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*Opaque distributional generalisations in Tundra Nenets**

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Based on primary data from Tundra Nenets, this paper explores phonological patterns which seem to require restrictions on the input, and thus present a particular challenge to Optimality Theory. In these patterns, a contrastive segment appears only in the environments where it is also derived by active alternations in the language. I illustrate this with the behaviour of Tundra Nenets /k/, and argue that these patterns can be analysed as distributional generalisations that hold only at early derivational levels. A Stratal OT analysis is proposed. Tundra Nenets also presents a pattern which appears to involve unnatural classes, but is reanalysed with only natural class alternations in my account.

1 Introduction

Classical Optimality Theory (OT) allows no restrictions on the input – a principle labelled Richness of the Base by Prince & Smolensky (2004), and criticised by Vaysman (2002), Hansson (2003) and Rasin & Katzir (2017). Despite the criticism, no real alternatives to Richness of the Base have been proposed within OT; existing computational implementations of OT evaluation and typology rely on it (Staubs *et al*. 2010, Hayes *et al*. 2013, Prince *et al*. 2018), and synchronic analyses of sound patterns presuppose it.

In this paper, I explore a particular kind of phonological pattern in which a contrastive segment emerges only in the environments where it is also derived by a process, using the example of /k/ in Tundra Nenets. As argued by McCarthy (2005), such patterns call for incorporating input restrictions in the phonological theory, against Richness of the Base. However, I argue that Richness of the Base can be maintained if

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these patterns are analysed as OPAQUE DISTRIBUTIONAL GENERALISATIONS. These are defined as phonotactic generalisations which hold at early stages of derivation but are not surface-true, since they are relaxed at later derivational stages. Just like opaque processes, opaque distributional generalisations can be formalised within Stratal OT (Bermúdez-Otero 1999, Kiparsky 2000) as restrictions on the output of early strata. This expands on ideas in Bermúdez-Otero (2001, 2006, 2007) and Ito & Mester (2003).

The non-surface distributional generalisations discussed here are similar to morpheme structure rules or constraints (e.g. Halle 1959, 1962, Stanley 1967, Booij 2011), recently dubbed 'constraints on underlying representations' by Rasin & Katzir (2017). Such non-surface constraints have been criticised for duplicating either surface constraints or otherwise applicable rules (Clayton 1976, Kenstowicz & Kisseberth 1977: §3.1), and conventions intended to avoid such duplication were proposed in early work on constraints on underlying representations (Stanley 1967, Shibatani 1973). The opaque distributional generalisations discussed here are not subject to the duplication problem, since they are not surface-true, nor do they duplicate any processes, since they are encoded in a constraint-based framework.

The proposed account touches upon a number of hotly debated topics in theoretical phonology, including abstractness and free rides (Zwicky 1970, McCarthy 2005, Lloret & Pons-Moll 2016), and Duke-of-York derivations (Pullum 1976, Bermúdez-Otero 2001, McCarthy 2003b, Rubach 2003). These will be further discussed in what follows.

My analysis captures the fact that Tundra Nenets /k/ never occurs phrase-initially, even though initial position is typically associated with higher degrees of faithfulness (Casali 1996, Beckman 1998), and no known positional augmentation constraints prohibit initial /k/ (Smith 2005, Flack 2007, 2009).

I also provide a general way to formally characterise some patterns which appear to involve unnatural classes, but result from the derivational interaction of regular natural class alternations. For example, coronal and labial stops in Tundra Nenets undergo voicing after vowels, but dorsal stops are apparently excluded from this process. This pattern can be understood if we assume that the voicing process targets only stops which are present at the relevant derivational stage, and that /k/ is not present at that stage. This proposal is also in line with the finding that patterns involving unnatural classes can be productive (Gallagher 2019).

§2 introduces Tundra Nenets, and reviews my data sources. §3 surveys the relevant data, and §4 provides an analysis. Alternatives are considered in §5. §6 concludes.

2 Background on Tundra Nenets

Tundra Nenets is a Uralic language spoken in northern Russia (Castrén 1854, Tereshchenko 1947, 1956, Janhunen 1984, 1986, Salminen 1997, 1998a, b, Nikolaeva 2014). The distribution and alternations of Tundra Nenets consonants are described extensively by Janhunen (1986) and Salminen (1997, 1998b).

The patterns to be presented here largely correspond with these sources. The data have been expanded and verified against two corpora of recorded Tundra Nenets speech. The first corpus comes from the author's fieldwork on a Western Tundra Nenets dialect spoken in the village of Nelmin Nos, in the Nenets district of Russia. The second corpus consists of transcribed and glossed texts recorded by Irina Nikolaeva (see also Nikolaeva 2014).[1] The author's fieldwork results come from six female speakers, all of whom were born and raised in the Nenets district. They ranged in age from 44 to 65 at the time of recording.

The dialect of Nelmin Nos belongs to the Western Tundra Nenets dialect group, and differs from Central Tundra Nenets, which can be considered standard. My consultants are aware of the differences between Western and Central pronunciations, and produce both dialectal and standard forms, depending on the social context of the conversation. In what follows, I will mostly focus on the patterns common to the two dialects, while acknowledging specifically Western Tundra Nenets traits where relevant.

The surface inventory of Tundra Nenets consonants is given in (1). Allophonic variants in free variation or complementary distribution are listed with '~'.

(1) *Surface consonant inventory of Western Tundra Nenets*

	labial	coronal	dorsal	glottal
stops	p pʲ b~β bʲ	t tʲ d~ð dʲ	k~g	ʔ
fricatives		s sʲ	x~xʲ	
nasals	m mʲ	n nʲ	ŋ	
affricates		ʦ~z ʦʲ~zʲ		
liquids		r rʲ l lʲ		
glides	w wʲ	j		

All dialects show obstruent voicing after nasals, and this process is the only source of surface [g z zʲ]. In some Western dialects, the resulting homorganic nasal + obstruent sequences are regularly simplified to yield just the obstruent, e.g. /nt/ → |nd| → [d] (Salminen 1997), yielding instances of intervocalic [g z zʲ].[2] The Nelmin Nos dialect shows a similar tendency, but the process of denasalisation here is variable, and sometimes phonetically incomplete. I list [g z zʲ] as allophonic variants of /k ʦ ʦʲ/ respectively in (1), and return to this issue in §3.2. In many dialects of Tundra Nenets, /d/ is often realised as [ð], and in Nelmin Nos /b/ is also occasionally

[1] Nikolaeva's corpus is available at http://elar.soas.ac.uk/Collection/MPI120925.

[2] I use / / for underlying phonemes, | | for intermediate non-surface representations and [ ] for surface segments, whether contrastive or not.

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realised as [β]. The palatalised glide /wʲ/ occurs only in the Western dialects, including Nelmin Nos. Finally, the palatalised dorsal fricative appears only in /xʲiˑbʲa/ 'who', and can probably be treated as an allophone of /x/, since the former never occurs before a sequence of /iˑ/ + palatalised consonant (Salminen 1997).

The vowel inventory is given in (2) (cf. Salminen 1993a, b).[3]

(2) *Surface vowel inventory of Tundra Nenets*

i iˑ iː			u uˑ uː
e eː			o oː
	ʌ ʌː	°	
	a aː		

The inventory in (2) contains the 'null vowel', represented as /°/, which may occur as the head of syllables in Tundra Nenets. This vowel is derived from /ʌ/ by a process of reduction, usually applicable in word-final and even-numbered syllables (Helimski 1989, Salminen 1993a, 1997, 1998b). The null vowel can be realised as an overshort vowel or as the release of a consonant; in some cases it is not pronounced. The surface long vowels listed in (2) are derived from an underlying sequence of a vowel + /ʌ/. Despite its highly variable realisation, the null vowel triggers a number of surface alternations, such as postvocalic voicing (*pace* Kavitskaya & Staroverov 2010). Tundra Nenets syllable structure is CV(CC), with a limited inventory of complex codas. Word-initial /ŋ/ is dropped in Western dialectal speech, producing onsetless syllables.

Tundra Nenets phonology and morphology show some evidence of cyclic or stratal organisation. In the phonology, there is a clear distinction between processes that apply across word boundaries and those that do not. This distinction is paralleled by two well-defined morphological domains: the word (including stem and suffixes) and the phrase (usually comprising two words). Phrasing patterns depend on speech rate: neighbouring words are more often phrased together in faster speech.

3 Evidence for opaque distributional generalisations

This section outlines two patterns in the phonology of Tundra Nenets /k/ that can be analysed by postulating an opaque distributional generalisation. §3.1 shows that the distribution of phrase-initial stops is a challenge for positional faithfulness, and §3.2 demonstrates that the undergoers of a medial voicing process are an apparently unnatural class, which includes coronal and labial stops, but not dorsals. In §3.3, I show that surface [k]

[3] Unlike Nikolaeva (2014), I transcribe the central non-low vowel as [ʌ] rather than [ə], since this seems to capture the pronunciation more closely. The potential existence of [æˑ] contrasting with [e] in the initial syllable (Salminen 1997, Nikolaeva 2014) may need further investigation for the Nelmin Nos dialect. None of the examples in this article have this vowel.

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in fact only appears in the environments where it is (or could be) derived from /x/. I argue that deriving all surface dorsal stops from an underlying fricative solves both problems mentioned above. The examples in this section include underlying representations, which will be substantiated in detail in §4.

3.1 Initial stops

Initial position typically exhibits preservation of contrasts (Casali 1996, Beckman 1998, Smith 2005), yet in Tundra Nenets the initial inventory of stops includes only coronals and labials; dorsals are not found.[4] Tundra Nenets does not have prefixes, and therefore the initial position coincides with the left edge of the stem. The restrictions in (3) are observed at the left edges of phrases, since phrase-medial words are subject to additional boundary alternations.

(3) *Phrase-initial stops*

	p pʲ	t tʲ	k
#__V	✓	✓	*

The lack of initial /k/ is a productive generalisation in Tundra Nenets phonology: the vast majority of loanwords with initial /k/ in Russian are recorded with a /x/-initial variant or exclusively as /x/-initial in the Tundra Nenets dictionary (Tereshchenko 1965), e.g. /xos°ka ~ koʃ°ka/ from Russian /koʃkə/ 'cat', /xorawa ~ korowa/ from Russian /kɐrovə/ 'cow'. My consultants are usually aware of both variants for such words. All the consultants are native speakers of Russian, and code-switching is very common. The loan pronunciations with unadapted initial /k/ could thus simply come from Russian, while the variants with initial /x/ clearly show influence of Tundra Nenets phonology.

To summarise, even though Tundra Nenets has contrastive /k/, it never shows up in phrase-initial position. This is a potential problem for the claim that initial position is associated with contrast preservation (Casali 1996, Beckman 1998). Moreover, as discussed in §5.1 below, there are no known positional augmentation constraints prohibiting phrase-initial /k/ (Smith 2005, Flack 2007, 2009).

3.2 Phrase-medial voicing

The stops /p pʲ t tʲ/ undergo voicing after a vowel, and an account of Tundra Nenets phonology should ideally explain why /k/ escapes this process. Recall that /ʌ/ and /°/ alternate, as the result of a general vowel-

[4] The restrictions on Tundra Nenets initial consonants are actually more pervasive: voiced stops and the affricates [ʦ ʦʲ] also never occur phrase-initially. The distribution of these consonants can also be analysed in terms of opaque distributional generalisations. Janhunen (1986) argues that it makes sense to assume that the consonants prohibited word-initially always derive from one of the 'primary obstruents' /p pʲ t tʲ s sʲ x/. Here I focus on the distribution and alternations of /k/ and /x/, but similar arguments extend to other consonants.

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reduction process, and that /Vʌ/ sequences merge, surfacing as a long vowel (e.g. /pʌniʌ/ → [pʌniː] in (4b)).[5]

(4) *Postvocalic voicing*

a. [b d] *after vowels*

/ja-ta/ earth-POSS.SG3SG	jada
/ŋinʌ-ta/ bow-POSS.SG3SG	ŋin°da
/nʲebʲa-toN/ mother-POSS.SG3PL	nʲebʲadoʔ
/pʲa-pʌʔ/ start-COND	pʲab°ʔ
/mʲarʲojʌ pʌniʌ-naʔ/ bald garment-POSS.PL1PL	mʲarʲoj° bʌniːnaʔ

b. [p t] *elsewhere*

/jar-ta/ side-POSS.SG3SG	jarta
/xajer-ta/ sun-POSS.SG3SG	xajerta
/ŋob-toN/ one-POSS.SG3PL	ŋobtoʔ
/mʌlʌr-pʌʔ/ chirp-COND	mʌlʌrp°ʔ
/pʌniʌ/ garment	pʌniː

In Western dialectal speech, the voiced stops /b d/ (especially /d/) undergo variable lenition to [β ð]. Postvocalic voicing operates within words, and across phrase-medial word boundaries. Examples containing more than one word in (4) and in what follows illustrate word-boundary processes in relatively fast connected speech, where the two words form a phrase. These boundary processes are heard in recorded texts, and are often not transcribed in the phonemic notation of Nikolaeva (2014).

Importantly, there are no parallel examples of voicing for the dorsal stop /k/. This fact is even more puzzling since intervocalic [g] is allowed in Western Tundra Nenets. In the standard dialect, [g] normally occurs only after nasals, where it derives from underlying /x/ by strengthening. However in Western dialects [ŋg] varies with [g], and other nasal + stop clusters are also simplified. The Western dialect examples in (5) are taken from a corpus of spontaneous

[5] /N/ stands for a nasal whose place cannot be determined; see also Staroverov & Kavitskaya (2017). The Leipzig glossing rules (Comrie *et al*. 2015) are used for glosses, with the addition of AFF = affirmative and CONNEG = connegative. Possessive markers in Tundra Nenets encode the number of both possessor and possessee, and are notated as, for example, POSS.SG3SG.

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speech described by Nikolaeva (2014). Although the same words have not been recorded with [ŋg], there is little doubt that this pronunciation is possible in more careful or formal speech. Very similar examples with clusters are recorded in Nikolaeva's corpus, sometimes from the same consultants. Some of the words in (5) come from a larger phrase, and show initial [d dʲ] from phrasal voicing. Finally, the last word in (5) shows an additional regular alternation whereby intervocalic /m/ changes to [w].

(5) *Intervocalic* [g] *in Western Tundra Nenets*

/tʲeʦʲʌ-Nxu/	dʲeʦʲ°gu[6]
cold-FUT.SBJ.3SG	
/tara-Nxuʔ/	daraguʔ
need-FUT.SBJ.3PL	
/sʲerʌ-Nxunaʔ/	sʲer°gunaʔ
wear-FUT.OBJ.PL.SBJ.1PL	
/nʲaN-xʌmamʌ/	nʲag°waw°
mouth-AFF.POSS.SG1SG	

Salminen (1997, 1998b) reports dialects where /ŋg/ to [g] simplification is more regular, creating a clear contrast between intervocalic [k] and [g]. In Nelmin Nos, the phonemic status of [g] is more complicated, since it varies with [ŋg].

In sum, the undergoers of postvocalic voicing form an unnatural class, which can only be described by a disjunction, *viz.* 'coronal or labial stops'. /k/ does not undergo voicing, despite the fact that intervocalic [g] is found. If the class of undergoers included /k/, it could be characterised as natural, for example as [−continuant, −constricted glottis], where the specification [−constricted glottis] is required to exclude the glottal stop, which, as in many languages, does not undergo voicing.

3.3 Derivational sources of [k]

Despite the existence of postvocalic voicing, Tundra Nenets also allows surface postvocalic voiceless stops. Thus postvocalic voicing is non-neutralising; this may be connected to consonant-cluster simplification. For some relevant URs, we have no evidence for the underlying voicing specification of stops: /P T/ will be used in these cases. The distribution of relevant Tundra Nenets voiceless obstruents is given in (6). As my main focus is on dorsals, I postpone the discussion of the distribution of voiced stops until §5.2.3.

(6)

	p pʲ	t tʲ	k	x
#__V	✓	✓	*	✓
V__V	✓	✓	✓	✓
C__V	✓	✓	✓	*

[6] It may be possible to derive [ʦʲ] in this example from underlying /sʲ/; see note 4.

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Let us briefly summarise the alternations underlying this distribution, as described by Janhunen (1986). Postvocalic /p pʲ t tʲ k/ alternate with obstruent clusters. As seen in (6), /k/ is special not only in not occurring phrase-initially, but also in its apparent complementarity with /x/ after consonants. As we shall see, both of these distributional facts can be reduced to a single generalisation: /k/ occurs only in the environments where it could be derived from a /Cx/ cluster. In what follows, I provide data illustrating consonant-cluster alternations, in order to substantiate Janhunen's description in more detail.

I first briefly introduce some facts about Tundra Nenets codas. I spell out only the relevant details of the coda processes, since an extensive account of Tundra Nenets clusters would lead us too far afield (see Staroverov & Kavitskaya 2017 for a more detailed account). Tundra Nenets exhibits restrictions on codas which essentially require each syllable-final consonant to be placeless. Different coda consonants meet this requirement differently: coronal obstruents and nasals (/T s n/) lose their place features, becoming [ʔ], while coda liquids (/r l/) and labials (/P m/) are followed by [ʔ].[7] The nominal forms in (7) illustrate these alternations. In the nominative, the final consonant of the stem is phrase-final, hence stems in coronals (7a) end in [ʔ], and stems in labials and laterals end in [Cʔ] (7b). The genitive suffix is vowel-initial, and here the final consonant of the stem is revealed. The forms in (7a) also show regular vowel-reduction alternations between [ʌ] in non-final syllables and [°] in final syllables.

(7) *Coda glottal stops*

	stem	*nominative*	*genitive singular* (/-ʌN/)
a.	/mʲaT/ tent	mʲaʔ	mʲad°ʔ
	/mʌrʌT/ city	mʌr°ʔ	mʌrʌd°ʔ
	/maʌs/ chest pocket in traditional clothing	maːʔ	maːs°ʔ
	/mʌnʌs/ lump	mʌn°ʔ	mʌnʌs°ʔ
b.	/ŋoP/ one	ŋobʔ	ŋob°ʔ
	/xajer/ sun	xajerʔ	xajer°ʔ
	/sʲar/ surface	sʲarʔ	sʲar°ʔ
	/num/ sky	numʔ	nuw°ʔ

[7] The patterning of coda /ŋ/ is somewhat less clear, but is irrelevant to our current purposes. In the descriptions of Tundra Nenets and in my own field data, most examples where a coda consonant alternates with [ŋ] (aside of place assimilation) come from accusative plural forms, which may be suppletive.

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Based on the alternations in (7), we would expect to see coda glottal stops phrase-medially before obstruents, including /x/. However, a later process involves the simplification of /ʔC/ clusters to yield single voiceless consonants.

Cluster simplification is illustrated in (8) for /ʔ+t/ becoming [t] and /ʔ+p/ becoming [p]. Crucially, the result of this simplification is a voiceless stop that is not subject to postvocalic voicing, thus creating a voicing contrast intervocalically.

The examples in (8) compare postvocalic voicing after vowel-final stems in (c) to the lack of voicing after obstruent-final stems that lose their final obstruent (b). The forms in (a) show that the stem is indeed consonant-final.

(8) *Postvocalic voiceless stops derived from underlying consonant clusters*

a. *stems with final consonants*

/mʲaT/ tent	mʲaʔ
/nʲe-T/[8] woman-GEN.PL	nʲeʔ
/mʌnes-ŋa/ see-SBJ.3SG	mʌneʔŋa

b. [p t] *after consonant-final stems*

/mʲaT-ta/ tent-POSS.SG3SG	mʲata
/sʲo-T-toN/ throat-GEN.PL-POSS.PL3PL	sʲotoʔ
/mʌnes-pʌʔ-ta/ see-COND-3SG	mʌnep°ta

c. [b d] *after vowels*

/ja-ta/ earth-POSS.SG3SG	jada
/nʲebʲa-toN/ mother-POSS.SG3PL	nʲebʲadoʔ
/pʲa-pʌʔ/ start-COND	pʲab°ʔ

Clusters of the form /ʔ/ + fricative are also simplified, deriving [k] from /ʔx/ and [ʦ ʦʲ] from /ʔs ʔsʲ/. These alternations are shown in (9) for dorsals. The first two forms in (b) reflect fast-speech pronunciation variants where two words form a phrase (see §2). These are compared with the pronunciation of each word in isolation. The intermediate representations in (9b) are given to highlight the derivation of dorsals.

[8] The genitive plural form of /sʲo/ does not appear in my dataset, hence an example with another stem is given. The genitive plural is analysed as /T/ underlyingly, based on the parallel examples of plural /d/ in verbal paradigms (Janhunen 1986: 61).

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(9) *Postvocalic* [k] *derived from consonant* + /x/ *clusters*

a. *stems with final consonants*		
/nʲe-T/ woman-GEN.PL		nʲeʔ
/ŋob/ one		ŋobʔ
/jas/ piece.of.hair		jaʔ
/jar/ side		jarʔ
b. [k] *after consonant-final stems*		
/nʲe-T xʌnʌ/ woman-GEN.PL sledge	|nʲeʔ xʌn°|	nʲe kʌn°
/ŋoP xasawa/ one man	|ŋobʔ xasawa|	ŋob kasawa
/jas-xʌna/ piece.of.hair-LOC.SG	|jaʔx°na|	jak°na
/jar-xʌna/ side-LOC.SG	|jarʔx°na|	jark°na
c. [x] *elsewhere*		
/xʌnʌ/ sledge		xʌn°
/xasawa/ man		xasawa
/ja-xʌna/ earth-LOC.SG		jax°na
/pedara-xʌna/ forest-LOC.SG		pedarax°na

(10) provides a summary of how these patterns can be analysed in a derivational account (Janhunen 1986). These schematic examples assume coda debuccalisation as in (7a); the situation is similar for coda consonants that add a glottal stop (7b).[9]

[9] The analysis proposed here incorporates the idea that coda glottal stop addition in (7b) (or ‘added glottal stop’ in Janhunen’s terms) applies word-medially as well as word-finally. However, for Janhunen (1986) this process is exclusively word-final. In this respect, my derivations differ from Janhunen’s. This difference is not related to the alternations of dorsals.

(10)

(*earlier output*)	pa	aCpa	apa	ta	aCta	ata
debuccalisation		aʔpa			aʔta	
postvocalic voicing			aba			ada
CC simplification		apa			ata	
output	pa	apa	aba	ta	ata	ada

(*earlier output*)	xa	aCxa	axa
debuccalisation		aʔxa	
postvocalic voicing			
CC simplification		aka	
output	xa	aka	axa

These derivations predict the observed distribution of Tundra Nenets stops, but, crucially, inputs containing /k/ are missing. The correct distribution of surface stops emerges if we assume that at some derivational stage Tundra Nenets has no /k/. The processes in (10) also exist as historical changes in prior stages of Tundra Nenets (Janhunen 1986, Salminen 2018), but detailed evidence of their timing is not always available, as in the case of *k > /x/, discussed below. Thus, while the derivations are motivated by what is known about the history of Samoyedic languages, my analysis makes no claim to correspond exactly to the sequence of sound changes.

The stage preceding the historical counterparts of the processes in (10) has no /k/, but in present-day Tundra Nenets there are no remaining alternations to show how exactly /k/ was avoided. On the basis of comparative evidence (Janhunen 1977, Salminen 2018) and loanword-adaptation patterns (§3.1), we can hypothesise that /k/ spirantised to /x/.[10]

In the synchronic analysis, we can assume that /k/ is first turned into /x/, but that new instances of /k/ emerge as a result of consonant-cluster simplification. Such an analysis explains two otherwise puzzling facts about the patterning of /k/. First, postvocalic voicing applies to all obstruent stops. /k/ does not undergo voicing, simply because there is no /k/ to act as the input to voicing: only /x/ is found at the relevant derivational stage (Janhunen 1986). Since underlying clusters never undergo voicing, and since /k/ derives from underlying clusters, voicing also does not apply when surface [k] emerges. Second, /k/ is not allowed phrase-initially, since Tundra Nenets disallows syllable-initial consonant clusters, and consonant clusters are the only possible source of surface [k]. /k/ and /x/ contrast intervocalically, since both underlying /Cx/ clusters and underlying singleton /x/ are found in this environment.

[10] Proto-Samoyedic is reconstructed with a dorsal stop *k, but no dorsal fricative (Janhunen 1977). Comparative evidence for *k > /x/ spirantisation before back vowels is particularly strong in word-initial and intervocalic position (see e.g. Janhunen 1977: 30, 34–35, 51–79). It is harder to pinpoint the history of /k/ after a consonant; here the reconstructed *k matches the present-day reflex in Tundra Nenets.

In this abstract analysis, we take a 'free ride' (Zwicky 1970, McCarthy 2005), deriving all surface [k]'s from underlying clusters, even in cases where no surface evidence from alternations is available. Thus stem-internal intervocalic /k/ in words such as /wenʲeko/ 'dog' and /tʲukuː/ 'this' never alternates with /x/, but the proposed analysis assumes that there is an underlying /Cx/ cluster in this case as well. In what follows, I propose a way to formally express this analysis within Stratal OT, discuss the implications of the analysis and compare it to alternatives.

4 Analysis

This section spells out the analysis of Tundra Nenets with opaque distributional generalisations encoded as deep-level phonotactic constraints within Stratal OT. The architecture of Stratal OT, which incorporates many of the assumptions of Lexical Phonology (see e.g. Kiparsky 1982, 1985, Mohanan 1986), includes several OT evaluations that are tied to morphological strata or levels (Bermúdez-Otero 1999, 2011, Kiparsky 2000). Three strata will be important for our purposes: the stem level, the word level and the postlexical level. Importantly, while the input to the initial evaluation (i.e. the stem level) is completely unrestricted, in line with Richness of the Base, the outputs of each level constitute the set of inputs for each subsequent level. In this way, the phonology of earlier strata restricts the inputs for later levels (Bermúdez-Otero 2001, 2006, 2007, Ito & Mester 2003).

The derivations assumed here are schematically similar to (10). Table I gives an overview of the processes found at each stratum. In general, I will assume that the grammars of the three levels are the same unless there is evidence to the contrary. In other words, all processes apply as widely as possible. When a process may be applicable at a given level but there is no direct evidence for this, its application is given in parentheses in Table I. The restrictions on /k/ are active at the stem level, but it is allowed postlexically. The domain of coda debuccalisation is a word, so this process is active only at the word level. Consonant-cluster simplification becomes active postlexically: this process presupposes the prior application of coda debuccalisation, and also operates across word boundaries, as seen in (8) and (9). Postvocalic voicing operates across word boundaries, and there is no evidence that it is inactive at the lexical level. Finally, the lack of voicing in underlying clusters may be active at all levels, but is only seen postlexically, since it can only be visible at the stage where cluster simplification takes place. At any given level, the process itself and the resulting distributional generalisations are captured by the same constraint rankings, much in the spirit of Classical OT.

§4.1 introduces the constraints used in my analysis. The subsequent sections trace the derivation of Tundra Nenets /k/ from the stem level to the postlexical level. The ranking at each derivational level was tested using OT-Help (Staubs *et al*. 2010), and the corresponding files are provided as online supplementary materials.[11] The rankings derived by OT-Help

[11] Available at https://doi.org/10.1017/S0952675720000135.

	stem level	word level	postlexical level
/k/ spirantisation	✓	(✓)	
coda debuccalisation		✓	
cluster simplification			✓
postvocalic voicing		(✓)	✓
no voicing in underlying clusters	(✓)	(✓)	✓

Table I

Summary of the stratal affiliation of processes in Tundra Nenets.

are consistent with the ranking diagrams given below for each level, but some of the rankings may be transferred from another stratum, rather than supported at a given stratum. As ranking information can be derived from the supplementary materials, I will not discuss the detailed evidence for each ranking in what follows, focusing instead on the overall patterns, the crucial candidates and the ranking differences between strata.

4.1 Constraints

The constraints used in my analysis are the same at all levels of Tundra Nenets phonology; this section gives a preview. Additional details are provided in the following sections.

I assume standard faithfulness constraints within the correspondence theory of McCarthy & Prince (1995, 1999). Some of the mappings to be analysed involve merger or coalescence; the relevant constraint, Uniformity, is given in (11a).

Certain Tundra Nenets coda processes involve mapping a consonant to a glottal stop. I analyse the glottal stop as a placeless consonant, as discussed above, and treat coda glottalisation as debuccalisation (see also McCarthy 2008, Kavitskaya & Staroverov 2010, Staroverov & Kavitskaya 2017). This analysis relies on the idea that place features are privative and can be deleted or inserted (Lombardi 2001), and are hence subject to Max and Dep constraints. The relevant constraint, Max(place), is defined in (11b). For features other than place, I remain agnostic about the relevant faithfulness constraints, and tentatively assume that all these features are protected by Ident[F] constraints.

(11) a. Uniformity
Assign a violation for each output segment that has more than one input correspondent.

b. Max(place)
Assign a violation for each C-place node that is present in the input but absent in the output.

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The markedness constraints I propose are related straightforwardly to the processes and generalisations described above. First, the lack of /k/ (and /g/) at the stem level will be accounted for by the constraint against dorsal stops in (12a). This constraint comes from a family of context-free OT constraints responsible for defining segment inventories (see Morén 2007 for a more detailed theory of inventory constraints appealing to features).

The competition and alternations between /k/ and /x/ in Tundra Nenets will be accounted for by the relative ranking of *K and the constraint against fricatives in (12b) (de Lacy 2006).

(12) a. *K
Assign a violation for each output dorsal stop.
b. *[+cont]
Assign a violation for each output [+continuant] segment.

Tundra Nenets word-level coda processes are triggered in part by a constraint from the CodaCond family (Itô 1986, 1989). The specific requirement is that all C-final syllables end in a placeless consonant. The formulation of this constraint and its relation to coda conditions in other languages will be discussed in §4.3; a definition is given in (13a).

At the postlexical level, placeless consonants are avoided through merger, a process which is driven by HavePlace in (13b) (McCarthy 2008).

(13) a. CodaCond
Assign a violation for each consonant at the end of a syllable that is specified for place features.
b. HavePlace
Assign a violation for each placeless consonant.

Finally, Tundra Nenets has a voicing process that applies after vowels. Since the exact nature of laryngeal feature alternations is orthogonal to our main topic, I will analyse this process with the relatively ad hoc constraint *VT in (14).

(14) *VT
Assign a violation for each voiceless stop preceded by a vowel.

The non-application of voicing to underlying clusters can be viewed as a gang effect, and the relevant theoretical apparatus will be discussed in §4.4.

4.2 Stem level

My analysis relies on the assumption that Tundra Nenets prohibits /k/ at the stem level. As mentioned in §3.3, there are no alternations to show how exactly /k/ is avoided. However, comparative evidence and

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loan adaptation converge in supporting the spirantisation of /k/ to |x|. Thus I will assume that /k/ is mapped to |x| in Tundra Nenets stem and word domains.

(15) presents the analysis of stem-level /k/ spirantisation. The tableaux are presented in comparative format (Prince 2002), with numbers showing violation count. In this and the following tableaux, I will omit the constraints that are satisfied by all candidates. The tableau in (15) compares the winner, (a), to the faithful candidate, (b): to change input /k/ to |x|, the constraint *K must dominate Ident[cont] and *[+cont]. We also need to make sure that input /k/ is not deleted altogether (represented in candidate (c) as ∅), which is ruled out by Max.

(15)

/k/	*K	Max	Ident[cont]	*[+cont]
☞ a. x			1	1
b. k	W1		L	L
c. ∅		W1	L	L

This picture of stem-level phonology characterises the distribution of /k/ in stems, but there is more to be said about affixes.[12] Tundra Nenets has no prefixes, and, as far as we know, all productive suffixes are attached at the word level. In line with a number of proposals within Stratal OT (Baker 2005, Buckler 2009, Trommer 2011, Zimmermann 2016, Bermúdez-Otero 2018), it can be assumed that Tundra Nenets suffixes go through stem-level optimisation separately from other morphemes, and hence obey the same constraints as stems. This assumption correctly predicts that suffixes do not contain /k/. However, the proposed analysis would work even if stem-level optimisation did not apply to suffixes. /k/ spirantisation in (15) does not contradict any of the word-level rankings, and hence I assume it applies at the word level as well, meaning that suffixes that could contain /k/ behave in the same way as suffixes with /x/.

In addition to the ban on /k/, there is one other distributional generalisation that should be mentioned – the ban on complex onsets. This generalisation seems to hold true of all strata in Tundra Nenets, and hence is simply true of its phonology in general. Establishing how exactly the generalisation is enforced (i.e. what would happen to inputs that have potential complex onsets) would involve an extensive study of loanwords, and perhaps of Tundra Nenets history. For now, I leave the investigation of the exact rankings responsible for this generalisation for future research. Since word-initial clusters are excluded, the word level and postlexical level will also not derive word-initial [k].

To summarise, the Tundra Nenets stem level avoids dorsal stops by changing /k/ to |x|. The rankings responsible for this mapping are presented in the diagram in (16). This diagram presents only the rankings

[12] I am grateful to Eva Zimmermann and Jochen Trommer for fruitful discussion of this point.

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which are motivated by stem-level mappings, and omits the constraints whose ranking can only be inferred at later levels.

(16) *Stem-level rankings*

*K Max

*[+cont] Ident[cont]

These rankings can be assumed to also hold of later strata in Tundra Nenets phonology, with one important exception. The ranking *K ≫ *[+cont] is reversed at the postlexical level, where [k] is derived from |ʔx|. In this way, reranking in Stratal OT expresses the fact that some distributional generalisations are opaque. This analysis is also similar to a Duke-of-York derivation, where the stem-level phonology maps /k/ to |x|, but the postlexical phonology maps |ʔx| to [k].

4.3 Word level

Two alternations in Tundra Nenets are limited to the word level. First, the word level enforces the restrictions on codas through debuccalisation and glottal stop insertion (see the examples in (7)). Second, it is the locus of vowel reduction, producing the null vowel |°|. In line with the assumed stratal affiliation of these processes, they never apply or are blocked across a word boundary.

In addition, there are other processes that may apply at the word level, but are also active at other strata. Thus I assume that stem-level /k/ spirantisation is also active at the word level. At the same time, it is important that the dorsal stop is absent in the input to Tundra Nenets word-level phonology. Finally, postvocalic voicing clearly applies at the postlexical level (it spans word boundaries; see (4)), but it may already be active at the word stratum. The analysis of stop voicing will therefore be presented in this section.

In what follows, I spell out a detailed analysis for some coda alternations and for postvocalic stop voicing. For reasons of space, I abstract away from vowel reduction, and from a fuller range of codas. The restrictions on codas in Tundra Nenets have a clear resemblance to coda conditions in other languages, but display one important feature: the coda condition relates specifically to syllable-final consonants, not to all consonants in the coda. This is reflected in the definition of the constraint CodaCond in (13a), which in effect requires that every C-final syllable ends in a placeless glottal stop.

The Tundra Nenets version of coda conditions is more similar to the formulation of CodaCond in Itô (1989) than to the alignment-based formulation in Itô & Mester (1994). Tundra Nenets implements a variety of responses to CodaCond: while some consonants lose place and change to a glottal stop, others trigger glottal stop insertion (see e.g. [ŋobʔ] and [xajerʔ] in (7b)). These latter examples, where the coda consonant stays unchanged, but is separated from the syllable edge by a glottal stop, suggest the somewhat unusual formulation of CodaCond in (13a). In what follows however, I focus only on the debuccalisation examples, since these most clearly illustrate the derivation of dorsals.

The analysis of Tundra Nenets postvocalic voicing is presented for the form [jada] 'earth-poss.sg-3sg' in (17), where the voicing candidate defeats both the fully faithful and the deletion candidates.

(17)

|jata|	Max	*VT	Ident[voi]
☞ a. jada			1
b. jata		W1	L
c. jaa	W1		L

A word-level input may contain a voiceless labial stop /p/, which would undergo voicing in a way that is fully parallel to (17). However, a word-level input may not contain /k/, which is part of my account of the lack of postvocalic voicing alternations with dorsals.

The analysis of the mapping |mʲatxʌna| → |mʲaʔx°na| 'tent-loc.sg' is presented in (18). The output is mapped to [mʲak°na] postlexically. This tableau omits the analysis of vowel reduction, hence all candidates have |°| in the second syllable. As the winner in (17) was a candidate with voicing, similar candidates are considered in (18b, c). Indices show non-trivial instances of input–output correspondence.[13]

(18)

|mʲat$_1$x$_2$ʌna|	Max	Coda Cond	Have Place	*[+cont]	*VT	Max (pl)	Ident [voi]	Ident [c.g.]
☞ a. mʲaʔ$_1$x$_2$°na			1	1	1	1		1
b. mʲad$_1$x$_2$°na		W1	L	1	L	L	W1	L
c. mʲad$_1$°na	W1		L	L	L	L	W1	L

The winner, (18a), has two violations which deserve comment. First, a side-effect of coda debuccalisation is that the consonant has to change its specification for [constricted glottis]: Tundra Nenets does not have [−constricted glottis] placeless consonants. Second, the winner violates the constraint *VT, since this constraint penalises all postvocalic stops that are not voiced, including the glottal stop. Coda debuccalisation is driven by CodaCond, and the high ranking of this constraint disqualifies the faithful candidate, (18b). Candidate (18c) shows that CodaCond cannot be satisfied by deleting one of the consonants, establishing the high ranking of Max.

As I argue in §4.4 below, postlexical cluster simplification should be treated as coalescence, which technically involves correspondence between two input segments and one output segment, and violates the

[13] The tableau in (18) has an input |t| in coda position, not |T|, since in a fuller analysis Tundra Nenets prohibits voiced stops at the stem level (see also Janhunen 1986).

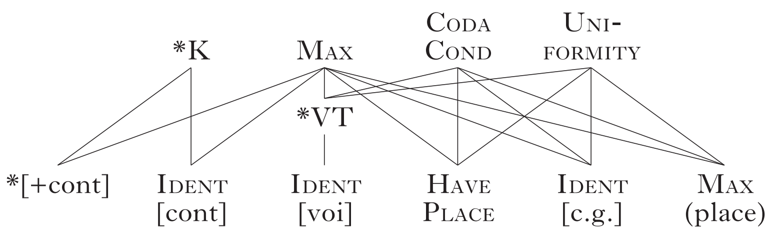
constraint Uniformity (see also Staroverov & Kavitskaya 2017). However, coalescence does not apply at the word level, not even in forms where two identical segments would coalesce, and hence all of their features could be preserved in the output. The tableau in (19) illustrates my analysis of this fact with the mapping |mʲatta| → |mʲaʔta| 'tent-poss.sg3sg'. This tableau focuses on the high ranking of Uniformity at the word level, and presents only two suboptimal candidates, omitting other candidates which yield the same ranking information as the losers in (18).

(19)

|m^{j}at$_1$t$_2$a|	Coda Cond	Uniformity	Have Place	*VT	Max (pl)	Ident [voi]	Ident [c.g.]
☞ a. m^{j}aʔ$_1$t$_2$a			1	1	1		1
b. m^{j}ad$_1$t$_2$a	W1		L	L	L	W1	L
c. m^{j}ad$_{1,2}$a		W1	L	L	L	W1	L

The word-level ranking conditions are summarised in (20).

(20) *Word-level rankings*



4.4 Postlexical level

Consonant-cluster simplification (see § 3.3) belongs exclusively to the postlexical level, and applies across phrase-medial word boundaries. Because of word-level coda debuccalisation, consonant clusters entering the postlexical level start with a glottal stop, and I follow Staroverov & Kavitskaya (2017) in analysing Tundra Nenets cluster simplification as a single-step coalescence mapping. Roughly speaking, sequences like |ʔx| merge to produce a dorsal stop [k], thus preserving the manner of the first consonant and the place of the second. Staroverov & Kavitskaya (2017) also argue that such an account is compatible with independent evidence from Tundra Nenets lexical and phrasal domains.

Postvocalic voicing, illustrated in (4) and analysed in (17), also applies postlexically, as it is attested across word boundaries. Cluster simplification may yield voiceless consonants that fail to undergo postvocalic voicing (see (8)). This blocking effect will be treated formally as a gang effect, modelled with constraint conjunction (Staroverov & Kavitskaya 2017). The blocking of postvocalic voicing is also responsible for the very limited distribution of [g], mentioned in § 3.2. Finally, the postlexical

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grammar differs from earlier strata in two respects: coalescence is allowed, and [k] is no longer banned. If |k| appeared in the input to this level, it would survive even in positions where it doesn't occur in Tundra Nenets. However, the input to the postlexical level is crucially restricted by the phonology of the preceding strata: no |k| is allowed in the word-level outputs.

The tableau in (21) illustrates the fact that consonant clusters are disallowed postlexically, and avoided through coalescence. The tableau gives the mapping |mʲaʔta| → [mʲata] 'tent-POSS.SG3SG', which is the derivational step following the evaluation in (19). All candidates in (21) violate the constraint *VT. The potential candidates with postvocalic voicing will be considered below, after the emergence of [k] is discussed.

(21)

$\|m^j aʔ_1 t_2 a\|$	MAX	CODA COND	HAVE PLACE	UNI-FORMITY	*VT	IDENT [c.g.]
☞ a. $m^j at_{1,2}a$				1	1	1
b. $m^j at_2 a$	W1			L	1	L
c. $m^j aʔ_1 t_2 a$			W1	L	1	L
d. $m^j at_1 t_2 a$		W1		L	1	1

The winner in (21) violates IDENT[c.g.], since it involves correspondence between a [+constricted glottis] glottal stop and a [−constricted glottis] coronal stop. Alternatives to coalescence include preserving the cluster (c) or deleting one of the consonants (b). The fully faithful candidate, (c), loses on HAVEPLACE, which was ranked below UNIFORMITY at the word level. Finally, candidate (d) satisfies both UNIFORMITY and HAVEPLACE by spreading place features onto the glottal stop and effectively undoing word-level debuccalisation. However, this last candidate fatally violates CODACOND.[14]

Unlike the earlier strata, the postlexical level allows both [k] and [x]. While [k] emerges from consonant clusters, surface [x] trivially corresponds to input |x|. This identity mapping is illustrated in (22): the faithful candidate wins over deletion or a change in the feature value for [continuant].

(22)

|x|	MAX	IDENT[cont]	*[+cont]	*K
☞ a. x			1	
b. k		W1	L	W1
c. ∅	W1		L	

[14] Despite the ranking HAVEPLACE ≫ IDENT[c.g.], surface placeless [ʔ] is not avoided through inserting or spreading place from some other segment. This is due to the high ranking of DEP(place) and *SPREAD(place). I do not consider the derivation of onset glottal stops, for reasons of space.

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The tableau in (22) shows the emergence of [x] after vowels and word-initially. However, after a consonant, input |x| is subject to coalescence, as in (21). The application of coalescence to clusters with |x|, and the emergence of [k], are shown for the mapping |mʲaʔx°na| → [mʲak°na] ‘tent-LOC.SG’ in (23), the next derivational step after (18).

(23)

$\|m^jaʔ_1x_2°na\|$	MAX	CODA COND	HAVE PL	ID [cont]	*[+cont]	*K	UNIFORMITY	*VT	ID [c.g.]
☞ a. $m^jak_{1,2}°na$				1		1	1	1	1
b. $m^jax_2°na$	W1			L	W1	L	L	L	L
c. $m^jaʔ_1x_2°na$			W1	L		L	L	1	L
d. $m^jak_1x_2°na$		W1		L	W1	1	L	1	1
e. $m^jax_{1,2}°na$				1	W1	L	1	L	1

The coalescence mapping |ʔx| → [k] in the winning candidate introduces a one-to-many correspondence relation, and incurs all the IDENT violations that would be incurred if both |ʔ| and |x| mapped to [k]. Specifically, the winner in (23) violates IDENT[cont] and IDENT[c.g.]. The tableau in (23) is in many ways parallel to (21), except it adds the extra rankings relevant to fricatives established in (22). Candidates (23b–d) are presented simply to confirm that the rankings in (21) can be combined with those in (22). Particularly interesting is candidate (23e), which lacks a parallel in (21). This candidate involves coalescence which results in a fricative [x] rather than a stop [k]. Just like the winner, this candidate violates IDENT[cont], but is ruled out since *[+cont] dominates *K.[15] This ranking (the opposite of that at the stem level) is thus crucial to the emergence of [k].

One final postlexical generalisation to be accounted for is the fact that postvocalic voicing is blocked in consonants derived from clusters. Here we have a chain-shift mapping whereby /Vt/ → [Vd] and /Vtt/ → [Vt]. I propose to treat the lack of voicing in underlying clusters as a gang effect. While voicing of input consonants is allowed in Tundra Nenets, changing both [voice] and [constricted glottis] in one mapping is not allowed. I will formalise this account in terms of constraint conjunction (Smolensky 1993), using the conjoined constraint IDENT[voi] & IDENT[c.g.], although a Harmonic Grammar account is also possible (see e.g. Pater 2009).

A simple voicing mapping was presented in (17), and the same process applies at the postlexical level, since voicing operates across word boundaries. To illustrate the blocking of voicing, we need to show that candidates with a voiced postvocalic stop would be suboptimal in (21) and (23).

[15] I am assuming that the glottal stop is [−continuant] in Tundra Nenets, since it triggers strengthening of the following consonant under coalescence. McCarthy (1988) argues that laryngeals are underspecified for the feature [continuant] (see also Trigo 1988 and Cser 1999), and some additional evidence is discussed by Gussenhoven & Jacobs (2017: 73–74). However, Fallon (2002: 184–193) presents a number of cases where the glottal stop arguably patterns with stops. It therefore seems that (under-)specification of laryngeals for manner should be viewed as language-specific; McCarthy (2008: 289) makes a similar point with respect to their place specification.

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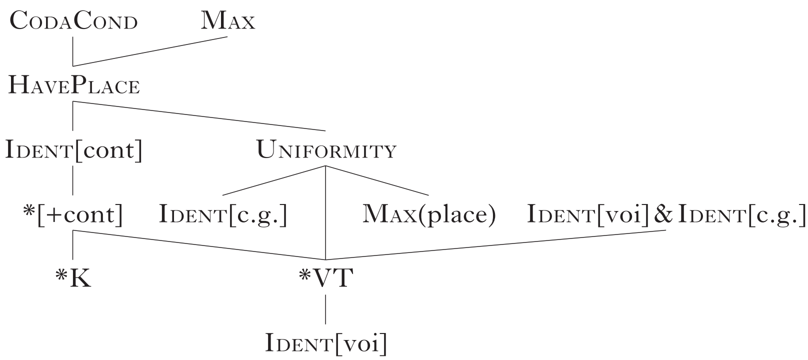
Tableau (24) considers additional alternatives to the winning candidate in (23), [mʲak°na], and shows that [g] does not arise from postvocalic voicing. It compares the winner to two candidates with a voiced stop [g]. The voicing + coalescence candidate, (b), is ruled out by the conjoined constraint IDENT[voi] & IDENT[c.g.], while the voicing + deletion candidate in (c), with the same pronunciation as (b), is ruled out by MAX. The evaluation of similar alternative candidates for [mʲata] in (21) would be entirely parallel to (24).

(24)

|mʲaʔ$_1$x$_2$°na|	MAX	ID[voi] & ID[c.g.]	ID [cont]	*K	UNIFORMITY	*VT	ID [voi]	ID [c.g.]
☞ a. mʲak$_{1,2}$°na			1	1	1	1		1
b. mʲag$_{1,2}$°na		W1	1	1	1	L	W1	1
c. mʲag$_2$°na	W1		1	1	L	L	W1	L

The postlexical ranking is summarised in (25). While most rankings here are motivated by postlexical ranking conditions, some are simply preserved from the word level, and hold throughout the Tundra Nenets phonology.

(25) *Postlexical rankings*



In the next section, I will summarise the overall account and explore its implications, focusing in particular on the ranking differences between the strata.

4.5 Summary and implications

The dorsal stop is excluded at the stem level, but is allowed to emerge postlexically through coalescence. Formally, *K is ranked above *[+cont] and IDENT[cont] at the stem and word levels, but postlexically this ranking is reversed. Because of this, surface [k] is derived only from consonant clusters in coalescence environments. Since syllable-initial (and by extension phrase-initial) consonant clusters are disallowed at all levels, this also means that [k] will never emerge phrase-initially. This explains why

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Tundra Nenets prohibits dorsal stops phrase-initially – in a position typically associated with contrast preservation (Casali 1996, Beckman 1998).

With this difference in ranking, the derivation of Tundra Nenets /k/ resembles a Duke-of-York derivation: /k/ changes to |x| at an early derivational stage, but later |Cx| changes to [k]. Since constraint reranking is a crucial component in my account of the derivation, this account cannot be directly translated into theories of opacity where one and the same ranking has to hold throughout the derivation. It therefore remains to be seen how these data could be analysed in Harmonic Serialism, a framework that has been applied to a variety of opaque phonological alternations (McCarthy 2007, Wolf 2008, 2016, Kavitskaya & Staroverov 2010, Jarosz 2014, Torres-Tamarit 2015, 2016).

Tundra Nenets word-level phonology mandates that every consonant-final syllable ends in a glottal stop, but disallows coalescence, while the postlexical phonology avoids glottal stops by merging them with a following consonant where possible. Formally, at the word level UNIFORMITY is ranked over HAVEPLACE, but this ranking is reversed postlexically. Because of this, the postlexical level can distinguish between voiceless stops deriving from clusters and singleton voiceless stops, with postvocalic voicing only applying to the latter group. Postvocalic voicing is not artificially restricted to the unnatural class /p pʲ t tʲ/, but is restricted by the derivational history of the different voiceless stops. Since [k] is underlyingly a cluster, and since clusters never undergo postvocalic voicing, dorsal stops might appear to be excluded from voicing altogether, but this is in fact a consequence of the much broader ban on dorsals operating early on in the grammar. My analysis of voicing being blocked in underlying clusters relies on a gang effect, and it seems that distinct constraints on laryngeal feature changes are among the likely ones to gang up more generally in languages (Pater 2009).

Patterns involving unnatural classes present a general problem for phonological theory (Mielke 2008), but there has been relatively little research on how exactly these patterns can be represented, and how they interact with the rest of the grammar (Gallagher 2019). The proposed analysis demonstrates that some unnatural classes may be OPAQUE, i.e. they follow from an ordering of natural class alternations. At an early derivational level (and probably an early historical stage), a full natural class of sounds may undergo a process. For example, Tundra Nenets /p pʲ t tʲ/ are the only voiceless oral stops at the word level, and undergo postvocalic voicing. However, later processes may introduce a new member into the relevant class, which could fail to undergo the original process. In Tundra Nenets, cluster simplification creates [k], which fails to undergo voicing. Thus it may appear that a surface pattern is targeting an unnatural class, even though only natural class alternations are found at each derivational stage. The present study provides a formal way to analyse such opaque unnatural classes in OT, and also opens the possibility that some unnatural classes in other languages may arise for similar reasons. While it remains to be seen how many unnatural class alternations can be analysed in this way, opaque distributional generalisations have been reported in Catalan (Bermúdez-Otero 2001, 2006, 2007, Lloret & Pons-Moll 2016), Japanese (Ito & Mester 2003) and a number of other languages (Gnanadesikan 1997, McCarthy 2005).

Finally, I have argued that ranking differences between levels in Stratal OT provide a way to analyse the patterns that apparently challenge Richness of the Base (Vaysman 2002, Hansson 2003, Rasin & Katzir 2017) without abandoning the basic mechanisms of OT. Opaque distributional generalisations need to be stated independently precisely because they are opaque, and therefore not duplicated by any surface constraints, which has been cited as a problem for many non-surface distributional generalisations (Clayton 1976, Kenstowicz & Kisseberth 1977: §3.1). Of course, not all distributional generalisations are opaque. Stratal OT also allows for surface-true distributional generalisations to enter the grammar at early levels – this is the case for the ban on complex onsets in Tundra Nenets.

5 Alternatives

This section reviews potential alternative analyses, focusing particularly on whether a feasible account without opaque distributional generalisations can be found, and on whether Tundra Nenets can be reanalysed in an entirely parallel Classical OT system.[16] §5.1 discusses positional markedness as a possible alternative account for the lack of phrase-initial [k]. §5.2 deals with three kinds of alternative approaches to voicing and cluster alternations: transparent blocking, chain shifts and derived environment effects.

Before turning to concrete alternative proposals, it is appropriate to briefly address the abstractness of the proposed analysis. Abstractness has been recognised as a general challenge for generative phonology at least since the 1970s (Kiparsky 1973). In Tundra Nenets, I assume (and attribute to the speakers) a free-ride grammar (Zwicky 1970, McCarthy 2005, Lloret & Pons-Moll 2016) that derives [k] from underlying clusters even in cases where there is no evidence from alternations.

It is often assumed that abstract analyses are harder to learn or less readily available to the learner than concrete ones. However, existing learnability research shows that such a general characterisation is likely too coarse. Formal algorithms succeed in learning at least some abstract URs (McCarthy 2005, Jarosz 2006, Tesar 2006, 2014, O'Hara 2017) and some opaque mappings (Jarosz 2016, Nazarov & Pater 2017, Chandlee *et al*. 2018). Nazarov & Pater (2017) address the learning of opaque mappings in Stratal OT, and Bermúdez-Otero (2003) proposes that opaque distributional generalisations can be learned by applying phonotactic

[16] The discussion in this section owes a great deal to the insightful comments of the reviewers and the associate editor. I am extremely grateful for their comments and suggestions.

learning (Hayes 2004, Prince & Tesar 2004) to the set of input strings, although the kinds of generalisations that can be learned in this way are limited to simple phonotactic statements (see also Rasin & Katzir 2017). Although much more research is needed to understand the relative difficulty of learning opaque and abstract patterns, it seems premature to reject an abstract analysis on learnability grounds. As I will show in the rest of this section, the proposed analysis has some potential advantages over more concrete proposals: it fits the data well (i.e. without assuming that some generalisations are accidental), and it connects distributional generalisations to otherwise general processes in Tundra Nenets, using the same constraint rankings.

5.1 Positional markedness and the lack of phrase-initial [k]

Positional constraints on word- and phrase-initial position have been studied by Smith (2005) and Flack (2007, 2009). It is therefore important to show that these proposals do not imply the existence of a positional constraint *φ[K, which would prohibit phrase-initial [k]. Such a constraint could describe the Tundra Nenets pattern without appealing to input restrictions.

Flack (2007, 2009) proposes that the otherwise established pressures on syllable onsets and codas can be generalised as constraints on higher-order prosodic constituents. This theory would only predict a constraint like $*_{\varphi}$[K if there were also an independently established constraint like $*_{\sigma}$[K. However, Flack's extensive typological survey does not reveal any robust cases of /k/ being prohibited in the onset, and no such cases are known to me from other sources.

Smith (2005) proposes that the only viable positional markedness constraints are those enhancing perceptual salience. However it is not clear how a constraint against initial /k/ could serve this goal. In fact, /k/ and other voiceless stops are relatively salient onsets, with robust perceptual cues (Wright 2004). Moreover, general featural markedness constraints like *MidV are explicitly cited as constraints that are not relativised to initial position by Smith (2005). The constraint $*_{\varphi}$[K would thus be excluded by Smith's theory.

In sum, the existing theories of positional markedness offer no independent reason to expect the existence of the constraint $*_{\varphi}$[K. Ito & Mester (2003: §3.1) come to the same conclusion for *G in Japanese. In fact, based on these theories we expect such a constraint *not* to exist. Attempting to reanalyse the Tundra Nenets data with this constraint would thus be a stipulation.

5.2 Alternative accounts for the unnatural class of voicing undergoers

Recall that coronals and labials show postvocalic voicing alternations, but no such alternations are recorded for /k/, leading to a pattern apparently

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involving an unnatural class. This section considers three potential alternative accounts of this pattern: transparent blocking in Classical OT (§ 5.2.1), chain shifts (§ 5.2.2) and derived environment effects (§ 5.2.3).

5.2.1 *Blocking and the distribution of* [g]. One reason why /k/ would escape postvocalic voicing could be a general or contextual ban on [g] in the relevant environment. Importantly, however, no such blocking analysis is available, because intervocalic [g] is allowed in the Nelmin Nos dialect of Tundra Nenets, as exemplified in (5) above.[17] Consequently, if a constraint specifically prohibiting [g] – call it *G – were active in Tundra Nenets, it would not be ranked high enough to block voicing. Input /g/ does not surface as [k], implying the ranking IDENT[voi] ≫ *G, but the opposite ranking would be required to block intervocalic voicing of /k/: *G ≫ *VT ≫ IDENT[voi]. The fact that the two rankings are contradictory shows that a blocking analysis would not account for the surface instances of intervocalic [g].

5.2.2 *Chain shifts*. Another potential alternative to opaque distributional generalisations involves postulating a series of chain shifts. In fact, McCarthy (2005) and Gnanadesikan (1997) propose chain shifts as a general approach to free-ride cases where (as in Tundra Nenets) all surface As derive from underlying Bs. Moreover, my account makes use of a chain shift /Vtt/ → /Vt/ → /Vd/ to analyse postvocalic voicing, so why wouldn't a similar account work for surface dorsals?

In Tundra Nenets, we have evidence that surface [g] always emerges from /ŋg/. A chain-shift analysis would assume that underlying /g/ maps to some other segment (say /k/ or /x/). In Classical OT, these two assumptions would imply that input /ŋg/ also maps to that output segment, but in McCarthy's (2005) theory this could be ruled out as a gang effect, since such a mapping changes several features at a time. A serious challenge for such an account is that Tundra Nenets does have mappings in which input /NC/ sequences change several features simultaneously. For example, underlying /Nx/ sequences map to [ŋg] ~ [g], as seen in datives and locatives of nasal-final stems such as /sʲalʌN-xʌn-Ta/ → [sʲal°ŋgʌnda] ~ [sʲal°gʌnda] 'underarm-DAT-POSS.SG3SG' (Staroverov & Kavitskaya 2017). This mapping shows that a non-derivational Parallel OT grammar of Tundra Nenets must allow the features [nasal], [voice] and [continuant] to change at the same time, and it is not entirely clear how this can be reconciled with the chain-shift account.

A chain-shift analysis of the alternations between /k/ and /x/, though perhaps possible, would fail to explain some aspects of the pattern. In particular, underlying sequences of fricatives such as /sx/ ultimately yield a stop [k] on the surface. On the proposed derivational analysis, the mapping from consonant clusters to surface singleton stops involves an

[17] Recall that, although nasal-cluster simplification in the Nelmin Nos dialect is variable, Salminen (1997, 1998b) mentions Tundra Nenets dialects where /ŋg/ to [g] simplification is more regular.

intermediate stage of coda debuccalisation to a glottal stop: /sx/ → |ʔx| → [k]. As a side-effect of coda debuccalisation, a stop is introduced in the cluster, and its [−continuant] value ultimately survives in the output (Staroverov & Kavitskaya 2017).[18] A non-derivational chain-shift analysis of the same facts would have nothing to say on why a stop emerges from a sequence of continuants. In sum, some opaque interactions in Tundra Nenets cannot be reanalysed as chain shifts, while for others some explanatory insight is lost in the chain-shift analysis. Thus, although I have argued for a chain-shift analysis of stop voicing, the overall patterning of Tundra Nenets obstruents cannot be analysed with just chain shifts.

5.2.3 *Derived environment effects.* Another potential way to account for the apparently unnatural class of voicing undergoers would be to restrict postvocalic voicing to derived environments (Kiparsky 1973). Recall that there are no suffixes in Tundra Nenets which start with /k/, so if voicing only applied at a morphological boundary, /k/ would be excluded from this process by its distribution (Tundra Nenets has only suffixes, so there are no other morphological boundaries). On this account, there would be no distributional restrictions on /k/ other than the restrictions on suffixes, which, since suffixes are a closed class, could be accidental. Postvocalic voicing would also be inapplicable within stems, where surface [p t] and [b d] contrast in voicing. Although the surface undergoers of voicing may be in a morphologically derived environment, they are phonologically underived. Thus a concrete implementation of this proposal in OT would have to rely on a detailed theory of both phonological and morphological derived environment effects. Relevant proposals include Łubowicz (2002), McCarthy (2003a) and van Oostendorp (2007).

The derived environment analysis would miss many of the stem-internal distributional generalisations that a derivational account of Tundra Nenets captures. Thus [x] does not occur after consonants on the surface, even within stems. Similarly, voiced stops never occur phrase-initially, and are very limited after consonants. Specifically, voiced stops occur after nasals, where they are also derived by a voicing process, and [b] may occur after other sonorants, where it also alternates with [w]. The generalisation here is that voiced stops and [k] appear only in environments where they are derived by voicing or strengthening. These environments do not always provide strong perceptual cues to voicing; voiced stops do appear before voiceless obstruents in clusters such as [bt] or [dt].

A straightforward extension of my proposal would capture these distributional facts with an opaque distributional generalisation whereby, just like /k/, voiced stops are first prohibited, but later derived (see also Janhunen 1986 and Salminen 1997). However, if there were no opaque distributional generalisations (as in the derived environment account),

[18] This assumes that [ʔ] is [−continuant] rather than underspecified. See note 15 for references to related cross-linguistic discussion.

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we would expect that voiced stops and [x] would freely occur phrase-initially and after a consonant within stems.

To summarise, I have considered a number of potential alternative accounts for the fact that dorsals escape postvocalic voicing in Tundra Nenets. A transparent blocking account fails to capture surface intervocalic [g]. A chain-shift analysis is hardly possible, since multiple features do apparently change in licit input–output mappings in Tundra Nenets. An analysis treating voicing as a derived environment phenomenon misses the distributional generalisations about Tundra Nenets stem-internal voiced stops and /x/. Finally, none of these accounts has anything to say about the lack of phrase-initial /k/ and voiced stops, a distributional fact which follows from the derivational account.

6 Conclusion

Opaque distributional generalisations manifest themselves in situations where a contrastive segment only arises in the environments where it is also derived by an active process. Although the constraints on URs are arguably subject to a duplication problem (Kenstowicz & Kisseberth 1977: §3.1), this problem does not apply to opaque generalisations, because their effect is obscured by the phonology of later levels. Therefore, such generalisations must be captured in the phonology. In this paper, I have explored a way to capture such generalisations as the result of deep-level phonotactic constraints in Stratal OT (Bermúdez-Otero 2001, 2006, 2007, Ito & Mester 2003). On this account, a phonotactic restriction is imposed early on, but relaxed at a later stratum. I have illustrated this pattern with the analysis of /k/ in Tundra Nenets. The language also has other examples of opaque distributional generalisations, involving voiced stops and affricates (Janhunen 1986), and thus presents a good testing ground for exploring the theory of input restrictions in future research.

The proposed account also has consequences for a number of topics in phonology. Classical OT is committed to Richness of the Base (Prince & Smolensky 2004), and although this assumption has been challenged (Vaysman 2002, Hansson 2003, Rasin & Katzir 2017), there are few formal proposals for how OT might work without it (Bermúdez-Otero 2001). In this paper, I have argued that Stratal OT provides a theory of input restrictions compatible with Richness of the Base. I have also defended an abstract derivational free-ride analysis (Zwicky 1970, McCarthy 2005) against potential alternatives, showing that such an analysis provides a good fit for the data, and uses the very same constraints and rankings to capture the processes involved and the resulting distributional generalisations.

The present proposal identifies and formally analyses a class of opaque patterns involving unnatural classes (Mielke 2008). These patterns result from an interaction of regular natural class alternations in which a later alternation introduces new members of a class targeted by an earlier one. The derivation of Tundra Nenets /k/ resembles a Duke-of-York derivation (Pullum 1976, Bermúdez-Otero 2001, McCarthy 2003b, Rubach 2003), and thus serves as another illustration for the fact that different derivational levels may have different OT rankings.

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