The fact that nasalization often leads to neutralization of vowel height seems to have a perceptual basis. (In effect, the perceptual height 'space' shrinks under nasalization; see Wright 1986, Padgett 1997, and references therein.) What is interesting here is the direction of neutralization: *pin* and *pen* are both realized as [pɪn], and not [pɛn]. (In some dialects [ɪ] itself is realized differently, e.g., [piən], but it remains true that neutralization occurs in favor of the more peripheral of the two underlying vowels /ɪ/ and /ɛ/.) Is there a principled reason for this? Note the similarity to the post-velar fronting scenario, as depicted below.

(44)						
	pɪt	*pɛt*	*pæt*	*pi*	*pɨ*	*pu*
	[pɪn ←	*pɛn]*	*pæn*	*[* ←	*kɨ]*	*ku*
				↓		
				tʃʲ		

The Southern American facts differ from the post-velar fronting facts in one respect. The shift in vowel quality associated with post-velar fronting was made possible because the earlier shift [k^{j}i] > [$tʃ^{j}$] removed the danger of a *MERGE violation. In the case of Southern American, *MERGE *is* violated. However, the two facts are similar in other respects. First, in both cases the vowel quality shift is in the direction of greater perceptual distance: [ɪ] versus [æ] is better than [ɛ] versus [æ]. Second, in both cases the shift occurred only in a certain context, velars in the case of post-velar fronting, nasals in the case of Southern American. Further, in neither case is this context one that can be made obvious sense of in syntagmatic terms. Why should *raising* occur before nasals? In fact, the predicted effect of nasalization on vowel quality is generally one of centralization of vowel height: high nasalized vowels should perceptually lower, and low nasalized vowels raise (Wright 1986). In systemic terms, on the other hand, the direction of this shift makes sense.

6. Conclusion

This paper has argued that both neutralization avoidance and perceptual distinctiveness are important to an understanding of sound change, focusing on East Slavic post-velar fronting. It has argued in addition that these notions can be adequately captured only given a systemic approach to phonology as in Dispersion Theory, that is, one in which the objects of evaluation are sets of forms rather than forms in isolation, where the sets of forms are here understood as highly idealized languages. These conclusions bear equally on our understanding of synchronic phonology, since the course of sound change in part determines synchronic patterns: today's allophonic rule by which Russian velars can be followed by [i] but not [ɨ] originated as post-velar fronting in East Slavic. (Whether functional notions should play a *direct* role in synchronic accounts is another question; see section 5.1.)

Phonology has generally had little to say about why allophonic rules exist, especially non-assimilatory ones. If the analysis here is on the right track, then at least some allophonic rules must be understood as a response to the pressures of contrast. Padgett (2001a,b) makes a similar argument concerning a different allophonic rule of Russian. This result is perhaps surprising, since allophonic rules involve by definition the distribution of *non*-contrastive features. This traditional theoretical divide between 'phonemic' and 'allophonic' phonology may in some cases impede our understanding of sound patterns.

Notes

*. I am especially indebted to Luigi Burzio, Eric Holt, Junko Itô, Michael Kenstowicz, Armin Mester, Máire Ní Chiosáin, Nathan Sanders, Jennifer Smith, Caro Struijke, and three NLLT reviewers for comments on this paper at various stages of completion. I would also like to thank participants at the Symposium on Contrastiveness at UC Berkeley, December 1999, and at the Workshop on Features in Phonology at the University of Konstanz, December 2000; the

audiences at talks at UC Santa Cruz, MIT, Johns Hopkins University and the University of Maryland, College Park; and the participants in my seminar and Phonology A courses in 2001.

1. Compare the notion of 'enhancement' of Stevens et al. (1986), Stevens and Keyser (1989).

2. I will take the term 'Dispersion Theory' to imply the properties described just below. However, the reader should bear in mind that the model developed here differs in important respects from that of Flemming (1995a). See section 5.2.

3. The sound [ʃʲː] of Contemporary Standard Russian is often analyzed as a sequence of other sibilants, as in Halle (1959), in order to explain both its length and regular alternations like /s + tʃʲ/ → [ʃʲː]. The voiced counterpart of this sound, [ʒʲː], has at best a marginal status today.

4. Some irrelevant predictable effects, including vowel reduction, are not transcribed.

5. 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* + *it͡sa* → *lisʲit͡sa* (**lʲisɨt͡sa)* 'fox (fem.)', (Gvozdev 1949). The output respects the allophonic rule, but the causality seems to be reversed. Because of such facts, Rubach (2000) assumes that [i] and [ɨ] are distinct phonemes. This assumption, which may not be crucial to his paper's main point, is hard to reconcile with the facts discussed here. Rubach's facts rather invite analysis making use of some notion of lexical level (as in Kiparsky 1982a, 1985), or morphologically-governed phonology.

6. There are loans in Contemporary Standard Russian such as *kemping* 'camping' and *kɨrgɨzia* 'Kirgizia' in which velars might be pronounced non-palatalized, but these are very few in number in comparison to words with palatalized velars before back vowels; unlike the latter, they are very often regularized, i.e., *kʲemping*, *kʲirgʲizia*.

7. As one reviewer points out, some of the northernmost areas of East Slavic may have had velars followed by front vowels at this time, either because one of the velar mutations (the 'second velar palatalization') did not occur there, or because its effects were leveled out by this time. Since this was true only of a comparatively small portion of East Slavic, it seems plausible to pursue the explanation for post-velar fronting given here. The fact that post-velar fronting affected these dialects too suggests that it spread to them from other East Slavic dialects. Along similar lines, in the period preceding post-velar fronting, East Slavic was acquiring loan words (in association with the spreading influence of Christianity) with velars before front vowels, such as *evangʲelie* and the name *gʲeorgʲij* (Chernykh 1962:143). The account here of post-velar fronting therefore assumes that these loanwords had not been integrated into East Slavic phonology, at least by many speakers.

8. As we have seen, [ɨ] also cannot occur word-initially (unless a velarized consonant precedes within the phrase). This was true at the time of post-velar fronting as well. This fact is *not* because of fronting of [ɨ] to [i], but because at a much earlier stage of the language, when [ɨ] was [u] (see below), a general rule of prothesis placed [w] before this vowel word-initially, giving [wu], and later [wɨ] or [vɨ]. In other words, for reasons independent of post-velar fronting, [ɨ] never

occurred word-initially.

9. Implicit in Jakobson's discussion is the assumption that the change that needs to be explained is the fronting of [ɨ] to [i], while the palatalization of velars before this new [i] was a consequence of this change, and of the requirement that velars be palatalized before front vowels in general. Most researchers have followed Jakobson in this assumption. Timberlake (1978) argues for the opposite view, however: secondary palatalization of velars preceded fronting of [ɨ] to [i], and actually caused the latter change. This view has an important drawback: it requires the claim that secondary palatalization of velars was triggered not only by front vowels, but by [ɨ], a back or central vowel. In particular, Timberlake assumes that palatalization was triggered by vowels that were contrastively [-round]. This assumption simply squares very badly with cross-linguistic facts: palatalizations are extremely common and they are invariably triggered by front vocoids. (See Bhat's 1978 survey, for example.) Palatalization must have either followed post-velar fronting or occurred simultaneously with it.

10. Since Padgett (2001a) argues that [pɨ] is actually [pˠi] in contemporary Russian, it is worth asking whether the line of explanation suggested above would carry over supposing [kɨ] were actually [kˠi] at the time of post-velar fronting. It would: [kʲi] is more distinct from [ku] than [kˠi] is, since the velarized [k] of [kˠi] is more similar to the labiovelarized [k] of [ku]. Though there is suggestive evidence that "ɨ" was diphthongized already in Late Common Slavic, consistent with the view that this sound represented [i] preceded by a velarized consonant (Meillet 1951, Shevelov 1965), for the purposes of the analysis I will hold to the more traditional and prevalent assumption that "ɨ" was indeed [ɨ] at that time. See Padgett (2001b), however.

11. Of course, the relationship between contrast and phonological patterning has long been explored in phonology: besides Trubetzkoy (1969), the extensive literature on underspecification stands out (see Steriade 1995 for an overview and a critique). Dispersion Theory differs from past work in its assumption that forms must be evaluated with *direct* reference to contrasting forms, as seen below.

12. McCarthy and Prince (1995) assume that indexing is entirely free, and not ordered as suggested here. This assumption works well for the evaluation of faithfulness. In order to employ correspondence to gauge contrast, though, the ordering is required. We wouldn't want to say that $k_1a_2p_3$ and $p_3a_2k_1$ fail the minimal pair test because they happen to be indexed as shown here, for example.

13. This ignores minimal pairs that differ in number of segments, that is, in which contrast between a segment and 'zero' is required, as in *bat* versus *bats*, or *bat* versus *brat*. Comparing such forms seems to require introducing a 'segment' [0], indexed as other segments are, having silence as its phonetic correlate. Thus *bat* versus *bats* passes the minimal pair test presumably because [s] is sufficiently distinct from [0].

14. It follows from this idealization that the vowel 'i', to take just one example, is phonetically implemented somewhat differently depending on how many vowels it contrasts with, as can be

seen from this diagram: the vowel space used by any given vowel 'shrinks' or 'expands', and its center shifts, depending on the number of contrasts employed. Nothing here hinges on this claim, but the general idea has some support based on impressionistic descriptions. For example, the Australian language Nyangumarda contrasts only the three vowels /i,a,u/; the phonemes /i,u/ are generally realized as [ɪ] and [ʊ] (Hoard and O'Grady 1976). Similarly, in French and Norwegian, which include front rounded vowels in their inventory, /u/ is 'darker', and more consistently so, than that of English or Japanese. In English /u/ can be realized as [ɯ], [ʉ], or even [y]. Moving beyond impressionistic data, a phonetic study by Manuel (1990), shows that vowel-to-vowel coarticulation (one source of variability) is significantly restricted in one language having more contrasting vowels compared to another having fewer contrasting vowels.

15. The symbols [ɨ̟] and [ɨ̠] are chosen for convenience, since [ɨ] is the symbol employed for the vowel occupying the center of the high vowel color space. On another note, it is well known that some languages have an inventory like [i,y,u] in which the vowels are not evenly dispersed in color. (Many languages, of course, *do* have an [i,ɨ,u] contrast.) See Schwartz et al. (1997a,b) for an account of this, adding a preference for 'focalization' to that for dispersion.

16. Steriade (1994), Flemming (1995b, 2001), Kirchner (1997, 2001), and Ní Chiosáin and Padgett (2001) argue that phonological theory must appeal to more distinctions than those justified by the usual criterion of potential contrast familiar from distinctive feature theory. In this view, it is up to phonological output constraints, and not the inventory of features assumed, to predict what the potential contrasts are across languages. Therefore, we are free to posit more features than would be permitted within distinctive feature theory (and these works argue that this is required). Though features no longer make up the theory of contrasts, they remain important both for stating phonological generalizations, and for making clear what *phonetic* distinctions might be relevant to phonology. The account to come assumes featural identity constraints, for example.

17. Flemming (1995a) argues convincingly that articulation-based features such as [coronal] and [dorsal] cannot adequately explain mutations of this sort. (See also Ní Chiosáin and Padgett 1993.) As a separate point, it is interesting to note that the sound change [tʃ] > [kʲ] does *not* occur; this also has a perceptual basis, though it is not well understood (Guion 1989 and references therein): listeners mistake velars for palato-alveolars before front vocoids much more readily than the reverse. This is why IDENT(kʲ→tʃʲ) is formulated in this directional way.

18. Transcriptions of the Common Slavic vowels vary, representing different views on the right characterization of the oppositions and their precise phonetic realization. The transcriptions used here might well overemphasize the phonetic extremity of the vowels; [e] is often used for [æ], for example. All agree on the basic two-way oppositions based on height, color, and length, however.

19. A reviewer wonders whether the assumed ranking *pʲ >> *kʲ should be possible, given markedness facts. In particular, the mutation of velars to palato-alveolars before front vocoids is a common sound change, as noted above. There is a sense in which palatalized velars are therefore avoided cross-linguistically. In Slavic, for example, the result of velar mutations (see below) and

other changes was a set of languages having palatalized labials and coronals, but not velars. However, I am assuming, as historical Slavists generally do, that place-mutated velars in fact derive from an earlier stage in which velars are palatalized. If this is true, then palatalized velars are at least as common as the palato-alveolars derived from them. The frequency of the sound change can be seen as a fact about perceptual similarity, as we saw.

20. Syllable onsets were largely or completely required in Common Slavic. Therefore a possible candidate having onsetless forms (therefore vacuously satisfying PAL) is not considered.

21. Sanders (to appear-a,b) offers another means by which sound change may mimic the synchronic base hypothesis, one that adheres to a strictly monostratal view of phonology but assumes a 'strong' version of Lexicon Optimization (Prince and Smolensky 1993), by which allomorphs are stored in the lexicon. For further discussion of these issues, see also Padgett (2001b).

22. East Slavic [u] and [a] were also derived from Common Slavic back and front nasalized vowels respectively. (Consonants were palatalized before this [a].)

23. There is a candidate not shown below that would beat the desired winner: one in which underlying /au/ surfaces directly as [ɨ], while underlying /u/ remains [u]. This kind of derivation, in which /au/ moves to [ɨ] by a kind of 'end run' around [u], should probably be ruled out universally, though I leave open how this should be handled.

24. This question is of course bound up with the question of why sound change occurs. Some, e.g., Gess (2000) and Hutton (1996), have argued that constraint rerankings must be seen as a result of sound change, and not a cause of it. They instead look to phonetic factors for an explanation of sound change.

25. Prior to post-velar fronting, in the later stages of Proto-Slavic, allophonic secondary palatalization before front vowels began to affect all consonants. In our idealization, the sound [p] stands in for all consonants other than velars and palato-alveolars, that is, for labial and dental places of articulation. These were the consonants affected, since velars did not occur before front vowels anymore, while palato-alveolars were already palatalized. It was the ranking $*p^j$ >> PAL that accounted for the lack of palatalization on [p] above. Palatalization of this sound follows given a reversal of this ranking, though this is not shown.

26. This represents a kind of positional markedness understanding of the facts. An alternative is to retain simple *ɨ and appeal to a kind of positional faithfulness instead, for example factoring IDENT(BACK) into something like IDENT(BACK)/K__ and IDENT(BACK)/P__, ranking only the latter above *ɨ. This move is subject to the same criticisms as the positional markedness move.

27. This is not to say that actual lexical items have no role to play in determining phonological patterns. But any theory appealing to them must avoid artifactual puzzles like those mentioned here.

28. These works, incidentally, note the following correlation: the Slavic dialects that experienced post-velar fronting are roughly those that developed phonemic palatalization. Why should this be the case? It seems that the languages that developed phonemic palatalization harnessed the pre-existing contrast between [i] and [ɨ] in support of that contrast. In those languages, contrasts such as C^ji versus *Cɨ* (the former allophonically palatalized at first) were reinterpreted as involving phonemic palatalization, that is, as underlyingly /C^ji/ versus /Ci/; hence the well-known rule backing /i/ to [ɨ] after non-palatalized consonants in Russian, for example. Now, in those Slavic dialects that did not develop phonemic palatalization, historical [ɨ] fronted in *all* contexts, merging with [i], perhaps because it was not required for palatalization. In these languages, in other words, both [kɨ] and [pɨ] fronted. Thus, the reason post-velar fronting as a specific process did not occur in these languages is apparently simply that *all Cɨ* sequences were fronted.

References

Anderson, Stephen R. 1985. *Phonology in the Twentieth Century*, Chicago, IL, University of Chicago Press.

Avanesov, Ruben Ivanovich. 1947. 'Iz istorii russkogo vokalizma', *Vestnik MGU* **1**,41-57.

Avanesov, Ruben Ivanovich, and Vladimir Nikolaevich Sidorov. 1945. *Ocherk grammatiki russkogo literaturnogo iazyka, chast' 1: fonetika i morfologia*, Moscow, Gosudarstvennoe uchebno-pedagogicheskoe Izdatel'stvo.

Bhat, D.N.S. 1978. 'A general study of palatalization', in Joseph H. Greenberg (ed), *Universals of human language, vol. 2: phonology*, Stanford, CA, Stanford University Press, 47-92.

Boersma, Paul. 1998. *Functional phonology: formalizing the interactions between articulatory and perceptual drives*, The Hague, Holland Academic Graphics.

Borkovskii, Viktor Ivanovich, and Petr Savvich Kuznetsov. 1963. *Istoricheskaia grammatika russkogo iazyka*, Moscow, Akademiia Nauk SSSR.

Campbell, Lyle. 1999. *Historical linguistics: an introduction*, Cambridge, MA, MIT Press.

Carlson, R., B. Granström, and Gunnar Fant. 1970. 'Some studies concerning perception of isolated vowels', *Speech transmission laboratory - quarterly progress and status report* **2-3**, Stockholm, Royal Institute of Technology, 19-35.

Carlton, Terence R. 1991. *Introduction to the phonological history of the Slavic languages*, Columbus, OH, Slavica.

Chernykh, P. Ja. 1962. *Istoricheskaia grammatika russkogo iazyka*, Moscow, Gosudarstvennoe Uchebno-Pedagogicheskoe Izdatel'stvo Ministerstva Prosveshcheniia RSFSR.

Evans-Romaine, Dorothy Kathleen. 1998. *Palatalization and coarticulation in Russian*, Doctoral dissertation, University of Michigan.

Fant, Gunnar. 1960. *Acoustic theory of speech production*, The Hague, Mouton.

Farina, Donna Marie. 1991. *Palatalization and jers in modern russian phonology: an underspecification approach*, Doctoral dissertation, University of Illinois at Urbana-Champaign.

Filin, Fedot Petrovich. 1972. *Proiskhozhdenie russkogo, ukrainskogo i belorusskogo iazykov*, Leningrad, Nauka.

Flemming, Edward. 1995a. *Auditory representations in phonology*, Doctoral Dissertation, University of California, Los Angeles.

Flemming, Edward. 1995b. 'Phonetic detail in phonology: evidence from assimilation and coarticulation', in K. Suzuki and D. Elzinga (eds), *Proceedings of the Arizona Conference: Workshop on Features in Optimality Theory: Coyote Working Papers*, University of Arizona, Tuscon, 39-50.

Flemming, Edward. 1999. 'How to formalize constraints on perceptual distinctiveness', handout of paper presented at 'The role of speech perception phenomena in phonology', a satellite workshop to ICPhS, San Francisco.

Flemming, Edward. 2001. 'Scalar and categorical phenomena in a unified model of phonetics and phonology', *Phonology* **18.1**, 7-44.

Flier, Michael S. 1982. 'Morphophonemic change as evidence of phonemic change: the status of the sharped velars in Russian', *International journal of Slavic linguistics and poetics* **25-6**,137-148.

Gess, Randall. 2000. 'On constraint re-ranking in phonological change', unpublished manuscript, University of Utah.

Guion, Susan Guignard. 1998. 'The role of perception in the sound change of velar palatalization', *Phonetica* **55**,18-52.

Guy, Gregory R. 1996. 'Form and function in linguistic variation', in G. R. Guy, C. Feagin, D. Schiffrin and J. Baugh (eds), *Towards a social science of language: papers in honor of William Labov, Volume 1: variation and change in language and society*, Amsterdam, John Benjamins, 221-252.

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*, The Hague, Mouton.

Halle, Morris. 1962. 'Phonology in generative grammar', *Word* **18**, 54-72.

Hamilton, William S. 1980. *Introduction to Russian phonology and word structure*, Columbus, OH, Slavica.

Hawkins, John A., and Murray Gell-Mann (eds). 1992. *The evolution of human languages*, Reading, MA, Addison-Wesley Publishing Company.

Hayes, Bruce. 1999. 'Phonetically-driven phonology: the role of Optimality Theory and inductive grounding', in M. Darnell, E. Moravscik, M. Noonan, F. Newmeyer and K. Wheatly (eds), *Functionalism and formalism in linguistics, vol. 1: general papers*, Amsterdam, John Benjamins, 243-285.

Hoard, James, and G. N. O'Grady. 1976. 'Nyangumarda phonology, a preliminary report', in R. M. W. Dixon (ed), *Grammatical Categories in Australian languages*, Canberra, Australian Institute of Aboriginal Studies.

Holt, Eric. 1997. *The Role of the Listener in the Historical Phonology of Spanish and Portuguese: An Optimality-Theoretic Account*, Doctoral dissertation, Georgetown University.

Hutton, John. 1996. 'Optimality Theory and historical language change', unpublished manuscript, University of Manchester.

Ivanov, Valerii Vasil'evich. 1990. *Istoricheskaia grammatika russkogo iazyka*, Moscow, Prosveshchenie.

Jakobson, Roman. 1929. 'Remarques sur l'évolution phonologique du russe comparée à celle des autres langues slaves', *Travaux du Cercle linguistique de Prague* **2**. [In Jakobson, Roman. 1962. *Selected writings, vol. 1: phonological studies*, 'S-Gravenhage, Mouton, 7-116.]

Keating , Patricia, and Aditi Lahiri. 1993. 'Fronted velars, palatalized velars, and palatals', *Phonetica* **50**, 73-101.

Kingston, John, and Randy L. Diehl. 1994. 'Phonetic knowledge', *Language* **70.3**, 419-454.

Kiparsky, Paul. 1982a. 'Lexical phonology and morphology', in I.S. Yang (ed), *Linguistics in the Morning Calm*, Seoul, Hanshin.

Kiparsky, Paul. 1982b. *Explanation in Phonology*, Dordrecht, Foris.

Kiparsky, Paul. 1985. 'Some consequences of Lexical Phonology', *Phonology* **2**, 85-138.

Kiparsky, Paul. 1995. 'The phonological basis of sound change', in J.A. Goldsmith (ed), *The handbook of phonological theory*, Cambridge, MA, Blackwell, 640-670.

Kiparsky, Paul. 1998. 'Paradigm effects and opacity', unpublished manuscript, Stanford University.

Kirby, Simon. 1999. *Function, selection, and innateness: the emergence of language universals*, Oxford, Oxford University Press.

Kirchner, Robert. 1996. 'Synchronic chain shifts in Optimality Theory', *Linguistic Inquiry* **27**, 341-350.

Kirchner, Robert. 1997. 'Contrastiveness and faithfulness', *Phonology* **14.1**, 83-111.

Kirchner, Robert. 2001. 'Phonological contrast and articulatory effort', in L. Lombardi (ed), *Segmental phonology in Optimality Theory: constraints and representations*, Cambridge, Cambridge University Press, 79-117.

Kohler, K.J. 1990. 'Segmental reduction in connected speech in German: phonological facts and phonetic explanations', in W. J. Hardcastle and A. Marchal (eds), *Speech production and speech modelling*, Dordrecht, Kluwer, 69-72.

Labov, William. 1994. *Principles of language change. Volume 1: internal factors*, Oxford, Basil Blackwell.

Ladefoged, Peter. 1993. *A course in phonetics*, Fort Worth, TX, Harcourt Brace Jovanovich.

Ladefoged, Peter, and Ian Maddieson. 1996. *The sounds of the world's languages*, Cambridge, MA, Blackwell.

Lass, Roger. 1997. *Historical linguistics and language change*, Cambridge, Cambridge University Press.

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 J. Ohala and J. Jaeger (eds), *Experimental Phonology*, Orlando, FL, Academic Press, 13-44.

Lindblom, Björn. 1990. 'Explaining phonetic variation: a sketch of the H&H theory', in W. J. Hardcastle and A. Marchal (eds), *Speech production and speech modelling*, Dordrecht, Kluwer, 403-439.

Manuel, Sharon. 1990. 'The role of contrast in limiting vowel-to-vowel coarticulation in different languages', *Journal of the acoustical society of America* **88.3**, 1286-1298.

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 phonéticos,* Madrid, Editorial Gredos [Translation into Spanish of Économie des changements phonétiques, 1955.].

McCarthy, John J., and Alan Prince. 1993. 'Prosodic Morphology I: Constraint Interaction and Satisfaction', unpublished manuscript, University of Massachusetts, Amherst, and Rutgers University, New Brunswick, NJ.

McCarthy, John J., and Alan S. Prince. 1995. 'Faithfulness and reduplicative identity', in J. Beckman, S. Urbanczyk and L. Walsh (eds), *University of Massachusetts Occasional Papers in Linguistics (UMOP)* **18**, Amherst, MA, GLSA, 249-384.

Meillet, Antoine. 1951. *Obshcheslavianskii iazyk*, Moscow, Izdatel'stvo Innostrannoi literatury [Translation into Russian of Le Slave Commun, 2nd edition].

Nettle, Daniel. 1999. *Linguistic diversity*, Oxfor, Oxford University Press.

Ní Chiosáin, Máire, and Jaye Padgett. 1993. 'Inherent VPlace', *Linguistics Research Center Report* LRC-93-09, University of California, Santa Cruz.

Ní Chiosáin, Máire, and Jaye Padgett. 2001. 'Markedness, segment realization, and locality in spreading', in L. Lombardi (ed), *Segmental phonology in Optimality Theory: constraints and representations*, Cambridge, Cambridge University Press, 118-156.

Ohala, John J. 1983. 'The origin of sound patterns in vocal tract constraints', in P. MacNeilage (ed), *The production of speech*, New York, Springer Verlag, 189-216.

Ohala, John J. 1989. 'Sound change is drawn from a pool of synchronic variation', in L. E. Breivik and E. H. Jahr (eds.), *Language Change: Contributions to the Study of its Causes*, Berlin, Mouton de Gruyter, 173-198.

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, 258-275.

Öhman, S.E.G. 1966. 'Coarticulation in VCV utturances: spectrographic measurements', *Journal of the acoustical society of america* **39**, 151-168.

Padgett, Jaye. 1997. 'Perceptual distance of contrast: vowel height and nasality', in R. Walker, M. Katayama and D. Karvonen (eds), *Phonology at Santa Cruz Vol. 5*, Santa Cruz, CA, Linguistics Research Center, UC Santa Cruz, 63-78.

Padgett, Jaye. 2001a. 'Contrast dispersion and russian palatalization', in E. V. Hume and K. Johnson (eds), *The role of speech perception phenomena in phonology*, San Diego, CA, Academic Press, 187-218.

Padgett, Jaye. 2001b. The emergence of contrastive palatalization, unpublished manuscript, University of California, Santa Cruz.

Prince, Alan, and Paul Smolensky. 1993. 'Optimality theory: Constraint interaction in generative grammar', unpublished manuscript, Rutgers University, New Brunswick, NJ, 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, Aleksandr Aleksandrovich. 1957. 'Fonologicheskie zametki', *Voprosy iazykoznania* **2**, 101-102.

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, 494-499.

Rubach, Jerzy. 2000. 'Backness switch in Russian', *Phonology* **17.1**, 39-64.

Sanders, Nathan. to appear-a. 'Preserving synchronic parallelism: diachrony and opacity in Polish', in M. Andronis, C. Ball, H. Elston and S. Neuvel (eds), *CLS 37: The main session. Papers from the 37th meeting of the Chicago Linguistic Society, Vol. 1*, Chicago, Chicago Linguistic Society. [Also handout of paper presented at the third Generative Linguistics in Poland conference, Warsaw, Poland, 2001.]

Sanders, Nathan. to appear-b. *Opacity and sound change in the Polish lexico*, Doctoral dissertation, University of California, Santa Cruz.

Saussure, Ferdinand de. 1959. *Course in general linguistics*, New York, McGraw-Hill.

Schaarschmidt, Gunter. 1998. *A historical phonology of the Upper and Lower Sorbian languages*, Heidelberg, Universitätsverlag C. Winter.

Schenker, Alexander M. 1993. 'Proto-Slavonic', in B. Comrie and G.G. Corbett (eds), *The Slavonic languages*, London, Routledge, 60-121.

Schwartz, Jean-Luc, Louis-Jean Boë, Nathalie Vallée, and Christian Abry. 1997a. 'The dispersion-focalization theory of vowel systems', *Journal of phonetics* **25**, 255-286.

Schwartz, Jean-Luc, Louis-Jean Boë, Nathalie Vallée, and Christian Abry. 1997b. 'Major trends in vowel system inventories', *Journal of phonetics* **25**, 233-253.

Shevelov, George Y. 1965. *A prehistory of Slavic*, New York, Columbia University Press.

Smolensky, Paul. 1995. 'On the internal structure of the constraint component *Con* of UG', handout of talk given at University of Arizona.

Steriade, Donca. 1994. 'Complex onsets as single segments: the Mazateco pattern', in J. Cole and C. Kisseberth (eds), *Perspectives in phonology*, Stanford, CSLI Publications, 203-291.

Steriade, Donca. 1995. 'Underspecification and markedness', in J. Goldsmith (ed), *Handbook of phonological theory*, Cambridge, MA, Blackwell, 114-174.

Steriade, Donca. 1997. 'Phonetics in phonology: the case of laryngeal neutralization', unpublished manuscript, University of California, Los Angeles.

Stevens, Kenneth, and Samuel Jay Keyser. 1989. 'Primary features and their enhancements in consonants', *Language* **65**, 81-106.

Stevens, Kenneth N., Samuel Jay Keyser, and Haruko Kawasaki. 1986. 'Toward a phonetic and phonological theory of redundant features', in J. S. Perkell and D. H. Klatt (eds), *Invariance and variability in speech processes*, Hillsdale, New Jersey, Lawrence Erlbaum, 426-449.

Stieber, Zdzislaw. 1968. *The phonological development of Polish*, Ann Arbor, University of Michigan, Department of Slavic Languages and Literatures.

Sussex, Roland. 1992. 'Russian', W. Bright (ed), *International encylopedia of linguistics*, New York, Oxford University Press, 350-358.

Timberlake, Alan. 1978. 'K istorii zadnenebnykh fonem v severoslavianskikh iazykakh', in H. Birnbaum (ed), *American contributions to the Eighth International Congress of Slavists: volume 1: linguistics and poetics*, Columbus, OH, Slavica, 699-726.

Townsend, Charles E., and Laura A. Janda. 1996. *Common and comparative Slavic: phonology and inflection*, Columbus, OH, Slavica.
Trubetzkoy, Nikolai. 1969. *Principles of Phonology*, Berkeley, University of California Press.
Wright, J. T. 1986. 'The behavior of nasalized vowels in the perceptual vowel space', in J. Ohala and J. Jaeger (eds), *Experimental Phonology*, Orlando, FL, Academic Press, 45-67.
Zoll, Cheryl. 1996. 'Consonant mutation in Bantu', *Linguistic inquiry* **26.3**, 536-545.