Opaque distributional generalisations in Tundra Nenets *

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Abstract

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 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 on my account.

1 Introduction

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

In this paper, I explore a particular kind of phonological pattern where a contrastive segment emerges only in the environments where it is also derived by an alternation, 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 RoTB . However, I argue that RoTB can be maintained if these patterns are analyzed as OPAQUE DISTRIBUTIONAL GENERALIZATIONS. These are defined as phonotactic generalizations which hold only at early stages of derivation, but are not surface-true since they are relaxed at later derivational stages. Just like opaque processes, opaque distributional generalizations can be formalized within Stratal OT (Bermúdez-Otero, 1999; Kiparsky, 2000) as restrictions on the output of early strata. This proposal expands on the ideas in Bermúdez-Otero (2001, 2006, 2007); Itô & Mester (2003).

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The non-surface distributional generalizations to be discussed here are similar to morpheme structure rules or constraints (Halle, 1959, 1962; Stanley, 1967; Booij, 2011, a.o.), recently also dubbed 'constraints on underlying representations' by Rasin & Katzir (2017). Such non-surface constraints have been criticized for duplicating either the surface constraints or otherwise applicable rules (Clayton (1976); Kenstowicz & Kisseberth (1977, §3.1)). Conventions intended to avoid such duplication have been proposed in early work on UR constraints (Stanley, 1967; Shibatani, 1973). Opaque distributional generalizations discussed here are not subject to the duplication problem since they aren't surface-true, and don't 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). Both of these will be further discussed in what follows.

My analysis captures the fact that Tundra Nenets /k/ never occurs phrase-initially, even though the 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 characterize some patterns which appear to involve unnatural classes but result from a derivational interaction of regular natural class alternations. Thus coronal and labial stops in Nenets undergo voicing after a vowel, 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 available at the relevant derivational stage, and that [k] is not available at that stage. This proposal is also in line with the finding that unnatural class patterns can be productive (Gallagher, 2019).

Section 2 introduces Tundra Nenets and reviews my data sources. Section 3 surveys the relevant Nenets data, and section 4 provides an analysis. Alternatives are considered in section 5. Section 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 have been described extensively by Janhunen (1986) and Salminen (1997, 1998b).

The patterns to be presented here largely match these published sources. The data have been expanded and verified against two corpora of recorded 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 ranging in age from forty-four to sixty-five at the time of recording. All speakers were born and raised in the same area (Nenets district of Russia).

The dialect of Nelmin Nos belongs to the Western Tundra Nenets dialect group and therefore differs from Central Tundra Nenets that can be considered standard. My consultants are aware of both Western and Central Tundra Nenets pronunciations, and produce both standard and dialectal forms depending on the social context of conversation. In what follows, I will

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

mostly focus on the patterns common to the two dialects, while acknowledging the specifically Western Tundra Nenets traits where necessary.

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

(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		ts/z tsʲ/zʲ		
liquids		l lʲ r rʲ		
glides	w wʲ	j		

All Tundra Nenets dialects show obstruent voicing after nasals, and this voicing process is the only source of surface [g z zʲ]. In some Western dialects, the homorganic nasal + obstruent sequences are then 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 tendency for nasal cluster simplification, but the process of denasalization here is variable and sometimes phonetically incomplete. I list [g z zʲ] as allophonic variants of [k ts tsʲ] respectively in (1), and return to this issue in section 3.2. In many dialects of Tundra Nenets, /d/ is often realized as [ð], and the Nelmin Nos dialect also occasionally realizes /b/ as [β]. The palatalized glide [wʲ] occurs only in the Western dialects, including the Nelmin Nos dialect. Finally, the palatalized dorsal fricative appears only in the root /xʲiˑbʲa/ 'who', and can probably be treated as an allophone of /x/ since the former never occurs before sequences of /iˑ/ + palatalized consonant (Salminen, 1997).

The vowel inventory of Tundra Nenets is given in (2) (see also 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 written 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 syllables and in even syllables (Helimski, 1989; Salminen, 1993a, 1997, 1998b). The vowel [°] may be pronounced as an over-short vowel, a release of a consonant, or it may not be pronounced in some cases. Surface long vowels listed in (2) are derived from underlying sequences of a vowel followed by /ʌ/. Despite its highly variable realization, the null vowel triggers a number of surface alternations, such as postvocalic voicing (pace Kavitskaya & Staroverov, 2010), and thus it needs to be represented in the transcription. Tundra Nenets syllable structure is CV(CC), with a limited inventory of complex codas.

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

[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 first syllables (Salminen, 1997; Nikolaeva, 2014) may need further investigation for the Nelmin Nos dialect. None of the examples in this article have this vowel.

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

3 Evidence for opaque distributional generalizations

This section outlines two patterns in the phonology of Tundra Nenets /k/ that are illuminated by postulating an opaque distributional generalization. Section 3.1 shows that the distribution of phrase-initial stops is a challenge for positional faithfulness. Section 3.2 demonstrates that the undergoers of a medial voicing process are an apparently unnatural class including coronal and labial but not dorsal stops. In section 3.3, I show that surface /k/ 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 more detail in section 4.

3.1 Initial stops

Initial position typically exhibits preservation of contrasts (Casali, 1996; Beckman, 1998; Smith, 2005), yet in Nenets the initial inventory of stops includes only coronals and labials but not dorsals (3).[4] Tundra Nenets does not have prefixes, and therefore the initial position coincides with the left edge of the root. 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 generalization in Tundra Nenets phonology: the vast majority of Russian loanwords that start in /k/ in Russian are recorded with a /x/-initial variant, or exclusively as /x/-initial in the Nenets dictionary (Tereshchenko, 1965), witness Nenets [xos°ka ∼ koʃ°ka] from Russian [koʃkə] 'cat'; Nenets [xorawa ∼ korowa] from Russian [kɐrovə] 'cow'. My consultants are usually aware of both variants for such words. All the consultants are fluent 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 Nenets phonology.

To summarize, even though Tundra Nenets has contrastive /k/, it never shows up in a phrase-initial position. This is a potential problem for the idea that initial position is associated with contrast preservation (Casali, 1996; Beckman, 1998). Moreover, as discussed in section 5.1

[4] The restrictions on Tundra Nenets initial consonants are actually more pervasive: voiced stops and the affricates /ts tsʲ/ also never occur phrase-initially. The distribution of these consonants can also be analyzed in terms of opaque distributional generalizations. 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.

below, no known positional augmentation constraints prohibit 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 would ideally explain why /k/ escapes this process. Postvocalic voicing is illustrated in (4). Recall that /ʌ/ and /°/ alternate in a general vowel reduction process and that /V+ʌ/ sequences merge to surface as a long vowel (e.g. [pʌniː] 'garment' in (4)).

In Western dialectal speech, the voiced stop stops /b d/ (especially /d/) undergo variable lenition to [β, ð]. Postvocalic voicing operates within words and across phrase-medial word boundaries. The multi-word examples in (4)[5] and in what follows illustrate word-boundary processes in relatively fast, connected speech, where the two words form a phrase together. These boundary processes are heard in texts, and they often are not transcribed in the phonemic notation of Nikolaeva (2014).

(4) Postvocalic voicing

a. [b d] after vowels		b. [p t] elsewhere	
/ja-ta/ earth-POSS.SG3SG	jada	/jar-ta/ side-POSS.SG3SG	jarta
/ŋinʌ-ta/ bow-POSS.SG3SG	ŋin°da	/xajer-ta/ sun-POSS.SG3SG	xajerta
/nʲebʲa-toN/ mother-POSS.SG3PL	nʲebʲadoʔ	/ŋob-toN/ one-POSS.SG3PL	ŋobtoʔ
/pʲa-pʌʔ/ start-COND	pʲab°ʔ	/mʌlʌr-pʌʔ/ chirp-COND	mʌlʌrp°ʔ
/mʲarʲojʌ pʌniʌ-naʔ/ bald garment-POSS.PL1PL	mʲarʲoj° bʌniːnaʔ	/pʌniʌ/ garment	pʌniː

Importantly, there are no parallel examples 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] 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 speech described by Nikolaeva (2014). Although the words in (5) have not been recorded with a cluster there is little doubt that in more careful or formal speech they may be pronounced with [ŋg]. Very similar examples with clusters are recorded in Nikolaeva's corpus even from the same consultants. Some of the words in (5) come from a larger phrase and show initial [d dʲ] from phrasal voicing, though the source of voicing is not shown. Finally, the last word in (5) shows an additional regular alternation whereby intervocalic /m/ changes to /w/.

[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(irmative) and CONNEG(ative). Possessive markers in Tundra Nenets encode the number of both possessor and possessee, notated as in POSS.SG3SG.

(5) Intervocalic [ɡ] in Western Tundra Nenets

/tʲetsʲʌ-Nxu/	cold-FUT.SUBJ.3SG	dʲetsʲ°ɡu [6]
/tara-Nxuʔ/	need-FUT.SUBJ.3PL	daraɡuʔ
/sʲerʌ-Nxunaʔ/	wear-FUT.OBJ.PL.SUBJ.1PL	sʲer°ɡunaʔ
/nʲaN-xʌmamʌ/	mouth-AFF.POSS.SG1SG	nʲaɡ°waw°

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

In sum, the undergoers of postvocalic voicing in Tundra Nenets are an unnatural class described by a disjunction 'coronal or labial stops'. /k/ does not undergo voicing despite the fact that intervocalic [ɡ] is allowed. If this class included /k/, it could be characterized as natural, e.g. [–continuant; –constricted glottis]. 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-neutralizing, and this may be connected to consonant cluster simplification. For some relevant URs, we have no evidence for the underlying voicing 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 voiced stop distribution until section 5.2.3.

(6) Distribution of Tundra Nenets voiceless obstruents

	p pʲ	t tʲ	k	x
#_V	✓	✓	*	✓
V_V	✓	✓	✓	✓
C_V	✓	✓	✓	*

Let us briefly summarize 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 could be reduced to a single generalization: /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 will only spell out the relevant details of Tundra Nenets coda processes since a detailed account of Tundra Nenets clusters would lead us too far afield (see Staroverov & Kavitskaya, 2017, for a more detailed story). Tundra Nenets exhibits restrictions on codas which essentially require each syllable-final consonant to be placeless. Different coda consonants adhere to this requirement differently: coronal obstruents and nasals, /T s n/, lose their place features, becoming /ʔ/, while coda liquids, /l r/, and labials, /P m/, are followed by /ʔ/.[7] The nominal forms in (7) illustrate these

[6]It may be possible to derive /tsʲ/ in this example from undelrying /sʲ/, see note 4.

[7]The patterning of coda /ŋ/ is somewhat less clear, but it 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.

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 liquids end in /C+ʔ/ (7b). Genitive is a vowel-initial suffix, and here the final consonant of the stem is revealed. The forms in (7) also show regular vowel reduction alternations between [ʌ] in non-final syllables and [°] in final syllables.

(7) Coda glottal stops

	Stem UR	Nom.	Gen.sg /-ʌN/	Gloss
a.	/m^{j}aT/	m^{j}aʔ	m^{j}ad°ʔ	'tent'
	/mʌrʌT/	mʌr°ʔ	mʌrʌd°ʔ	'city'
	/maʌs/	maːʔ	maːs°ʔ	'chest pocket in traditional clothing'
	/mʌnʌs/	mʌn°ʔ	mʌnʌs°ʔ	'lump'
b.	/ŋoP/	ŋobʔ	ŋob°ʔ	'one'
	/xajer/	xajerʔ	xajer°ʔ	'sun'
	/s^{j}ar/	s^{j}arʔ	s^{j}ar°ʔ	'surface'
	/num/	numʔ	nuw°ʔ	'sky'

Based on the alternations in (7), we would expect to see coda glottal stops phrase-medially before obstruents, including before /x/. However, a later process involves simplifying the /ʔ+C/ 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-ʌʔ/ tent-GEN.SG	mʲad°ʔ
/nʲe-T/[8] woman-GEN.PL	nʲeʔ
/mʌnes-ŋa/ see-SUBJ.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	pʲa-b°ʔ

Clusters of the form /ʔ+fricative/ are also simplified, deriving /k/ from /ʔ+x/ and /ts, tsʲ/ from /ʔ+s, sʲ/. These alternations are shown in (9), for dorsals. The first two forms in (b) reflect the fast-speech pronunciation variants where the two words are phrased together (see section 2). These are compared with the pronunciation of each word in isolation. The intermediate representations are given to highlight the derivation of dorsals.

[8]The genitive plural marker has not been recorded with /sʲo-/ 'throat' in my dataset, hence an example with another stem is given. Genitive plural is analyzed as /T/ underlyingly, based on the parallel examples of plural /d/ in verbal paradigms (Janhunen, 1986, 61).

(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

It is useful to summarize how these patterns can be analyzed in a derivational account (Janhunen, 1986). Such a derivational summary is presented in (10). These schematic examples assume coda debuccalization as in (7a), but 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 way my overall derivations are distinct from Janhunen's. This difference is not related to the alternations of dorsals.

(10) Derivations of certain Tundra Nenets obstruents

(earlier output)	/pa/	/aCpa/	/apa/	/ta/	/aCta/	/ata/	/xa/	/aCxa/	/axa/
debuccalization		aʔpa			aʔta			aʔxa	
postvocalic voicing			aba			ada			
CC simplification		apa			ata			aka	
output	[pa]	[apa]	[aba]	[ta]	[ata]	[ada]	[xa]	[aka]	[axa]

These derivations predict the observed distribution of Tundra Nenets stops, but, crucially, inputs containing /k/ are missing. Thus the correct distribution of surface stops emerges if we assume that at some derivational stage Tundra Nenets had 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, and this also applies to the *k > x change discussed below. Thus, while these derivations are motivated by what is known about the history of Samoyedic languages, my analysis will make no claim to also 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. Based on comparative evidence (Janhunen, 1977; Salminen, 2018) and on loanword adaptation patterns (section 3.1) we can hypothesize that /k/ spirantized to /x/.[10]

Going back to the synchronic analysis, we can assume that /k/ is first turned into /x/, but then 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/ in the input to voicing, there is only /x/ 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 between vowels since in this environment both underlying /Cx/ clusters and underlying singleton /x/ exist.

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

4 Analysis

This section spells out the analysis of Tundra Nenets facts with opaque distributional generalizations encoded as deep level phonotactic constraints within Stratal OT. The architecture of Stratal OT, which incorporates many assumptions of Lexical Phonology (Kiparsky, 1982, 1985; Mohanan, 1986, a.o.), includes several OT evaluations that are tied to morphological

[10]Proto-Samoyedic is reconstructed with a dorsal stop *k and no fricative (Janhunen, 1977). Comparative evidence for *k > x spirantization 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.

strata or cycles (Bermúdez-Otero, 1999, 2011; Kiparsky, 2000). Three strata will be important for our purposes: postlexical, word, and stem levels. Importantly, while the input to the initial evaluation (i.e. stem level) is completely unrestricted in line with RoTB, the previous outputs constitute the set of inputs for evaluation at each subsequent level. In this way the phonology of earlier strata restricts the inputs for later levels (Bermúdez-Otero, 2001, 2006, 2007; Itô & Mester, 2003).

The derivations assumed here are schematically similar to (10). The Table 1 gives an overview of the processes happening 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, it is assumed that each process applies as widely as possible. When a process may be applicable at a given level but there is no direct evidence its application is recorded in parentheses in Table 1. The restrictions on /k/ are active at the stem level, but /k/ is later allowed postlexically. The domain of coda debuccalization is a word, and this process is active only at the word level. Consonant cluster simplification becomes active postlexically: this process presupposes prior application of coda place loss, 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 happens. For all relevant processes, the process itself and the resulting distributional generalizations are captured by the same constraint rankings at a given level, much in the spirit of Classical OT.

	Stem level	Word level	Postlexical level
/k/ spirantisation	✓	(✓)	
coda debuccalisation		✓	
cluster simplification			✓
postvocalic voicing		(✓)	✓
no voicing in underlying clusters	(✓)	(✓)	✓

Table 1: Summary of the stratal affiliation of processes in Tundra Nenets

Section 4.1 introduces the constraints used in my analysis. The following sections trace the derivation of Tundra Nenets /k/ from the stem level to the postlexical level. At each derivational level, the ranking has been tested using OT-Help software (Staubs et al., 2010), and the corresponding tableau files are provided as online supplementary materials.[11] The rankings derived by OT-Help are consistent with the ranking diagrams given below for each level, but some rankings given below may be transferred from another stratum rather than supported at a given stratum. As ranking information can be derived from the supplementary material, I will not discuss the detailed evidence for each ranking in what follows, focusing instead on the overall ranking patterns, on crucial candidates, and on ranking differences between strata.

4.1 Constraints

The OT constraints used in my analysis are the same at all levels of Tundra Nenets phonology, and this section gives a preview of the constraint definitions. Some additional details are provided in the following sections.

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

I will assume the standard faithfulness constraints within the correspondence theory of McCarthy & Prince (1995, 1999) – see (11). Some of the mappings to be analyzed involve merger or coalescence, and the relevant constraint UNIFORMITY (abbreviated UNIF) is given in (11-a).

(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

Certain Tundra Nenets coda processes involve mapping a consonant to a glottal stop. I analyze the glottal stop as a placeless consonant, and treat coda glottalization as place loss (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, hence protected by MAX and DEP constraints (Lombardi, 2001). The relevant constraint MAX(PLACE) is defined in (11-b) above. 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.

The markedness constraints I propose are related straightforwardly to the processes and generalizations described above. First off, the lack of /k/ (and /g/) at the stem level will be accounted for by the constraint against dorsal stops – *K in (12-a). 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 – *[+continuant] (de Lacy, 2006), abbreviated *[+CONT] and defined in (12-b).

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

Tundra Nenets word-level coda processes are triggered in part by a constraint from the CODA-COND family (Itô, 1986, 1989), abbreviated CC. In Tundra Nenets, 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 section 4.3, a preview is given in (13-a). At the postlexical level, placeless consonants are avoided through merger, and this process is driven by the constraint HAVEPLACE in (13-b) (McCarthy, 2008), to be abbreviated HVPLC in what follows.

(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 analyze this process with a 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 section 4.4.

4.2 Stem level

My analysis relies on the assumption that Tundra Nenets prohibits /k/ at an early derivational level. I assume that this restriction enters the grammar already at the stem level, in line with the life cycle of phonological processes (Bermúdez-Otero & Trousdale, 2012; Bermúdez-Otero, 2015).

As mentioned in section 3.3 there are no alternations to show how exactly /k/ is avoided. However, both comparative evidence and loan adaptation converge in supporting the spirantization of /k/ to |x|. Thus I will assume that /k/ is mapped to |x| in Tundra Nenets stem and word domains.

Example (15) presents my analysis of stem-level /k/ spirantization. The tableaux are presented in comparative format throughout the paper (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 to the fully 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 (written as '<Ø>' below), as in the candidate (c), which is ruled out by MAX.

(15) Stem-level avoidance of /k/

/k/	*K	MAX	ID(CONT)	*[+CONT]
☞ a. x			1	1
b. k	W1		L	L
c. <Ø>		W1	L	L

This picture of stem-level phonology relates to the distribution of /k/ in stems, but there is more to be said about affixes.[12] Tundra Nenets has no prefixes, and so far as we know, productive suffixes are all attached at the word level. In line with a number of recent 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 optimization of their own, and hence obey the same constraints as Tundra Nenets stems. This assumption correctly predicts that Tundra Nenets suffixes do not contain /k/. However, the proposed analysis would work even if stem-level optimization didn't apply to suffixes. /k/ spirantization in (15) does not contradict any of the word level rankings, and hence it is assumed here to apply at the word level as well meaning that suffixes that could contain /k/ behave the same as suffixes with /x/.

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

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

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

(16) Stem-level rankings

*K MAX

*[+CONT] ID(CONT)

The rankings in (16) can be assumed to also hold of later strata in Tundra Nenets phonology, with one important exception. The ranking *K≫*[+CONT] is to be reversed at the postlexical level, where /k/ is derived from |ʔ+x|. In this way reranking in Stratal OT expresses the fact that some distributional generalizations are opaque. This analysis also presents a derivation similar to Duke-of-York where stem-level phonology maps /k/ to |x| but postlexical phonology maps |ʔ+x| to /k/ (Pullum, 1976; Bermúdez-Otero, 2001; McCarthy, 2003b; Rubach, 2003).

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 debuccalization and glottal stop insertion (examples in (7)). Second, word stratum is the locus of vowel reduction producing the null vowel |°|. In line with the assumed stratal affiliation of these processes, they aren't ever applied or blocked across a word boundary.

In addition to those, 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/ spirantization is also active at the word level. At the same time, it is important that dorsal stop is already 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 could start being active already at the word stratum. Therefore the analysis of stop voicing will be presented in this section.

In what follows, I spell out a detailed analysis for some coda alternations in Tundra Nenets 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 (13-a), repeated below. Practically, this constraint 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, other consonants trigger glottal stop insertion (see e.g. [ŋobʔ] 'one' and [xajerʔ] 'sun' in (7)). 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 (13-a). In what follows however, I focus only on the debuccalization examples since these illustrate the derivation of dorsals most clearly.

The analysis of Tundra Nenets postvocalic voicing is presented in (17) for the form [jada] 'earth-POSS.SG3SG', where the voicing candidate defeats both the fully faithful and the deletion candidates.

(17) Analysis of Tundra Nenets voicing after vowels

|jata|	MAX	*VT	ID(VOI)
☞ a. ja.da			1
b. ja.ta		W1	L
c. ja.a	W1		L

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

The analysis of the mapping |mʲat-xʌna| → |mʲaʔx°na| 'house-LOC.SG' is presented in (18). The output will later be mapped to [mʲak°na] postlexically. This tableau omits the analysis of vowel reduction, hence all candidates have |°| in the second syllable. Numeric indices show non-trivial instances of input-output correspondence. As the winner in (17) was a candidate with voicing, similar candidates are considered in (18b-c).[13]

(18) Analysis of Tundra Nenets word level place loss

|mʲat$_1$x$_2$ʌna|	MAX	CC	HVPLC	*[+CONT]	*VT	MAX(PLC)	ID(VOI)	ID(CG)
☞ 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 in (18) has two violations which deserve a comment. First, a side effect of coda place loss 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 penalizes all postvocalic stops that aren't voiced, including the glottal stop. Coda place loss is driven by CODACOND, and the high ranking of this constraint disqualifies the faithful candidate (18b). The candidate (18c) shows that CODA-COND cannot be responded to by deleting one of the consonants, establishing the high ranking of MAX.

As I argue in section 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 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 |mʲat-ta| → |mʲaʔta| 'house-POSS.SG3SG'. This tableau focuses on the high ranking of UNIFORMITY at the word level, and presents only two suboptimal candidates (fully faithful and the coalescence candidate), omitting other candidates which yield the same ranking information as the losers in (18) above.

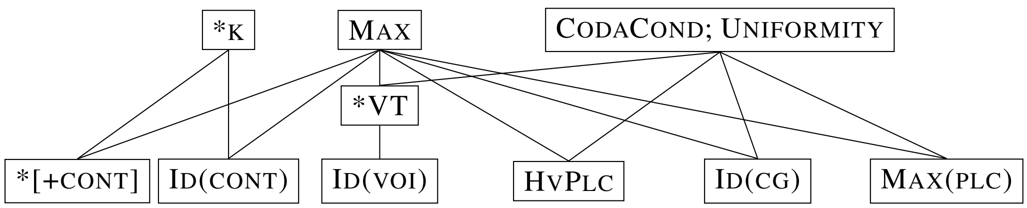
[13] The tableau (18) has an input |t|, not |T| in a coda position since in a fuller analysis Tundra Nenets stem level prohibits voiced stops (see also Janhunen, 1986).

(19) Lack of coalescence in Tundra Nenets word level

$\vert m^j at_1 t_2 a\vert$	CC	UNIF	HVPLC	*VT	MAX(PLC)	ID(VOI)	ID(CG)
☞ 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 summarized in (20).

(20) Word-level rankings



4.4 Postlexical level

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

Postvocalic voicing illustrated in (4) and analyzed in (17) also does apply postlexically as it's attested across word boundaries. Cluster simplification may yield voiceless consonants that fail to undergo postvocalic voicing (see example (8)). This blocking effect will be treated formally as a gang effect modeled with constraint conjunction (Staroverov & Kavitskaya, 2017). The blocking of postvocalic voicing is also responsible for the very limited distribution of Tundra Nenets [g], mentioned in section 3.2. Finally, the postlexical 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. Here, we look at the mapping $\vert m^j aʔ\text{-}ta\vert$ 'tent-POSS.SG3SG' → [m^jata], 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) Tundra Nenets postlexical coalescence with [t]

|m^{j}aʔ$_1$t$_2$a|	MAX	CC	HVPLC	UNIF	*VT	ID(CG)
☞ 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 [+c.g.] glottal stop and a [–c.g.] 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 – this constraint used to be ranked below UNIFORMITY at the word level. Finally, the candidate (d) satisfies both UNIFORMITY and HAVEPLACE by spreading place features onto the glottal stop and effectively undoing word-level debuccalization. However this last candidate fatally violates CODACOND.[14]

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

(22) Tundra Nenets postlexical identity map for |x|

|x|	MAX	ID(CONT)	*[+CONT]	*K
☞ a. x			1	
b. k		W1	L	W1
c. <Ø>	W1		L	

The tableau in (22) shows the emergence of [x] after vowels and word-initially. However, after a consonant input |x| is subject to coalescence, already introduced in (21). The application of coalescence to clusters with |x| and the emergence of /k/ is analyzed in (23). Here we are dealing with the mapping |m^{j}aʔ-x°na| → [m^{j}ak°na] 'tent-LOC.SG', which is the next derivational step after (18).

(23) Analysis of Tundra Nenets postlexical [k] emergence

|m^{j}aʔ$_1$x$_2$°na|	MAX	CC	HVPLC	ID(CONT)	*[+CONT]	*K	UNIF	*VT	ID(CG)
☞ a. m^{j}ak$_{1,2}$°na				1		1	1	1	1
b. m^{j}ax$_2$°na	W1			L	W1	L	L	L	L
c. m^{j}aʔ$_1$x$_2$°na			W1	L		L	L	1	L
d. m^{j}ak$_1$x$_2$°na		W1		L	W1	1	L	1	1
e. m^{j}ax$_{1,2}$°na				1	W1	L	1	L	1

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

The coalescence mapping |ʔ+x| → [k] in the winning candidate introduces a one-to-many correspondence relation and incurs all the IDENT violations that would be incurred if |ʔ| mapped to [k] and if |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). The candidates (23b-d) are thus presented simply to verify 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).[15] This last suboptimal candidate is ruled out since *[+CONT] dominates *K. This ranking (the opposite of stem level) is thus crucial to [k] emergence.

One final postlexical generalization 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], /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 formalize 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).

The analysis of a simple voicing mapping has been presented in (17), and the same process applies at the postlexical level since voicing operates across word boundaries. The blocking of voicing is formally manifested in the fact that candidates with a voiced postvocalic stop would be suboptimal in (21) and (23). Tableau (24) considers additional candidates for the output [m^jak°na] 'tent-LOC.SG' first analyzed in (23), and establishes the fact 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(CG) while the voicing + deletion candidate (c) (pronounced the same as (b)) is ruled out by MAX. The evaluation of similar candidates for [m^jata] 'tent-POSS.SG3SG' (21) would be entirely parallel to (24).

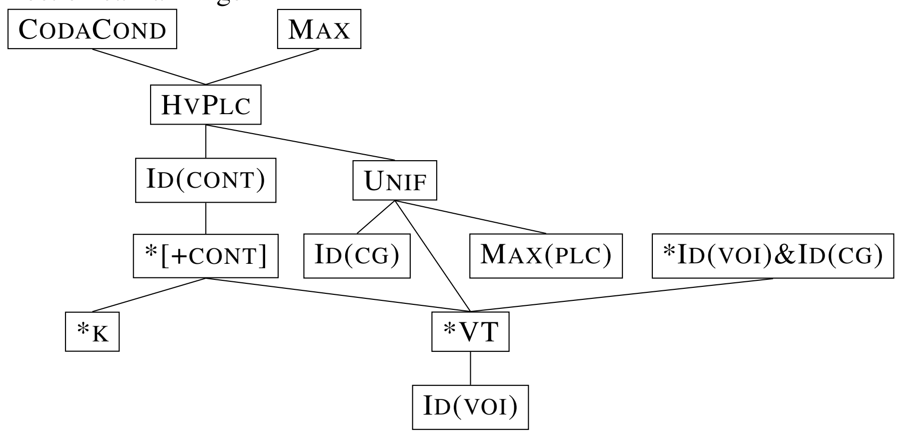
(24) Analysis of Tundra Nenets postlexical non-voicing

|m^jaʔ$_1$x$_2$°na|	MAX	ID(VOI) &ID(CG)	IDENT (CONT)	*K	UNIF	*VT	IDENT (VOI)	IDENT (CG)
☞ a. m^jak$_{1,2}$°na			1	1	1	1		1
b. m^jag$_{1,2}$°na		W1	1	1	1	L	W1	1
c. m^jag$_2$°na	W1		1	1	L	L	W1	L

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

[15] I am assuming that glottal stop is [–cont] 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; Cser, 1999), and some additional evidence is brought up by (Gussenhoven & Jacobs, 2017, 73 - 74). However, (Fallon, 2001, 184 - 193) presents a number of cases where glottal stop arguably patterns with stops. Therefore it seems that manner (under)specification of laryngeals should be viewed as language-specific; (McCarthy, 2008, 289) makes a similar point for their place specification.

(25) Postlexical rankings



Two of the rankings in (25) have been reversed in the course of derivation, and these are particularly important to my account of opaque distributional generalizations. In the next section, I will summarize 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 allowed to emerge postlexically through coalescence. Formally speaking, *k is ranked over *[+cont] and Ident(cont) at the stem and word level, but postlexically this ranking is reversed. Because of this, surface /k/ is derived only from consonant clusters in environments of coalescence. 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 is why Tundra Nenets prohibits dorsal stops phrase-initially – in a position typically associated with contrast preservation (Beckman, 1998; Casali, 1996).

With this difference in ranking, the derivation of Tundra Nenets /k/ resembles a Duke-of-York derivation (Pullum, 1976; Bermúdez-Otero, 2001; McCarthy, 2003b; Rubach, 2003): /k/ changes to |x| at an early derivational stage, but later |Cx| changes to [k]. Since constraint reranking is a curical component in my account of this derivation, this account cannot be directly translated into theories of opacity where one and the same ranking has to hold throughout the derivation. Therefore it remains to be seen how these data could be analyzed in Harmonic Serialism – a framework that has recently 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 syllable ends in a glottal stop but disallows coalescence while postlexical phonology avoids placeless glottal stops by merging them with a following consonant where possible. Formally, at the word level Uniformity ranks 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, only applying postvocalic voicing to the latter group. Postvocalic voicing is not artificially restricted to the unnatural class of voiceless stops /p p^j t t^j/, but rather it is restricted by the derivatonal history of different voiceless stops. Since /k/ is an underlying cluster, and since clusters never undergo postvocalic voicing, dorsal stops appear to be excluded from voicing altogether while in fact this is a consequence of a much broader ban on dorsals operating early on in the grammar. My analysis of blocked voicing 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 in the world's languages (Pater, 2009).

Unnatural class patterns present a general problem for phonological theory (Mielke, 2008), but there is relatively little research on how exactly these patterns may be represented and how they interact with the rest of the grammar (Gallagher, 2019). The proposed analysis demonstrates that some unnatural classes may beǎopaque, 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, /p p^j t t^j/ are all and only voiceless oral stops in the Tundra Nenets word level, and they undergo postvocalic voicing. However, later processes may introduce a new member in the relevant class, which could fail to undergo the original process. In Tundra Nenets, cluster simplification creates /k/ which fails to undergo voicing. This way it may appear that a surface pattern targets an unnatural class while at each derivational stage only natural class alternations happen. The present study provides a formal way to analyze such opaque unnatural classes in OT. It 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 analyzed this way, opaque distributional generalizations are reported in a number of languages including Catalan (Bermúdez-Otero, 2001, 2006, 2007; Lloret & Pons-Moll, 2016), Japanese (Itô & Mester, 2003), and a number of others (Gnanadesikan, 1997; McCarthy, 2005). The derivation of unnatural classes proposed here within Stratal OT may resemble, but not be fully identical to the diachronic history of the relevant processes (Scheer, 2015).

Finally, I have argued that Stratal OT and ranking differences between strata present a way to analyze 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 generalizations need to be stated independently precisely because they are opaque, and therefore they are not duplicated by any surface constraints, which has been cited as a problem for many non-surface distributional generalizations (Clayton (1976); Kenstowicz & Kisseberth (1977, §3.1)). Of course, not all distributional generalizations are opaque. Stratal OT also allows for surface-true distributional generalizations to enter the grammar at early levels – this is the case for the ban on complex onsets in Tundra Nenets.

5 Alternatives

This section[16] reviews the potential alternative analyses, focusing particularly on whether a feasible account without opaque distributional generalizations can be found and on whether Tundra Nenets can be reanalyzed in an entirely parallel Classical OT system. Section 5.1 discusses positional markedness as a potential alternative account for the lack of phrase-initial /k/. Section 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 known as a general challenge for generative phonology at least since the 1970s (Kiparsky, 1973, et passim). In Tundra Nenets, I assume (and attribute to the speakers) a free-ride grammar (Zwicky, 1970; McCarthy, 2005;

[16]This section owes a lot to the deep comments by three reviewers and the associate editor. I am immensely grateful for their comments and suggestions.

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, the existing learnability research shows that such a general characterization is likely too coarse. Formal algorithms succeed in learning at least some abstract URs (McCarthy, 2005; Tesar, 2006, 2014; Jarosz, 2006; O'Hara, 2017) and some opaque mappings (Jarosz, 2016; Chandlee et al., 2018; Nazarov & Pater, 2017). Nazarov & Pater (2017) address the learning of opaque mappings in Stratal OT and Bermúdez-Otero (2003) proposes that opaque distributional generalizations can be learned by applying phonotactic learning (Prince & Tesar, 1999; Hayes, 2004) to the set of input strings, although the kinds of generalizations 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 ease or difficulty in 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 Tundra Nenets data well (i.e. without assuming that some generalizations are accidental), and it connects Tundra Nenets distributional generalizations to otherwise general processes, using the same constraint rankings for both.

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

Positional constraints on word- and phrase-initial position have been studied by Smith (2002, 2005) and Flack (2007, 2009). It is therefore important to show that these proposals do not imply the existence of a positional constraint like $*\text{K}[_{Phr}$ prohibiting /k/ at the beginnings of phrases. 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 generalized as constraints on higher-order prosodic constituents. This theory would only predict a constraint like $*\text{K}[_{Phr}$ if there was an independently established constraint like $*\text{K}[_{\sigma}$ in the first place. 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 (2002, 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, enjoying robust perceptual cues (Wright, 2004). Moreover, general featural markedness constraints like *MIDV are explicitly cited as constraints that are not relativized to initial position by Smith (2005). The constraint $*\text{K}[_{Phr}$ 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 $*\text{K}[_{Phr}$. Itô&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 reanalyze 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 an apparent unnatural class pattern. This section considers three potential alternative accounts of this pattern: transparent blocking in Classical OT (section 5.2.1), chain shifts (section 5.2.2), and derived environment effects (section 5.2.3).

5.2.1 Blocking and the distribution of [ɡ]

One reason why /k/ would escape postvocalic voicing could be a general or contextual ban on [ɡ], in the relevant environment. Importantly however, no such blocking analysis is available because intervocalic [ɡ] is allowed in the Nelmin Nos dialect of Tundra Nenets, as exemplified in (5) above.[17] Consequently, if a constraint specifically prohibiting [ɡ] – call it *G – would be active in Tundra Nenets, this constraint would not be ranked high enough to block voicing. Input /ɡ/ does not surface as /k/, implying a ranking IDENT(voi) ≫ *G, but the opposite ranking of these two constraints 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 [ɡ].

5.2.2 Chain shifts

Another potential alternative to opaque distributional generalizations involves postulating a series of chain shifts. In fact, McCarthy (2005) and Gnanadesikan (1997) propose chain shifts as a general approach to the free ride cases where (as in Nenets) all surface As derive from undelrying Bs. Moreover, my account makes use of a chain shift e.g. /VCt/ → /Vt/ → /Vd/ to analyze postvocalic voicing, so why wouldn't a similar story work for surface dorsals?

In Tundra Nenets, we have evidence that surface [ɡ] always emerges from /ŋɡ/. A chain shift analysis would assume that underlying /ɡ/ maps to some other segment *S* (say /k/ or /x/). In Classical OT, these two assumptions would imply that input /ŋɡ/ also maps to output *S*, 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 where input /NC/ sequences change several features at a time. For example, underling /nasal + x/ sequences map to [ŋɡ]∼[ɡ], as seen in datives and locatives of nasal-final stems such as /sʲalʌN-xʌn-Ta/ 'underarm-DAT-POSS.SG3SG' [sʲal°ŋɡʌnda] ∼ [sʲal°ɡʌnda] (Staroverov & Kavitskaya, 2017). This mapping shows that a non-derivational Parallel OT grammar of Tundra Nenets must allow changing the features [nasal], [voice], and [continuant] at the same time, and it is not entirely clear how to reconcile this 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 /s + x/ ultimately yield a stop /k/ on the surface. On the proposed derivational analysis, the mapping from consonant clusters to surface singleton stops involves an intermediate stage of coda debuccalization to a glottal *stop*: /sx/ → |ʔx| → /k/. As a side effect of coda debuccalization, a stop is introduced in the cluster, and its [–continuant] value ultimately

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

survives in the output (Staroverov & Kavitskaya, 2017).[18] A non-derivational chain shift analysis of the same facts would have nothing to say as to why a stop emerges from a sequence of continuants. In sum, some opaque interactions in Tundra Nenets cannot be reanalyzed as chain shifts, while for others some explanatory insight is lost in the chain shift analysis. Thus, although I argued for a chain shift analysis of Tundra Nenets stop voicing, the overall patterning of Tundra Nenets obstruents cannot be analyzed with just chain shifts.

5.2.3 Derived environment effects

Another potential way to explain away the apparent unnatural class of voicing undergoers would be to restrict postvocalic voicing to derived environments (Kiparsky, 1973). Recall that no suffixes in Tundra Nenets start with /k/, so if voicing only applied at a morphological boundary then /k/ would be excluded from this process by its distribution (Tundra Nenets is exclusively suffixing, so there are no other morphological boundaries). On this account, there would be no distributional restrictions on /k/, except for the restrictions on suffixes, which could be accidental since suffixes are a closed class. 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 occurring in a morphologically derived environment, phonologically speaking they are *un*derived. 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 (DEEs). Some relevant proposals include Łubowicz (2002); McCarthy (2003a); van Oostendorp (2007).

The DEE analysis would miss many stem-internal distributional generalizations that a derivational account captures. Thus Tundra Nenets /x/ does not occur after consonants on the surface, even within stems. Similarly, Tundra Nenets 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 generalization 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 generalization where just like /k/ voiced stops are prohibited early on, but later derived (see also Janhunen, 1986; Salminen, 1997). However, if there were no opaque distributional generalizations (as in the DEE account), we would expect that voiced stops and /x/ would freely occur after a consonant within stems and phrase-initially.

To summarize, I have considered a number of potential alternative accounts for the fact that dorsals escape postvocalic voicing in Tundra Nenets. A transparent blocking account would fail to capture the surface intervocalic [ɡ]. 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 would miss the distributional generalizations about Tundra Nenets stem-internal voiced stops and /x/. Finally, all of these accounts have nothing to say about the lack of phrase-initial /k/ and voiced stops, but this distributional fact follows from the derivational account.

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

6 Conclusion

Opaque distributional generalizations manifest themselves in a situation where a contrastive segment only arises in the environments where it is also derived by an active alternation. Although the constraints on URs are arguably subject to a duplication problem (Kenstowicz & Kisseberth, 1977, §3.1), this problem does not apply to opaque generalizations because their effect is obscured by the phonology of later levels. Therefore, such generalizations must be captured in 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; Itô & 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. This language also has other examples of opaque distributional generalizations, pertaining to voiced stops and affricates (Janhunen, 1986), and thus it presents a good test ground for exploring the theory of input restrictions in the future.

The proposed account also has consequences for a number of debated topics in phonology. Classical OT is commited to RoTB (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 RoTB (Bermúdez-Otero, 2001). In this paper, I have argued that Stratal OT provides for a theory of input restrictions compatible with RoTB. I have also defended an abstract derivational free-ride analysis (Zwicky, 1970; McCarthy, 2005) against potential alternatives, showing that such an analysis provides good fit for the data, and uses the very same constraints and rankings to capture the processes and the resulting distributional generalizations.

The present proposal identifies and formally analyzes a class of opaque unnatural class patterns (Mielke, 2008). These patterns result from an interaction of regular natural class alternations where 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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