

Restricted Structure Preservation in Stratal OT

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Abstract

Through analyses of Russian voicing assimilation and German dorsal fricative assimilation, this paper argues for a restricted version of structure preservation and a stratal model of Optimality Theory. Structure preservation (Kiparsky 1985) prohibits the creation of allophones early in the phonological computation. The parallel architecture of Optimality Theory undermines the assumptions of structure preservation and the principle has been widely rejected within OT. This paper demonstrates that processes that are both neutralizing and non-structure-preserving and which involve overlapping sets of targets and triggers, such as Russian voicing assimilation, result in a ranking paradox in parallel OT. Purely allophonic processes, such as German fricative assimilation, do not pose the same difficulties. Analyses of both processes are proposed within the framework of Stratal OT. The use of multiple strata eliminates the ranking paradox illustrated in Russian voicing assimilation and accounts for the interaction of German fricative assimilation and umlaut. By using a solution that relies on stratal OT, this analysis also makes predictions about the interaction between non-structure-preserving phonological processes and morphological structure. Whereas there are cases of strict allophony, like German dorsal fricative assimilation, which have been shown to apply prior to the addition of word-level affixes, this account predicts that non-structure-preserving neutralization cannot take place at the earliest level of evaluation but must apply after the Rich Base is filtered to the language-specific inventory and stem-level processes are applied. In the case of Russian, this is substantiated by application of assimilation across clitic boundaries, requiring phrase-level application.

Keywords: Stratal OT, structure preservation, assimilation, neutralization, allophony

1 Introduction

The principle of structure preservation (Kiparsky 1985) is intended to prohibit the creation of allophones during the course of operations in the lexical phonology. Although structure preservation has played an important role in the theory of lexical phonology, a number of empirical and conceptual challenges have been leveled against the principle, in both rule-based and constraint-based frameworks. This paper demonstrates that a restricted version of structure preservation can be upheld within Optimality Theory, if we distinguish between different types of structure preservation violations. Specifically, non-structure-preserving neutralization and purely allophonic processes are shown to have distinct properties when analyzed in OT. The analysis of non-structure-preserving neutralization processes which have overlapping targets and triggers results in a ranking paradox in classic, parallel OT. This ranking paradox follows from the architecture of OT

grammars, in conjunction with the principle of Richness of the Base. This provides an argument in support of a stratal model of OT (e.g., Bermúdez-Otero 1999; Kiparsky 2000; Rubach 2003) and shows that one type of structure preservation violation is ruled out at the earliest level of evaluation, substantiating a restricted structure preservation principle. Purely allophonic processes, on the other hand, do not result in a ranking paradox in a parallel OT evaluation. In a stratal OT account, this predicts that strictly allophonic processes can occur at any level, including the earliest level of evaluation, whereas non-structure-preserving neutralization is restricted to later levels, such as the word- or phrase-level.

Section 2 provides background on the principle of structure preservation and its status within rule-based theories and Optimality Theory. Section 3 provides a description of Russian voicing assimilation and a discussion of the challenges that this case has posed to a variety of theoretical frameworks since Halle's (1959) foundational analysis. A well-known case of a process that is both neutralizing and non-structure-preserving with overlapping targets and triggers, Russian voicing assimilation provides an illustration of the ranking paradox that arises when such processes are analyzed in a single OT evaluation. An analysis is proposed within the framework of Stratal OT. Section 4 considers German dorsal fricative assimilation as an example of an allophonic process that applies at the stem level. Section 5 concludes the paper.

2 Structure preservation

Phonological processes are often characterized as allophonic, processes which result in allophones, or neutralizing, processes which map phonemes to other phonemes. As developed in the theory of lexical phonology, the principle of structure preservation (Kiparsky 1985) prohibits the creation of allophones during the course of operations in the lexical phonology. As part of the constellation of properties distinguishing lexical from post-lexical processes, the principle has played an important role in lexical phonology's theory of morphology/phonology interaction. Empirical challenges to structure preservation emerged early, however, with many works presenting cases of non-structure-preserving processes that appeared to take place at the lexical level (e.g., Borowsky 1989; Harris 1987, 1990). These cases lead to various proposals weakening the claims of structure preservation. These include proposals that structure preservation holds only of the stem level, rather than throughout the lexical phonology (e.g., Borowsky 1993; Kaisse and Hargus 1994) as well as proposals that structures created through assimilation are not subject to structure preservation if they result in multiply-linked representations in an autosegmental framework (Macfarland and Pierrehumbert 1991).

In addition to empirical arguments, conceptual challenges to structure preservation have also been raised within rule-based frameworks (e.g., Reiss 2017). A process that is allophonic in one language may be neutralizing in another while nonetheless being identical in terms of the mapping between inputs and outputs (e.g., Katz 2016; Reiss 2017). In fact, a single process can be both neutralizing and allophonic within the same language, depending on the particular target affected. This is illustrated in Halle's (1959) famous analysis of Russian voicing assimilation, considered in detail in section 3. Voicing assimilation in Russian is neutralizing for most inputs but results in

allophones when applied to segments that do not have voiced counterparts in the phonemic inventory. Reiss (2017) argues that these patterns show that contrast plays no role in phonology. In this view, there is no substantive difference between neutralizing processes and allophonic ones and the principle of structure preservation has no role in the grammar.

Conceptual challenges to structure preservation have further sharpened with the advent of Optimality Theory (Prince and Smolensky 2004). OT's principle of Richness of the Base eliminates the concept of a basic inventory of underlying structures and, hence, the underpinnings of the principle of structure preservation. Structure preservation has largely been rejected within Optimality Theory, even by proponents of stratal OT models which adopt some of the level ordering of Lexical Phonology (e.g., Roca 2005; Bermúdez-Otero 2018; Kiparsky 2018). Given the empirical arguments against structure preservation, and the various complications proposed to deal with them, the fact that the assumptions of OT are inconsistent with the principle of structure preservation has been argued to be an advantage of the framework. Bermúdez-Otero states that parallel OT is "happily unable to express invalid claims like...Structure Preservation" (2018: 102).

The rejection of structure preservation in OT is not complete, however, especially within stratal models. Ito and Mester (2001) argue for a model of OT with distinct constraint rankings for lexical and post-lexical evaluations. They argue that outputs of the lexical level are subject to structure preservation, described as "limitation to a restricted inventory of elements and structures" (2001: 28). Similarly, Kiparsky (2018) states that "Stratal OT has no principle of Structure Preservation" (2018: 61) in the lexical phonology but that structure preservation at the stem level "is a theorem of Stratal OT, because the phonological inventory and stem structure of a language derives from its stem-level constraint system" (2018: 61, fn. 9). Although these works claim that the output of the stem-level constraint ranking results in a limited set of structures, it is unclear what properties, if any, these structures share crosslinguistically. The restrictions of stem-level outputs have not been shown to align with the phonemic inventory, making the connection between the original claims of structure preservation and the restrictions that follow from constraint ranking in a stratal OT model unclear.

The following sections address the issue of structure preservation in Optimality Theory by considering two well-known cases of non-structure-preserving processes, Russian voicing assimilation and German dorsal fricative assimilation. I will argue that certain types of non-structure-preserving processes cannot be analyzed in a single, parallel OT evaluation. Processes that are both non-structure-preserving and neutralizing and which have overlapping sets of targets and triggers result in a ranking paradox whereas purely allophonic processes do not. This provides an argument in support of stratal OT, with non-structure-preserving neutralization analyzed at the word- or phrase-level in a multi-step OT evaluation.

3 Russian voicing: non-structure-preserving neutralization

Russian voicing assimilation presents a well-known example of a process that is both neutralizing and non-structure-preserving (Halle 1959). This case has famously been presented as an argument against the structuralist phoneme (Halle 1959) and, more recently, against any role for contrast in the phonological grammar (Reiss 2017). Section 3.1 presents the basic pattern of Russian voicing assimilation. Section 3.2 briefly summarizes Halle's (1959) analysis and the challenges it poses for structuralist phonology and theories of contrastive specification. In section 3.3, I show that, while the assumptions critiqued by Halle (1959) have been superseded by subsequent theoretical models, Russian voicing assimilation also poses challenges to parallel Optimality Theory. In section 3.4, I propose a Stratal Optimality Theory analysis of Russian voicing assimilation.

3.1 Russian voicing assimilation

In Russian, obstruents both trigger and undergo regressive voicing assimilation whereas sonorants fail to participate in the process. This is illustrated in the data in (1), below.

- (1) a. s-jexatʲi 'to ride down' iz-lagatʲi 'to set forth'
 b. s-prositʲi 'to ask' is-ključatʲi 'to exclude'
 c. z-dělatʲi 'to do' iz-gnatʲi 'to drive out' (Padgett 2002: 2)

The forms in (1a) show the underlying voicing value of the prefixes as they surface before sonorant consonants. Examples in (b) and (c) show that the final segment of the prefix surfaces as voiceless before voiceless obstruents and as voiced before voiced obstruents, regardless of underlying voicing specification.

Voicing is generally contrastive for obstruents in Russian but not for sonorants. Voicing assimilation is therefore neutralizing, with most outputs of the process being members of the phonemic inventory. The restriction of the process to the class of obstruents, with sonorants neither triggering nor undergoing assimilation, is consistent with the 'contrastivist hypothesis' (Hall 2007a) which states that only contrastive features are active in phonological processes. However, as shown in the obstruent inventory chart below, a small set of voiceless obstruents do not have voiced counterparts in the phonemic inventory.

(2) Inventory of Russian obstruents¹

manner		bilabial	labio-dental	alveolar	post-alveolar	velar
stops	vls	p		t		k
	vcd	b		d		g
fricatives	vls		f	s	ʃ	x
	vcd		v	z	ʒ	
affricates	vls			ts	tʃ	
	vcd					

(3) a. ʒɛʃ li 'should one burn?' (Halle 1959)
b. ʒɛɟ bi 'were one to burn'

(4) a. *liek-* ‘to heal’
 lieḑ-ba ‘healing, archaic’⁴ (Timberlake 2004: 69)
 b. *nadžbol* ‘a member of National Bolshevik party’ (/natsional-bolʃevʲik/)
 nadždʲif ‘the head of a military division’ (/naʃʃalʲnʲik-dʲivʲizʲii/)
 c. *bidžbol* ‘beach-ball’ loan (loan, English)
 alidžgiejmier ‘Alzheimer’s (disease)’ (loan, German) (examples Kochetov, p.c.)

(5) biez oziëra ‘without a lake’
 biez xlieba ‘without bread’
 biez tzeni ‘without price’
 biez tfestiji ‘without honour’

(Calabrese 1995: 440–442)

5

rules for Russian voicing assimilation. For the unpaired obstruents, /ts, tʃ, x/, representations containing voiceless segments are consistent with this requirement even in contexts where voicing assimilation results in voiced variants on the surface (1959: 22-23). For example, the representation /zɛʃ bi/, for the form for ‘were one to burn?’, meets the bi-uniqueness requirement. This form will always surface with a voiced affricate, given the assimilation rule. The voiced affricate on the surface can only be the realization of the underlying voiceless affricate, given the structure of the inventory, and specifically, the absence of underlying /dʒ/. For morphemes which undergo voicing alternations involving other obstruents, however, there is no single representation that meets the requirements of bi-uniqueness. A form like [m’og bi] ‘were (he) getting wet’ will always surface with a voiced [g] but there is no unique representation that can be inferred from this form as both underlying /k/ and /g/ would be associated with the same pronunciation. Instead of two, highly similar rules, Halle proposes that a single rule can account for voicing assimilation, if the requirement of bi-uniqueness is rejected and, with it, the distinction between morphophonemic and phonemic rules.

In Halle’s analysis, the pattern of Russian voicing assimilation illustrates fundamental problems with structuralist models of the phonological grammar. In particular, Halle characterizes the requirement that every surface form be associated with a unique phonological representation as “an unwarranted complication which has no place in a scientific description of language” (1959:24).

Although the distinction between morphophonemic and phonemic representations has been rejected in contemporary phonological theory, Reiss (2017) claims that additional implications of Halle’s analysis have not had the same impact. Reiss argues that a logical consequence of Halle’s analysis is that contrast plays no role in phonological grammars (2017: 26). Reiss’s argument challenges proposals, such as the contrastivist hypothesis, that tie phonological activity to inventory shape. According to Reiss (2017), the fact that /ts, tʃ, x/ do not have partners in the inventory that contrast minimally in voicing, yet nonetheless behave like other obstruents with respect to voicing assimilation, invalidates any theory that links feature specification and activity to contrasts in inventories.⁵ Reiss argues that the contrastive status of a feature is irrelevant, both to the determination of assimilation targets and to the determination of assimilation triggers (2017: 28). In this view, Halle’s analysis shows that there is no distinction between allophonic rules and neutralizing ones.

The conclusions that Reiss draws from Halle’s analysis of Russian assume a minimal-pair definition of contrast (e.g., Archangeli 1988; Nevins 2010), according to which a feature is contrastive for a given segment only if there is another segment in the inventory identical in all other feature specifications. However, other definitions of contrast do not require a minimal distinction between segment pairs for a feature to be designated as contrastive. Contrastive Hierarchy Theory (Dresher 2009) proposes that contrasts are determined by language-specific orderings of features. Features are assigned in order, dividing the inventory into contrasting subsets, until every segment is uniquely specified. Analyses of Russian voicing assimilation within Contrastive Hierarchy Theory (Dresher 2009; Hall and Dresher 2016; Dresher and Hall 2021) show that if the feature [voice] is ordered low in the hierarchy, below place and manner features that distinguish

/x/, /ts/, and /tʃ/ from other obstruents, it will not be designated as contrastive for these segments. However, the theory of the contrastive hierarchy allows for variation in the ordering of features between languages. If [voice] is ordered high, it will be contrastive even for these unpaired members of the inventory. Drescher and Hall (2021) show that, not only can the behavior of /x/, /ts/, and /tʃ/ be accounted for using specifications consistent with the contrastive hierarchy, a contrastive hierarchy analysis also accounts for other aspects of Russian phonology.⁶ In light of this work, Reiss's (2017) claim that Halle's analysis of Russian voicing assimilation eliminates any role for contrast in phonological grammars is unconvincing. Interpreted more narrowly, however, Reiss's argument shows that Russian voicing assimilation and its analysis in Halle (1959) pose fundamental challenges to a definition of contrast that relies on minimally differing segment pairs.

Halle's analysis of Russian challenges the architecture of structuralist grammars and the role and definition of contrastive representations in rule-based theories. The following section will illustrate that Russian voicing assimilation also poses a distinct problem for the model of the phonological grammar proposed in classic, parallel Optimality Theory.

3.3 A ranking paradox in Optimality Theory


In Optimality Theory, the phonemic inventory, like all other phonological patterns, is determined by the interaction of ranked and violable constraints. The principle of Richness of the Base requires inputs to be free from language-particular restrictions related to inventory structure. In this framework, processes that are both neutralizing and non-structure-preserving, like Russian voicing assimilation, result in a ranking paradox. The paradox follows from the need for constraint rankings to map potential inputs that are absent from the inventory to well-formed outputs. Rankings which successfully filter the rich base to the language-specific phonemic inventory require input-output mappings that are also available to satisfy markedness constraints motivating phonological processes. This paradox has been identified in OT analyses of epenthesis (Krämer 2006) and local (Bermúdez-Otero 2007) and long-distance (Mackenzie 2016) assimilation. The paradox arising in the case of Russian voicing assimilation specifically, is considered in Hall (2007b) and in a recent paper by Gouskova (2022). Given the structure of the Russian consonant inventory, high-ranking markedness constraints must prevent the voiced obstruents [dz, dʒ, ʎ] from surfacing in output forms in most contexts. However, these segments are required to surface as the output of voicing assimilation when applied to /ts, tʃ, x/. Any ranking which successfully accounts for the inventory will fail to account for assimilation.

The paradox can be illustrated using a fairly standard analysis of voicing assimilation, such as that in Padgett (2012). In this analysis, assimilation is motivated by the following constraint, using the formulation from Bakovic (2000).

(6) AGREE[voice]: adjacent obstruents have identical specifications for [voice]

In Padgett (2012), AGREE[voice] outranks both *D, a markedness constraint penalizing voiced obstruents, and the faithfulness constraint IDENT[voice]. To account for directionality of assimilation, Padgett uses an additional constraint, IDENT_{PRE-SONORANT}[voice]. This positional faithfulness constraint (Beckman 1997; Beckman 1998) is informed by Steriade’s (1997) arguments for a hierarchy of perceptually salient positions. With respect to voicing, perceptual cues such as VOT and release burst properties are more salient before sonorants than before obstruents. The use of IDENT_{PRE-SONORANT}[voice] can account for the right-to-left directionality of assimilation in Russian obstruent clusters, which is consistent even when both segments occupy the syllable onset. The basic analysis is illustrated in tableaux (7) below, adapted from Padgett (2012).


(7) Assimilation in onset clusters, adapted from Padgett (2012)

	IDENT _{PS} [voice]	AGREE [voice]	*D	IDENT[voice]
kdʲe				
a) kdʲe		*!	*	
b)  gdʲe			**	*
c) ktʲe	*!			*

In (7), the faithful candidate in (a) fatally violates AGREE[voice]. The optimal candidate in (b) satisfies AGREE[voice] through regressive assimilation, incurring two violations of *D and one violation of the context-free faithfulness constraint IDENT[voice]. The candidate in (c) shows progressive assimilation to the initial, voiceless segment. This satisfies AGREE[voice] and *D but incurs a fatal violation of the positional faithfulness constraint IDENT_{PRE-SONORANT}[voice].

Padgett’s (2012) analysis does not consider the behavior of the unpaired obstruents, /ts, tʃ, x/. Given the absence of the voiced counterparts /dz, dʒ, ɣ/ outside of assimilation contexts, additional markedness constraints will be needed to exclude these segments from surface forms. *[dʒ] is used in the tableaux below as a shorthand for a constraint penalizing particular feature combinations. In the tableau in (8), *[dʒ] is ranked above *D, reflecting the fact that voiced obstruents in general are part of the Russian inventory but /dz, dʒ, ɣ/ are not. With this ranking, otherwise identical to the ranking from Padgett (2012), illustrated above, the unpaired segments will undergo assimilation, just like other obstruents.

(8) Assimilation of /tʃ/

	IDENT _{PS} [voice]	AGREE [voice]	*[dʒ]	*D	IDENT[voice]
bitʃbol					
a) bitʃbol		*!		*	
b)  bidʒbol			*	**	*
c) bitʃpol	*!				*

In (8), the faithful candidate is eliminated due to violation of AGREE[voice]. The candidate in (c) satisfies AGREE[voice] by devoicing the rightmost consonant in the cluster. This satisfies the markedness constraints *[dʒ] and *D but fatally violates the positional faithfulness constraint IDENT_{PRE-SONORANT}[voice]. In candidate (b), the /tʃ/ undergoes assimilation, resulting in the allophonic occurrence of [dʒ]. This is the optimal and attested output.

Although it successfully accounts for assimilation, this analysis fails to account for the exclusion of /dʒ/ from the inventory in general. This is illustrated in (9) where devoicing of input /dʒ/ in candidate (b) results in a fatal violation of the positional faithfulness constraint. The faithful and unattested candidate in (a) is optimal.

(9) Evaluation of hypothetical input containing [dʒ]

	dʒox	IDENT _{PS} [voice]	AGREE [voice]	*[dʒ]	*D	IDENT[voice]
a)	⊗ dʒox			*	*	
b)	tʃox	*!				*

These tableaux demonstrate that a standard analysis of voicing assimilation that incorporates positional faithfulness results in a ranking paradox in Russian. It is tempting to try to avoid this paradox by considering additional output candidates and featural faithfulness constraints. In an example such as (9), where a hypothetical input is considered, we lack direct evidence regarding what such an input would actually surface as. In the absence of such evidence, any mapping to a possible, grammatical form is successful in accounting for the inventory. The tableau in (10) shows that the ranking from Padgett (2012) *can* account for the inventory if we include candidates that differ from the input in features other than voice. Here, the optimal candidate in (c) differs from the input in the feature [continuant]. The constraint IDENT[continuant] is included and must be ranked below *[dʒ] in order to prevent the faithful candidate from winning.

(10) Evaluation of hypothetical input containing [dʒ]: low ranking IDENT[continuant]

	dʒox	IDENT _{PS} [voice]	AGREE [voice]	*[dʒ]	IDENT[cont]	*D	IDENT[voice]
a)	dʒox			*!		*	
b)	tʃox	*!					*
c)	⦿ ʒox				*	*	*

Although tableau (10) shows that IDENT[continuant] can be ranked below *[dʒ] in a grammar that successfully accounts for the absence of [dʒ] from the phonemic inventory, this ranking is unable to account for assimilation. A tableau illustrating this ranking with an input with /tʃ/ in the assimilation context is shown in (11).

(11) Evaluation of /tʃ/ in assimilation context: low ranking IDENT[continuant]

bitʃbol	IDENT _{PS} [voice]	AGREE [voice]	*[dʒ]	IDENT[cont]	*D	IDENT[voice]
a) bitʃbol		*!			*	
b) ⊗ bidʒbol			*!		**	*
c) ↻ biʒbol				*	**	*
d) bitʃpol	*!					*

As in previous tableaux, the faithful candidate fatally violates AGREE[voice] and the attested output fatally violates *[dʒ]⁷. Violation of the positional faithfulness constraint IDENT_{PRE-SONORANT}[voice] eliminates the candidate in which the rightmost consonant in the cluster is devoiced, shown in (d). The winner in (c) satisfies AGREE[voice] and *[dʒ] by altering both voicing and continuancy of the target consonant. Because the consonant precedes an obstruent, IDENT_{PRE-SONORANT}[voice] is satisfied and only the lower-ranked constraints IDENT[continuant], *D, and IDENT[voice] are violated. With this ranking, the unfaithful mapping of [continuant], which is successfully able to account for the inventory as shown in (10), is also available to satisfy AGREE[voice], counter to the attested assimilation pattern.

Russian voicing assimilation is a process that, intuitively, is easy to characterize and rather unremarkable; obstruents assimilate in voicing to a following obstruent. Yet analysis of this process raises fundamental questions and poses significant challenges to a range of phonological theories. Assumptions about the interaction between phonological representations and operations that have been challenged by the analysis of Russian include the bi-uniqueness assumption of structuralism, the role of minimally different phoneme pairs in determining feature specifications in theories of contrastive specification, and Richness of the Base and strict parallelism in OT.

3.4 Stratal OT Analysis

The ranking paradox that arises in the analysis of Russian voicing assimilation, and in cases of non-structure-preserving neutralization more generally, can be resolved if we adopt a stratal model of Optimality Theory (e.g., Bermúdez-Otero 1999; Kiparsky 2000; Rubach 2003). Constraint ranking at the stem level determines the shape of the inventory and stem-level phonological processes. Constraints may be reranked in word- and phrase-level grammars in order to motivate phonological processes occurring at those levels.

In addition to the ranking paradox that arises in a single, classic OT evaluation of Russian, the assimilation facts show that the process applies post-lexically, adding further support to a stratal analysis. As illustrated in section 3.1, assimilation occurs across a variety of morphosyntactic boundaries, including the boundary between a preposition and a following word, as in the examples in (5), and the boundary between a stem and a following enclitic, as in the example in (3). Although prepositions such as /bʲiez/ ‘without’ form a prosodic word with a following lexical item, they are unambiguously syntactically

independent. Prepositions can attach freely to the leftmost element in a noun phrase, regardless of its lexical category, and can appear stranded without a phonological host in certain gapping constructions (Gribanova 2008). The application of voicing assimilation across the prefix boundary shows that it must apply post-lexically.⁸

The following analysis will demonstrate only stem- and phrase-level evaluations, with crucial ranking differences between them. Both of these levels are needed for the analysis at hand. Russian voicing cannot be accounted for in a single, stem-level evaluation and the pattern of assimilation across prefix and enclitic boundaries requires it to apply post-lexically. Gribanova (2008) argues that crucial ranking differences between the word- and phrase-levels are also needed to account for palatalization patterns and for morphosyntactic differences between prefixes and prepositions. These are not directly relevant to the analysis of voicing assimilation and I leave aside arguments for unique word-level ranking.

In the proposed analysis, *[dʒ], and parallel constraints prohibiting [dz] and [ʝ], must be ranked above some featural faithfulness constraint at the stem level in order to exclude outputs that are not members of the phonemic inventory. The constraint motivating assimilation, however, is not highly ranked at the stem level, consistent with the analysis of voicing assimilation as a phrase-level process. A stem-level evaluation of a hypothetical input containing /dʒ/ is illustrated in (12). Both the context-free version of IDENT[voice] and the positional faithfulness constraint IDENT_{PRE-SONORANT}[voice] are included in the tableau. Although not crucial here, use of both constraints is needed to account for the directionality of assimilation in later tableaux. I have chosen to show IDENT[voice] ranked above IDENT[continuant]. With this ranking, candidate (c), in which input /dʒ/ surfaces as [+continuant] [ʒ], is optimal. This choice is influenced by arguments in Dresher and Hall (2021) to the effect that, in Russian, voicing is preserved at the expense of continuancy. For the data considered here, nothing crucial hinges on the relative ranking of IDENT[voice] and IDENT[continuant]. Filtering the rich base to the Russian inventory requires input /dʒ/ to map to some output segment present in the language, whether [ʒ], as shown (12), or [tʃ], as would be expected if IDENT[continuant] outranked IDENT[voice].

(12) Stem-level evaluation of hypothetical input containing [dʒ]

	dʒox	*[dʒ]	IDENT[voice]	IDENT _{PS} [voice]	IDENT [cont]	AGREE [voice]
a)	dʒox	*!				
b)	tʃox		*(!)	*(!)		
c)	ʒox				*	

A stem-level evaluation of the form /bitʃbol/ is shown in (13). The ranking differs from tableaux used to illustrate the ranking paradox in that the constraint AGREE[voice], which motivates assimilation, is ranked low. This results in the selection of the faithful candidate in (a) as optimal. Other candidates that could satisfy the assimilation constraint,

shown in (b-d), necessarily violate IDENT[voice]. IDENT[voice] is ranked higher than AGREE[voice] and these candidates are eliminated.

(13) Stem-level evaluation of /bitʃbol/

bitʃbol	*[dʒ]	IDENT[voice]	IDENT _{PS} [voice]	IDENT [cont]	AGREE [voice]
a) bitʃbol					*
b) bidʒbol	*(!)	*(!)			
c) biʒbol		*!		*	
d) bitʃpɒl		*(!)	*(!)		

The stem-level ranking proposed for Russian is summarized in (14).

(14) *[dʒ], IDENT[voice], IDENT_{PS}[voice] >> IDENT[continuant], AGREE[voice]

The output of the stem-level serves as the input to the phrase-level evaluation. This input consists of members of the phonemic inventory and does not show the effects of voicing assimilation. The tableau in (15) shows a phrase-level evaluation of [bidʒbol]. There are two crucial differences in constraint ranking between the stem level and the phrase level. First, the markedness constraint AGREE[voice] is promoted above IDENT[voice], triggering assimilation. Secondly, the constraint against [dʒ] is ranked below both IDENT_{PRE-SONORANT}[voice] and IDENT[continuant]. With this ranking, IDENT[continuant] preserves the [-continuant] specification of [tʃ] in the input, eliminating candidate (c), and IDENT_{PRE-SONORANT}[voice] eliminates the ‘wrong-direction’ assimilation candidate in (d). Candidate (b), with [dʒ] as the output of assimilation, is optimal.

(15) Phrase-level evaluation of /bitʃbol/ [bidʒbol]

bitʃbol	AGREE [voice]	IDENT [voice]	IDENT _{PS} [voice]	IDENT [cont]	*[dʒ]
a) bitʃbol	*!				
b) bidʒbol		*			*
c) biʒbol		*		*!	
d) bitʃpɒl		*	*!		

In the case of Russian, voicing assimilation takes place at the phrase level. At the stem level, the rich base is filtered to result in output segments which are part of the phonemic inventory. Stem-level inputs undergo voicing assimilation at the phrase level where the constraint driving assimilation is ranked above markedness constraints like *[dʒ]. Assimilation is non-structure-preserving, leading to outputs which are not members of the phonemic inventory.

The phrase-level ranking for Russian is given in (16).

(16) AGREE[voice] >> IDENT[voice], IDENT_{PS}[voice], IDENT[continuant] >> *[d₃]

The pattern found in Russian, in which segments both trigger assimilation and undergo assimilation resulting in allophonic outputs for some inputs, is ruled out at the stem level due to the ranking paradox that follows from the need for constraint ranking to determine the inventory. However, the lexical phonology literature documents a number of cases of non-structure-preserving processes that appear to occur at the stem level, prior to word-level affixation. The analysis and implications of these processes are discussed in the following sections.

4 Against structure preservation: purely allophonic processes at the stem level

As discussed above, Optimality Theory poses a number of conceptual challenges to structure preservation. OT's premise of Richness of the Base requires inputs to be free, undermining the notion of language-specific inventories of basic structures to be preserved. Even within stratal OT, which incorporates many of the insights and some of the mechanisms of lexical phonology, structure preservation has been rejected as a basic principle (e.g., Bermúdez-Otero 2018). The discussion of neutralizing and non-structure-preserving processes presented above suggests that certain types of structure-preservation violations are ruled out at the earliest level of evaluation within a stratal OT model. In the case of Russian, I argued that voicing assimilation is not a stem-level process and requires reranking at the phrase level in order for voiced allophones of /x, ts, tʃ/ to surface. Yet many of the cases presented as arguments against structure preservation in the lexical phonology literature suggest that allophonic processes can occur early in the lexical phonology. The following sections consider one of those cases, namely German dorsal fricative assimilation.

I will present a stratal OT analysis of dorsal fricative assimilation and demonstrate that the ranking paradox shown in the analysis of Russian does not arise here. While Russian voicing assimilation is both neutralizing and non-structure-preserving, the German case is purely allophonic. Unlike in Russian, there is no overlap between the triggers and targets of assimilation. As a result, faithfulness of the assimilation trigger can be maintained by high-ranking constraints without resulting in unattested segments occurring outside of the assimilation context. This allows the allophonic output of assimilation to surface as optimal in a single evaluation.

4.1 German dorsal fricative assimilation

Harris (1990) introduced the term *derived contrasts* to characterize cases where processes that create allophones in the lexical phonology interact with morphological structure to create surface contrasts. Dorsal fricative assimilation in German provides one example. The velar fricative [x] and the palatal fricative [ç] are allophones, with [x] occurring after back vowels and [ç] occurring elsewhere (17). The velar fricative [x], however, does not occur when an affix boundary intervenes between the fricative and a preceding back vowel, resulting in the surface contrasts in (18).

- (17) Lichte [lɪçt] ‘light’ Nacht [naxt] ‘night’
 Chemie [çɛmi] ‘chemistry’ durch [dʊrç] ‘through’
 (18) Tau-chen [tauçən] ‘little rope’ tauch-en [tauxən] ‘dive-inf’
 Kuh-chen [kuçən] ‘little cow’ Kuchen [kuxən] ‘cake’


These data have received significant attention in the literature and have played a role in debates around structure preservation. The case has been argued to provide a counterexample to structure preservation, as it requires the allophonic process to occur early in the lexical phonology (e.g., Hall 1989; Harris 1990). McFarland and Pierrehumbert (1991) use the example of German dorsal fricative assimilation to argue that assimilatory processes which result in multiply-linked structures in autosegmental representations do not constitute violations of structure preservation. OT analyses of the process are presented in Merchant (1996) and Noske (1997), both of which use alignment constraints referring to prosodic constituents, and Goldrick (2000), who uses Turbidity Theory to account for the effects of morphological boundaries.

The following sections provide a stratal OT account of the German data. A stratal account is also proposed in Ito and Mester (2001), who focus on the interaction of dorsal fricative assimilation and /r/-vocalization. The analysis argued for here follows Ito and Mester (2001) in ascribing fricative assimilation to the lexical level. It differs in integrating the analysis of assimilation with constraint rankings needed to derive the inventory. This analysis also focuses on the derived contrasts which result from dorsal fricative assimilation and the interaction of assimilation and umlaut, neither of which are addressed in Ito and Mester’s (2001) account.

4.2 Inventory structure and the stem-level grammar

A markedness constraint against [+back, +continuant] consonants, abbreviated here as *[x], prevents [x] from surfacing outside of the context of assimilation, as illustrated in the tableau below. The tableau contains two versions of the faithfulness constraint IDENT[back], a general version, violated by any discrepancy in input-output specifications for [back], and a positional version, IDENT[back]_{NUCLEUS}, violated only by unfaithful mappings in segments occupying the syllable nucleus. This distinction will be crucial when we consider assimilation contexts.

(19) Stem-level evaluation of input [x]

	durx	IDENT [back] _{NUCLEUS}	IDENT[cont]	*[x]	IDENT[back]
a)	durx			*!	
b)	durk		*!		
c)	 durç				*


In (19), the faithful candidate violates the markedness constraint *[x]. The final consonant in the optimal candidate in (c) has a [back] specification that differs from that in the input. This allows this candidate to satisfy the markedness constraint *[x]. This candidate violates only the context-free version of IDENT[back] and is selected as the winner.

The data from German dorsal fricative assimilation suggests that the process applies at the stem level, before word-level suffixes like /-çən/ are added. In a stratal OT account, this requires the constraint ranking which motivates assimilation to be integrated with the constraint ranking which determines the inventory. In the analysis below, assimilation is motivated by an AGREE constraint, similar to that used in the analysis of Russian.

- (20) AGREE[back]_{VC}: If a vowel is specified as [+back], an immediately following consonant must also be specified as [+back]. Assign a violation mark for any consonant following a [+back] vowel that does not have a [+back] feature.

This constraint must be ranked high at the stem level, to account for the appearance of [x] in forms like [kuxən] ‘cake’. At the word level, AGREE[back]_{VC} must be demoted in order to allow [ç] to surface when it occurs after back vowels in morphologically complex forms like [ku-çən] ‘little cow’. In Russian, we have seen that voicing assimilation cannot apply at the stem level because of the ranking paradox that arises in non-structure-preserving applications of the process. The analysis of German dorsal fricative assimilation closely resembles that proposed for Russian in terms of the types of constraints and in the constraint rankings used to determine the phonemic inventory. However, the ranking paradox that arises in Russian voicing assimilation does not occur in the German case, allowing the assimilation process to apply at the stem level. This is illustrated in tableau (21), below.

- (21) Stem-level evaluation of input with /ç/ following a back vowel

	buç	AGREE[back] _{VC}	IDENT [back] _{NUCLEUS}	IDENT [cont]	*[x]	IDENT[back]
a)	buç	*!				
b)	 bux				*	*
c)	buk			*!		
d)	biç		*!			*

The faithful candidate in (a) violates AGREE[back]_{VC} because the fricative following [+back] /u/ is not specified as [+back]. The winning candidate in (b) satisfies AGREE[back]_{VC} through assimilation, surfacing with [+back] [x] as an allophone of /ç/. This is the attested output. The candidate in (c) contains the back consonant /k/ as an output correspondent of the input fricative. Although this candidate satisfies both

AGREE[back]_{VC} and *[x], it violates high-ranking IDENT[continuant] and is eliminated. Candidate (d) satisfies the AGREE constraint by changing the [back] specification of the vowel, rather than the dorsal consonant. This violates high-ranking IDENT[back]_{NUCLEUS}, resulting in elimination.

A ranking analogous to that shown in the evaluation of [bux], above, is possible in the analysis of Russian voicing assimilation and was discussed in relation to tableaux (8) and (9), repeated below as (22) and (23). The types of constraints used in the German and Russian tableaux are the same and the relative ranking of constraints is also similar with an AGREE constraint motivating assimilation ranked above a markedness constraint penalizing segments which are absent from the inventory. A positional faithfulness constraint is also ranked high, above the markedness constraint, but the relevant context-free faithfulness constraint is ranked below. Despite these similarities, in Russian, this ranking is able to select the attested output of assimilation, as in (22), but fails to account for the absence of unpaired segments like [dʒ] in other environments, as shown in (23). This ranking paradox shows that, in Russian, the attested pattern, in which assimilation is satisfied by allophonic variation, cannot be selected in a single, parallel evaluation which is also required to determine the inventory.

(22) Russian unpaired obstruents: ranking paradox

	IDENT _{PS} [voice]	AGREE [voice]	*[dʒ]	*D	IDENT[voice]
bitʃbol					
a) bitʃbol		*!		*	
b) bidʒbol			*	**	*
c) bitʃpɒl	*!				*

(23)

	IDENT _{PS} [voice]	AGREE [voice]	*[dʒ]	*D	IDENT[voice]
dʒox					
a) dʒox			*	*	
b) tʃox	*!				*

In the German example in (21), on the other hand, the ranking which selects the correct, allophonic output is consistent with the ranking needed to account for the inventory. This is because, in German, the set of segments which trigger assimilation does not overlap, in featural composition or prosodic distribution, with the set of segments which undergoes assimilation. In Russian, assimilation requires input-output mappings which change the feature [voice]. In the attested pattern, assimilation leads unpaired obstruents, such as /tʃ/, to map to allophonic outputs, such as [dʒ]. However, any ranking that makes [dʒ] an optimal output of assimilation will be unable to prevent [dʒ] from surfacing in other contexts, as illustrated in (23). Positional faithfulness constraints protecting feature specifications in pre-sonorant position are unable to circumvent this problem and will simply result in faithful, and unattested, realization of input [dʒ] in onset positions in the

language more generally. The paradox arises because the set of assimilation targets and triggers overlap in Russian. Any ranking that protects faithfulness in prominent positions, like the position preceding a sonorant, at the expense of allowing marked allophones to surface, as in (22), will also allow the marked segments to surface if they occur before a sonorant in the input, as in (23). Positional faithfulness constraints therefore will not work for this pattern. High ranking of faithfulness constraints referring to particular segment classes or feature combinations will also not work, as the voiced obstruents which trigger assimilation in examples like (22) must also undergo assimilation when they occur before a voiceless obstruent.

The overlap in targets and triggers which results in the ranking paradox in Russian is a common, although not necessary, property of neutralization processes, including cases of non-structure-preserving neutralization. In purely allophonic processes, on the other hand, the set of target and trigger segments does not overlap. As a result, the mapping in which the attested trigger of assimilation changes to satisfy the assimilation constraint, which was problematic in Russian, can be avoided in allophonic cases like German by high ranking of positional faithfulness constraints. In German, IDENT[back]_{NUCLEUS} prevents any change in [back] specification for the vowel, resulting in the attested pattern in which the consonant surfaces as a [+back] allophone. This does not create any problems for deriving the inventory structure, as the dorsal fricatives do not occur in nucleus position. High ranking of the positional faithfulness constraint will therefore not create an unattested contrast between [x] and [ç]. Other analyses are also available to derive the allophonic distribution of [x] and [ç] in a single OT evaluation. Again, because there is no overlap in the set of targets and triggers in dorsal fricative assimilation, the attested pattern could also be achieved through high ranking of faithfulness constraints that refer to features in the context of segments of a particular class. For example, IDENT[back]_V could maintain faithfulness in [back] specifications for [-consonantal] segments. Because the target of assimilation is [+consonantal], this would also successfully derive the distribution of [x] and [ç] in German. Neither of these mechanisms will avoid the ranking paradox illustrated in Russian voicing assimilation because the set of targets and triggers overlap and can occupy the same prosodic positions.

The observation that neutralization processes can involve an overlap between the set of targets and triggers, whereas purely allophonic processes cannot, is consistent with the contrastivist hypothesis. By definition, a process which is neutralizing, like Russian voicing assimilation, affects features which serve to contrast members of a phonemic inventory. Those segments which trigger assimilation contrast in the active feature, [voice]. Thus, the active feature triggering assimilation is contrastive. Because targets and triggers overlap, the relevant feature is also contrastive in targets of assimilation. In purely allophonic cases like German dorsal assimilation, on the other hand, the target of assimilation does not have a contrastive value for the relevant feature. In the German inventory, [back] is only contrastive among the vowels. Because the process is triggered by back vowels, the active feature is contrastive, as predicted by the contrastivist hypothesis. The target, however, does not contrast in the relevant feature. This is what makes the process allophonic. If the target was contrastively specified for [back], the

process would be neutralizing. For allophonic processes, there cannot be an overlap between triggers and targets and the ranking paradox illustrated in Russian will not arise. Note that the ranking paradox also does not arise in the analysis of processes which are purely neutralizing which do not require outputs which are not part of the phonemic inventory. It is the neutralizing and non-structure-preserving aspect of Russian voicing assimilation that results in a ranking paradox.

As illustrated above, the allophonic process of dorsal fricative assimilation in German can be analyzed in a single, parallel evaluation. Nonetheless, a multi-stratal model is required in the German case, in order to account for the effects of morphological constituency on assimilation. The ranking illustrated above holds for the stem-level. The proposed stem-level ranking is summarized in (24).


- (24) AGREE[back]_{VC}, IDENT[continuant], IDENT[back]NUCLEUS >> *[x] >>
IDENT[back]

In most contexts, this ranking is able to map the rich base to outputs that are members of the German phonemic inventory. However, if a dorsal consonant is preceded by a [+back] vowel, this ranking also requires that consonant to be specified as [+back]. The resulting output segment is a [+back] fricative, [x], which is not a member of the inventory. At the word-level, the constraint driving assimilation must be ranked below the constraint penalizing [x] in order to prevent assimilation from applying to sequences of back vowels and dorsal fricatives that arise through word-level affixation.

4.3 Word-level analysis

The preceding section provides an analysis of the stem-level grammar. The constraint ranking accounts for the inventory and the application of dorsal fricative assimilation in forms like [bux], ‘book’, and [kuxen], ‘cake’. At the word-level, however, a different constraint ranking is needed in order to account for the failure of assimilation to apply in forms like [ku-çən], ‘little cow’. Outputs of the stem-level evaluation serve as inputs to the word-level grammar. The constraint AGREE[back]_{VC} must be ranked below the faithfulness constraint referring to [back] to prevent assimilation from applying to sequences of back vowels and dorsal fricatives that are created at the word level by affixation.


- (25) Word-level evaluation of [ku-çən] ‘little cow’

ku-çən	IDENT[back]	IDENT[cont]	*[x]	AGREE[back] _{VC}
a)  kuçən				*
b) kuxən	*!		*	
c) kukən	*(!)	*(!)		
d) kiçən	*!			

In (25), the faithful candidate in (a) is selected as optimal. Candidate (b) satisfies the constraint AGREE[back]_{VC} and shows the effects of assimilation. However, it violates the faithfulness constraint IDENT[back], which is ranked above AGREE[back]_{VC}.⁹ The candidate in (c) satisfies the assimilation constraint by mapping [ç] to [k]. This candidate satisfies both AGREE[back]_{VC} and *[x] but incurs violations of both IDENT[continuant] and IDENT[back]. Candidate (d) contains a front vowel as a correspondent of the back vowel in the input, allowing it to satisfy AGREE[back]_{VC}. However, this candidate also fatally violates IDENT[back].

The tableau above shows that, at the word level, the faithfulness constraint referring to input values of [back] must be ranked above the constraint that drives assimilation in order to prevent assimilation from occurring when its environment is created through word-level affixation. In addition, [+back] dorsal fricatives created at the stem level, must surface faithfully at the word level in order to account for the presence of [x] in forms like [kuxen], ‘cake’. This is also achieved through high-ranking of IDENT[back] at the word level. Because the [+back] specification of [x] in [kuxen] was created in the stem-level evaluation, faithfulness to [back] will ensure that this segment surfaces in the output of the word level grammar. This is illustrated below.

(26) Word-level evaluation of [kuxen] ‘cake’

kuxən	IDENT[back]	IDENT[cont]	*[x]	AGREE [back] _{VC}
a)  kuxən			*	
b) kuçən	*!			*
c) kukən		*!		

The optimal candidate in (26) is the faithful candidate in (a). This candidate violates the constraint *[x]. However, it faithfully realizes the [+back] feature in the input, thereby satisfying high-ranking IDENT[back].

The tableaux above illustrate the crucial differences in ranking between the stem level and the word level. At the word level, the constraint IDENT[back] must outrank AGREE[back]_{VC} in order to prevent assimilation from applying to newly created sequences of [+back] vowels and dorsal consonants. The markedness constraint *[x] must also be ranked below the faithfulness constraint IDENT[back] so that [+back] dorsal consonants created through assimilation at the stem level surface faithfully in the output of the word-level evaluation. The proposed word-level constraint ranking is given below¹⁰.

(27) IDENT[back], IDENT[cont] >> *[x], AGREE[back]_{VC}

4.4 Interaction of fricative assimilation and umlaut

The proposed word-level ranking maintains the [+back] specification of [kuxen], ‘cake’, by high ranking faithfulness to input specifications of [back]. High ranking faithfulness to [back] also prevents novel instances of [x] from being created at the word level, accounting for underapplication of assimilation in forms like [ku-çen] ‘little cow’. This follows the spirit of rule-based analyses such as Harris (1990). By altering the ranking that motivates assimilation, the ‘rule’ is ‘turned off’ at the word level.

One additional complication of the fricative assimilation facts is the presence of forms in which the application of umlaut at the word level results in the palatal fricative surfacing even in forms where the input contains a [+back] [x], created at the stem level. Examples are shown below.

- | | | | |
|------|----------------|-----------|----------------|
| (28) | [bax] ‘river’ | [beçlajn] | ‘little brook’ |
| | [brux] ‘break’ | [bryçig] | ‘breakable’ |

These forms require an unfaithful mapping from [x] to [ç] at the word level, potentially posing a challenge to the analysis with high ranking IDENT[back], argued for above. In accounts of fricative assimilation within the framework of lexical phonology, the data in (28) have been taken as evidence that assimilation applies late in the lexical phonology, after affixation and the application of umlaut (e.g., Iverson and Salmons 1992).¹¹ Such analyses are clearly inconsistent with the analysis proposed here which ascribes assimilation to the stem level and accounts for the failure of assimilation to apply across morpheme boundaries by constraint reranking at the word level. However, within the framework of OT, the appearance of the palatal fricative in the umlauted forms in (28) does not require fricative assimilation to apply after umlaut. The analysis presented below shows that the palatal fricatives can be derived through the use of LINEARITY requiring identical ordering of elements between input and output forms (e.g., McCarthy and Prince 1995).


Although a detailed analysis of umlaut is beyond the scope of this paper, previous analyses account for umlaut through the use of a floating [–back] feature, either associated with the suffix (e.g., Lieber 1992) or the stem (e.g., Wiese 1996) or both (e.g., Trommer 2016). Regardless of the details of the analysis, if a [–back] feature is present in the input in order to trigger umlaut, faithful realization of that feature can account for the presence of the palatal fricative. This is consistent with the word-level ranking proposed above in conjunction with high ranking of an additional faithfulness constraint requiring the linear order of [back] features to be maintained between input and output.

- (29) LINEARITY[back]: If a feature x [+back] precedes a feature y [–back] in the input, x precedes y in the output

The following tableau illustrates the word-level evaluation of a form with umlaut and a palatal fricative. The input shows a sequence of three specifications for [back]. The first [+back] feature is associated with the back vowel. The second [+back] feature is

associated with the dorsal fricative and is present in the input due to the application of assimilation at the stem level. The final specification is the floating [−back] feature which triggers umlaut. Only forms with an umlauted vowel are considered as output candidates.

(30) Word-level evaluation of [bɛç-lajn] ‘little brook’

bax-lajn [+b][+b][−b]	LINEARITY [back]	IDENT[back]	*[x]	AGREE[back] _{VC}
a) bɛxlajn [−b][+b]	*!	*	*	
b)  bɛçlajn [−b][−b]		**		

In the form [ku-çen], ‘little cow’, dorsal fricative assimilation fails to apply at the word level and the [ç] surfaces faithfully. In [bɛç-lajn], on the other hand, the input to the word level contains the [+back] fricative present in [bax]. Candidate (a) in (30) retains this [+back] specification for [x]. However, application of umlaut in this candidate requires the [−back] feature present in the input to precede the [+back] specification of the fricative in the output, resulting in a fatal violation of LINEARITY[back]. In the optimal candidate in (b), the palatal fricative is specified as [−back]. This candidate violates IDENT[back] twice as neither of the [+back] specifications present in the input surface faithfully in the output. IDENT[back], however, is ranked below LINEARITY[back] and this form satisfies LINEARITY while realizing the [−back] feature of umlaut. Note that it is not assimilation between the vowel and consonant per se that motivates the unfaithful mapping of the fricative in this case. Rather, the requirement for umlaut on the vowel prevents faithful realization of the [+back] feature of the fricative.

5 Other approaches

The challenge that non-structure-preserving neutralization poses to parallel OT has been recognized in previous work (e.g., Krämer 2006; Bermúdez-Otero 2007; Mackenzie 2016). Stratal OT accounts, similar to that outlined here, have been advocated in analyses of laryngeal neutralization in Catalan (Bermúdez-Otero 2007) and consonant harmony in Nilotic (Mackenzie 2016). Krämer (2006) provides an analysis of glottal epenthesis in German that relies on the mechanism of Comparative Markedness (McCarthy 2002). In this section, I focus on works that address this issue with respect to voicing assimilation in Russian specifically, namely Hall (2007b) and Gouskova (2022).

Hall (2007b) provides a discussion of Russian voicing assimilation and analysis of analogous data in Czech. His proposal uses a strictly parallel model of OT in conjunction with the theory of specifications elaborated in Contrastive Hierarchy Theory (Dresher 2009). As discussed in section 3.2, Contrastive Hierarchy theory proposes that contrastive feature specifications are assigned according to language specific hierarchies such that higher ordered features are contrastive for a greater number of segments and lower ordered features are assigned only when needed to ensure that each member of a phonemic inventory is uniquely specified. Although this has been formalized as a step-

wise procedure (e.g., Dresher 2009), representations consistent with the contrastive hierarchy can be enforced in a strictly parallel OT grammar (Mackenzie and Dresher 2004; Dresher 2009). In such analyses, the feature hierarchy corresponds to a ranking of feature-specific faithfulness constraints. Both segments that are absent from the inventory and features which are designated as non-contrastive by the proposed feature hierarchy are excluded from output representations by constraints of the form $*[\alpha F, \Phi]$ which penalize specification for any value of $[F]$ in segments that are also specified for the feature or features $[\Phi]$. In the case of Russian or Czech, the feature $[\text{voice}]$ must be ordered high enough in the hierarchy to ensure contrastive specification among the affricates and low enough to be unspecified among sonorants, which neither trigger nor undergo assimilation. In Hall's OT analysis, (see also Hall and Dresher 2016; Dresher and Hall 2021) the constraint $*[+\text{son}, \text{voice}]$ is ranked above $\text{IDENT}[\text{voice}]$, both preventing voiceless sonorants from surfacing and eliminating specification of any value of $[\text{voice}]$ in $[+\text{sonorant}]$ segments. $\text{IDENT}[\text{voice}]$ is ranked above $*[+\text{voice}, \text{delayed release}]$ which, in turn, is ranked above $\text{IDENT}[\text{delayed release}]$. This ranking prevents the voiced affricates from surfacing while ensuring faithful realization of input $[-\text{voice}]$ specifications for $[\text{ts}, \text{tʃ}]$, consistent with their behavior as triggers of assimilation. However, this analysis encounters the same ranking paradox outlined in section 3. In assimilation contexts, candidates with allophonic voicing of the affricates violate $*[+\text{voice}, \text{delayed release}]$ and lose to structure-preserving forms that satisfy assimilatory constraints by changing affricates to stops.

Hall (2007b) proposes a solution to this problem that reformulates the markedness constraints that account for the inventory and contrastive specifications. Instead of feature cooccurrence constraints of the form $*[\alpha F, \Phi]$, Hall uses disalignment constraints which prohibit the specification of $[F]$ and $[\Phi]$ in a single segment only if they have an identical span of association. Assuming an autosegmental view of assimilation as multiple-linking, $[\text{d}_3, \text{dz}]$ created through assimilation will not violate the constraint $\text{DISALIGN}[+\text{voice}, \text{delayed release}]$ because the feature $[\text{voice}]$ is linked, not only to the affricate, but also to the trigger of assimilation. This analysis is similar in spirit to proposals by McFarland and Pierrehumbert (1991) that structure-preservation does not rule out segments created through multiple-linking.

Although this analysis succeeds in avoiding the ranking paradox posed by voicing assimilation in Russian and Czech, Hall (2007b) acknowledges that the constraint formalisms required in this approach are somewhat complex and may not be easily extended to account for other assimilatory patterns such as long distance harmony (2007b: 13). More importantly for our purposes, the use of DISALIGN constraints does not make predictions about how voicing assimilation interacts with other aspects of Russian phonology and morphology. In the stratal OT account argued for here, non-structure-preserving neutralization processes such as Russian voicing assimilation cannot apply at the stem level. This is supported in the Russian case by the application of assimilation across clitic boundaries in forms that must be created post-lexically, at the phrase level.

Recent work by Gouskova (2022) proposes a solution to the ranking paradox encountered by OT analyses of Russian voicing assimilation by introducing a constraint type novel to OT. The Morpheme Structure Constraint $*/\text{d}_3/$ prohibits the voiced affricate

from occurring in lexical representations, not in output forms. In Gouskova's proposal, the ranking of this constraint relative to other markedness constraints is undetermined because they refer to different representations (2022: 7). The constraint */dz/ refers only to inputs whereas markedness constraints refer to output forms. Gouskova's analysis shares with the stratal analysis proposed here the need for a level of representation in which there are no voiced affricates. In Gouskova's analysis, that level is the input, requiring a retreat from Richness of the Base. In the analysis outlined here, voiced affricates are prohibited from the output of the stem level, allowing Richness of the Base to hold for inputs to the earliest level of evaluation. Like the DISALIGN approach of Hall (2007b), this analysis does not make predictions about the relationship between voicing assimilation and other morphophonological processes.

In advocating limitations on Richness of the Base, Gouskova states that the gaps in the inventory need not be motivated by other aspects of phonological patterning but rather, should be accepted "as a fact of life" (2022: 18). This is not the view taken here. It is the need to derive the gaps in the inventory through constraint ranking, and the resulting ranking paradox, that predicts non-structure-preserving neutralization processes to take place at the word level or above. Furthermore, constraint rankings which determine the inventory at the stem level may play an important role in shaping phonological patterns that take place at this level. Processes that apply at later levels may also be affected by stem-level rankings which shape the representations that serve as inputs to subsequent levels. In the case of Russian, Drescher and Hall's (2021) analysis of voicing assimilation within the framework of Contrastive Hierarchy Theory argues that feature specifications are tied to inventory shape and to language-specific feature hierarchies. In this view, the unpaired segments are specified for [voice] but the gaps in the inventory of voiced obstruents result in an absence of specification for [continuant] for some segments with consequences for alternations between fricatives and non-continuant. Aspects of this analysis have been adapted into classic OT (Hall 2007b) and previous work (Mackenzie 2016) has shown that Contrastive Hierarchy Theory can be incorporated into stratal OT, compatible with the approach outlined in this paper. The account of non-structure-preserving neutralization argued for here is consistent with a model that adopts Richness of the Base for the initial input and expects gaps in inventories to have consequences for the phonological system more generally.

6 Conclusion

The principle of structure preservation has been challenged, both within rule-based phonology and in OT. The analyses presented here show that non-structure-preserving neutralization which involves overlapping sets of targets and triggers, such as the voicing assimilation process seen in Russian, results in a ranking paradox in a single, parallel evaluation. This provides an argument for a stratal version of OT in which rankings can vary between lexical levels (e.g., Bermúdez-Otero 1999; Kiparsky 2000). In addition, the paradox illustrated here validates a restricted version of structure preservation in which only these cases of non-structure-preserving neutralization are ruled out from stem-level application. Processes that are both neutralizing and non-structure-preserving and that

have an overlap between targets and triggers must apply at the word or phrase level, when constraint rankings are no longer required to filter the rich base to members of the language-particular inventory. Purely allophonic processes, however, can apply at the stem level and do not lead to the same ranking paradox encountered in the case of non-structure-preserving neutralization. In purely allophonic processes, constraint rankings needed to prevent relevant allophones from surfacing in general do not necessarily impede the application of the process. Because targets and triggers do not overlap, positional faithfulness constraints or faithfulness constraints referring to particular feature classes can protect assimilation triggers while allowing allophones to surface.

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¹ Palatalized consonants have been omitted from the inventory chart.

² Although the labio-dental fricatives are included like other voiced-voiceless pairs in the chart in (2), they do not pattern analogously to other obstruent pairs that differ in voicing. /v/ undergoes voicing assimilation and final devoicing, like other obstruents, but behaves

like sonorants in failing to trigger assimilation. The idiosyncratic behavior of /v/ is addressed in a number of works (Hayes 1984; Kiparsky 1985; Padgett 2002a; Hall 2004; Reiss 2017). An analysis of /v/ is not considered here.

³ Note that the loanwords included here contain [dz, dʒ] in the context of a following voiced obstruent and can be derived by assimilation. See Gouskova (2022: 19) for evidence that [dʒ] is not directly borrowed into Russian but is instead realized as a heterorganic cluster [dz] in forms such as [dʒɪnsi] ‘jeans’.

⁴ /-jba/ is a palatalizing suffix which triggers the /k/ > [tʃ] illustrated in this example. The suffix is no longer productive.

⁵ Although Reiss’s (2017) argument against contrast in phonology refers to Halle’s analysis of the unpaired obstruents, much of his analysis focuses on the idiosyncratic behavior of /v/ in Russian, a topic not addressed here.

⁶ A feature ordering that results in contrastive specification of [voice] for /x/, /ts/, and /tʃ/ naturally results in the lack of contrastive specification for some features elsewhere in the inventory. Dresher and Hall (2021) show that one consequence of their proposed feature hierarchy is the lack of contrastive specification for [continuant] in the voiced obstruents /z, ʒ, g/. They argue that the absence of [continuant] on these segments accounts for their alternations with non-continuant stops and affricates in phonological processes such as First Velar Palatalization. See section 5 for additional discussion of this point.

⁷ /bitʃbol/ is used as the underlying representation here and as the input to the tableau in (11), consistent with the fact that [dʒ] is not part of the Russian phonemic inventory. Because this form does not exhibit alternations, [dʒ] may be expected to be present in the underlying representation based on Lexicon Optimization. The voicing value of the affricate in the input has no impact on the ranking paradox illustrated here. It is not a faithfulness violation that leads to the elimination of the attested output, but the violation of the markedness constraint penalizing [dʒ].

⁸ Although examples of voicing assimilation across lexical words are included in a number of sources (e.g., Halle 1959), application in this context is reported to be gradient and variable (e.g., Shapiro 1993; Padgett 2012). This is in contrast to the pattern of voicing assimilation found within words and across prefix boundaries. In light of the fundamental differences in the application of assimilation within and across lexical words, previous studies have argued that the domain of phonological assimilation is restricted and the gradient and variable assimilation found across lexical words can be attributed to the phonetic component (Padgett 2002; Padgett 2012). Phonological assimilation must apply post-lexically to account for its systematic application across prefix and enclitic boundaries. Reference to prosodic boundaries is needed to account for the failure of assimilation across word boundaries. A number of prosodic accounts have been proposed, including restricting assimilation to the clitic group (Padgett 2002), and blocking of assimilation by the left edge of a maximal prosodic word (Gouskova 2010).

⁹ This assumes that affixes added at the word level are restricted to the inventory of structures permitted as outputs of the stem-level grammar. This can be ensured if word-level affixes pass through stem-level evaluations, a proposal advocated in Buckler and Bermúdez-Otero (Buckler and Bermúdez-Otero 2012).

¹⁰ The constraint IDENT[back]_{NUCLEUS} is not shown here or in the tableaux in (25) and (26). Every candidate which violates IDENT[back]_{NUCLEUS} will also necessarily violate IDENT[back]. Given the high-ranking of IDENT[back] at this level, the relative ranking of IDENT[back]_{NUCLEUS} will not play a deciding role in determining the optimal output.

¹¹ Hall (1989) is able to account for the umlaut facts by formulating the assimilation rule with a stipulation requiring the fricative undergoing assimilation and the vowel that triggers it to occur in the same morpheme. This allows Hall (1989) to order assimilation relatively late in the lexical phonology while preventing application in forms like [ku-çen] ‘little cow’ simply because the target and trigger are not in the same morpheme. The stipulation requiring target and trigger to be tautomorphemic is undesirable in a lexical phonology framework where the architecture of level ordering is available to account for effects of morphological constituency.