Phonology Project Part II: Laryngeal Neutralization and Syllable Structure

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Contents

1 Introduction

1.1 Laryngeal Neutralization

We examine cases in which Laryngeal features are prohibited in certain positions. The core phenomena under discussion will be Laryngeal neutralization, reassociation (transfer) of Laryngeal features, and behavior of aspiration in geminates and moraic consonants. In Section 1, we briefly discuss the theoretical status of Laryngeal features, and provide an overview of the relevant processes in Sanskrit and Icelandic, which are considered throughout the investigation. In Section 2, we discuss proposals that characterize Laryngeal neutralization as a prosodically-governed process; specifically, we examine syllabic licensing along the lines of Lombardi (1991). Section 3 presents arguments by Blevins (1993) and Steriade (1997) that the syllable is not involved in neutralization. Section 4 examines two Optimality-Theoretic treatments of neutralization phenomena in Sanskrit. In Section 5, we present our Optimality-Theoretic analysis of Icelandic preaspiration and devoicing, correcting errors in previously published work and concluding that neither a peculiar interpretation of multiply linked `[s.g.]` features nor an ordered gemination process need be invoked in the analysis. We also make some observations on the role of LINEARITY and NO-GAP constraints in Optimality Theory. Section 6 concludes.

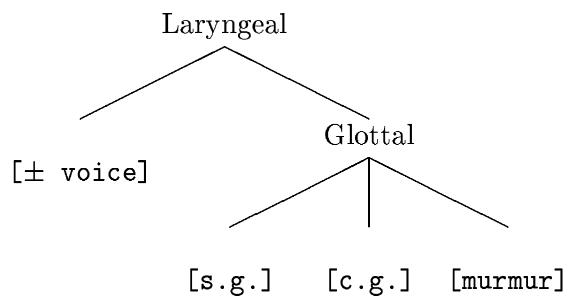
1.2 Privative Features

Lombardi (1991) proposes that `[spread glottis]` and `[constricted glottis]` are irrelevant to phonology and that the relevant features are `[voice]`, `[asp]`, and `[gl]`. Kim (2000) is not content with the extent to which these three features describe natural classes of features that undergo the same phenomena; in particular, she believes that voiced aspirates contain a feature `[murmur]`, and that voiceless aspirates consist of `[asp]`, and never the twain shall meet:

> Voiced aspirates or voiceless murmured stops do not exist. (Kim 2000:5)

In this formulation, `[murmur]` and `[asp]` (for Kim, `[s.g.]`) belong to the sub-node Glottal, under the Laryngeal node:[1]

[1] Actually, the precise feature geometry shouldn't matter at all for Kim, since she describes alternations based on single-feature constraints.



Kim cites arguments all the way back to Chomsky and Halle's SPE that voicing and aspiration are incompatible, and thus murmur is needed. We will adopt the hypothesis that `[s.g.]` and `[c.g.]` are privative, and make reference to `[murmur]` where it may provide insight into analysis.

1.3 Laryngeal Processes in Icelandic and Sanskrit

In this paper, we will consider in depth laryngeal processes in Icelandic and Sanskrit which have long puzzled linguists. On Sanskrit throwback we have treatments by the Indian grammarian Pāṇini and Whitney's influential 1889 grammar. Thráinsson made a pioneering analysis of Icelandic preaspiration in 1978 using the then-novel autosegmental theory. We will examine the role of syllable structure and consider the various ways Optimality Theory has been brought to bear on the issues involved. For Icelandic, we will propose a new OT treatment that solves several outstanding issues with published analyses.

1.3.1 Icelandic Overview

Icelandic[2] contrasts unaspirated stops /p, t, k/ and aspirated stops /p^h, t^h, k^h/, as shown in the data from Thráinsson (1978) and Ringen (1999) presented in (1):

		written	**surface form**	**gloss**	**written**	**surface form**	**gloss**
(1)	a.	*bar*	[paːr]	'bar'	*par*	[p^{h}aːr]	'pair'
	b.	*dalur*	[taːlʏr]	'valley'	*tala*	[t^{h}aːla]	'talk'
	c.	*gata*	[kaːt^{h}a]	'street'	*kaka*	[k^{h}aːk^{h}a]	'cake'

Note that symbols /b, d, g/ in Icelandic orthography do not actually denote voiced stops; they are used instead to represent unaspirated stops.[3] Examples (2) show that long (geminate) unaspirated stops occur, but where long aspirated stops would be expected *preaspirated* stops are found instead, as shown in the adjective formations in (3). Note that the neuter singular is formed from the root (as exposed by the feminine singular) by adding the suffix /-t^h/.

[2]All surface forms presented here are from the northern dialect of Icelandic; the southern dialect deaspirates all non-initial-syllable stops without, however, affecting the distribution of preaspiration.

[3]It is likely that this indicates a language change from Old Icelandic, which perhaps did voice these stops.

The geminate /t^h+t^h/ becomes [ht]. Example (3)(c) shows that sonorants also devoice before aspirated stops, which allows us to determine in this case that the suffix is aspirated underlyingly (compare with (6)).[4]

(2)

	written	surface form	gloss
a.	*haddur*	[hatːʏr]	‘hair’
b.	*flibbi*	[flɪpːɪ]	‘collar’
c.	*tryggur*	[t^{h}rɪkːʏr]	‘faithful’

(3)

	fem. sg.	UR	SR	neut. sg.	UR	SR	gloss
a.	*feit*	/feit^h/	[feiːt^h]	*feitt*	/feit^h+t^h/	[feiht]	‘fat’
b.	*sæt*	/sait^h/	[saiːt^h]	*sætt*	/sait^h+t^h/	[saiht]	‘sweet’
c.	*sár*	/saur/	[sauːr]	*sárt*	/saur+t^h/	[saur̥t]	‘painful’

Preaspirated stops also surface when an aspirated stop occurs before /l/, /m/,[5] or /n/, as shown in (4). But note the example Thráinsson (personal communication, Dec 18, 2000) gives in (5): preaspiration does *not* occur preceding /r/. We will return to this (apparently) surprising fact in section 5.

(4)

	nom. sg.	UR	SR	gen. pl.	UR	SR	gloss
a.	*pípa*	/p^{h}ip^h+a/	[p^{h}iːp^{h}a]	*pípna*	/p^{h}ip^h+na/	[p^{h}ihpna]	‘pipe’
b.	*gata*	/kat^h+a/	[kaːt^{h}a]	*gatna*	/kat^h+na/	[kahtna]	‘street’
c.	*kaka*	/k^{h}ak^h+a/	[k^{h}aːk^{h}a]	*kakna*	/k^{h}ak^h+na/	[k^{h}ahkna]	‘cake’

(5)

written	UR	SR
daprir	/dap^{h}ir/	[daːp^{h}rir]

The most widespread Icelandic dialect also devoices /l, m, n, r/ before /p^h, t^h, k^h/, as (6) shows. In section 5 we will show that this is due to the same constraints which cause the preaspiration of geminates shown in (3). For now simply note that aspiration is moving from the *onset* to the *coda*—as we will see, Lombardi (1991) will claim that laryngeal features are only licensed in the onset; precisely where the feature is moving *from*.

[4] Actually, Thráinsson (1978) and others referencing him (for example, Keer (2000)) incorrectly assume the suffix is unaspirated /-t/. Both Ringen (1999) and Jónsson (1994) note their correction in footnotes.

[5] According to Thráinsson (1978), a native speaker, although he does not provide any examples.

(6)

	written	surface form	gloss
a.	*úlpa*	[ul̥pa]	'coat'
b.	*heimta*	[heim̥ta]	'demand'
c.	*vanta*	[van̥ta]	'lack'
d.	*vinka*	[viŋ̥ka]	'wave'
e.	*sárt*	[saur̥t]	'painful' (neut. sg.)

Finally, when two non-homorganic aspirated stops become adjacent, the first is realized as a fricative and the second loses its aspiration. This process is shown in (7), from Thráinsson (1978). This data is presented for completeness, but we will not further discuss the spirantization process in this paper.

(7)

	inf.	UR	SR	past.	UR	SR	gloss
a.	*leysa*	/leis+a/	[leisa]	*leysti*	/leis+t^h+ɪ/	[leistɪ][6]	'untie'
b.	*gleypa*	/kleip^h+a/	[kleip^{h}a]	*gleypti*	/kleip^h+t^h+ɪ/	[kleiftɪ]	'swallow'
	fem. sg.	**UR**	**SR**	**neut. sg.**	**UR**	**SR**	**gloss**
c.	*rík*	/rik^h/	[riːk^h]	*ríkt*	/rik^h+t^h/	[rixt]	'rich'

Thráinsson (1978) provided the first autosegmental analysis of the preaspiration process, producing the rule shown in (8), which delinks all supralaryngeal features in a cluster to obtain the preaspiration sequence [h+STOP].

(8)

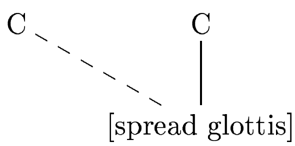
$$
\begin{array}{llll}
\text{laryngeal features:} & \begin{bmatrix} -\texttt{s.g.} \\ -\texttt{c.g.} \\ -\texttt{stiff v.c} \\ -\texttt{slack v.c} \end{bmatrix} & \begin{bmatrix} +\texttt{s.g.} \\ -\texttt{c.g.} \\ +\texttt{stiff v.c} \\ -\texttt{slack v.c} \end{bmatrix} & \begin{bmatrix} +\texttt{s.g.} \\ -\texttt{c.g.} \\ +\texttt{stiff v.c} \\ -\texttt{slack v.c} \end{bmatrix} \\
 & | & | & | \\
\text{phonological segments:} & V & C_1 & C_2 \\
 & | & \nmid & | \\
\text{supralaryngeal features:} & \begin{bmatrix} \pm\texttt{high} \\ \pm\texttt{back} \\ \vdots \\ \\ \end{bmatrix} & \begin{bmatrix} -\texttt{son} \\ -\texttt{cont} \\ \alpha\texttt{lab} \\ \beta\texttt{cor} \\ \gamma\texttt{high} \end{bmatrix} & \begin{bmatrix} -\texttt{son} \\ -\texttt{cont} \\ \alpha\texttt{lab} \\ \beta\texttt{cor} \\ \gamma\texttt{high} \end{bmatrix}
\end{array}
$$

Thráinsson's rule misses an important environment generalization, however: the preaspiration process occurs exactly when the post-aspirated stop becomes moraic. We will return to this in more depth when we formulate our OT analysis of the Icelandic data in section 5.

[6]Note that the fact that the /t/ is unaspirated here strongly suggests that, as Vaux (1998) has suggested, /s/ has an underlying `[s.g.]` feature just like /t^h/ does.

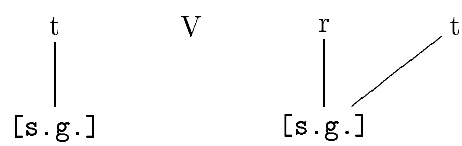
Ringen (1999), following Iverson and Salmons (1995) (but see Calabrese and Halle 1998), proposes that sonorant devoicing is accomplished via spreading from the adjacent `[s.g.]` segment, as illustrated in (9).[7] She presents the figure reproduced in (10) to describe the phonetic realization of the structures her analysis posits. We will later see that such representational games are unnecessary for a successful OT treatment, although they help illuminate the nature of OT constraints such as No-Gap.

(9)



a. aspirated stop b. unaspirated stop c. unaspirated stop

(10)



1.3.2 Sanskrit Overview

Sanskrit shows final neutralization of aspiration (and voice):

(11)

/agnima**t**$^{\mathbf{h}}$/	[agnima**t**]
/viiru**d**$^{\mathbf{h}}$/	[viiru**t**]
/suhr̥**d**/	[suhr̥**t**]
/tris̥t̥u**b**$^{\mathbf{h}}$/	[tris̥t̥u**p**]

In Sanskrit, a root can never have more than one voiced aspirate. There are two laws:

Grassmann's Law: throwback of aspiration
Bartholomae's Law: transfer of aspiration (to the second consonant in a cluster)

[7]Note that we treated Iverson and Salmons's (1995) devoicing analysis in the first part of this project. One of the ways that Icelandic differs from English is that devoicing occurs across syllable boundaries: English *Atlantic* becomes [ˌətˈlæn.tɪk], not *[ˌətˈl̥æn.tɪk] (English's progressive devoicing is blocked by the syllable boundary); while Icelandic *vanta* becomes [ˈvan̥.ta] (Icelandic's regressive devoicing is not blocked by the syllable boundary).

These processes are illustrated below for the root /budh/, 'to know':

		Root:	
	a.	budh	
		Affixation, no neutralization:	
	b.	bodhati	3sg present indicative
	c.	bubodha	3sg perfect
(12)		**Grassmann's Law:**	
	d.	bhotsayi	3sg future
	e.	abhutsi	root noun, nom. singular
	f.	bhudbhis	root noun, instr. plural
		Bartholomae's Law:	
	g.	buddha	past participle

In (12)(d-f), aspiration is not licensed in the coda of the first syllable. There has been a long and contentious literature on whether autosegmental "throwback" of the aspiration occurs, or whether the initial onset is underlyingly aspirated as well, and only surfaces when the coda undergoes laryngeal neutralization.[8] We adopt the former position, that there is only one underlying `[asp]`, throughout the course of this paper. Throwback in Sanskrit, as well as progressive assimilation, will be discussed in detail in sections 2.3, 3.2, and 4.

2 Syllabic Licensing: The Laryngeal Constraint

Lombardi (1991) suggests that laryngeally-neutralized consonants altogether lack a Laryngeal node. Such a claim is rather powerful in describing neutralization of aspiration and glottalization in certain positions. For example, glottalized obstruents are neutralized in codas of Maidu:

	a.	/hyt'/	'fat, grease'
		[batam hyt'i]	'butter'
		[hytpe]	'fat, obese'
(13)	b.	/pit'/	'defecate'
		[pit]	'feces'
		[pit'ik'atanoky]	'dung-rolling beetle'
		[pitk'ololo]	'intestines'

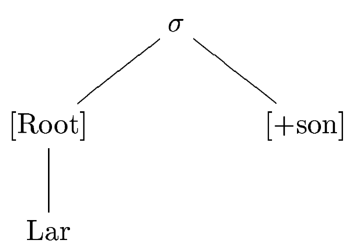
As (13) illustrates, consonants with a Laryngeal node can only appear in syllable-initial position. In Marathi, final deaspiration occurs for obstruents (Lombardi 1991), citing data from Houlihan and Iverson (1979):

	/taph/	[tap]	'fever'	tapala	'to the fever'
(14)	/toph/	[top]	'cannon'	tophela	'to the cannon'
	/vadh/	[vad]	'discussion'	vadala	'to the discussion'
	/dudh/	[dud]	'milk'	dudhala	'to the milk'

[8]Proponents of this analysis suggest that both segments are not aspirated in b(h)odhati due to something like the OCP.

Lombardi proposes a Positive Constraint licensing a segment with a Laryngeal node when it precedes a tautosyllabic sonorant, as shown in (15).

(15)



2.1 Limitations of the Laryngeal Constraint

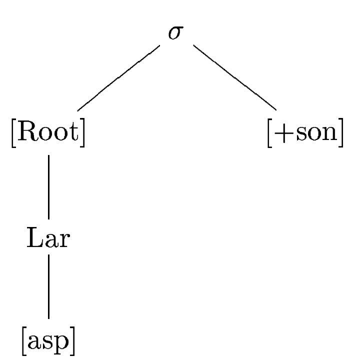
In some cases, the Laryngeal constraint as stated is overly general. Lombardi notes that in Tol and in Hupa, aspiration is neutralized, but glottalization is not. The following Tol data (Lombardi 1991) show final deaspiration (a), and immunity of glottalization to the constraint (b):

(16)

a.	sit	sit^{h} in	'avocado'
	c'ec	cec^{h} em	'tortilla'
	lup	lup^{h} uk	'hail'
b.	mac'	moc'ik	'toasted corn drink'
	cec'	cec'em'	'giant'
	wɨt'	wɨt'is	'firewood'

The forms in (a), such as [sit], show neutralization of an aspirated stop when it is in the coda, while the forms of (b), such as [mac'], show that glottalized consonants are indeed licensed in the coda. The data in (16), then, indicate that (15) is too general, and a more specific constraint, with the form of (17), is needed:

(17)



As a Positive Constraint, (17) licenses aspiration in presonorant onsets, while glottalization (as well as voicing) are licensed everywhere.

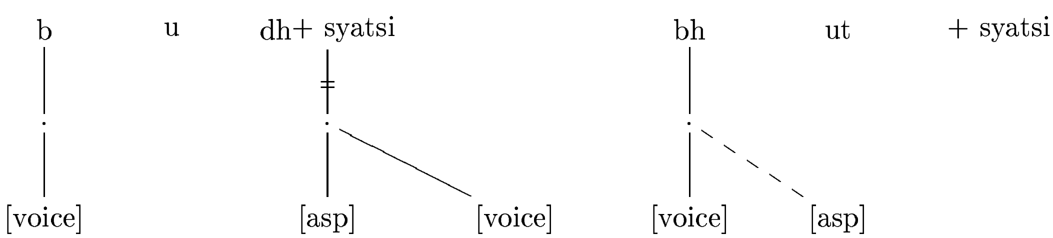
2.2 Surface Syllabification

It is worth noting that the Laryngeal Constraint applies only on surface syllabification. Lombardi cites work by Kingston, indicating that obstruent-sonorant clusters must first be syllabified separately for the rules of vowel deletion to work properly; after vowel deletion, these are resyllabified as complex onsets. In the initial syllabification, $[\text{t'}]_\sigma$ $[\text{r}]_\sigma$ (the result of a vowel deletion rule), clearly the [t'] is not licensed by the Laryngeal Constraint. However, assuming the LC awaits resyllabification, $[\text{t'r}]_\sigma$ is a configuration in which glottalization is licensed. Thus, the Laryngeal Constraint must not apply to the initial syllabification, or else the glottalization would be lost. The Laryngeal Constraint licenses the glottalization in the resyllabified complex onset, in which the obstruent and sonorant are now tautosyllabic. As a general remark, the sensitivity of a licensing constraint to distinct levels of syllabification seems tolerable in the standard theory.

2.3 Sanskrit: Repair Strategies for the Laryngeal Constraint

Unlike many of the languages discussed above, Laryngeal nodes do not seem to merely neutralize in Sanskrit. Rather, the Laryngeal feature (in this case, aspiration on a voiced stop, or `[murmur]`) reassociates elsewhere. Recall that the root /budh/, 'to know', undergoes *throwback* of aspiration, under Grassmann's law. Hence, budh+syatsi → bhotsyati:

(18)



While (18) shows fairly straightforward delinking and reassociation for Grassmann's Law, Bartholomae's Law of progressive assimilation (19) involves more complex facts about geminates:

	bud$^{\text{h}}$ + ta	→ budd$^{\text{h}}$a
(19)	rund$^{\text{h}}$ + t$^{\text{h}}$as	→ rundd$^{\text{h}}$as
	lab$^{\text{h}}$ + ta	→ labd$^{\text{h}}$a

In (19), one hypothesis is that aspiration is fully transferred to the following coronal consonant of the clusters, while another hypothesis is that a geminate is formed, in which both segments share a Laryngeal node. Lombardi adopts the latter, and suggests that the CCh (rather than ChC) pattern of aspiration is the result of a phonetic implementation, in which aspiration must be realized on the release. Some readers may find this explanation unsatisfactory; in addition, depending on one's theory of geminates, the arguments can become quite complicated, as we shall see with Icelandic preaspiration. As we discuss in section 4.2.3, Kim (2000) argues that no geminate is formed, and that the aspiration is delinked and reassociated with the second segment, although quite a few OT acrobatics are needed to locally constrain the association site.

2.3.1 Interaction of Grassmann's and Bartholomae's Laws

Another question arises, about the interaction of Bartholomae's Law and Grassmann's law: if aspiration does not delink, but progressively assimilates with a following coronal (as Lombardi assumes), will throwback occur as well? Consider /dugh/ + dhi $\rightarrow$ [dugdhi]; under the hypothesis that Laryngeal neutralization is always a case of delinking, the logical prediction is that throwback should occur; for the delinked [asp] feature cannot associate with the already-aspirated onset of the suffix. However, since no throwback actually occurs, it must be the case that no delinking took place; rather, Fusion of the two aspirated stops must have happened. Those who maintain that Bartholomae's law is a case of delinking and reassociation of [asp] are at a loss to explain what happens to the first aspiration feature;[9] the only possible explanation is Fusion, which is tantamount to claiming that an assimilatory process does in fact take place. Note that the conclusion that Fusion (and in fact, gemination of the Laryngeal node) occurs must be accompanied by Lombardi's suggestion that the aspiration is realized on the second segment of the cluster. In this case, then, Bartholomae's law, implemented as Fusion, prevents application of Grassmann's law (throwback). Thus, the interaction of these two processes provides strong evidence that it is Fusion/assimilation, and not delinking, that occurs in the case of an aspiration stop suffixed with a following coronal.

The story is still not so simple, however. Forms like *bhudbhis*, with an underlyingly aspirated onset in the suffix, show evidence of throwback! Must the entire account above be discarded, then? Lombardi, following Borowsky and Mester (1983), suggests that /-bhis/ has a word boundary before it. If this is the case, then sensitivity of the Laryngeal constraint to the word boundary might capture what is going on: deaspiration of the final consonant in /budh/ occurs on the word cycle, causing throwback. Subsequently, the affix is added, without any occurrence of progressive assimilation.[10] The account remains straightforward enough if we can find independent evidence for why /-bhis/ has a word-boundary but /-dhi/ doesn't.[11].

2.3.2 Grassmann's Law: The Lack of Throwback for Voiceless Aspirates

Lombardi (1991) and Kim (2000) both note that aspiration throwback only occurs for voiced aspirates. In other words, aspiration is never "thrown back" to a *voiceless* stop. If throwback is a simple case of delinking and reassociation of the Laryngeal node, then it shouldn't matter

[9] Kim (2000) admits in a footnote that her analysis of Bartholomae's law as complete delinking is insufficient in explaining [dugdhi].

[10] Note that an account of Bartholomae's Law as transfer, rather than assimilation, is still compatible with this word-cycle effects.

[11] Whitney, following Pānini, treats such suffixes as instances of *sarvanāmasthāna*, a highly technical term for suffixes that block word-cycle processes.

if the onset consonant is voiced or not. On the other hand, if one adopts `[murmur]` as a privative feature, then throwback can be seen as a process only operating on that feature, and not on `[asp]` at all; a `[murmur]` feature simply cannot associate with a voiceless consonant. However, if one remains committed to the view that only `[asp]` and `[gl]` exist, one can turn to distributional evidence from Sanskrit. Whitney (1889) has some arguments that in Sanskrit, the *surds* (voiceless aspirates) simply do not occur root-initially with aspirated word-final consonants, so that the case of throwback to voiceless stops never arises.[12]

2.3.3 Reduplication: Loss of Aspiration

When an aspirated consonant is reduplicated, the reduplicate is not aspirated: b^{h}id reduplicates as bib^{h}id. Lombardi cites Mester (1986), who argues that reduplication is a case of *Tier Conflation*, in which two skeletal remnants are adjoined. Such a process would not occur with suffixation; but in reduplication, the resulting doubly-linked aspiration is prohibited due to root-level OCP effects. This OCP effect would rule out any long-distance linking of `[asp]`. Perhaps vowels are also opaque to association. Lombardi assumes that vowels cannot bear Laryngeal features; association of aspiration across the vowel, in *[b^{h}i^{h}] would violate a Line-Crossing Constraint. However, see Golston and Kehrein (1998) for a compelling argument that vowels do bear Laryngeal features; they claim that the contrast between pre- and postaspirated and pre- and postglottalized sounds can be best explained in terms of aspirated and glottalized nuclei:

(20)	Glottalized consonants		Creaky Vowels	
	j̰a^{4}	'rainbow'	ja̰^{4}	'I carry'
	Aspirated consonants		Breathy Vowels	
	k̤a^{34}	'stubble'	ka̤^{3}	'bad smelling'

Here, the [x̰] diacritic indicates [c.g.], while the [x̤] indicates [s.g.]. Raised digits mark four distinctive Mazatec tones. Golston & Kehrein campaign for the above representation based on its ability eliminate the need for distinctive ordering of segments within onsets. If vowels can in fact bear `[asp]`, then their opacity to long-distance linking would be language-particular in the case of Sanskrit.

2.4 Final Exceptionality

Tojolabal, a Mayan language described in Lombardi (1991), citing Furbee-Losee 1976, has *final exceptionality* for glottalization: glottalized stops licensed in onsets preceding sonorants/vowels, as described by (15), are not licensed in word-internal codas, but *are* licensed in word-final

[12] Of course, there are a few exceptions, i.e., cases in which voiceless aspirates do precede a voiced aspirate stop and throwback does not occur; such cases would have to be relegated to "the exigencies of historical change".

consonants

(21)

potot'	'class of plant'
c'okop'	'thread'
ʔak'	'reed'
soc'	'owl'

Similarly, in Gujarati, the Laryngeal Constraint holds for `[asp]`; aspirated stops cannot occur at the end of word-internal syllables (a), but they can occur word-finally (b):

(22)

a.	/ləkhto/	→ ləkto	'writing'
	/ləkhnar/	→ ləknar	'writer'
b.	/wag^h/	'tiger'	
	/dud^h/	'milk'	
	/lak^h/	'a lac'	

Thus, in some languages, the Laryngeal Constraint is violable, in a manner parallel to that of devoicing in Yiddish, in which devoicing occurs at word-internal codas, but is licensed in the final syllable, e.g. *schmut.zig*. Under the fairly standard assumption that `[voice]` is also under the Laryngeal node, the final exceptionalities of Yiddish voicing, Gujarati aspiration, and Tojolobal glottalization are all birds of the same feather.

3 Is the Syllable involved in Neutralization?

The previous section examined the role of syllabic configuration as a licenser for Laryngeal features. In this section, we discuss research that may indicate that syllabic constituency is sometimes irrelevant and can be better described by simple linear constraints. Additionally, we consider evidence that while syllabification can be highly variable in a particular language, nonetheless Laryngeal neutralization may remain consistent.

3.1 Linear Constraints in Klamath

Contrary to Lombardi (1991), Blevins (1993) disagrees that syllable structure plays a role at all in certain cases.

In Klamath, deglottalization of sonorants is a linear constraint, independent of syllable constituency. Observe below that /m'/ and /l'/ deglottalize before obstruents:

(23)

/wt'am'/	'make a lid'
[wt'am'.sl'iiya]	'gets a lid for it'
[wt'am.bli]	'put a lid back on'
[wt'am's']	'lid,top'
go.ʔoo.l'as	'tadpole'
go.ʔoo.l.k'a	'little tadpole'

The licensing of R' remain the same in (23) whether the glottalized sonorant is tautosyllabic or not with a following continuant. Consequently, immediate problems arise for a purely syllable-based account of Laryngeal licensing, at least for non-obstruents. Thus, Blevins argues that in many cases, introducing syllable structure to account for neutralization needlessly mispredicts a linear process.

3.2 Syllabic Variation, Consistent Neutralization

Steriade (1997:25) claims that "any observable connection between being a coda and being laryngeally neutralized represents an accidental by-product of facts unrelated to syllable structure." The basic insight is that syllabification and cluster assignment show extensive variation (due to dialect, period, and literary style) throughout the history of Sanskrit, but that the patterns of laryngeal neutralization never change. One telling paradigm comes from the reduplicative *intensive prefix*, which induces variable vowel length; before a single root-initial C, the vowel is long, while before a cluster, the vowel is short:

(24)

Long vowel		Short Vowel	
gan-**iː**-gam	'go'	gan-**i-g.**m-atam	'go'
mar-**iː**-mrɨj-	'wipe'	kan-**i-k.**rand	'cry out'
b^{h}ar-**iː**-b^{h}rɨ-	'bear'	b^{h}ar-**i-b^{h}.**ra-ti	'bear'
tav-**iː**-tuat-	'be strong'	dav-**i-d.**yut-	'shine'

On the basis of (24), Steriade concludes for the intensive prefix, the pre-stem syllables must be heavy. This heavy syllable is achieved by long vowels in the cases shown on the left, and by heterosyllabification on the right. Thus, with a complex onset in the root, [b^{h}a.rib^{h}.ra.ti] results, which clearly shows an aspirated stop in a coda. Thus, there are cases in which VC.CV syllable division results, yet laryngeal neutralization is not induced in the coda.

Throwing up one's hands at the prospect of a suprasegmental account, however, by refusing to seek a prosodic account of Laryngeal neutralization would seem to undermine the explanatory spirit of phonology. However, Steriade, in her (1997) cue-based framework, argues that aspiration has the perceptual effect of prolonging Voice Onset Time. Subsequently, aspiration neutralization sites are those in which VOT values cannot be observed and compared; namely, before obstruents, and word-finally. In other words, aspiration contrasts cannot be *perceived* without certain onset cues, which function as licensers of contrast; in the absence of such cues, the need for a contrastive feature (aspiration) disappears.

4 Optimality Theoretic Treatments of Sanskrit

We turn our attention to explanatory accounts of Laryngeal neutralization in the extended Optimality Theory framework of Prince and Smolensky (1993), and discuss particular conceptual and empirical advantages and disadvantages as they arise.

4.1 Lombardi: Alignment Constraints

4.1.1 Align Constraints and Resulting Typologies

Lombardi (1995), pursuing an OT framework, suggests that the relevant constraint to describe the tendency for [asp] to appear in onsets and not in codas might be an Alignment constraint, that aligns the left edge of a natural class of consonants with the left edge of a syllable. In particular, Lombardi posits the following constraint:[13]

(26) ALIGN-LEFT(LARYNGEAL, SYLLABLE)

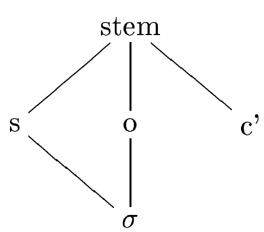
Although not explicitly stated, the obvious assumption here is that Laryngeal features are floating, and can be associated with any segment in the output. Hence, they are aligned with the leftmost segment in the syllable (the onset), without reference to any violation of the faithfulness constraint IDENT(F).

While ALIGN-LEFT and CRISPNESS characterize the constraints needed to prohibit Laryngeal Nodes in codas, recall the case of Final Exceptionality, as discussed in section 2.4, which requires further analysis. Lombardi proposes a familiar solution for those who have seen OT accounts of extrametricality with stress assignment, namely the presence of an ALIGN-RIGHT constraint, in addition to ALIGN-LEFT:

(27) ALIGN-RIGHT(stem, σ)

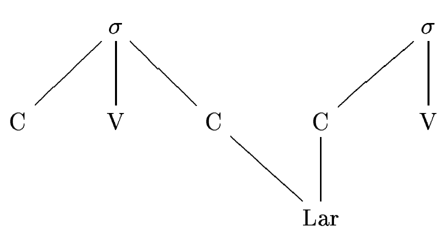
The essence of (27) is that a stem must end at the right edge of a syllable. Hence, (27) is crucially violated in cases like (28), /soc'/ ('owl', from Tojolobal), as shown:

(28)



[13] In addition, Lombardi adds CRISPNESS to (26), requiring that edges align precisely, so that a doubly-linked Laryngeal node is subject to constraints; hence, the representation below, in (25) constitutes a violation to CRISPNESS:

(25)



The doubly-linked Laryngeal node is aligned with *both* the left edge of a syllable (satisfying ALIGN-LEFT), but, *also* with the right edge of the preceding syllable. As a representation of a word-medially C.C cluster, (25) would allow Laryngeals in Codas, which (26) is trying to rule out. Thus ALIGN-LEFT alone is not sufficient to prohibit Laryngeals in Codas; CRISPNESS is needed as well.

Final Exceptionality arises in cases of a word-final Laryngeal nodes, as in (28). As shown, Final Exceptionality arises in cases in which the right edge of the stem (a segment with a Laryngeal node) must be aligned with the right edge of a syllable (the coda).

In addition to the alignment constraints, an OT Faithfulness constraint like PARSE(LAR) is needed; with its inclusion, a typology of Laryngeal neutralization thus derived. Languages that do not exhibit Laryngeal neutralization have PARSE(LAR) ranked higher than the above alignment constraints. When ALIGN-LEFT is ranked higher than PARSE(LAR), Laryngeal Neutralization in the Coda results. When ALIGN-LEFT dominates ALIGN-RIGHT, no Final Exceptionality results, but when ALIGN-RIGHT dominates ALIGN-LEFT, then Final Exceptionality results, and Laryngeal nodes are licensed in the word-final Coda. However, the Alignment constraints make reference only to the Laryngeal node, and thus still encounter a problem in cases such as Tol and Hupa, in which aspiration is neutralized, but glottalization is not. One can envision a set of further constraints to deal with the problem, such as ALIGN-LEFT([ASP],σ) and so forth.

4.1.2 Theoretical Remarks on Alignment

Lombardi points out a few advantages for the reformulation of Laryngeal Constraints in terms of OT Alignment as opposed to earlier proposals in which the crucial configuration depended on tautosyllabicity with a sonorant. In the delinking account discussed in Lombardi (1991), the rule would depended on syllable structure being present in the underlying form, a thorn in the side of phonological theory. However, since OT constraints are active on *surface* structure, where syllabification has already occurred, the issue of syllable structure in the UR does not arise.

Lombardi points out that her earlier proposal also had the unsatisfying reference to the pre-sonorant environment (where both vowels and sonorant consonants are `[+son]`) as a configuration to license laryngeal nodes. In a syllable-based discussion of licensing, it seems preferable that vowels (syllable nuclei) and sonorant consonants should not form a relevant natural class. In fact, Lombardi notes that sonority sequencing principles will require that when there is a complex onset consisting of an obstruent and a sonorant, these will be ordered in terms of rising sonority anyway, and a laryngeal licensing rule need not redundantly state this fact.

4.2 Kim: Interaction of Ident(F) and Max(F)

Kim rekindles the raging debate over the lack of aspiration throwback to voiceless aspirates in Sanskrit. When the root-initial consonant is *voiceless*, the aspiration on the coda simply deletes: /pat^{h}/ $\rightarrow$ [pat], not *[p^{h}at]. In addition to the lack of throwback for voiceless aspirates, Kim cites the lack of aspiration transfer (assimilation) for voiceless stops, e.g. /pat^{h} + ta $\rightarrow$ [pat.ta], not *[pat.t^{h}a]. On the basis of these different processes for voiced and unvoiced stops, Kim argues that the glottal feature of voiced stops is `[murmur]`, which is phonologically distinct from aspiration. Subsequently, Kim's suggestion is that the different behavior of [murmur]ed stops and aspirated stops follow from different relative rankings of the faithfulness constraints MAX(F) and IDENT(F). With the division of glottal features into `[asp]` and `[murmur]`, then, OT constraints that operate on distinct features can capture the fact that murmured stops undergo throwback and transfer from codas, while the aspirated stops simply delete.

4.2.1 Local Transfer of Murmur

Kim argues against Lombardi's representation of geminate murmurs, in which the murmur is doubly linked to both obstruents but phonetically realized on the onset of the following syllable; she suggests that a wholesale *transfer* of the feature occurs, always to another voiced segment. Local transfer (e.g., to a following suffix) is preferred, but cannot occur when there is no following suffix (i.e., word-final), or when the following consonant is a fricative (which cannot accept murmur features)[14]. In addition, local transfer to the suffix is prevented when the suffix begins with a murmur.[15] However, murmur transfer to the following consonant can occur when the suffix begins with an *aspiration*. Thus, in Sanskrit, /rund^h + t^{h}as/ → [rund.d^{h}as] is possible. The question arises why preserving murmur is more important than preserving aspiration, which disappears in this case; one could posit a higher-ranked MAX constraint, of course.

In addition, such murmur transfer does not search for a target in a gradiential fashion; in other words, if the following consonant is a fricative, the murmur does not "keep searching" for the next possible voiced stop with which it can associate. For example, in /budh/ + /syati/, the floating murmur does not go way downstream to the first available obstruent to form *[budsyadhi]. When murmur cannot locally transfer, and due to MAX, the feature cannot be stray-erased, then throwback occurs. In this light, then, transfer and throwback are part of the same process of satisfying MAX(MURMUR).

4.2.2 Feature Transfer versus Feature Deletion

Based on OT faithfulness constraints, Kim derives the following repair strategies for features that cannot remain where they are in the input:[16]

(29) A feature transfers locally or undergoes throwback when MAX(F) dominates IDENT(F).

[14] There is no voiced fricative /z/ in Sanskrit. Perhaps if there were, it could accept [murmur], which is compatible with [voice]. Following Vaux (1998), we assume that fricatives have an underlying [s.g.] feature; under Kim's bifurcation, /s/ would bear [asp], while /z/ would bear [murmur], and the incompatibility of [murmur] and /s/ would be predicted.

[15] In autosegmental terms, if the following obstruent already has a `[murmur]` feature F_1 associated with it, it cannot act as host to another floating murmur feature F_2. If the Stray Erasure Convention were to eradicate F_2, the highly ranked MAX(MURMUR) would be violated. Note, however, that Kim's account, which crucially depends on transfer, cannot account for the apparent Fusion of features in /dugh + dhis/ → [dughdis]

[16] Kim does not devote much space to any OT constraints for the more fundamental problem of *why* murmur cannot remain in the coda.

(30) A feature deletes when IDENT(F) dominates MAX(F).

Motivation for the repair strategies of (29) and (30) are illustrated in the following table:

(31)

	Feature Deletion	Feature Transfer
Input	X(αF).Y	X(αF).Y
Output	X.Y	X.Y(αF)
Violations	1 MAX(F), 1 IDENT(F)	0 MAX(F), 2 IDENT(F)

As (31) depicts, transfer is better for the sake of MAX(F), while deletion is better for the sake of IDENT(F). On this model of different repair strategies as the result of differing constraint satisfaction, the deletion of aspiration, contrasted with the transfer/throwback of murmur must be the result of different relative rankings of their respective constraints in Sanskrit:

(32) MAX(MURMUR) $\gg$ IDENT(MURMUR)
IDENT(S.G.) $\gg$ MAX(S.G.)

4.2.3 Alignment Constraints: Extension of the Morphological Domain

While throwback exhibits a case of root-internal transfer of `[murmur]`, the transfer of murmur to the onset of a following suffix is clearly not root-internal. Kim claims that the domain of a morphological category (e.g. the root) can differ from the input to the output. Thus, murmur transfer to a suffix is the result of *extension of the domain* of the root. To make such domain extension possible, Kim postulates a few new OT constraints. First among these is I-ANCHOR-CAT(ROOT, MURMUR), which has the effect that if a feature is in the root in the input, then the segment to which it belongs in the output is also part of the root. Thus, /lab$^{\mathrm{h}}$+da/ $\rightarrow$ [labd$^{\mathrm{h}}$+a] satisfies I-ANCHOR-CAT(ROOT, MURMUR); the aspiration is in the root in the input, and thus the /d$^{\mathrm{h}}$/ in the output becomes part of the root. Essentially, I-ANCHOR-CAT is a constraint against shrinking the root domain, which does not occur. However, the form [labd$^{\mathrm{h}}$+a] violates O-ANCHOR-CAT(ROOT, MURMUR), a second constraint that prohibits extension of the root domain. Thus, if I-ANCHOR-CAT(ROOT, MURMUR) dominates O-ANCHOR-CAT(ROOT, MURMUR), the domain of the root in the output depends on the position to which the feature from the root is transferred. With the reverse ranking, O-ANCHOR-CAT(ROOT, MURMUR) >> I-ANCHOR-CAT(ROOT, MURMUR), no root extension is allowed.

Similar category-based anchoring constraints exist for the suffix: I-ANCHOR-SUFFIX(ROOT, MURMUR) and O-ANCHOR-SUFFIX(ROOT, MURMUR), which penalize reduction and extension of the suffix domain. In cases such as [labd$^{\mathrm{h}}$a], in which the root is extended to the initial segment of the suffix, the right edge of the root and the left edge of the suffix are aligned,[17] in concordance with the last relevant constraint: ALIGN(SUFFIX,L,ROOT,R). However, in non-local transfer, the left edge of the suffix and the right edge of the root are would not be aligned. Thus, the local transfer of murmur in Sanskrit is derivable given the following ranking:

(33) ALIGN(SFX,L,RT,R), I-ANCHOR-RT(F), I-ANCHOR-SFX(F) $\gg$ O-ANCHOR-RT(F), O-ANCHOR-SFX(F)

[17] Note that Kim's analysis thus allows a segment to be ambi-morphemic.

Having derived that local transfer of murmur is possible given root extension, the question remains, why is progressive transfer preferred to throwback? In other words, these five constraints permit local transfer to the suffix, but if the murmur remains in the root anyway, as it does in throwback, then none of these concerns arise. Shouldn't throwback guarantee satisfaction of all of these anchoring constraints, and thus derive the winning output candidate every time? To this end, Kim suggests that Sanskrit has a highly-ranked constraint of the form ALIGN-RIGHT(MURMUR),[18] which drives the preferability of rightwards transfer over leftwards transfer, despite the morphological complications.

Kim's separation of the processes of deletion for aspiration and transfer/throwback for murmur are quite well-motivated, and avoid the hand-waving of Lombardi (1991), who attributes the lack of transfer/throwback in voiceless aspirates to a coincidental lack of the triggering environments in Sanskrit; if pressed hard enough, Lombardi's proposal *would* predict throwback to the voiceless aspirate in these cases. Thus, Kim achieves a cleaner explanation of the difference in behavior of voiced and voiceless aspirates through different ranking of faithfulness constraints.

However, while Kim's analysis has the initial appeal of unifying throwback and progressive transfer as one process, such a move has its disadvantages. Lombardi has made convincing arguments for the status of Bartholomae's rule as one of assimilation and gemination of a Laryngeal node; in order to characterize the suffix-initial obstruent's acquisition of [murmur] as a case of transfer, Kim has to introduce an analysis of feature transfer as extending a morphological category. Note that the initial segment in the suffix is not "part of the root" in any discernible way (say, morphosemantically). Moreover, in cases of feature transfer across word boundaries, constraints like those above would allow the extension of one word's morphological category to a following word;[19] it is not even clear what this would mean. It seems that there is no independent reason, besides attempting to constrain the locality of left-to-right feature transfer, to suggest that every time a feature reassociates, the word changes its morphological boundaries correspondingly; similarly, there is no independent reason to posit the ambimorphemic/schizophrenic status of suffixal segments that pick up a Laryngeal feature.

5 An OT Analysis of Icelandic Preaspiration and Devoicing

The decision to adopt a theory of morphological domain extension rather than a geminate explanation for the post-aspiration facts of geminates in Sanskrit echoes a similar debate among analyses of Icelandic preaspiration. The reader will recall that in section 2.3, we mentioned the claim of Lombardi (1991) that the CC^h aspiration of an underlying C^hC^h pattern is a result of phonetic realization only, predicting from implementation constraints that no language would adopt a C^hC or C^hC^h realization of these forms. On such a view, Kim's resort to morphological

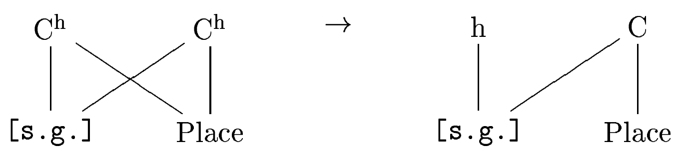
[18]The attentive reader will notice that this is the exact opposite of the ALIGN-LEFT(LAR) of Lombardi (1995).

[19]Of course, one could introduce even more finely-tuned anchoring constraints distinguishing word-internal morpheme boundaries from across-word boundaries, and left-right alignment constraints but these would result in somewhat of a Pyrrhic victory.

domain extension to explain Sanskrit transfer becomes unnecessary, although it retains the advantage of unifying throwback and transfer.

However, Lombardi's view loses luster when faced with the Icelandic preaspiration phenomenon. Recall from the data given in (3) that in Icelandic the $\mathrm{C^hC^h}$ pattern is realized consistently as hCC! Although Lombardi certainly didn't predict *against* this, the presence of multiple surface realizations for underlying $\mathrm{C^hC^h}$ shows that simple resort to phonetic realization doesn't answer the underlying question: what factor underlies the choice of a particular realization, whether $\mathrm{CC^h}$ or hCC or the unattested $\mathrm{C^hC}$ or $\mathrm{C^hC^h}$?

The two recent attempts at providing an OT analysis of Icelandic preaspiration both address this question. Ringen (1999) uses a multiply linked representation inherited from Iverson and Salmons (1995) and shown in (34). In Ringen's analysis, $\mathrm{C^hC^h}$ converts to hC through a simple debuccalization[20] of the leading segment, driven by a prohibition on moraic aspirated stops.

(34)


Keer (2000) instead represents the aspiration as its own segment—i.e. ChCh rather than (the superscripted, yet subsegmental) $\mathrm{C^hC^h}$—and regards preaspiration as a selective violation of linearity constraints driven by the marked status of Ch "clusters."[21] In his view, rather than preaspiration being triggered by certain environments, the reordering associated with preaspiration is the *default*, and is *blocked* word-initially and after long vowels.

Both authors see their analyses as supporting one-root theories of geminates. However, the analysis we will present here does not impose any requirements on geminate representation (other than that geminates are underlyingly moraic) and does not require certain representational departures in explaining deaspiration. Icelandic does not have any consonant length difference on the surface, so it can be argued that consonant length cannot constitute a source of evidence either way for arguments over the number of geminate roots.

We present our analysis in the next sections, and then discuss comparisons with the analyses of Ringen in section 5.3.1 and Keer in section 5.3.2.

5.1 Icelandic Vowel Lengthening and Stress

A comparison of the Icelandic forms [kʰaːkʰa] (from *kaka*, 'cake') and [ehpli] (from *epli*, 'apple') has led many researchers to conclude that the preaspiration phenomenon is in some way related

[20] Delinking of the place node, producing an aspirate. Also noted in some Spanish dialects, where final /s/ is debuccalized to /h/.

[21] Keer is able to do this in part because he has inherited Thráinsson's (1978) misunderstanding about the underlying representation of certain forms. For example, he regards the Icelandic neuter singular adjective suffix as /-t/ rather than /-tʰ/, which allows a reordering of /tht/ to /htt/ without violating Max.

to vowel lengthening, which in turn is related to Icelandic stress. We will see shortly that this is a mistake—a more subtle syllabic feature is actually at work—but we begin our OT analysis with the constraints that derive Icelandic syllable and stress structure.[22]

Stress in Icelandic is always on the initial syllable,[23] Stressed syllables are always heavy (bimoraic), and of the form CVV, CVC, or CVCC – except word finally, where CVVC appears. It seems then that vowel lengthening occurs where necessary to maintain weight on stressed syllables. The word-final consonant is extrametrical, therefore lengthening is necessary in open syllables, and in monosyllabic words that do not end in a cluster. Icelandic does have word-final geminates (e.g., [visː] 'certain'), and these exhibit the pattern of other consonant clusters: lengthening does not occur.

It remains uncertain to the present authors the extent to which extent vowel length is underlying in Icelandic. Kager (1999) indicates that is a feature of the underlying representation, but it is our view that to attempt to explain the length of stressed syllables—which is completely regular and without exception—by resorting to information in the Lexicon information (as Ringen does in her analysis) is a somewhat of a mistake. Both Kager and Keer show that under their constraint systems, vowel length in stressed syllables will surface correctly *regardless* of the underlying representation, which Lexicon Optimization[24], as stated by Itô and Mester (1995), will guarantee in this case. We will follow this approach and begin by presenting Kager's constraints for vowel length, given stress assignment. We present a concise summary here, and refer the interested reader to (Kager 1999:265-271) for additional detail.

5.1.1 Kager: Prosodic Constraints

Kager uses the following five constraints to explain the behavior of Icelandic vowel lengthening:

(35) STRESS-TO-WEIGHT [STOW] (Kager 1999:268)

If stressed, then heavy.

[22] The correctly formulated stress constraints will properly position moras in the output; as we shall see, moraic constraints are crucial to an understanding of postaspiration. The analysis of Ringen suffers from a misunderstanding of the amoraic requirement on final consonants in monosyllabic words.

[23] Well, not *always*, though this is stated in footnote 10 of Ringen (1999) who is not a native speaker. A reference on the Internet (`http://astro.temple.edu/~feeley/icetrans.html`) points out that two exceptions exist:

1. Words that have the negative prefix *ó-* 'un-' as in *óhreinindi* 'unwilling.'
2. Words that have the prefix *all-* 'rather, very' as in *allfeginn* (no gloss given).

In these cases the accent either falls equally on the first two syllables (no comment given about vowel lengthening in this case) or on the second syllable (first syllable of the root). Despite such exceptions, all of the examples in Thráinsson (1978), Ringen (1999), and Keer (2000), as well as all of the data in the current paper, are accented word-initially.

[24] *Lexicon Optimization*: Of several potential inputs whose outputs all converge on the same phonetic form, choose as the real input the one whose output is the most harmonic.

(36) *FINAL-C-μ [*FINμC] (Kager 1999:268)

The final consonant is weightless.

(37) *3μ (Kager 1999:268)

No trimoraic syllables.

(38) WEIGHT-BY-POSITION [WBYP] (Kager 1999:269)

Coda consonants are moraic.

(39) WT-IDENT-IO [ID(μ)] (Kager 1999:269)

If $\alpha \in$ Domain(f),
if α is monomoraic, then $f(\alpha)$ is monomoraic. ('no lengthening')
if α is bimoraic, then $f(\alpha)$ is bimoraic. ('no shortening')

These are all fairly standard constraints that are well-attested elsewhere; Kager himself provides several alternative references for each. We will consistently use the abbreviations shown in the brackets above in our tableaus to save space.

Given these constraints, Kager determines the ranking shown in (40).

(40) STRESS-TO-WEIGHT, *FINAL-C-μ, *3μ $\gg$ WEIGHT-BY-POSITION $\gg$ WT-IDENT-IO

We provide two tableaus to illustrate: /sko/ → [skoː] 'shoe' and /has/ → [haːs] 'hoarse'. Both examples are taken from Kager.

/sko/	STOW	*FINμC	*3μ	WBYP	ID(μ)[25]
►a. ˈskoː ($\mu\mu$)					*
b. ˈsko (μ)	*!				

/has/	STOW	*FINμC	*3μ	WBYP	ID(μ)[26]
►a. ˈhaːs ($\mu\mu$)				*	*
b. ˈhas ($\mu\mu$)		*!			
c. ˈhas (μ)	*!			*	

From the evidence we have, STRESS-TO-WEIGHT and *3μ are inviolate in Icelandic. From this point forth, they will be omitted from the tableaus. Similarly, WT-IDENT-IO is always lowest ranked; its ranking is never crucial, and will thus also be omitted from the following tableaus.

[25] Note that this violation is immaterial to the result, so that an input of /skoː/ (with underlying vowel weight) would result in the same output. Lexicon optimization would then posit that the /skoː/ form would be the UR, as it has fewest violations, but the same output should be produced regardless of the weight of the input.

[26] Note again that the input weight is immaterial to the result.

5.2 A New Set of Constraints for Preaspiration and Devoicing

The first observation to be made from the preaspiration data is an apparent dispreference for aspirated stops being moraic. Given Kager's stress constraints, this explains why one finds postaspiration word-finally in monosyllables like [fei:t^{h}] but preaspiration in /feit^{h}+t^{h}/ $\rightarrow$ [feiht] and /ep^{h}li/ $\rightarrow$ [ehp.li], where the geminate status of the final consonant and syllabic constraint, respectively, ensure that the aspirated stop must be moraic (we return to the geminate case below). We thus propose the following crucial markedness constraint:

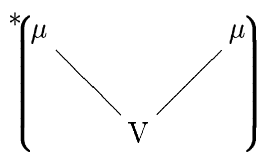
(41) *μ-ASPSTOP

Aspirated stops must not be moraic.

This constraint is perhaps easily justified by analogy: many languages exhibit markedness constraints that ban aspirated stops from the inventory (Spanish, for instance) or prohibiting them in certain positions (English; see Iverson and Salmons 1995). Similarly, some languages have constraints on moraic consonants; as discussed in Itô and Mester (1995), Japanese prohibits [p] in non-geminate positions.[27]

We also propose a low-ranked markedness constraint on long vowels, following Keer; though it will turn out that this constraint is low-ranked and never crucial.

(42) NO-LONG-V [*LV] (Prince and Smolensky 1993)



The standard constraints DEP(ROOT) and ONSET are also employed.

(43) DEP(ROOT)

Root nodes present in the output must have a correlate in the input.

(44) ONSET

Syllables must have an onset.

Aspiration is never deleted in the examples we have seen, prompting a MAX([S.G.] constraint.[28]

[27]It may be proposed that all markedness constraints are of a generalized form, and may be instantiated with specifications for position and feature (and possibly a small set of additional arguments). In this case, "moraic" would be the position argument and "aspirated stop" the feature argument.

[28]Alternately, one could propose a MAX(SUBSEG) constraint along the lines of Zoll (1996), and analyze the aspiration as a floating feature; in further research we may in fact pursue this line of inquiry.

(45) MAX([S.G.])

Spread glottis features present in the input must have a correlate in the output.

The above constraints will be enough for initial expository purposes. We present a first tableau, in which preaspiration does not occur, to illustrate the relevant rankings:

/feitʰ/	*μ-ASPSTP	STOW	MAX([S.G.])	DEP(RT)	*FINμC	*LV	WBYP
μμ ▶a. ˈfeiːtʰ						*	*
μμ b. ˈfeit			*!		*		
μ μ c. ˈfeitʰ	*!				*		
μ d. ˈfeitʰ		*!					*
μ μ e. ˈfeiht				*!			*

Crucial constraints: STOW, DEP(RT) ≫ *LV (d, e).

The crucial constraints are marked beneath the tableau. There are few surprises; only that DEP(ROOT) outranks *LONG-VOWEL, i.e., epenthesis never occurs simply to avoid a long vowel in the output.

Next, a we present a case in which preaspiration *does* occur:

/feitʰ+tʰ/	*μ-ASPSTP	MAX([S.G.])	DEP(RT)	ALIGNL[29]	*FINμC	*LV	WBYP
μμ a. ˈfeit		*!			*		
μ μ b. ˈfeitʰ	*!			**	*		
μμ c. ˈfeith			*	***!			*
μ μ ▶d. ˈfeiht			*	**			*

Crucial constraints: MAX[S.G] ≫ ALIGNL[30] (a), *μ-ASPSTOP ≫ DEP(ROOT)[31] (b).

We have introduced an additional constraint in this case, ALIGN-LEFT([S.G.], WD) (which we uniformly abbreviate as ALIGNL in our tableaus. This constraint causes preaspiration rather

[29] Note that in the evaluation of ALIGNL we are assuming that the monomoraic [ei] dipthong counts as a single `[s.g.]` attachment site.

[30] Assuming DEP(ROOT), ALIGNL $\geqq$ *FINAL-C-μ.

[31] Assuming DEP(ROOT) $\geqq$ *FINAL-C-μ.

than postaspiration to occur. This constraint will also be responsible for sonorant devoicing, to be discussed.

We see that MAX[S.G.] outranks ALIGN-LEFT([S.G.], WD), which rules out simply deleting a problematic right-hand aspiration. We also see that the constraint against moraic aspirated stops, *μ-ASPSTOP outranks DEP(ROOT), allowing epenthesis to resolve the markedness problem.

Consider two cases in which preaspiration and postaspiration occur word-medially. First, post-aspiration in an onset:

/k^{h}ak^{h}a/	MAX([S.G.])	DEP(RT)	ALIGNL	ONS	*FINμC	*LV	WBYP
▶a. ˈk^{h}aː.k^{h}a			**			*	
b. ˈk^{h}ak.a	*!			*			
c. ˈk^{h}ah.ka		*!	**				

Crucial constraints: MAX[S.G] $\gg$ ALIGNL[32] (b), DEP(ROOT) $\gg$ *LV (c).

The crucial rankings as remain as before. Next, consider pre-aspiration in a (moraic) coda:

/ep^{h}li/	*μ-ASPSTP	MAX([S.G.])	DEP(RT)	ALIGNL	ONS	*LV	WBYP
a. ˈep^h.li	*!			*	*		
b. ˈep.li		*!			*		
c. ˈeph.li			*	**!	*		*
▶d. ˈehp.li			*	*	*		*

Crucial constraints: *μ-ASPSTOP $\gg$ DEP(ROOT) (a),
MAX([S.G.]) $\gg$ DEP(ROOT), ALIGNL, WBYP (b).
(Note that the candidate [ˈeː.p^{h}li] is ruled out by inviolate onset cluster licensing constraints.)

Here we see that MAX([S.G.]) is very highly ranked. In fact, it is inviolate in the examples we are studying, as is *μ-ASPSTOP. As inviolable constraints, they will be omitted from subsequent tableaus.

The "true geminate" case illustrates that our analysis is not dependent on a particular one-root or two-root representation of geminates. We make reference to MAX(ROOT) in the tableau, but a high-ranked constraint preserving the moraicity of geminates would achieve the same results.

[32]Assuming ALIGNL $\geqq$ ONS.

/kʰapʰpʰɪ/	*μ-AspStp	Max(Root)†	Max([s.g.])†	AlignL	*LV	WbyP
a. ˈkʰapʰ.pʰɪ	*!			** ***		
b. ˈkʰaː.pʰɪ‡		*!		**	*	
c. ˈkʰap.pɪ			*!*			
d. ˈkʰaːpʰ.pʰɪ‡				** *!**	*	*
e. ˈkʰap.pʰɪ				***!		
f. ˈkʰap.hɪ				***!		
▶g. ˈkʰah.pɪ				**		

Crucial constraint: Max([s.g.]) ≫ AlignL (c).

To determine the ranking of Dep(Root), we study a case where epenthesis may be used to avoid a long vowel in the output and/or to prevent a violation of Onset:

/tʰala/	Dep(Rt)	AlignL	Ons	*FinμC	*LV	WbyP
▶a. ˈtʰaː.la					*	
b. ˈtʰal.a			*!			
c. ˈtʰaC.la	*!					

Crucial constraints: Ons ≫ *LV (b), Dep(Root) ≫ Ons (c).

We provide a further example of a case in which Dep(Root) militates against a marked long vowel:

/has/	Max([s.g.])	Dep(Rt)	AlignL[33]	Ons	*FinμC	*LV	WbyP
▶a. ˈhaːs			**			*	*
b. ˈhas			**		*!		
c. ˈhasp		*!	**				*

Crucial constraints: *FinμC ≫ *LV, WbyP (b), Dep(Root) ≫ *LV (c).

†Note that the two Max constraints may easily be combined into one.

‡These two cases may alternatively be ruled out by an Ident(μ) constraint requiring underlying geminates to possess a mora in the output. But as you can see, such a constraint is not strictly necessary.

We should mention that Kager uses Wt-Ident-IO in his text, but explains in footnote 5 that the behaviour of word-final geminates requires a highly ranked constraint preserving the moraic status of geminates. The tableau below for /visː/ (‘certain’) shows that in a two-root geminate theory, this rule could be replaced by Max(Root), with no loss of generality. In either case, the relevant constraint is inviolate.

/visː/	Max(Root)	Max([s.g.])	AlignL	*FinμC	*LV	WbyP
▶a. ˈvisː			** ***			*
b. ˈviːs	*!		**		*	
c. ˈviːsː			** ***		*!	*!*

Crucial constraints: Max(Root) ≫ AlignL (b).

Actually, Max(Root) and Max([s.g.]) may be merged into a single generic Max constraint here. In fact, this is true for all of our examples, which never show deletion.

The reader is reminded that Kager’s Ident-μ(G) constraint may be substituted for Max(Root), should one prefer a one-root geminate theory; we remain neutral on this issue.

Returning to the correct ranking of Dep(Root), it can be observed in the following tableau that this constraint is not violated in order to prevent violation of Onset:

/óð/	Dep(Rt)	AlignL	Ons	*FinμC	*LV	WbyP
▶a. ˈouːð			*		*	*
b. ˈouð			*	*!		
c. ˈhouːð	*!				*	*

Crucial constraints: *FinμC ≫ *LV, WbyP (b),
Dep(Root) ≫ Ons (c).

At this point, it becomes important consider constraints on spreading. Recall from the data in (6), repeated below as (46), it is clear that `[s.g.]` spreading cannot cross a vowel.

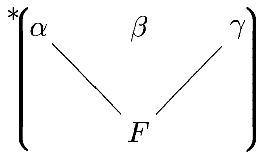
(46)

	written	surface form	gloss
a.	*úlpa*	[ul̥pa]	‘coat’
b.	*heimta*	[heim̥ta]	‘demand’
c.	*vanta*	[van̥ta]	‘lack’
d.	*vinka*	[viŋ̊ka]	‘wave’
e.	*sárt*	[saur̥t]	‘painful’ (neut. sg.)

[33]Recall that we counting fricatives as already having an underlying `[s.g.]` feature, following Vaux (1998).

The standard constraint to address this prohibition on features skipping intermediate anchors is NO-GAP:

(47) NO-GAP (Itô and Mester 1995)



A feature F may not be linked to α and γ without also being linked to β, where β is a possible anchor for F.

However, this requires that we adopt the representation of Ringen (1999) and Iverson and Salmons (1995) which both employ linked `[s.g.]` features (see (10) for Ringen's chosen representation). We prefer to remain impartial when it comes to such unorthodox representations, while acknowledging that *some* sort of limiting constraint is necessary. The exact nature of this constraint remains a bit mysterious, however. If we entertain the above formulation of NO-GAP and Ringen's representation, than we must assume that vowels cannot accept `[s.g.]` features, despite the evidence from Golston and Kehrein (1998) that they can.[34] Furthermore, from the available data, we cannot determine what the desired output of the following tableau should be:

/elsk^{h}a/	MAX([S.G.])	DEP(RT)	ALIGNL	ONS	*FINμC	*LV	WBYP
a. ˈel.sk^{h}a			***	*			
?b. ˈel.ska			**	*			
?c. ˈel̥.ska			*	*			

We propose a general constraint BLOCK, parameterized[35] on two features F_α and F_β, which allows us to express a variety of such opacity effects without resorting to NO-GAP:

(48) BLOCK(F_α, F_β)

Given strings S_1 and S_2 and a correspondence relation $\Re$ between them, for every α in S_1 with feature F_α and β in S_1 with feature F_β where both α and β are in the domain of $\Re$,

$$\alpha \text{ precedes } \beta \text{ iff every element in } \Re(\alpha) \text{ precedes every element in } \Re(\beta).$$

One violation is counted for every segment α for which this is not true.

The relevant constraint for Icelandic is BLOCK([S.G.], V), which is assumed to be never violated.

[34] Note also that footnote 24 of Thráinsson (1978) notes that in some dialects deaspiration also occurs following a long vowel, which *might* be profitably analyzed as phoenetically-indistinguishable transfer of `[s.g.]` to the last vocalic segment.

[35] In the terminology of Computer Science, BLOCK would be considered a "polymorphic" function.

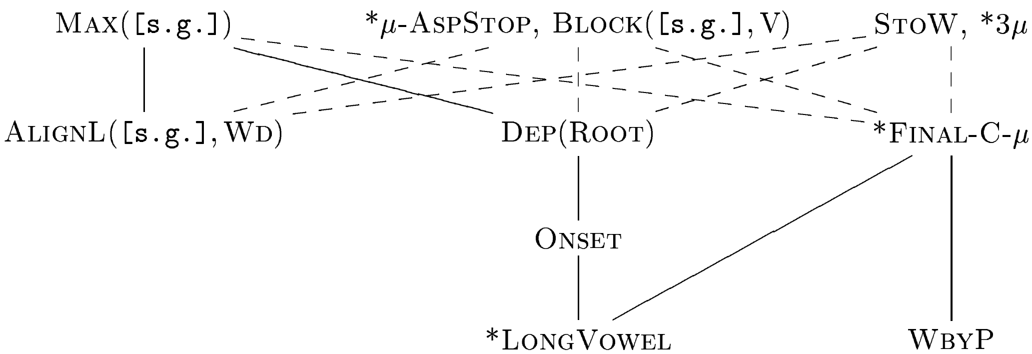


Figure 1: A complete ranking of constraints governing Icelandic preaspiration

Thus, we can obtain a complete ranking, as shown in figure 1. Dashed lines indicate implicit rankings necessary to ensure that the inviolate constraints remain undominated. Crucial rankings are indicated by a solid line.

We indulge in a final comment on the constraint LINEARITY. The conventional definition is given below.

(49) LINEARITY [LINEARA] (McCarthy and Prince 1995)

$S1$ reflects the precedence structure of $S2$, and vice versa.

$$\text{For } \alpha_i, \alpha_j \in \text{Dom}(f), \alpha_i < \alpha_j \text{ iff } f(\alpha_i) < f(\alpha_j)$$

This formulation, which we subsequently refer to as LINEARA,(inadvertently) penalizes feature sharing, because a shared feature does not strictly precede itself. We can formulate a new rule (LINEARB)[36] using a less strict notion of precedence, which is closer to what is needed to cover the facts of Icelandic.

(50) LINEARB

$S1$ reflects the precedence structure of $S2$, and vice versa.

$$\text{For } \alpha_i, \alpha_j \in \text{Dom}(f), \alpha_i \leq \alpha_j \text{ if } f(\alpha_i) < f(\alpha_j) \text{ and } f(\alpha_i) \leq f(\alpha_j) \text{ if } \alpha_i < \alpha_j$$

The following tableau for /epli/ illustrates the difference:

/ep[h]li/	LINEARB	DEP(RT)	ALIGNL	LINEARA
▶a. ˈehp.li ($\mu\mu$)		*	*	**
b. ˈel̥.pi ($\mu\mu$)	*!*		*	**

Crucial constraints: LINEARB ≫ DEP(ROOT) (b).

[36]The language puns are intentional.

Note that while LINEARA is violated by many assimilation processes in Icelandic, LINEARB is inviolate. Thus, it may be sensible to talk about LINEARB as a universally highly-ranked constraint, discrimination between "genuine" segment reordering and simple assimilation/feature sharing processes.[37, 38]

5.3 Comparison with Recent OT Analyses

We will now briefly compare our analysis with that of Ringen (1999) and Keer (2000).

5.3.1 Ringen: Feature Spreading and Moraic Identity

Ringen's analysis is heavily dependent on the representational notion that `[s.g.]` feature spreading may prevent the expression of the feature on all but the first linked feature, despite it being present on all of them. However, the geminate ChCh → CCh process present in many languages is generally explained by an expression of linked `[s.g.]` on the *last* linked feature. Relying on differing phoentic implementation to explain the difference in language process seems to put the cart before the horse. We've shown in our analysis that it is not necessary to assume any special implementation of `[s.g.]` to explain the Icelandic data, and that the use of NO-GAP to limit the spreading is not precise enough, given the uncertainty about the presence of glottal features on vowels.

Similarly, Ringen does not examine stress structure at all, and assumes implicitly that the long vowels in the output are all underlying. For this reason her analysis cannot explain why the final aspirate in /feit^h/ is retained.

5.3.2 Keer: Linearity Violations and Bisegmental Stops

Keer's analysis breaks down due to a fundamental misunderstanding of Icelandic syllabification. As confirmed by Höskuldur Thráinsson (p.c.), the word *epli* is syllabified as *ep.li*, not *e.pli* as Keer repeatedly writes. He also relies on SONSEQ to prohibit /ph/ onsets, which may be justified, but has little theoretical basis; most authors do not rank aspirates on the sonority scale at all.

Keer also proposes a very non-standard treatment of vowel lengthening, where VCV transforms to VC.CV; the standard analysis proposes that vowel lengthening happens in this case,

[37] See footnote 7 in Lamontagne and Rice (1995) for more discussion regarding the inadequacy of LINEARITY and several more candidates for its replacement.

[38] If the vowel devoicing described in footnote 34 is to occur, one might profitably consider rewriting our BLOCK constraint (48) with a similar nonstrict definition of precedence, in order to allow feature sharing with and/or transfer to the "blocking" feature F_β. But it is clear that "strict" blocking does exist, so both BLOCK-STRICT and BLOCK-NONSTRICT would be required in *CON*.

not gemination. Furthermore, as we have seen, the Icelandic data does not require this behavior. As we have noted before, Icelandic does not contrast consonant length on the surface, so arguments *pro* or *con* are very hard to prove.

Finally, as Thráinsson (1978) notes, pre- and post-aspiration are *not* inverses, as Keer assumes:

> ... I shall transcribe preaspiration as [h] in this paper.
>
> This way of indicating preaspiration in phonetic transcription is also meant to imply that preaspiration typically has a normal segment length in Icelandic, whereas postaspiration is generally much shorter.

We believe that the analysis presented in this paper explains more of the Icelandic data, with less recourse to unconventional phonology and constraints.

6 Conclusion

We have presented an overview of a range of theoretical treatments to Laryngeal Neutralization, with particular emphasis on Icelandic and Sanskrit. The Laryngeal Constraint of Lombardi (1991) affords a good deal of empirical coverage, with a few limitations on its generality, its application only to surface syllabification, and the admission of Final Exceptionality. However, there seems to be merit to the counterproposals that claim that the syllable is not universally involved in Laryngeal licensing. Within the framework of Optimality Theory, Sanskrit throwback and transfer can be well-described by Alignment constraints on aspirated features. On the other hand, the bifurcation of aspiration on voiceless stops from murmur on voiced stops amounts to a significant empirical generalization for Sanskrit, and once this move is made, Sanskrit murmur transfer can be explained in terms of Faithfulness constraints, with some provisions made for morphological locality. Finally, the OT treatment of Icelandic preaspiration highlights many interesting issues for geminates, phonetic realization, and the nature of the NO-GAP and LINEARITY constraints. In further research, in the spirit of phonological generality, we would like to attempt to present a unified treatment of Sanskrit and Icelandic.

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