Harmonic scales as faithfulness[*]

DARIN HOWE — *University of Calgary*
DOUGLAS PULLEYBLANK — *University of British Columbia*

ABSTRACT:

Optimality Theory predicts that harmonic scales (⟦α ≻ β⟧) can be encoded in grammar as markedness hierarchies (⟦*β ≫ *α⟧) or else as faithfulness hierarchies (⟦FAITHβ ≫ FAITHα⟧ or ⟦FAITHα ≫ FAITHβ⟧). Most research assumes that harmony is encoded as markedness (e.g., ⟦COR ≻ LAB⟧ ∴ ⟦*LAB ≫ *COR⟧), though many investigators have argued that some harmonic relations are better captured as faithfulness hierarchies which forestall deletion/insertion of less harmonic elements (e.g., ⟦COR ≻ LAB⟧ ∴ ⟦FAITHLAB ≫ FAITHCOR⟧). We demonstrate in this paper that at least two perceptually-motivated harmonic scales — one concerning vowel quality, the other concerning glottalisation on consonants— need to be grammatically encoded as faithfulness hierarchies which ensure that more harmonic elements which are also more perceptible are more faithfully adhered to (⟦α ≻ β⟧, where |α| > |β| ∴ ⟦FAITHα ≫ FAITHβ⟧).

1. INTRODUCTION

Across numerous linguistic dimensions, some feature set α (a segment or subsegment) may be better formed according to some set of criteria than a related feature set β. Such a situation of "relative harmony" fits the schema in (1), where the symbol "≻" means "more harmonic than".

(1) *Harmonic scale*: α ≻ β

The basic mechanism of Optimality Theory for distinguishing between grammars is the relative ranking of constraints (C_i, C_j,…C_n) (Prince and Smolensky 1993). Hence one grammar may rank C_i above C_j while a second grammar may adopt the opposite ranking.

(2) *Optimality theoretic grammars*
  a. *Language M*: $C_i \gg C_j$
  b. *Language N*: $C_j \gg C_i$

Prince and Smolensky propose that harmonic scales are immune to such reranking. While other constraints may be inserted between the members of a harmonic scale, the

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actual members of the scale have a fixed ranking with respect to each other —thereby encoding the "harmonic" nature of the relationship.

(3) *Harmonic ranking*:
  a. *Universal ranking*: $C_i \gg C_j$
  b. *Universally prohibited*: $*(C_j \gg C_i)$

If we adopt this basic characterisation of harmonic scales, constraint interaction and harmonic constraint interaction, we are left with an interesting question. Two basic types of constraints are distinguished in Optimality Theory (Kager 1999a:4, McCarthy 2002:13): (a) constraints that penalise structural complexity in the output ("markedness"), and (b) constraints that preserve lexically encoded properties ("faithfulness"). Interpreting harmonic scales in relation to these two constraint types, there are two (non-exclusive) possibilities for the encoding of a harmonic scale: (a) encoding as markedness (Prince and Smolensky 1993), and (b) encoding as faithfulness (Kiparsky 1994).

(4) *Possible grammatical encodings of "relative harmony"*: $\alpha \succ \beta$
  a. *Harmony-as-markedness*
    $*\beta \gg *\alpha$
  b. *Harmony-as-faithfulness*
    i. FAITH[β] $\gg$ FAITH[α]
    ii. FAITH[α] $\gg$ FAITH[β]

According to the first hypothesis (4a), instances of both α and β incur violations but violations of the more harmonic α are penalised less severely than violations of the less harmonic β. According to the second hypothesis (4b), there are again two (non-exclusive) possibilities: on the one hand, faithfulness to the less harmonic β may rank higher than than faithfulness to more harmonic α (4bi), such that instances of β will be less subject to grammatical change than instances of α. On the other hand, faithfulness to α may be higher-valued than faithfulness to β (4bi), so occurrences of α will exhibit greater stability than instances of β in input-output mappings. To evaluate these different interpretations one must examine specific instances of harmonic scales. In particular, we first need to ask: in what tangible respect is α "more harmonic than" β?

Consider the well-known harmonic scale ⟦CORONAL ≻ LABIAL⟧ (Prince and Smolensky 1993:180–1), which ostensibly mirrors articulatory complexity (ib.). The tongue's neuromusculature affords the tongue tip more flexibility, rapidity and sensitivity than the lips (Hudgins and Stetson 1937:92, Bowman 1971, Sussman et al. 1973, Hardcastle 1976:89, Perrier et al. 1996) such that, for instance, the briefest consonants are (apical) coronals while the most protracted are labials (Dobrovolsky 1996). Formalising this biomechanical disparity as markedness (4a) is largely effective for treating epenthesis: "The universal domination relation *PL/LAB ≫ *PL/COR entails that, *ceteris paribus*, epenthetic consonants are coronals" (Smolensky 1993:6). But markedness fails to predict typical yet "[a]pparently antiharmonic" (ib., p. 14) effects in assimilation/coalescence: "Why does /[COR][LAB]/ → <[COR]>[LAB] and not *[COR]<[LAB]>?" (ib.).

This "[o]pen problem" (ib.) is resolved by interpreting Place harmony through faithfulness as in (4bi): FAITH[LAB] $\gg$ FAITH[COR]. As demonstrated by Kiparsky (1994), Gnanadesikan (1995), Jun (1995), Pater (1997), Pulleyblank (1998), de Lacy (2002), Pater and Werle (to appear) among others, this ranking ensures not only that coronals are favoured in epenthesis, but also that labials are retained at the expense of coronals in assimilation/coalescence. In the latter respect, harmony-as-faithfulness (4bi) properly captures the biomechanics of ⟦COR $\succ$ LAB⟧: "'pure' coronals [i.e., apical/alveolar] are articulatorily simple along a number of dimensions and as such, give way to the various control, coupling, flexibility, and inertial requirements of more complex articulations [such as labials]" (Dobrovolsky 1996:6).

In this article, we discuss different cases where relative harmony depends on what we assume to be *perceptibility*, that is, where α is "more harmonic" because it is more audible ($|\alpha| > |\beta|$). In such cases we find that resulting patterns of distribution and alternation support the interpretation of harmony as faithfulness in (4bii). The evidence comes from comparing patterns of deletion with patterns of insertion and association. The table in (5) summarises relevant patterns:

(5) *Preferred targets for various processes*: $\alpha \succ \beta$

		Deletion	*Insertion*	*Association*
a.	*Harmony-as-markedness*			
	$*\beta \gg *\alpha$	β	α	α
b.	*Harmony-as-faithfulness* (4bii)[1]			
	MAX[α] $\gg$ MAX[β]	β		
	DEP[α] $\gg$ DEP[β]		β	
	DEPPATH[α] $\gg$ DEPPATH[β]			β

According to harmony-as-markedness (5a), a process of deletion will target the less perceptible β more readily than the more perceptible α because β incurs higher violation marks than α. That is, segments that are less perceptible should delete rather than segments that are more perceptible. The same prediction is made by harmony-as-faithfulness (5b) but for a different reason. Since faithfulness to the more perceptible α is more important than faithfulness to the less perceptible β, α will be preferentially retained and β more readily lost. The two approaches diverge when processes of insertion/association are considered. For harmony-as-markedness, since the more perceptible α incurs less damaging violation marks, it should be preferentially inserted and it should result preferentially from patterns of association. The picture is different for harmony-as-faithfulness: faithfulness to the more perceptible value α implies both pressure to retain the harmonic value (MAX[α])

[1] MAX[X] forbids the deletion of [X] (McCarthy and Prince 1995), DEP[X] forbids the insertion of [X] (ib.), and DEPPATH[X] forbids the creation of X through association (Archangeli and Pulleyblank 1994, Pulleyblank 1997, Zoll 1998).

and pressure not to insert it (DEP[α]) or create it by linking (DEPPATH[α]). In summary, harmony-as-markedness predicts that less perceptible segments should be targeted by deletion and more perceptible segments should be targeted by insertion and association. Harmony-as-faithfulness uniformly predicts that deviations from input representations should involve those segments that are lower on the harmonic scale, hence less perceptible segments should be targeted by deletion, insertion and association.

We discuss two types of phenomena that support harmony-as-faithfulness (4bii)/(5b), the first involving vowel quality and the second involving glottalisation on consonants.

2. HARMONY AS FAITHFULNESS: EVIDENCE FROM VOWELS

Establishing the appropriateness of either harmony-as-faithfulness or harmony-as-markedness depends on (i) establishing a harmonic scale, and (ii) establishing a pattern of deletion/insertion. We begin with patterns based on vowel quality. In this domain, harmony can plausibly be based on sonority, and processes of vowel deletion and epenthesis are well documented.

2.1. Harmony defined by sonority

It is widely accepted that vowels differ in their intrinsic sonority. In a series of experiments designed to probe the physical correlates of sonority, Parker (2002) found that the height-based scale in (6) is most robustly motivated, both acoustically and aerodynamically.

(6) *Relative sonority of vowels*

LOW > MID > HIGH
æ,a... e,o... i,u...

F_1, duration and intraoral air pressure each correlate especially strongly (in an inverse direction) with this three-way scale (p. 141, 236). Parker's findings were based on American English and Spanish but we assume them to be generalisable to other languages. For instance, Kent and Read (2002:119ff.) confirm the high (negative) correlation between vowel height and F_1 in Hebrew, Madrid Spanish, Japanese, Estonian, Swedish, Greek, Dutch, British English, Korean, and Hindi.

Our first task is to show that the vowel sonority scale (6) has phonological (not just phonetic) significance. To this end, consider the case of CV reduplication in Nakanai (Aru: Broselow and McCarthy 1983, Spaelti 1996). As illustrated in (7), the reduplicant shows a preference for higher sonority in that the second vowel of the base is copied instead of the first vowel just in case V_2 is more sonorous than V_1.[2]

[2] We only consider here cases where V_2 is more sonorous than V_1. Where V_1 is more sonorous, both vowels are copied, becoming a falling diphthong (e.g. pati > paipati 'floating'). Such cases continue to depend on the identification in the grammar of relative sonority distinctions.

(7) *Reduplication in Nakanai*: RED = C_1V_2 if $V_2 \rangle V_1$

$C_1V_1C_2V_2$	C_1V_2 - $C_1V_1C_2V_2$	
pita	pa – pita	'muddy'
beta	ba – beta	'wet'
biso	bo – biso	'members of the Biso subgroup'
sile	se – sile	'tearing'
tuga	ta – tuga	'depart/walk'
sio	so – sio	'carrying on ceremonial litter'
toa	ta – toa	'treading/kicking'

This reduplicative pattern, in which relatively more sonorous vowels are preferentially copied, is consistent with the following harmonic scale being active in phonology:

(8) *Harmonic scale for vowels*

LOW ≻ MID ≻ HIGH

"Relative harmony" in (8) can be grammatically encoded in either of two ways. One possibility is to express the universal preference for higher sonority syllable nuclei as a series of well-formedness conditions on representations, for example, by the HNUC constraint family of Prince and Smolensky (1993).

(9) *HNUC*

$|x| > |y| \Rightarrow Nuc/x \succ Nuc/y$

"If *x* is more sonorous than *y*, then *x* is a better syllable peak/head/nucleus than *y* is."

Expressed as well-formedness constraints on nuclei ("harmony as markedness"), the harmonic sonority scale can be encoded as a set of ranked markedness constraints as in (10) (Prince and Smolensky 1993, Alderete et al. 1999, Kager 1999a, etc.).

(10) *Harmony as markedness*

*HIGH ≫ *MID ≫ *LOW

Alternatively, the harmonic sonority scale can be directly woven into the fabric of the faithfulness constraints:

(11) *Harmony as faithfulness*

FAITHLOW ≫ FAITHMID ≫ FAITHHIGH

If the harmonic scale for vowels is formalised as a markedness hierarchy (10), we can understand Nakanai reduplication as follows: MAX_{BR} —the faithfulness constraint responsible for maximising the copy of the base in the reduplicant (McCarthy and Prince 1995)— is equally violated whether the reduplicant vowel corresponds to the first or to the second vowel of the base. The choice between the two vowels is therefore determined by the markedness hierarchy, which evidently ranks higher in Nakanai grammar than CONTIG

—the faithfulness constraint against noncontiguous mapping (ibid.). This interaction of constraints results in an “emergence of the less marked” (cf. Alderete et al. 1999), as illustrated in (12) for /RED-beta/ → [babeta] ‘wet’ and /RED-biso/ → [bobiso] ‘members of the Biso group’.

(12) *Harmony-as-markedness in Nakanai reduplication*

			MAX$_{BR}$	*HI	*MID	*LO	CONTIG
/RED-beta/	a.	be-beta	**		**!	*	
	b.	☞ ba-beta	**		*	**	**
/RED-biso/	c.	bi-biso	**	**!	*		
	d.	☞ bo-biso	**	*	**		**

Nakanai reduplication is also readily interpreted if the harmonic scale for vowels is encoded as a faithfulness hierarchy (11). Here there is no “general” faithfulness. The second vowel of the base is copied in the reduplicant at the expense of the first vowel, because faithfulness to a more harmonic vowel ranks relatively higher, and CONTIGUITY ranks low. This constraint interaction in Nakanai grammar is illustrated in (13).

(13) *Harmony-as-faithfulness in Nakanai reduplication*

			MAX$_{BR}$LO	MAX$_{BR}$MID	MAX$_{BR}$HI	CONTIG
/RED-beta/	a.	be-beta	*!			
	b.	☞ ba-beta		*		**
/RED-biso/	c.	bi-biso		*!		
	d.	☞ bo-biso			*	**

Below we focus on simpler patterns which isolate high vowels but which do not discriminate between mid and low vowels. Following Prince and Smolensky (1993; cf. de Lacy 2002) we assume that in these cases the harmonic scale of sonority (8) is encapsulated and collapsed into a two-level hierarchy as in (14a) or (14b).

(14) a. *Harmony as markedness*
*HI ≫ *NONHI
b. *Harmony as faithfulness*
FAITHNONHI ≫ FAITHHI

We demonstrate that these two different grammatical expressions of sonority are equally appropriate for handling deletion phenomena (§2.2), but only the faithfulness-based hierarchy (14b) can be used to explain a frequently observed class of insertion phenomena (§2.3). More specifically, only harmony-as-faithfulness can account for the coincidence observed by Hooper (1972), viz. that “the particular vowel found in insertion rules will be the same as the vowel of deletion” (§2.4).

Note that our discussion is concentrated on vowel height. The relation between front and back vowels appears to be non-harmonic, so we discuss it only in the Appendix.

2.2. On the treatment of vowel preservation

Weak elements drop before strong ones do. (Foley 1977:44)

We have just seen that a grammar can be sensitive to the differential sonority of vowels in reduplicative copying. We now turn to the broader issue of vowel preservation in input-output mappings. Of main concern is that deletion processes single out high vowels in many languages. For instance, only high vowels delete obligatorily in medial open syllables in many Modern Arabic dialects such as Cairene (Angoujard 1990:155) and Tunisian (Wise 1983:167):

(15) *High vowel syncope in Arabic*

a. *Cairene*

	báːʕu kØtúb-na	'they sold our books'	kútub	'books'
	fi ħØlál-ha	'in her pot'	ħílal	'pot'
	jáxØd-u[3]	'they take'	/jaːxud/	'to take'
	fíhØm-it	'she understood'	/fihim/	'to understand'
cf.	ḍárab-it (*ḍárØbit)	'she beat'	/ḍarab/	'to beat'

b. *Tunisian*

	símØh-a	'beautiful (fem)'	símih	'beautiful (masc)'
	ɣáːlØṭ-a	'wrong (fem)'	ɣáːliṭ	'wrong (masc)'
	kúrkØb-i	'my carroway'	kúrkub	'carroway'
cf.	bálaħ-i ~ bálØħ-i[4]	'my dates'	bálaħ	'dates'

The same pattern is found in vernacular K'ichee' (Mayan: Isaacs and Wolter 2003):

(16) *High vowel syncope in K'ichee'*

slow speech		*fast speech*				
kab'inik	→	kab'nik	'he/she goes'	*cf.*	kun*(a)neːl̥	'doctor'
kukutiːχ	→	kuktiːχ	'he/she shortens it'		b'el*(e)jeb'	'nine'

Syncope is also directed at high vowels in Canadian French (Gendron 1966:150–1, Walker 1984:75–6, 101, Dumas 1987:104):

[3] This example shows regular closed-syllable shortening.

[4] Nonhigh vowels optionally delete in Tunisian, whereas high vowel syncope is obligatory (e.g., *kúrkub-i 'my carroway').

(17) *High vowel syncope in Canadian French*

/vilaʒ/	→	[vlaʒ]	'village'	/pɔpylasjɔ̃/	→	[pɔplasjɔ̃]	'population'
/gide/	→	[gde]	'guider'	/budɛ̃/	→	[bdɛ̃]	'boudin'
/pisin/	→	[psɪn]	'pool'	/tuʒuʁ/	→	[tʒuʁ]	'toujours'

There are as well many historical examples of high vowel syncope. For instance, such a process occurred in the development from Proto-Slavic into Old Bulgarian (Velcheva 1988).

(18) *High vowel syncope in the development of Bulgarian from Proto-Slavic*

*ʒeʒĭka	>	ʒeʃkə	'scorching'	*kratŭka	>	kratkə	'short'
*gorĭka	>	gorkə	'bitter'	*blizŭka	>	bliskə	'near'
*gladŭka	>	glatkə	'smooth'	*lovŭka	>	lofkə	'adroit'

To account for high vowel syncope, we can say that the general faithfulness constraint MAX intersects with the markedness subhierarchy ⟦*HI ≫ *NONHI⟧ (14a), as in (19i), or else that the general markedness constraint *STRUC (Prince and Smolensky 1993, Zoll 1998) intersects with the faithfulness subhierarchy ⟦MAXNONHI ≫ MAXHI⟧ (14b), as in (19ii). In both cases we assume that CONTIGUITY (not shown in (19)) is lowly ranked, as in Nakanai reduplication (cf. (12)–(13)).

(19) *High vowel deletion*

i. *Harmony-as-markedness*

		*HI	MAX	*NONHI
/i/	☞ Ø		*	
	[i]	*!		
/a/	Ø		*!	
	☞ [a]			*

ii. *Harmony-as-faithfulness*

		MAXNONHI	*STRUC	MAXHI
/i/	☞ Ø			*
	[i]		*!	
/a/	Ø	*!		
	☞ [a]		*	

Both approaches succeed in accounting for high vowel deletion and there seems to be no reason to prefer one account over the other. For detailed working analyses of (high vowel) syncope within each of these approaches, see Gouskova (2003) and Hartkemeyer (2000),[5] respectively.

Apocope, too, may specifically target high vowels. For instance, all and only high vowels delete word-finally in the native (Yamato) vocabulary of Kagoshima Japanese (Kibe 2001):

(20) *High vowel apocope in Kagoshima Japanese*

tobu	→	toʔ	'fly'	*cf.*	buta	'pig'
kaki	→	kaʔ	'persimmon'		take	'bamboo'
inu	→	iN	'dog'		kimono	'clothes'
kami	→	kaN	'paper'		hana	'nose'

[5] Hartkemeyer substitutes *V for *STRUC; cf. $*\sigma_\mu$ in Broselow (1992) and Sherer (1994).

çiru	→	çij	‘noon’	sakura	‘cherry’
mari	→	maj	‘ball’		
k^waʃi	→	k^waʃ	‘sweets’		
kazu	→	kas	‘number’		

Likewise, Proto-Micronesian high vowels were lost word-finally in Gilbertese (Kiribati), though only after nasal consonants (21). Blevins (1997) suggests that high vowel deletion may have been general in Gilbertese but that it applied “only where the resulting string has an optimal syllable coda” (p. 244, n.16), namely a nasal.[6]

(21) *Postnasal apocope of Proto-Micronesian high vowels in Gilbertese*

Proto-M.		*Gilbertese*			*Proto-M.*		*Gilbertese*	
*kaŋi	>	kaŋ	‘eat’	*cf.*	*kana	>	kana	‘food’
*kinikini	>	kinikin	‘pinch’		*laŋo	>	naŋo	‘fly (insect)’
*manu	>	man	‘creature’		*maane	>	mmaane	‘man, male’
*puŋu	>	puŋ	‘fall, rain/come down’					

High vowels may systematically apocopate because they are the most marked vowels according to the markedness hierarchy (14a)/(19i), or else because faithfulness to high vowels ranks lowest in the faithfulness hierarchy (14b)/(19ii). A plausible faithfulness-based analysis is illustrated in the following tableau from Kaneko and Kawahara (2002), who impute apocope to FINAL-C: “A prosodic word must not end with a vocalic element” (McCarthy and Prince 1990, Piggott 1991; see also Gouskova 2003:153, 170ff.).[7]

(22) *High vowel apocope*

			MAXNONHI	FINAL-C	MAXHI
/inu/		[inu]		*!	
	☞	[iN]			*
/hana/	☞	[hana]		*	
		[haN]	*!		

Our last example of high vowel deletion comes from Yoruba (Benue-Congo: Pulleyblank 1988, 2003a). In this language, vowel hiatus is normally resolved by deleting the first vowel (23a), but high vowels delete in favour of nonhigh vowels whether they are in V_1 position (23b), or in V_2 position (23c). Note that the remaining vowel spreads to the

[6] As with syncope (e.g., (18)), historical examples of high vowel apocope are rather common. For instance, in Old English (Hogg 2000) high vowels were lost after heavy syllables, e.g., *flæsci* > *flæsc* ‘flesh’, *lāru* > *lār* ‘learning’ (fem.nom.sg.), as well as after two light syllables, e.g., *werodu* > *werod* ‘troops’ (nom.acc.pl.).

[7] De Lacy (2002:124, fn. 60) suggests instead that apocope is due to high-ranking CONTIGUITY.

vacated mora in the Ekiti dialect which is represented here (Adeniyi 1988, Omisore 1989).[8]

(23) *Hiatus resolution in Yoruba: Ekiti dialect*

a.	[ulé òdʒó]	→	[ulóòdʒó]	'house of Ojo'
	[àbá ɛgbɛ́]		[àbɛ́ɛgbɛ́]	'father of club/patron'
	[ɔdʒà ɔba]		[ɔdʒɔ̀ɔba]	'market of king'
b.	[omĩ ɛrã]		[omɛ̃ɛ̃rã]	'water of meat'
	[ìlú ɔ̀wɔ̀]		[ìlɔ́ɔ̀wɔ̀]	'a town'
c.	[eó igi]		[eóogi]	'money for wood'
	[ulé ʊʃɛ́]		[uléeʃɛ́]	'place of work'

The question remains: are high vowels singled out for deletion because they are most rigorously prohibited (14a)/(19i) or because they are the least faithfully adhered to (14b)/(19ii)? The latter faithfulness approach is illustrated in the tableau in (24), which implicates the following constraints:

NOHIATUS (Ọla Orie and Pulleyblank 2002):

$$*\begin{array}{cc}\mu & \mu \\ | & | \\ \mathrm{Rt} & \mathrm{Rt}\end{array}$$

ANCHORL (McCarthy and Prince 1995; cf. Casali 1997, Nelson 2003):
Any root node at the left edge of a morpheme in the input has a correspondent root node at the left edge of the morpheme in the output.

NOHIATUS always forces the deletion of a vowel in hiatus context (24a,d). ANCHORL normally ensures that V_2 is preserved over V_1 (24c), but higher-ranking MAXNONHI compels V_2-deletion (24e).

(24) *Hiatus resolution in Yoruba: Harmony-as-faithfulness*

			NOHIATUS	MAXNONHI	ANCHORL	MAXHI
[àbá ɛgbɛ́]	a.	[àbáɛgbɛ́]	*!			
	b.	☞ [àbɛ́ɛgbɛ́]		*		
	c.	[àbáagbɛ́]		*	*!	
[ulé ʊʃɛ́]	d.	[uléʊʃɛ́]	*!			
	e.	[ulʊ́ʊʃɛ́]		*!		
	f.	☞ [uléeʃɛ́]			*	*

[8] Moras delete along with vowels in Standard Yoruba. The latter dialect lacks *u*-initial nouns, so it is less useful in exemplifying high vowel deletion (Pulleyblank 1988).

To summarise so far, strong prohibition and weak faithfulness predict comparable behaviour. Any case where relatively less sonorous vowels are deleted could be interpreted via harmony-as-markedness (14a), or equivalently via harmony-as-faithfulness (14b). The relative markedness of different vowels could be grammatically expressed in either way. In other words, both hypotheses have potential explanatory power as far as vowel preservation phenomena are concerned, and their relative merit cannot be determined *a priori*.[9]

2.3. On the treatment of vowel insertion

Just as high vowels are frequent targets of deletion, so too are high vowels frequently favoured as default segments in epenthetic contexts. One of the best-known cases is that of high-vowel epenthesis in Yowlumne (Yok-Utian: Archangeli 1988): syllabification forces the insertion of [i] or [u], depending on an independent process of height-dependent round/back harmony progressing rightward.

(25) *Epenthesis in Yowlumne*

	stem	*aorist (-hin)*	*pass. aor. (-t̪ʰ)*	
[i]	paʔtʰ-	paʔitʰhin	paʔtʰit̪ʰ	‘fight’
	ʔaːml-	ʔaːmilhin	ʔamlit̪ʰ	‘help’
	logw-	logiwhin	logwit̪	‘pulverise’
[u]	luk’l-	luk’ulhun	luk’lut̪ʰ	‘bury’
	ʔukn-	ʔukunhun	ʔuknit̪ʰ	‘drink’
	wuːuʔj-	woːoʔujhun	woʔjut̪ʰ	‘ask’

Turkish (Clements and Sezer 1982:243–4) provides another well known example of high vowel insertion. Epenthetic vowels vary between [i, u, y, ɨ] due to rounding and backness harmony.

(26) *High vowel epenthesis in Turkish*

	nom.sg.	*3.poss.*			*nom.sg.*	*3.poss.*	
[i]	fikʲir	fikʲr-i	‘idea’	*cf.*	fakʲir	fakʲir-i	‘poor’
[u]	kojun	kojn-u	‘bosom’		kojun	kojun-u	‘sheep’
[y]	hykʲym	hykʲm-y	‘judgement’		kʲømyr	kʲømyr-y	‘coal’
[ɨ]	sabɨr	sabr-ɨ	‘patience’		sabɨr	sabr-ɨ	‘patience’

Consonant clusters are also avoided through high vowel epenthesis in Arabic dialects such as Palestinian (Abu Salim 1987). That the following examples involve epenthesis

[9] We here deal only with deletion. A reviewer suggests that the hierarchy ⟦FAITHLO ≫ FAITHMID ≫ FAITHHI⟧ fails to predict cases like Russian, in which /e, o/ reduce to [a] pretonically. Crosswhite (2001:84ff.) suggests the following analysis of Russian reduction in terms of licensing and featural faithfulness: LICENSENONPERIPHERAL/STRESS ≫ MAX[–high] ≫ DEP[+low]. This sort of analysis is compatible with harmony-as-faithfulness. It should be noted, however, that Crosswhite’s general approach to vowel reduction is far from successful. As she concedes (p. 125, 217–306), the majority (53.1%, N = 49) of her predicted reduction patterns in 5-vowel systems, and three quarters (74.8%, N=206) of her predicted reduction patterns in 7-vowel systems, are simply unattested.

(27a), not syncope (27b), is indicated by the location of stress; closed penults would normally attract stress, e.g., katáb-na (*kátab-na) ‘we wrote’ (ib.).

(27) *High vowel epenthesis in Palestinian Arabic*

a.	ʔákil-ha	‘her food’	b.	ʔákl-i	‘my food’
	ʔíbin-ha	‘her son’		ʔíbn-i	‘my son’
	d$^{\text{ʒ}}$ísir-ha	‘her bridge’		d$^{\text{ʒ}}$ísr-i	‘my bridge’
	fúrun-ha	‘her oven’		fúrn-i	‘my oven’
	ʃúɣul-ha	‘her job’		ʃúɣl-i	‘my job’
	ʕúrus-ha	‘her wedding’		ʕúrs-i	‘my wedding’

Loanword phonologies afford several examples of high-vowel epenthesis. For example, the syllabic adaptation of English words in Yoruba (Salami 1972, Pulleyblank 1988, Akinlabi 1993) involves inserting [i] or [u], depending on consonantal assimilation or vowel harmony.

(28) *High vowel epenthesis in Yoruba loans from English*

[i]	gírámà	‘grammar’	[u]	búrɛ́dì	‘bread’
	fírî	‘free’		súkúrù, súkúù	‘school’
	sílípáàsì	‘slippers’		dúrɔ́ɔ̀	‘drawer’

Similarly, Russian loanwords are adapted in Tuvan (Turkic: Harrison 1999) with epenthetic high vowels: [i ~ ɨ ~ u], depending on backness and rounding harmony.

(29) *High vowel epenthesis in Russian loans in Tuvan*

[i]	sjeks	→ seːkis	‘sex’	[ɨ]	pl̡an	→ pɨlan	‘plan’
	gips	→ giːpis	‘plaster cast’		at$^{\text{ʃ}}$ki	→ at$^{\text{ʃ}}$ɨki	‘eye-glasses’
	texnar	→ texinaːr	‘alcohol’	[u]	boks	→ boːqus	‘boxing’

We now turn to the formal analysis of the choice of vowels in epenthesis. Of special interest is the fact that the harmonic rankings of markedness (14a) and faithfulness (14b) make radically different predictions with regard to insertion phenomena. On the one hand, harmony-as-markedness incorrectly predicts that (all else being equal) *nonhigh vowels, not high ones, ought to be preferred in epenthesis*. Indeed, since according to harmony-as-markedness nonhigh vowels are always less marked than high vowels, the addition of a nonhigh vowel to the output is penalised less severely than similar addition of a high vowel. On the other hand, harmony-as-faithfulness correctly predicts that (all else being equal) *high vowels are preferred in epenthesis*. The reason is that epenthesis is a violation of faithfulness, and according to harmony-as-faithfulness, the addition of a high vowel to the output is a lesser violation of faithfulness than similar addition of a nonhigh vowel.

To explain the preference for high vowels in epenthesis in terms of *markedness*, phonologists have been forced to postulate markedness constraints independently of the harmonic scale for vowels. For instance, Kager (1999a:290) assumes that “the featural content of the epenthetic vowel ... depends on featural markedness” and therefore he proposes the “context-free markedness constraint *[–high]” (ib.). Archangeli and Suzuki (1997:200) adopt a similar line of thinking: to account for the fact that epenthetic vowels are typically high they propose a markedness constraint “preferring vowels to be [+high]” (p. 200). And according to Alderete et al. (1999), high vowels are favoured in epenthesis because of REDUCE (Kirchner 1997), a general markedness constraint against longer vowels.[10]

(30) *Proposed markedness constraints*

a. Kager (1999a), Kurisu (2000), Buckley (2003), etc.
    *[–high]   “Nonhigh vowels are not permitted”

b. Archangeli and Suzuki (1997)
    V≈[+high]   “Vowels are high”

c. Kirchner (1997), Alderete et al. (1999)
    REDUCE   “Minimise the duration of short vowels”

The isolated postulation of such constraints is problematic, both conceptually and empirically. The conceptual flaw is that these constraints are defined in a circular fashion: if the choice of vowel in epenthesis is up to markedness, then the fact that high vowels are preferred in epenthesis implies that they must be relatively unmarked in some way, hence *[–high], V≈[+high], REDUCE, etc. There is no independent evidence for the unmarkedness of epenthetic high vowels. As Archangeli and Suzuki (1997:205) admit, “the effect of V≈[+high] is visible only in the case of epenthetic vowels.” Kager’s (1999a:290) statement is also revealing: “Epenthetic [i] is *apparently* less marked than any other vowel. This result *follows* from the context-free markedness constraint *[–high]” (our emphasis).[11] Finally, consider Steriade’s (1995:139–140) suggestion “that the frequent choice of a high vowel [in epenthesis] —typically *i* or *ɨ* — indicates a preference for the vowels that are phonetically shortest” (see also Shinohara 2000:78). Crucially, there is no reason to interpret this “preference” as a markedness constraint (REDUCE).

The empirical problem with postulating markedness constraints such as *[–high], V≈[+high] and REDUCE in isolation is that they assert the unmarkedness of high vowels.[12] When viewed independently of epenthesis, however, the intrinsic unmarkedness of high vowels is far from obvious. For instance, Ladefoged and Maddieson (1996:286) observe that all languages make contrasts in the vowel height dimension, though not all languages have high vowels. Blevins (1995:220) states that “all languages have syllables containing non-high vocalic nuclei”, and she cites Kabardian (Circassian) as a language in which “the segment type [+high, –cons] is an impossible syllable nucleus” (ibid.). Less controversial examples of such languages include Arrernte (Pama-Nyungan), Ubykh (Ubyx) and

[10] See, e.g., Parker (2002) and Kent and Read (2002) for evidence that high vowels are shortest.

[11] Somewhat incongruously, Kager (1999a) also assumes *[+high], “a constraint militating against high vowels” (p. 128), as well as NO [i]: “/i/ is not allowed in light syllables” (p. 284).

[12] Kurisu (2000:171) gives the hierarchy ⟦*Mid-V, *Low-V ≫ *High-V⟧ to explain high vowel epenthesis in Japanese. But this reverses the markedness hierarchy (10)/(14a) needed to explain high vowel syncope in Japanese antiantigemination, e.g., /kakukoto/ [kakkoto] ‘writing’, /sentakuki/ [sentakki] ‘washing machine’ (Arai 1999); see (19i) above.

Abkhaz (Abkhaz-Abazin), which have just [ə] and [a] (Ladefoged and Maddieson 1996).[13] The range of syllabic segments cross-linguistically thus indicates that [–high, –cons] is less marked than [+high, –cons].

The conclusion seems clear. A markedness-based analysis of epenthesis fails to predict the preference for high vowels in this context, since high vowels are relatively marked according to the independently established markedness hierarchy for vowels.

Before proceeding to our analysis in terms of faithfulness, we now consider an alternative markedness-based account of the preponderance of high vowels in epenthesis. De Lacy (2002) suggests that the low sonority of high vowels makes them favourable elements in non-head positions of the prosodic hierarchy (Foot, Prosodic Word, Prosodic Phrase, etc.): "High vowels are highly marked in heads, but have low markedness in non-heads" (p. 249). For example, he reports that "there is usually a trochaic foot at the right edge of every Prosodic Word in Kiriwina (31a) (Lawton 1993, Senft 1986). However, the foot retracts if doing so will allow it to end up with a non-head vowel of low sonority (i.e. [i u]) (31b)" (p. 19).

(31) *Stress in Kiriwina (Kilivila)*

a.	ka(wála)	'canoe pole'	b.	(kúli)a, *ku(lía)	'cooking pot'
	ikoi(súvi)	'he puts in'		(páku)la, *pa(kúla)	'blame'

Inspired by such patterns, de Lacy proposes a family of constraints against nonhigh vowels in non-head positions of the prosodic hierarchy, e.g., $*\text{-}\Delta_{Ft}\geq\{e,o\}$: "Assign a violation for every foot non-DTE ['Designated Terminal Element' = head of prosodic constituent] that is equally or more sonorous than mid vowels ([e o a])" (p. 118). Crucially, de Lacy (2002:144ff.) uses these prosodic markedness constraints to explain high vowel insertion, since indeed epenthesis usually occurs in non-head positions (Broselow 1982, Alderete 1999).

However, high vowel epenthesis can also occur in head positions of prosodic structure. For instance, the following paradigm illustrates that epenthetic high vowels can bear main stress in Iraqi Arabic (Broselow 1982:119–20; see also Broselow 1992).

(32) *Stressed high vowel epenthesis in Iraqi Arabic*

	/kitab-t-ha/	→	[kitabítha]	'I wrote it (f.)'
	/kitab-t-l-ha/	→	[kitabtílha]	'I wrote to her'
	/kitab-t-l-a/	→	[kitabítla]	'I wrote to him'
cf.	/kitab-t/	→	[kitábit]	'I wrote'

Subminimal words in Iraqi Arabic are also augmented with stressed high vowels, e.g., /drus/ → [ídrus] 'study!' (Broselow 1982:117, 124ff.), English *Fred* → [í]*Fred* (Broselow 1992, Kenstowicz 1994:304). In analogous fashion, subminimal words in Mohawk (Iroquoian) are augmented with an epenthetic high vowel which is "invariably stressed" (Piggott 1995:295):

[13] Contra, e.g., Kager (1999a:3): "all languages have unrounded front vowels such as [i] and [e]".

(33) *Stressed high vowel epenthesis in Mohawk*

/k-tat-s/	→ [íktats]	'I offer it'	/k-ek-s/	→ [íːkeks]	'I eat'
/s-riht/	→ [íseriht]	'cook!'	/k-jʌs/	→ [íkjʌs]	'I put it'

As de Lacy (2002) admits, such cases are problematic for his approach to high vowel epenthesis: "The problem is that [i] is a low-sonority vowel, yet the position it appears in is the DTE of the highest prosodic level (in some utterances). In short, the DTE-sonority constraints cannot deal with the Arabic" (p. 159).[14]

In contrast to markedness approaches, a faithfulness-based analysis of high vowel epenthesis is successful. If the harmonic scale for vowels is represented with faithfulness constraints —specifically with "anti-epenthesis" constraints (DEP), then high vowels emerge as the optimal epenthetic vowels, because faithfulness to them ranks lowest in the harmonic hierarchy. We illustrate this approach to epenthesis with an example from Iraqi Arabic (32):

(34) *Harmony-as-faithfulness in Iraqi Arabic epenthesis*

/kitab-t-ha/	*CCC	DEPNONHI	DEPHI
a. kitabtha	*!		
b. kitabátha		*!	
c. ☞ kitabítha			*

The essence of the proposal is that faithfulness has as its purpose to ensure that input and output representations are identical. Deviations may be of two types, cases where material in the input fails to survive unchanged into the output and cases where material in the output does not reflect input content. Where constraints force the loss of phonological content contained in the input (MAX violations), the more salient the material the more serious the violation and the less salient the less serious. Where constraints force the presence of phonological content in the output not present in the input (DEP violations), then the more perceptible the output intrusion, the more serious the violation, and the less perceptible the less serious.

Of course we do not deny that markedness constraints play a role in grammar, including epenthesis. For instance, the featural markedness constraint *[+high] can compel the choice of epenthetic [e] over epenthetic [i], as happens in Persian, e.g.: [felorida] 'Florida', [pelɑstik] 'plastic', [eski] 'ski' (Muhammad Khan 1983, Shademan 2003). Epenthesis of nonhigh vowels can also be forced by various prosodic markedness constraints. For instance, Hagstrom (1997) argues that only epenthetic [a] is permitted after a nonmoraic coda consonant in Mohawk. De Lacy (2002:147ff.) argues that low [a] is used for epenthesis in Shipibo (Panoan: Elías 2000) due to a constraint against stressed high vowels

[14] This approach also makes it difficult to explain cases like Ibibio (Akinlabi and Urua 2003) in which high vowels are restricted to tonic positions; they are lowered in unstressed positions.

("*Δ_{Ft}≤{i,u}"), and in Coos (Oregon Penutian: Frachtenberg 1922:309ff.) due to a constraint against nonlow syllabic nuclei ("*Δ_{σ}≤{e,o}"). Such markedness constraints may override but do not annul harmony-as-faithfulness (DEPNONHI ≫ DEPHI), which explains only the otherwise ordinary use of high vowels in epenthesis.[15] Indeed, epenthetic [i] also occurs in Mohawk, Shipibo and Coos (in stressed position, in unstressed position, and after [s], respectively; see above references).[16]

2.4. Synthesis: harmony-as-faithfulness and the phonology of vowels

> *The /a/ sound, which appears to be virtually unaffected by phonological changes, is ranked strongest in the Japanese hierarchy, and /i, u/ are ranked the weakest.* (Tatsuki 1987:104)

So far we have shown that high vowel deletion can be treated by encoding the harmonic scale for vowels as a markedness hierarchy, or equally by encoding that scale as a faithfulness hierarchy. However, we have also shown that high vowel epenthesis is predicted only by encoding the harmonic scale for vowels as a faithfulness hierarchy. In this section, we focus on an obvious fact that has been side-stepped in our discussion until now —that high vowels are singled out for both deletion and insertion, even in the same language. For instance, we have seen that Yoruba and Modern Arabic dialects have deletion as well as insertion processes involving [i, u].

This coincidence, which was noted by Hooper (1972), is enigmatic in principle for any markedness-based analysis: high vowels appear to be *less* marked than nonhigh vowels, because they are favoured in insertion contexts, but they also appear to be *more* marked than nonhigh vowels, because they are targeted in deletion contexts. By contrast, this coincidence is expected once it is recognised that nonhigh vowels are universally more harmonic than high vowels (e.g., Blevins 1995:220), and that this harmonic relation can be grammatically encoded as faithfulness, as in (35) [≈(14b)]. In that case, we find that high vowels are most likely to be deleted since they rank lowest on the MAX faithfulness scale (35a) and they are also most likely to be inserted since they rank lowest on the DEP faithfulness scale (35b). We even predict them to be more likely to undergo metathesis since they rank lowest on the LINEARITY faithfulness scale (35c). (LINEARITY demands that the output be consistent with the precedence structure of the input, and vice versa; McCarthy and Prince 1995.)

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[15] For instance, Gouskova (2003:195) gives the following ranking for [a]-epenthesis in Mekkan Arabic and Axininca Campa: *NUC/i,u ≫ *NUC/e,o ≫ REC[a] ≫ REC[e,o] ≫ REC[i,u] (where REC ≈ DEP).

[16] Piggott (1995) shows that Mohawk has three epenthetic vowels. [i] is inserted to meet metrical constraints (p. 294-5), whereas [e] is inserted to meet syllabic contraints (p. 292). [a] is inserted for "idiosyncratic morphological factors" (p. 293). Piggott argues that epenthetic [e] and [a] are weightless (nonmoraic), e.g., they do not count for stress (p. 198). By contrast, epenthetic [i] appears to be moraic; as we saw in (33), it is "invariably stressed" (p. 295). It would seem that [i] cannot be used for all epenthesis in Mohawk because [+high] must be licensed by a mora; see Howe and Pulleyblank (2001) for another case in which marked features (or feature combinations) must be moraically licensed.

(35) *Harmony-as-faithfulness:* FAITHNONHI ≫ FAITHHI

a. "Anti-deletion"	b. "Anti-epenthesis"	c. "Anti-metathesis"
MAXNONHI ≫ MAXHI	DEPNONHI ≫ DEPHI	LINNONHI ≫ LINHI

These perhaps surprising predictions of harmony-as-faithfulness (35) —that high vowels are most likely to delete, most likely to epenthesise and also most likely to metathesise— are verifiable. For instance, high vowels are specifically involved in syncope (36a), epenthesis (36b) as well as metathesis (36c) in Palestinian Arabic (Abu Salim 1987, Yoshida 1993).

(36) *Palestinian Arabic*

a. *High vowel syncope*

	nízØl-u	'they descended'	nízil	'he descended'
	ʃirØb-u	'they drank'	ʃírib	'he drank'
cf.	dáras-u	'they studied' (*dárØs-u)	dáras	'he studied'

b. *High vowel epenthesis*

	ʔákil-ha	'her food'	ʔákl-i	'my food'
	ʔíbin-ha	'her son'	ʔíbn-i	'my son'
	fúrun-ha	'her oven'	fúrn-i	'my oven'
cf.	katáb-na	'we wrote' (*kátab-na)		

c. *High vowel metathesis*

	fílifl-i	'my pepper'	fílfil	'pepper'
	míʃimʃ-u	'his apricots'	míʃmiʃ	'apricots'
	tí-libs-u	'you (f.s.) wear'	tí-lbis	'you (f.s.) wear'
	tú-durs-i	'you (f.s.) study'	tú-drus	'you (f.s.) study'
	tú-kutb-i	'you (f.s.) write'	tú-ktub	'you (f.s.) write'
cf.	tí-fham-i	'you (f.s.) understand'	tí-fham	'you (m.s.) understand'

High vowel syncope and high vowel epenthesis in Arabic have already been discussed within harmony-as-faithfulness (§2.2, §2.3) so we now focus on the treatment of high vowel metathesis (36a). This process is further illustrated by the data in (37) from the dialect of Arabic spoken in the Ajloun Mountains of Jordan (Kenstowicz 1994:399ff.).[17] That we are dealing here with metathesis, and not with simultaneous syncope and epenthesis, is suggested by the fact that "the vowel in the CVCC alternant systematically matches the vowel in the CCVC alternant" (Kenstowicz 1994:401).

[17] Metathesis of [i, u] also occurs in Lenakel (Austronesian: Lynch 1978).

(37) *High vowel metathesis in Ajloun Mountains Arabic*

a. /ʔa-ḥrig-u/	[ʔáḥirgu]	‘I guard him’	(cf. ʔáḥrig ‘I burn’)
b. /ʔa-ḥrus-u/	[ʔáḥursu]	‘I burn him’	(cf. ʔáḥrus ‘I guard’)
c. /ʔa-fham-u/	[ʔáfhamu]	‘I understand him’	(cf. ʔáfham ‘I understand’)

According to Kager (1999b), metathesis results from the general stress system of Arabic: a light penult is avoided because it entails a violation of either NonFinality or Parse-2 —a constraint against two unstressed syllables (see Kager 1999b:226–32 for details).

(38) *Stress constraints in Arabic*

a. NonFinality	The head of the PrWd must not be final.
b. Parse-2	One of two adjacent syllables must be parsed by a foot.

The interaction of these metrical constraints with the faithfulness hierarchy (35c) is illustrated in (39). As shown, the metrical constraints compel the metathesis of high vowels, because they rank higher than LinHi. LinNonHi ranks higher than the metrical constraints, so there is no metathesis of nonhigh vowels.

(39) *Metathesis in Arabic*

			LinNonHi	NonFin	Parse-2	LinHi
/ʔa-ḥrus-u/	a.	ʔaḥ.(rúsu)		*!		
	b.	(ʔáḥ)rusu			*!	
	c. ☞	(ʔáḥur)su				
/ʔa-fham-u/	a.	ʔaf.(hámu)		*!		
	b. ☞	(ʔáf)hamu			*	
	c.	(ʔáfah)mu	*!			

To conclude this first section, we have argued for building prominence-sensitive markedness relations into the fabric of faithfulness conditions. In particular, we speculate that faithfulness moderates not only structural change but also perceptual change, that is, the perceptual consequences of structural change. For instance, under the assumption that nonhigh vowels are more perceptually salient than high vowels (due to higher F1, longer duration, more air pressure, etc.), the addition (Dep) or the removal (Max) of nonhigh vowels is penalised more severely than the addition/removal of the less salient high vowels. It follows —when all else is equal— that high vowels are preferentially introduced in epenthesis and, furthermore, that nonhigh vowels are preferentially retained in deletion contexts.

In the following section, we construct a similar argument in the domain of glottalised consonants. Assuming that ejectives are more perceptually salient than glottalised sonorants, the addition (Dep) and the removal (Max) of glottalisation in obstruents is penalised more severely than similar addition/removal in sonorants. We show that a single ranking derives the target properties of morphologically-triggered glottalisation, and also accounts for additional patterns such as the preferential preservation of glottalisation in obstruents both diachronically and synchronically.

3. HARMONY AS FAITHFULNESS AND TARGET CLASSES OF GLOTTALISATION

Our examination of glottalisation focusses on the relative markedness of glottalised obstruent stops and glottalised sonorants. We begin with observations about their cross-linguistic distribution.

3.1. Relative markedness of glottalisation

It has been noted that the presence in a language of glottalised resonants implies the presence of glottalised obstruent stops. This has been observed in a balanced survey such as Maddieson (1984:116):

> In general, laryngealized sonorants are found only in languages with glottalic stops. Nineteen of the 20 languages in UPSID [the UCLA Phonological Segment Inventory Database] which have laryngealized sonorants have ejective stops, implosives or voiced laryngealized plosives in their inventories.

The same implication has been noted by Sherzer (1976) in an areal-typological study of Native American languages. Sherzer explicitly concludes that glottalised resonants are more marked than glottalised obstruent stops (p. 258).

Interpreting this distributional implication in terms of the feature [constricted glottis] on sonorants and obstruent stops, we get the following harmonic scale:

(40) *"Relative harmony" scale for glottalisation (constricted glottis)*
CG/STOP ≻ CG/SON

There is a range of evidence in favour of this "relative harmony". Typologically, glottalised sonorants occur only in 20 (i.e. about 6%) of the 317 languages in Maddieson's (1984) survey. By contrast, the linguistic exploitation of glottal constriction in the production of obstruent stops seems relatively common, for example:

- *Ejective* stops occur in about 18 percent of the languages (N=317) surveyed by Maddieson (1984), making them the most common type of glottalic or laryngealised segment. As Ladefoged and Maddieson (1996:78) put it: "Ejectives are not at all unusual sounds".
- *Implosive* stops are not infrequent. They occur in about 10 percent of the languages of the world (Maddieson 1984).
- Stops with distinctive *creaky voice* occur in areally diverse languages. Ladefoged and Maddieson (1996:53) cite examples from Austro-Asiatic, Kam-Tai, Nilo-Saharan, Cushitic, Chadic, Hokan, and Arakawan.
- Stops with distinctive *stiff voice* occur in well-known languages such as Thai and Korean (Ladefoged and Maddieson 1996:55).

On the assumption that these various laryngeal activities —ejection, implosion, creaky voice, and stiff voice— all implicate the phonological feature [constricted glottis], one surmises that this feature characterises stops in about a third of the world’s languages.

There is also diachronic evidence that [constricted glottis] is more harmonic with stops than with sonorants. For instance, glottalised obstruents are reconstructed for 3 Kadai languages but glottalised sonorants are reconstructed for only one of these (Kam Sui) (Solnit 1992). Moreover, glottalisation is lost more frequently among sonorants than among stops. For example, Solnit (1992) reports that 4 Mon-Khmer languages have retained glottalised obstruents from the ancestral language, but only one of these (Bahnaric) has retained glottalised sonorants. Glottalised sonorants, but not glottalised obstruents, have also been lost in Upriver Halkomelem (Salish: Galloway 1984:22). The glottalised sonorants of Proto-Nootkan (South Wakashan) are retained in Nuu-chah-nulth (formerly Nootka), but they are variably lost in Ditidaht (formerly Nitinat) and completely lost in Makah. In the meantime, the glottalised stops remain intact (Gamble 1977:274; also Kingston 1985:320ff.).

(41) *Diachronic loss of glottalisation among sonorants in Nootkan*

	Proto-Nootkan		*Nootka*	*Nitinat*	*Makah*
a.	*t̰s̰’iːj̰uk’um	‘cup’	t̰s̰’iːj̰uk’um	t̰s̰’iːjuk’ub	t̰s̰’iːjukʷ’ub
b.	*kuːw̰iɬ	‘to steal’	kuːw̰iɬ	kuːwaɬ	kuːwiɬ

There is, furthermore, synchronic evidence that the loss of [constricted glottis] is more likely among sonorants than among obstruent stops. For example, syllable-final neutralisation affects glottalised sonorants but not glottalised stops in Heiltsuk (North Wakashan: Rath 1981, Howe 1998).

(42) *Synchronic loss of glottalisation among sonorants in Heiltsuk*

a.	χʷə̰l̰-í	χʷə́l-núkʷ
	seal.blubber-3	seal.blubber-have
b.	w̰át̰s̰’-i	w̰át̰s̰’-nukʷ
	dog-3	dog-have

Lastly, there is evidence from “baby talk” that glottalised stops are more harmonic than glottalised sonorants. Ferguson (1964:109) has observed that:

> “baby-talk items consist of simple, more basic kinds of consonant, stops and nasals in particular, and only a very small selection of vowels. One would expect that the rarer, more peculiar consonants or the consonants which tend to be learned later would not be found in baby talk (…).”

Crucially, Kess and Kess (1986:204) find that the laryngealised sonorants ([m̰ n̰ j̰ w̰] *vs.* [m n j w]) are neutralised in Nuu-chah-nulth baby talk whereas glottalised stops are attested, for example, t’iːq ‘sit down!’. Interestingly, w̰aw̰ik ‘farty one’ is suppleted by p’uːp’ik.

This range of facts makes it very clear that glottalisation is more harmonic among stops than among sonorants, as expressed in (40) above. As with vocalic markedness, such a harmonic scale can be interpreted as harmony-as-markedness (43a) or harmony-as-faithfulness (43b).

(43) *Hierarchy for glottalisation*

a. Harmony-as-markedness

*CG/SON ≫ *CG/STOP
("No [c.g.] on sonorant" ≫ "No [c.g.] on obstruent stop")

b. Harmony-as-faithfulness

MAXCG/STOP ≫ MAXCG/SON
("No deletion of [c.g.] from stop" ≫ "No deletion of [c.g.] from sonorant")

DEPCG/STOP ≫ DEPCG/SON
("No insertion of [c.g.] on stop" ≫ "No insertion of [c.g.] on sonorant")

As with the vowel distribution case, basic distributional patterns of glottalisation can be accounted for by either pattern. With harmony-as-markedness, a language can allow both glottalised obstruents and glottalised resonants by ranking the general MAXCG ("No deletion of [c.g.]" above both markedness constraints (44a); glottalised obstruents are allowed but glottalised resonants are disallowed by ranking MAXCG between the two cooccurrence constraints (44b); no glottalised consonants are allowed at all by ranking MaxCG lowly (44c).

(44) *Faithfulness interacting with markedness hierarchy for glottalisation*

a. Language has glottalised stops and glottalised sonorants
MAXCG ≫ *CG/SON ≫ *CG/STOP

b. Language has glottalised stops but no glottalised sonorants
*CG/SON ≫ MAXCG ≫ *CG/STOP

c. Language has no glottalised consonants
*CG/SON ≫ *CG/STOP ≫ MAXCG

The same effects can be achieved with the harmony-as-faithfulness approach by the relative ranking of a general prohibition of [constricted glottis] (*CG) with respect to the faithfulness constraints.

(45) *Markedness interacting with faithfulness hierarchy for glottalisation*

a. Language has glottalised stops and glottalised sonorants

MaxCG/Stop ≫ MaxCG/Son ≫ *CG

b. Language has glottalised stops but no glottalised sonorants

MaxCG/Stop ≫ *CG ≫ MaxCG/Son

c. Language has no glottalised consonants

*CG ≫ MaxCG/Stop ≫ MaxCG/Son

Of particular interest are cases where harmony-as-markedness and harmony-as-faithfulness make different predictions. As in the vowel patterns, this situation arises when glottalisation is introduced into a representation. In the next section, we consider a class of such cases involving glottalisation that is introduced by an affix in diverse Native American languages. Interestingly, these languages have both glottalised obstruents and glottalised sonorants, yet affixally induced glottalisation targets only sonorants. According to Steriade (1997) and Zoll (2001) this asymmetry shows the need for a sonorant-specific feature of glottalisation: [creak]. We will argue against this solution, showing instead that sonorant glottalisation is a consequence of encoding the harmonic scale for glottalisation as faithfulness.

3.2. Sonorant glottalisation

In this section we illustrate the process of sonorant glottalisation in several languages. Our first example is from Yowlumne (Yok-Utian: Newman 1944), a language with a full range of both ejectives and glottalised sonorants in its consonant inventory.

(46) *Yowlumne consonant inventory*

Voiceless unaspirated	p	t̪	t̪͡s̪	t	t͡s		k	
Voiceless aspirated	pʰ	t̪ʰ	t̪͡s̪ʰ	tʰ	t͡sʰ		kʰ	
Glottalised	p’	t̪’	t̪͡s̪’	t’	t͡s’		k’	
Fricatives		s̪		s			x	
Nasals	m			n				
Glottalised nasals	m̰			n̰				
Liquids and glides	w			l		j		h
Glottalised liquids & glides	w̰			l̰		j̰		ʔ

The forms below illustrate the fact that a morphologically provided glottalisation feature induces glottalisation on sonorants in Yowlumne (Archangeli 1988, Archangeli and Pulleyblank 1994:346–350). When a sonorant is *postvocalic* and immediately *adjacent* to the glottalising suffix, it is glottalised.

(47) *Glottalisation of sonorants adjacent to suffix*

a.	t̪͡s̪ʰaw-	t̪͡s̪ʰaːw̰aːhin	‘shout’
b.	t̪͡s̪’um-	t̪͡s̪’oːm̰aːhin	‘devour’
c.	nin-	neːn̰aːhin	‘quieten’

The postvocalic condition on target sonorants is a general one: glottalised sonorants occur only after vowels in Yowlumne; we refer the reader to Howe and Pulleyblank (2001) for a “grounded” explanation of this fact.[18] By contrast, the condition that the target be adjacent to the glottalising suffix is not necessary. With an intervening consonant, itself not an eligible target because of its non-postvocalic position, glottalisation skips over the consonant to affect a preceding sonorant. Note that in (48a) the skipped consonant is an obstruent stop, that is, a potentially glottalisable segment (cf. k’an̰aːʔin ‘goal touchers-O’, pok’en ‘will find’, ʔot’k’a ‘steal!’).

(48) *Glottalisation of sonorants over another consonant*

a.	ʔilkʰ-	ʔel̰kʰaːhin	‘sing’
b.	t̪ull-	t̪ol̰laːhin	‘climb’
c.	jawl-	jaw̰laːhin	‘follow’

If there is no eligible postvocalic sonorant target, then the affixal glottal feature surfaces as a glottal stop where syllabically possible.

(49) *Glottalisation as a glottal stop*

a.	max-	maxʔaːhin	‘procure’
b.	t̪os̪-	t̪os̪ʔoːhin	‘report’
c.	hot̪’-	hot̪’ʔoːhin	‘build a fire’

If there is no eligible postvocalic sonorant target and if a glottal stop would be syllabically illformed, then the glottal feature of the suffix fails to surface.

(50) *Deletion of glottalisation*

a.	hokn-	hoknaːhin	‘float’
b.	ʔit̪l-	ʔet̪laːhin	‘hunger’
c.	ʔakj-	ʔakjaːhin	‘pull’

What is directly relevant in these data is that the suffixal feature of glottalisation targets the first postvocalic *sonorant*.

Blake (1995) reports a similar pattern of glottalisation in Sliammon (and in many other Salishan languages), another language with both glottalised obstruents and glottalised sonorants.

[18] Howe and Pulleyblank (2001) defend a postvocalic condition for glottalised sonorants (“If [+son, +c.g.], then V__”), a constraint that is grounded in the universal tendency for sonorants to be preglottalised such that a preceding vowel favours the context cues for glottalisation in these segments (cf. Steriade 1997).

(51) *Sliammon consonant inventory*[19]

Plain stops and affricates	p	t͡θ	t	t͡ɬ		t͡ʃ	k	kʷ	q	qʷ	
Glottalised stops & affricates	p’	t͡θ’	t’	t͡ɬ’		t͡ʃ’	k’	kʷ’	q’	qʷ’	ʔ
Fricatives		θ	s	ɬ		ʃ		xʷ	χ	χʷ	h
Nasals	m		n								
Glottalised nasals	m̰		n̰								
Liquids & glides				l	L	d͡ʒ j		g w			
Glottalised liquids & glides				l̰	L̰	d͡ʒ’ j̰		g’ w̰			

The grammatical category diminutive/progressive in Sliammon involves both a reduplicative prefix and a glottalisation feature. It is the latter property that interests us here. The data in (52) illustrate the fact that glottalisation targets the rightmost sonorant of a stem. When a sonorant is stem-final, it is glottalised (52a,b). When a segment that is not a sonorant consonant intervenes, glottalisation skips it to affect a preceding sonorant consonant (52c,d). Crucially, even potentially glottalisable segments such as stops (52e) and affricates (52f) are skipped. (Note that glottalised sonorants occur only postvocalically in Sliammon, as in Yowlumne.)

(52) *Glottalisation of sonorants in Sliammon*

a.	t͡ɬ’əχʷaj	t͡ɬ’it͡ɬ’χaj̰	‘chum salmon/small salmon’
b.	qʷ’at’əm	qʷ’aqʷ’ət’əm̰	‘river/creek’
c.	walθ	wʌwal̰eθ	‘bullfrog/small ...’
d.	qʷ’aji	qʷ’aqʷ’aj̰i	‘talk/talking’
e.	juwəkʷ	jujəw̰əkʷəɬ (*jujəwəkʷ’əɬ)	‘wave/small ...’
f.	qʷ’ət͡θ’əm	qʷ’iqʷ’t͡θ’em̰t͡ʃ (*qʷ’iqʷ’t͡θ’emt͡ʃ’)	‘jump/I am jumping’

Morphologically-triggered sonorant glottalisation also occurs in Oowekyala (Howe 2000), a North Wakashan language with full sets of glottalised stops/affricates and glottalised sonorants.

(53) *Consonant inventory of Oowekyala*

Plain stops and affricates	p	t	t͡s	t͡ɬ	k	kʷ	q	qʷ	
Voiced stops and affricates	b	d	d͡z	d͡ɮ	g	gʷ	ɢ	ɢʷ	
Glottalised stops & affricates	p	t’	t͡s’	t͡ɬ’	k’	kʷ’	q’	qʷ’	
Fricatives			s	ɬ	x	xʷ	χ	χʷ	
Nasals	m	n							
Glottalised nasals	m̰	n̰							
Liquids and glides				l	j	w			h
Glottalised liquids & glides				l̰	j̰	w̰			ʔ

[19] /L/ alternates [w ~ j ~ ɬ]; /d͡ʒ/ alternates [d͡ʒ ~ j ~ i ~ t͡ʃ]; /g/ alternates [g ~ w ~ u ~ xʷ] (Blake 1995).

The plural in this language involves not only C[i]-reduplication but also glottalisation of root-initial modal sonorants, as shown in (54a). Examples in (54b) (Howe 2000) show that root-initial obstruents are unaffected by the process of glottalisation, in spite of the fact that they are (i) glottalisable segments in Oowekyala in general, and (ii) glottalisable segments in the plurals where the source of glottalisation is the root, not the affix.

(54) *Singular/plural pairs in Oowekyala*

a.	mam	mim̰am	'bed'	b.	pais	pipais	'flounder'
	nusa	nin̰usa	'to recount'		təwa	titəwa	'to walk'
	naq'bu	nin̰aq'bu	'thirsty'		qsu	qiqsu	'you, it's you'
	wiːkʷ	wiw̰iːkʷ	'eagle'		t͡ɬ'aː	t͡ɬ'it͡ɬ'aː	'black bear'
	jlχa	jij̰lχa	'to rub'		j̰ak	j̰ij̰ak	'bad'
	husa	hiʔusa[20]	'to tally'		l̰uxʷʔit	l̰il̰uxʷʔit	'to faint'
	japa	jij̰apa	'to send s.o.'		kʷ'xʷa	kʷ'ikʷ'xʷa	'to suck'
	wuːχʷla	wiw̰uːχʷla	'to toot'		ʔukʷ	ʔiʔukʷ	'to pity'
	lant͡sa	lil̰ant͡sa	'to go underwater'		ɬmba	ɬiɬmba	'moored to the end'

Our last example is provided by Klamath (Barker 1964). The consonant inventory of this Plateau Penutian language is given here, illustrating that like Yowlumne, Sliammon and Oowekyala, Klamath has a full range of glottalised stops and affricates and glottalised sonorants.[21]

(55) *Consonant inventory of Klamath*

Plain stops and affricates	p	t		t͡ʃ	t͡ɬ	k		q	
Aspirated stops and affricates	pʰ	tʰ		t͡ʃʰ	t͡ɬʰ	kʰ		qʰ	
Glottalised stops & affricates	p'	t'		t͡ʃ'	t͡ɬ'	k'		q'	ʔ
Fricatives			s						h
Nasals	m	n							
Aspirated nasals	m̥	n̥							
Glottalised nasals	m̰	n̰							
Liquids and glides					l	j	w		
Aspirated liquids and glides					l̥	j̥	w̥		
Glottalised liquids & glides					l̰	j̰	w̰		

We find evidence that copying prefixes in Klamath were (at least historically) accompanied by a floating glottalisation feature that targeted stem-initial sonorants only. As Kingston (1985:285) describes: "In the majority of cases where a morpheme beginning

[20] Note that laryngeals pattern with sonorants in this respect.

[21] This table leaves out ŋ and ɴ which "can be derived by a general rule or nasal assimilation from /n/" (White 1973:8).

with a sonorant is reduplicated, the original sonorant, but not the one in the reduplicated syllable shows up glottalized.” Compare the reduplicative forms in (56a) with those in (56b), where sonorant glottalisation is underlying. The example in (56c) shows that “[r]eduplicative glottalization is not always found with morphemes beginning with sonorants … but it applies more often than not” (Kingston 1985:287). Similarly, Kisseberth (1972:6, fn. 8): “Only sonorants show up glottalized in prefixed forms, and then only under special circumstances and with some irregularity.”

(56) *Distributive reduplication in Klamath*

a.	manq^h	‘housefly’	→	mam̰anq’aːk	‘little flies’ (dist.)
	meja	‘digs roots’	→	mem̰iː	‘digs roots’ (dist.)
	noːka	‘is cooked’	→	non̰oːka	‘are cooked’ (dist.)
	leːw̰a	‘plays’	→	lel̰eːw̰a	‘play’ (dist.)
	loːtʃw̰a	‘refl. covets’	→	lol̰oːtʃw̰a	‘refl. covet’ (dist.)
	weːt͡s’a	‘slobbers’	→	wew̰eːt͡s’a	‘slobber’ (dist.)
	jan̥w̥a	‘weakly’	→	jaj̰an̥w̥aːni	‘weak ones’ (dist.)
b.	m̰aːk^h	‘body hair’	→	m̰am̰aːk^{h}s	‘body hair’ (dist.)
	n̰aːq’a	‘brown bear’	→	n̰an̰aːq’aʔaːk	‘brown bears’ (dim. dist.)
	l̰ot͡s^{h}p^{h}ka	‘is kneeling’	→	l̰ol̰ot͡s^{h}p^{h}ka	‘kneel’ (dist.)
	w̰alq’at͡s^{h}ka	‘fisher’	→	w̰aw̰alq’at͡s^{h}kaʔaːk	‘little fishers’ (dist.)
	j̰am̥t^{h}ki	‘forgets’	→	j̰aj̰am̥t^{h}ki	‘forget’ (dist.)
c.	weːʔas	‘child’	→	weweːʔas	‘children’

To summarise, we have illustrated the process of sonorant glottalisation in languages from diverse linguistic groupings (Yok-Utian, Salishan, Wakashan, and Plateau Penutian). In the following sections we discuss two possible explanations of this pattern of glottalisation. The first, due to Steriade (1997), is that a sonorant-specific feature [creak] causes sonorant glottalisation. We show the inadequacy of such an approach and argue instead that sonorant glottalisation follows directly from treating the harmonic scale for glottalisation as faithfulness.

3.3. Sonorant glottalisation as [creak]?

Steriade (1997) and Zoll (2001) attribute the asymmetric patterns of glottalisation described in the previous section to differential phonetic realisation: glottalised sonorants are creaky voiced while glottalised obstruents are ejectives. By establishing [creak] and [ejection] features on the basis of such phonetic distinctions (cf. Flemming 1995, 2001), the “floating” affixal property can be identified as [creak] and its restriction to sonorants then follows. The proposed separation of [ejection] and [creak] is possible for Yowlumne – the case which Steriade and Zoll discuss – but is problematic in the broader context of glottalisation facts.

If [creak] is defined independently of [ejection], as argued by Steriade (1997) and Zoll (2001) for Yowlumne, then nothing prevents [creak] from appearing in languages without [ejection]. But as seen in §3.1, there is an implicational relation between “creak” (constricted glottis on resonants) and “ejection” (constricted glottis on obstruents). If a language exhibits creaky resonants, it also exhibits ejectives. It would be possible, of course, to rank constraints against [creak] and [ejection] harmonically.

(57) *[creak] ≫ *[ejection]

But even this would not achieve the implicational relation between the two segment types. If there are two faithfulness constraints, say MAX[creak] and MAX[ejection] (or equivalently IDENT[creak] and IDENT[ejection]), then by ranking faithfulness to [creak] above the prohibitions and faithfulness to [ejection] below them, the grammar would (falsely) allow glottalised resonants but rule out ejectives.

(58) MAX[creak] ≫ *[creak] ≫ *[ejection] ≫ MAX[ejection]

The separation of [ejection] and [creak] is also problematic for the treatment of glottalising affixes in many languages. For instance, in his *Klamath Grammar*, Barker (1964:263) posits a “morphophoneme ||’||, which is represented on the phonemic level by the glottalisation of some neighboring consonant”, and which Blevins (1993:266) interprets as “a floating [constricted glottis] feature”. Crucially, this feature, which accompanies the diminutive /-ˀaːk’/ for example, affects obstruents (59a) as well as sonorants (59b). As Kingston (1985:285) remarks: “Clearly both stops and sonorants can be glottalized by floating glottalization to their right.” Note, too, that with vowel-final stems (59c) glottalisation is realised as [ʔ], which involves a “constricted glottis” to be sure, but not necessarily “ejection” or “creaky voice”.

(59) *Klamath diminutive*

a.	/RED + manqʰ + ˀaːk’/	→	mam̰anq’aːk	‘little flies’ (dist.)
	/RED + n̰epʰ + ˀaːk’/	→	n̰enp’aːk	‘little hands’ (dist.)
	/RED + pʰet͡ʃʰ + ˀaːk’/	→	pʰept͡ʃ’aːk	‘little feet’ (dist.)
b.	/RED + qt͡ʃʰuːl + ˀaːk’/	→	qt͡ʃʰuqt͡ʃʰuːl̰aːk	‘little stars’ (dist.)
	/RED + som + ˀaːk’/	→	sosm̰aːk	‘little mouths’ (dist.)
	/RED + ʔankʰu + ˀaːk’/	→	ʔaʔankw̰aːk	‘little buffalo’ (dist.)
	/RED + ʔankʰu + ˀaːk’/	→	ʔaʔankw̰aːk	‘little buffalo’ (dist.)
c.	/RED + kʰow̰e + ˀaːk’/	→	kʰokw̰eʔaːk	‘little frogs’ (dist.)
	/RED + moq’oːka + ˀaːk’/	→	momq’oːkaʔaːk	‘little mice’ (dist.)

With a single feature, [constricted glottis], a pattern such as this is straightforwardly accounted for. If [creak] and [ejection] are distinguished, a unified account of Klamath is not possible.

Also in Kwakw’ala (North Wakashan: Boas 1947:302) as well as in Nisga’a (Tsimshian: Tarpent 1987) one finds numerous cases in which both sonorants and obstruents are glottalised by the same feature, presumably [constricted glottis]. These languages are especially revealing because they lack glottalised fricatives, yet glottalisation targets fricatives anyhow, turning them into glottalised sonorants (see Howe 1996, 2000 for an explanation).

(60) *Kwakw'ala glottalising suffix:* /-ˀm/ 'really'

a. *Stops*	/RED-giq-ˀm/	gəgiq'əm	'really a chief'
	/RED-łakʷ-ˀm/	łəłakʷ'əm	'really strong'
	/RED-glt-ˀm/	gəglt'əm	'really long'
b. *Sonorants*	/RED-w̰n-ˀm/	w̰əw̰ən̰əm	'really to hide'
	/RED-k'n-ˀm-xʔid/	k'ək'ən̰əmxʔit	'to get really loose'
	/RED-ml-ˀm-xʔid/	məməl̰əmxʔit	'to get really twisted'
	/RED-q'j-ˀm/	q'əq'əj̰əm	'really many'
	/RED-bw-ˀm/	bəbəw̰əm	'really to leave'
c. *Fricatives*	/RED-baχʷ-ˀm/	bəbaw̰əm	'really to swell'
	/RED-t͡s'uł-ˀm/	t͡s'ət͡s'ul̰əm	'exclusively black'
	/RED-pas-ˀm/	pəpaj̰əm	'real flounder'

(61) *Nisga'a glottalising suffix: indefinite antipassive* /-ˀskʷ/

a. *Stops*	/kíp-ˀskʷ/	gíp'iskʷ	'to eat berries while picking'
	/júːłimq-ˀskʷ/	júːłimq'askʷ	'to give advice to, tell s.o. how to behave'
	/jat͡s-ˀskʷ/	jat͡s'iskʷ	'grass (lit. covering)'
	/t͡sakʷ-ˀskʷ/	d͡zakʷ'iskʷ	'animal (lit. killing)'
b. *Sonorants*	/łimoːm-ˀskʷ/	łimoːm̰iskʷ	'to help out (traditional requirement)'
	/siːlín-ˀskʷ/	siːlín̰skʷ	'to hunt'
	/swán-ˀskʷ/	swán̰skʷ	'to blow on sth. (shaman cure)'
	/sə-táːw-ˀskʷ/	sidáːw̰iskʷ	'to freeze food'
c. *Fricatives*	/t'axʷ-ˀskʷ/	t'aw̰iskʷ	'to sweep'
	/luxʷ-ˀskʷ/	luw̰skʷ	'to be stingy, possessive, to refuse'
	/wilaːxʲ-ˀskʷ/	wilaːj̰iskʷ	'[a] relative (lit. knowing)'

The same pattern occurs in Nuu-chah-nulth (South Wakashan: Rose 1976, Howe 1996, Kim 1999, Pulleyblank 2003b). Before glottalising suffixes, stops become ejective (62a), except that uvulars become a preglottalised pharyngeal approximant [ʕ̰] (62b) —a general property of Nuu-chah-nulth; see Jacobsen (1969), Shank and Wilson (2000). Sonorants also become preglottalised (creaky) sonorants (62c), as do fricatives (62d). Vowel-final stems surface with [ʔ] (62e) (as in Klamath; recall (59e)). Once more, the simplest explanation is that the glottalising suffixes have a floating phonological feature [constricted glottis], which includes both ejection and creaky voice, as well as [ʔ].[22]

[22] The forms in (62c) are from George Louie (Ahousaht; Nakayama 1997:16). Kim (2002) argues on the basis of data that she has collected from the Ahousaht dialect of Nuu-chah-nulth that the glottalisation of sonorants is rare and exceptional, with the robust pattern exhibiting only the glottalisation of obstruent stops and fricatives. Two points are relevant. First, stem-final sonorants are very rare in the first place; only nasals are attested. Second, stem-final fricatives exhibit two patterns (i) fricatives that become glides when glottalised, (ii) fricatives that resist glottalisation and form fricative-glottal stop clusters. See Pulleyblank (2003b)

(62) *Some glottalising suffixes in Nuu-chah-nulth*

a.	/jat͡s-ˀas/	[jat͡s’as]	‘walk outside’	walk-outside
	/wik-ˀaħs/	[wik’aħs]	‘nothing in a canoe’	not-in a vessel
	/ʔinkʷ-ˀaħs/	[ʔinkʷ’aħs]	‘lamp, ceiling light’	fire-in a vessel
b.	/w̰aʃq-ˀaqt͡ɬ/	[w̰aʃʕ̰aqt͡ɬ’asna]	‘grouped inside’	together-inside
	/taːna(q)-ˀaqt͡ɬ/	[taːnaʕ̰aqt͡ɬiɬ]	‘bank’	money-inside
	/taːna(q)-ˀaɬuk(RED)/	[taːtaːnaʕ̰aɬuk]	‘cashier’	money-look after
	/t͡ʃ’iːq-ˀaqa/	[t͡ʃ’iːʕ̰aqa]	‘fighting’	fight-severally do
c.	/CV-ʔam-ˀiħta-ʔiː/	[ʔaʔam̰iħtaʔi]	‘the ends’	DIST-LOC-end-DEF
	/muw(at͡ʃ)-ˀiːt͡s/	[muw̰iːt͡s]	‘to eat deer’	deer-eat
d.	/t͡ʃamas-ˀaqt͡ɬ/	[t͡ʃamaj̰aqt͡ɬ]	‘pie’	sweet-inside
	/hiɬ-ˀaħs/	[hij̰aħs]	‘inside a canoe’	there-vessel
	/hiɬ-ˀaqt͡ɬ/	[hij̰aqt͡ɬ]	‘inside’	there-inside
	/ʔuxʷ-ˀiːt͡ɬ/	[ʔuw̰iːt͡ɬ]	‘fall on the ground’	fall-ground
	/t͡s’axʷ-ˀaqt͡ɬ/	[t͡s’aw̰aqt͡ɬ]	‘spear inside’	spear-inside
e.	/hi-ˀiːt͡s/	[hiʔiːt͡s]	‘eat up all food’	it-eat
	/ʔuː-ˀaɬuk/	[ʔuːʔaɬuk]	‘take care of sth.’	it-look after

In the Hokan language Kashaya, too, Buckley (1990:9) reports that “the Assertive morpheme is a floating [+constricted glottis] feature which links to an immediately preceding consonant, thereby glottalizing it” (see also Buckley 1994:68–9, 99–100, Fallon 2002:303–4). Obstruents (63a) and sonorants (63b) are both affected by the same glottalising feature. With vowel final stems (63c) the glottal feature surfaces as [ʔ], again as in Klamath (59e) and Nuu-chah-nulth (62e). The feature is lost when added to stems ending in a consonant that is already specified for a laryngeal feature (63d).

(63) *Kashaya assertive*

a.	ʃeʔet̪ + ˀ	→	ʃeʔet̪’	‘it’s a basket’
	watat͡ʃ + ˀ	→	watat͡ʃ’	‘it’s a frog’
b.	t͡ʃ’iʃkan + ˀ	→	t͡ʃ’iʃkan̰	‘it’s pretty’
	t͡ʃ’ahaw + ˀ	→	t͡ʃ’ahaw̰	‘it’s a boil’
c.	haju + ˀ	→	hajuʔ	‘it’s a dog’
	k’ili + ˀ	→	k’iliʔ	‘it’s black’
d.	bot’ + ˀ	→	bot’	‘it’s soft’
	dolom̰ + ˀ	→	dolom̰	‘it’s a wildcat’
	kilakʰ + ˀ	→	kilakʰ	‘it’s warm’

Also in Kashaya, coronal stops systematically debuccalise in regressive coronal dissimilation (Buckley 1994:91, 160, 165, Fallon 2002:169). Of special interest is that ejectives (64b)

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for discussion.

and glottalised nasals (64c) both debuccalise as [ʔ], once again presumably because they share the feature [constricted glottis].

(64) *Coronal debuccalisation in Kashaya*

a.	/hotʰ-t̺ʰ/	→	hoht̺ʰ	‘it wasn’t warm’
cf.	/hotʰ/	→	hotʰ	‘warm’
b.	/t͡ʃa-at͡ʃ’-t̺i/	→	t͡ʃaʔt̺i	‘about to fly (pl.)’
cf.	/t͡ʃa-at͡ʃ’-qa/	→	t͡ʃat͡ʃ’qʰ	‘must have flown (pl.)’
c.	/t͡ʃan̰-t̺ʰ/	→	t͡ʃaʔt̺ʰ	‘didn’t look’
	/t͡ʃan̰-ʃe/	→	t͡ʃaʔʃe	‘I wonder if he looked’
cf.	/t͡ʃan̰-pʰi/		t͡ʃan̰pʰi	‘if he sees’

Finally, glottalisation is also caused by underlyingly glottalised nasals, which regularly denasalise in syllable-onset position, for example, [t͡ʃan̰] ‘looked (factive), [t͡ʃan̰-pʰi] ‘if he sees’, but [t͡ʃad-u] ‘look!’ (Buckley 1990; see Howe and Pulleyblank 2001 for an explanation). When the preceding segment is a consonant, “the nasal spreads its glottalization to the preceding segment before undergoing oralization” (Buckley 1990:13, also Fallon 2002:170). Again, obstruents (65a) and sonorants (65b) are both affected in this manner. Moreover, this process of “glottal transfer” (Buckley 1994) feeds coronal stop debuccalisation (64), yielding [ʔ] (65c). As always, such interactions are easier to understand if [constricted glottis] underlies creakiness, ejection, and glottal stop.

(65) *Kashaya*

a.	n̰aʰjut + m̰a	→	dahjut’ba	‘after rubbing’
	t͡ʃaʰnot͡ʃ + m̰a	→	t͡ʃahnot͡ʃ’ba	‘after speaking’
b.	pʰanem + m̰a	→	pʰanem̰ba	‘after punching’
	n̰uʰtaj + n̰o	→	duhtaj̰do	‘they say he touched’
c.	n̰a + ʰjut̺ + n̰o	→	dahjuʔdo	‘they say he broke it’
cf.	n̰a + ʰjut̺ + qa	→	dahjut̺ʰqʰ	‘must have broken it’

In short, unless [creak] and [ejection] are the same feature, [constricted glottis], there is no unified treatment of the glottalising affixes in, for example, Klamath, Kwakw’ala, Nisga’a, Nuu-chah-nulth and Kashaya (also Heiltsuk and Oowekyala; see Howe 1998, 2000, Pulleyblank 2003b). In the next section we show that distinguishing between [creak] and [ejection] features is not necessary to explain asymmetric patterns of glottalisation, that is, we can explain patterns that single out either stops or sonorants with the unified feature [constricted glottis].

3.4. Harmony as faithfulness

Neither the harmony-as-markedness approach (43a) nor the harmonically ranked *creak ≫ *ejection appoach (57) can account for the patterns where morphologically induced glottalisation favours sonorants over obstruents. Indeed, these accounts predict exactly the opposite.

Consider first the harmony-as-markedness approach. Since the relevant languages allow both ejectives and glottalised sonorants, MAXCG must be ranked above the prohibitions on [constricted glottis] occurring with sonorants and obstruent stops. To ensure that the affixally introduced glottalisation feature is linked, not simply retained as a floater, we assume a constraint PARSECG (a [constricted glottis] specification must be associated to a prosodic anchor; see Akinlabi 1996, Zoll 1998, Pulleyblank 1996, etc.). PARSECG could be ranked in three ways relative to the other constraints.

(66) *Harmony-as-markedness*

a. Glottalisation targets both obstruent stops and sonorants

MAXCG, PARSECG ≫ *CG/SON ≫ *CG/STOP

b. Glottalisation targets obstruent stops but not sonorants

MAXCG ≫ *CG/SON ≫ PARSECG ≫ *CG/STOP

c. Glottalisation targets neither obstruent stops or sonorants

MAXCG ≫ *CG/SON ≫ *CG/STOP ≫ PARSECG

The ranking in (66a) would ensure that affixally introduced glottalisation would link to both sonorants and obstruents —the pattern for languages like Kashaya. The ranking in (66c) would prevent any affixal glottalisation from associating —a case of emergence of the unmarked. Of core interest here is the ranking in (66b). As shown in (67), this ranking would produce preferential association to the unmarked class, ejectives, rather than association to the class of sonorants.

(67) *Floating glottalisation added to stops but not to sonorants*

		MAXCG	*CG/SON	PARSECG	*CG/STOP
[c.g.] /p/	☞ a. [p’]				*
	b. [p] <?>			*!	
	c. [p]	*!			
[c.g.] /m/	a. [m̰]		*!		
	☞ b. [m] <?>			*	
	c. [m]	*!			

The incorporation of a constraint like PARSE into a harmonic constraint set such as (57) would also produce an adverse result (cf. Kim 1999 on Nuu-chah-nulth):

(68) *Harmonically ranked creak and ejection*

a. Both obstruent stops and sonorants undergo glottalisation

PARSE[creak], PARSE[ejection] ≫ *creak ≫ *ejection

b. Obstruent stops but not sonorants undergo glottalisation

PARSE[ejection], *creak ≫ *ejection, PARSE[creak]

c. Sonorants but not obstruent stops undergo glottalisation

PARSE[creak] ≫ *creak ≫ *ejection ≫ PARSE[ejection]

d. Neither obstruent stops or sonorants undergo glottalisation

*creak ≫ *ejection ≫ PARSE[creak], PARSE[ejection]

This interaction fails to explain the cross-linguistic generalisation described in §3.1, since nothing *a priori* favours sonorant-only glottalisation (68c) over obstruent-only glottalisation (68b). Comparable to the harmony-as-markedness approach (66), (57) falsely predicts that crosslinguistically the ranking (68b) ought to be preferred over the ranking (68c) — obstruent glottalisation (ejection) is less marked than sonorant glottalisation (creakiness).

Consider now the alternative possibility that the harmonic ranking between glottalisation in stops and glottalisation in sonorants is encoded as faithfulness: FAITHCG/STOP ≫ FAITHCG/SON.[23]

(69) *Harmony-as-faithfulness* (=(43b))

a. MAXCG/STOP ≫ MAXCG/SON

b. DEPCG/STOP ≫ DEPCG/SON

The MAX scale of this hierarchy can explain the “markedness” patterns associated with glottalisation, such as (i) why glottalised sonorants are less frequent than glottalised stops, (ii) why glottalised sonorants are lost diachronically more frequently than glottalised stops, and (iii) why glottalised sonorants but not glottalised stops are excluded from baby-talk (§3.1). This is illustrated in (70).

(70) *Glottalisation excluded from sonorants but not from stops*

		MAXCG/STOP	*CG	MAXCG/SON
/p’/	a. [p’] ☞		*	
	b. [p]	*!		
/m̰/	a. [m̰]		*!	
	b. [m] ☞			*

Crucially, the harmonic ranking of glottalisation through faithfulness FAITHCG/STOP ≫ FAITHCG/SON also predicts that floating glottalisation may target just sonorants (§3.2).

[23] We assume an asymmetric interpretation of these constraints with respect to inputs and outputs. For the MAX constraints, we assume that MAXF/Y is violated if F is associated to Y in the input and not present in the output; for the DEP constraints, we assume that DEPF/Y is violated if F, not present in the input, is associated to Y in the output.

The reason is that according to the DEP scale, adding [c.g.] to a sonorant is a lesser violation of faithfulness than adding [CG] to a stop. This is illustrated in the following tableau.

(71) *Floating glottalisation added to sonorants but not to stops*

		DEPCG/STOP	PARSECG	DEPCG/SON
[c.g.] /p/	a. [p’]	*!		
	b. [p] ☞		*	
[c.g.] /m/	a. [m̰]			*
	b. [m] ☞		*!	

In sum, treating harmony as faithfulness allows us to account for the implicational relation between glottalisation on obstruents and sonorants, and for the languages where glottalisation specifically targets sonorants.[24] Our treatment of such asymmetries begs the following question: why should a grammar choose to encode a harmonic scale as faithfulness? As discussed with regard to vowel quality (§2), the essential idea is that faithfulness moderates the perceptual consequences of structural change. To be concrete, consider van Eijk’s (1997:11) comments on glottalised sonorants in St’at’imcets Salish (a.k.a. Lillooet):

> “Glottalization of resonants consists of a tightening of the vocal cords rather than a complete closure (the latter is the case in glottalized obstruents and in the resonant ʔ). As a result, glottalized resonants are (1) pronounced with ‘creaky voice’ but not as ejectives, and (2) <u>phonetically closer to non-glottalized resonants than glottalized obstruents are to non-glottalized obstruents</u>.” (our emphasis)

The grammatical reflex of what we hypothesise to be a perceptual difference between “ejection” and “creakiness” (Steriade 1997) is that modification of glottalisation on obstruents (loss/addition) incurs more important violations of faithfulness constraints than with sonorants.[25]

[24] A reviewer avers that our analysis predicts the ranking [DEPCG/STOP ≫ DEPCG/SON, PARSECG ≫ *CG ≫ MAXCG/SON ≫ DEPCG/SON], which would derive glottalised sonorants in a language that otherwise lacks such segments. At present we are unable to confirm the existence of such a system, though we know of many cases in which other floating features create supposedly ungrammatical segments. For instance, the docking of floating tones (supplied by the grammar, or resulting from vowel deletion) often creates types of tone that are normally avoided in a given tonal language (see, e.g., Rice 1989 on Slave). A stylistically-provided floating [nasal] docks onto /d, l, b/ in Quileute, creating nasal consonants in this otherwise fully oral language (Zoll 1998:145). If this typological prediction of our analysis is truly pathological, it could be avoided by abandoning PARSECG. Indeed, the PARSE family of constraints has been gradually supplanted by the MAX family of constraints since McCarthy and Prince (1995). In particular, Zoll (1998) and Pulleyblank (1998) argue for replacing PARSE[FEATURE] with MAX constraints. We cannot delve into the details and consequences of such proposals here.

[25] A reviewer reminds us that Kingston (1985) gives an alternative *articulatory* explanation for phonological differences between ejectives and glottalised sonorants. He claims that glottalisation is anchored articulatorily to the release of stops, and uses this to explain the fact that “glottal articulations are less stablely associated with sonorants than stops” (p. 253). Kingston’s statements make it clear, however, that perception

4. CONCLUSION

Consider the following remark by Prince and Smolensky (1993:136) on the *alignment* of prominence scales like ⟦a > b⟧ (not to be confused with McCarthy and Prince's notion):

> [T]here are two essentially equivalent ways to enter the alignment into universal grammar. The first is to assert that the constraint hierarchies C_X ⟦*X/b $\gg$ *X/a⟧, C_Y ⟦*Y/a $\gg$ *Y/b⟧ of constraint alignment are universal, that they must be incorporated into the particular constraint hierarchy of any language. The second is to assert that the Harmony scales H_X ⟦X/a $\succ$ X/b⟧ , H_Y ⟦Y/b $\succ$ Y/a⟧ of harmonic alignment are universal, and the constraints *X/α, *Y/α are universal; particular languages must order these constraints in a way consistent with H_X, H_Y. It then follows as a consequence that individual languages' constraint hierarchies will always contain the sub-hierarchies C_X ⟦*X/b $\gg$ *X/a⟧, C_Y ⟦*Y/a $\gg$ *Y/b⟧, i.e. satisfy constraint alignment.

Observe that under either view of UG, constraints are assumed to be markedness-based. This assumption is natural for Prince and Smolensky, since they define even faithfulness constraints in terms of structural markedness.[26] However, in current Optimality Theory (e.g., McCarthy and Prince 1995) markedness and faithfulness are not equated, but are considered formally distinct types of constraints. And yet, most research continues to assume a markedness-based view of all harmonic relations in UG, for example:

> [T]he ranking of constraints that govern markedness relations along a single dimension (such as place of articulation) is universally fixed. … Presumably this ranking is universal, hence respected by every constraint hierarchy. (Kager 1999a:44)

> If, as in H_X, ⟦X/a $\succ$ X/b⟧, then as in C_X, ⟦*X/b $\gg$ *X/a⟧. In other words, for ***a*** to be a better instance of *X* than *b* is, the constraint against *X/b* must dominate the constraint against *X/a*. (McCarthy 2002:22)

As described in the introduction, a number of investigators (among them Kiparsky 1994, Gnanadesikan 1995, Jun 1995, Pater 1997, Pulleyblank 1998, de Lacy 2002, Pater and Werle to appear) have questioned the mechanized treatment of harmony as marked-

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plays a central role in "articulatory binding", e.g.: "The burst of noise which occurs at the release of the stop is an acoustically salient event to which glottal articulations which in one way or another contribute to changes in intraoral air pressure during the stop may be anchored." (p. 246); "The result of anchoring the glottal articulation to the release of the stop is that the acoustic effects of the glottal articulation will be packed into the brief interval between the stop and a following vowel" (p. 245); "…as a result of binding glottal articulations to the stop release, the consonant-vowel transition contains the essential cues to the glottal, as well as oral, type of the stop" (p. 251); "segments of equal and maximum obstruency competed for the glottal feature; the winner was the stop whose release would be most perceptually salient" (p. 320).

[26] "[T]he Faithfulness family of constraints … declare that perfectly well-formed syllable structures are those in which input segments are in one-to-one correspondence with syllable positions" (p. 85–6).

ness. They argue that at least some harmonic relations are better captured as faithfulness hierarchies which forestall changes involving *less* harmonic elements. For instance, encoding the scale of articulatory complexity ⟦COR ≻ LAB⟧ as faithfulness ⟦FAITHLAB ≫ FAITHCOR⟧ guarantees that labials are preferentially preserved in deletion and also that coronals are favoured in epenthesis. Our study builds on such work, but with a difference: we have demonstrated that at least two perceptually-motivated harmonic scales —one concerning vowel quality, the other concerning glottalisation on consonants— need to be grammatically encoded as faithfulness hierarchies which ensure that *more* harmonic elements are more faithfully adhered to.

(72) *Harmony as faithfulness*

a. *Vowels*
⟦NONHI ≻ HI⟧, |NONHI| > |HI|
∴ ⟦FAITHNONHI ≫ FAITHHI⟧

b. *Glottalisation*
⟦CG/STOP ≻ CG/SON⟧, |CG/STOP| > |CG/SON|
∴ ⟦FAITHCG/STOP ≫ FAITHCG/SON⟧

In each case, we have observed that all of deletion, insertion, and association appear to target preferentially segments and feature combinations that are lower on the harmony scale. In seeking to provide an explanation for these observations, we have hypothesised that the driving force behind the strength of a faithfulness constraint is perceptibility. We have suggested that those segments that are more perceptible rank higher on the relevant scale than those segments that are less perceptible, and that faithfulness acts like a constraint on inertia: deviations from input are optimal when perceptibly minimal. Hence segments that rank high on a scale of perceptibility will be retained over segments that rank low because the loss of a highly perceptible segment causes a greater perturbation of the string. Similarly, the creation of a highly perceptible segment by insertion or association will constitute a greater deviation from the input, and hence be nonoptimal. We have argued that surface representations are therefore not guided simply by the optimality of the segments involved, but by the optimality of the perceptual match between each unfaithful map (a↦b, a≠b) and the fully faithful one (a↦a).

APPENDIX

Front vs. back vowels: a non-harmonic relation

As described in §2.1, the height-based sonority scale LOW > MID > HIGH (6) is well motivated not only phonetically (Parker 2002, Kent and Read 2002) but also phonologically. We saw that Nakanai reduplication emulates this scale ((7), (12), (13)). Vowel height has also been found to be deterministic in several metrical systems (Kenstowicz 1997). For instance, in Kobon (Papuan: Davies 1981) stress is regularly penultimate (e.g., *dʒínup#dʒínup* 'to make squeaking noise'), but it is final just in case the last vowel is more sonorous. Specifically, stress shows a preference for low vowels over mid vowels (e.g., *kɨdolmáŋ* 'arrow type'; cf. *hagápe* 'blood'), and for mid vowels over high vowels (e.g., *si.óg* 'bird sp.'; cf. *mó.u* 'thus'). Similarly, Haraguchi (2001) describes a regular lexical process in Tsuruoka Japanese that shifts pitch accent to a following mora (e.g., /tó-deba/ → [todéba] 'take-COND', /tó-ta/ → [tottá] 'take-PAST') except if the following vowel is high (e.g., /tó-ru/ → [tóru], *[torú] 'take-PRES').

In contrast, there is little if any ground for a sonority distinction between front and back vowels.[27] Plausible phonetic correlates of sonority (F_1, duration, intraoral air pressure, etc.) do not consistently discriminate between front vowels [i, y, ɪ, e, ɛ, æ] and back ones [ɨ, u, ʊ, o, ɔ, ɑ] (Parker 2002, Kent and Read 2002), and phonological evidence for such a distinction in sonority is also lacking. For instance, there are no reported patterns similar to Nakanai reduplication but involving a front-back distinction among vowels. And as de Lacy (2002:93) remarks: "There are no stress systems in which … backness in vowels plays a role in assigning stress."[28] Finally, phonological processes that treat front and back vowels differentially provide conflicting evidence with regard to sonority.

Consider deletion first. Only high front vowels delete in many languages, including Cherokee (Flemming 1996) and Brazilian Portuguese (Abaurre et al. 2001). Moreover, deletion processes that affect all high vowels, such as syncope in Canadian French (17), may nonetheless show a preference for high front vowel deletion (Gendron 1966:150–1, Walker 1984:75, Dumas 1987:104). For instance, recall that in Ekiti Yoruba (23) high vowels delete in favour of nonhigh vowels in hiatus context. Crucially, when both vowels involved are high, front vowels delete in favour of back ones, e.g., [ɛrõ ìgbĩ̂] → [ɛrõ̀õgbĩ̂] 'mouth of snail', [etí ulé] → [etúulé] 'near house'. In our approach this implies that MAXHIGHFRONT is distinct and ranks lower than other faithfulness constraints. The effect of this distinction is illustrated in the following tableau.

(73) *Hiatus resolution in Ekiti Yoruba: HI][HI*

		NOHIATUS	MAXNONHI	MAXHIBK	ANCHORL	MAXHIFR
[ɛrõ ìgbĩ̂]	[ɛrõìgbĩ̂]	*!				
	[ɛrĩ̀ĩgbĩ̂]			*!		
	☞ [ɛrõ̀õgbĩ̂]				*	*
[etí ulé]	[etíulé]	*!				
	☞ [etúulé]					*
	[etíilé]			*!	*	

But the ranking MAXHIBK ≫ MAXHIFR is not fixed across languages. For instance, only high back vowels are targeted by deletion in other languages, such as Kashmiri (Indo-Aryan; Koul 2003:12–3, 16) where back [ɨ, u] but not front [i] regularly syncopate —a pattern that suggests the ranking MAXHIFR ≫ MAXHIBK.

[27] Work such as Kenstowicz (1997), Shaw et al. (1999) and Hargus (2001) introduces schwa into the hierarchy, ranked as less sonorous than all other vowels. Schwa is shorter and less intense than any other vowel though it behaves phonetically as a mid vowel in terms of F_1 frequency, intraoral air pressure and total air flow (Parker 2002:234). [ə] is often assumed to be nonmoraic because of its extreme brevity and its weightless behaviour in (metrical) phonology; see Shaw et al. (1999) on Salish, Hammond (1999) on English, Crosswhite (2001) on Mari, etc.

[28] According to Kenstowicz (1997, see also de Lacy 2002), Kobon stress treats central [ɨ] as less sonorous than peripheral [i,u] but relevant examples (e.g., *mú.ɨs* 'fungus sp.') show penultimate stress, which is expected in the event of a tie in sonority; cf. *dúbu#dúbu* 'to make noise by footsteps', *kɨdʒígɨl* 'tattoo'.

(74) *Kashmiri* (Koul 2003:12-3, 16)

a.	gobur 'son' + -is 'to'	→	gobris	'to the son'
b.	nəgɨr 'town' + -as 'to'	→	nəgras	'to the town'
c.	gɑgɨj 'turnip' + -i 'pl.'	→	gɑgji	'turnips'
d.	gagɨr 'rat' + -i 'pl.'	→	gagri	'rats'

In Korean (Ahn 1991), too, only back [ɨ] drops when adjacent to another vowel across a morpheme boundary:[29]

(75) *Korean*

a.	po-ɨlə	[poɾə]	'in order to see'
	cf. mak-ɨlə	[magɨɾə]	'in order to block'
b.	camkɨ-i	[camgi]	'to be locked'
	cf. camkɨ-ta	[camkɨda]	'to lock'
c.	k^hɨ-əto	[k^hədo]	'although it is big'

Similarly, consider the case of hiatus resolution in Classical Arabic, as described by Angoujard (1990:60, see also Bohas 1979, 1982):

> [E]very string of two consecutive sounds, associated with the vowel melody, is interpreted as V_iV_i, harmonisation being effectuated in favour of the most sonorous vowel: *ai → aa, *au → aa (the strings *ia and *ua are excluded as they would contradict the syllabic model …). If the string consists of two [+high] segments, *iu* or *ui*, the front vowel is dominant, and the result is, regularly, *ii*.

This pattern again points to the ranking MAXHIFR ≫ MAXHIBK, as illustrated in the following tableau (compare Ekiti Yoruba (73)).

(76) *Hiatus resolution in Classical Arabic: HI][HI*

		NOHIATUS	MAXNONHI	MAXHIFR	MAXHIBK
…i u…	…iu…	*!			
	…uu…			*!	
	☞ …ii…				*
…u i…	…ui…	*!			
	…uu…			*!	
	☞ …ii…				*

Now consider epenthesis. Only high front vowels are used for this process in many languages, such as Navajo (Athapaskan: McDonough 1996:236), Gilbertese (Micronesian: Blevins 1997:240), and Kinande (Southern Bantu: Downing 1999).[30] Furthermore, in

[29] Apparently back [u] does not delete in this way. It may be preserved by MAX[+ROUND].

[30] Icelandic (Orešnik 1972) is unusual in choosing [ʏ] as the epenthetic vowel, e.g., /beð-r/ → [beðʏr] 'bed-NOM.SG.' Note, however, that the [+round] (or [–back]) value is not phonologically active since, unlike

many languages that use high front vowels as well as high back vowels in epenthesis, such as Yowlumne (25), Palestinian Arabic (27) and Yoruba (28), the front ones act as defaults. In our faithfulness approach such patterns intimate the ranking DEPHIBK ≫ DEPHIFR, as illustrated here for Iraqi Arabic /kitab-t-ha/ → [kitabítha] 'I wrote it (f.)' (cf. (34)):

(77) *[i]-epenthesis in Iraqi Arabic*

	/kitab-t-ha/	*CCC	DEPNONHI	DEPHIBK	DEPHIFR
a.	kitabtha	*!			
b.	kitabútha			*!	
c.	☞ kitabítha				*

Again, however, the ranking DEPHIBK ≫ DEPHIFR is not fixed across languages, nor even within languages. Consider epenthesis in Japanese (Poser 1983, Kurisu 2000, Shinohara 2000). In Yamato ("native") vocabulary the epenthetic vowel is always [i], e.g., (78a); in Sino-Japanese vocabulary the epenthetic vowel is [i] or [u] depending on the backness of the preceding vowel, e.g., (78b); and in foreign vocabulary, it is [u], e.g., (78c).[31]

(78) *Epenthesis in Japanese*

a.	/mor/	[mori]	'a leak'
	/ojog/	[ojoŋi]	'a swim'
b.	/tek/	[teki]	'flute'
	/gak-bat/	[gakubat^{s}u]	'academic clique'
c.	*Fr.* kalme	[karume]	'to calm'
	Fr. sɛʁkl̥	[serukuru]	'circle'
	Fr. spɛktʁ̥	[supekutoru][32]	'spectrum'

Similarly, Paradis and Prunet (1989) show that in Fula (Atlantic-Congo) [i] is the default for phonologically-conditioned epenthesis (e.g., *Fr.* plato → [pilatɔ] 'plateau') whereas [u] is the default for morphologically-conditioned epenthesis. Back [u] is also used for epenthesis in Kambera (Central Malayo-Polynesian: Klamer 1994), Tangale (Chadic: Kidda

underlying [ʏ], it fails to trigger umlaut, e.g., /daːg-r/ → [daɣʏr] 'day-NOM.SG.'; cf. /daːg-ʏm/ → [dœːɣʏm] 'day-DAT.PL.' de Lacy (2002:155) suggests that Icelandic [ʏ] is not epenthetic but underlying in those morphemes with which it variably surfaces, viz. NOM.SG. and 3SG. This seems more likely to us than Gibson and Ringen's (2000:63, n. 17) claim that "[t]he least marked vowel is [ʏ]".

[31] Japanese /u/ is phonetically unrounded [ɯ] but we transcribe it [u] because it is phonologically labial. For instance, it causes an adjacent /h/ to be realised as a labial fricative, e.g., English 'Who's Who' is adapted as [ɸɯːzɯɸɯː] (Itô and Mester 1995:825–6).

[32] [o] is used instead of [u] after /t/ (Shinohara 2000:68). This is done to avoid regular assibilation before high vowels; cf. *Fr.* [tuluz] > [t^{s}uːruːzu] 'Toulouse'. Mah (2001) suggests that our perceptually-motivated "anti-epenthesis" hierarchy ⟦DEPLO ≫ DEPMID ≫ DEPHI⟧ is dominated in Japanese "foreign grammar" by DEP[strident], which is also perceptually-motivated.

1993), Diola Fogny (Atlantic-Congo: Sapir 1965:17), Sinhala (Indo-Aryan: Keer 1996:10), and in dialectal Kannada and Telugu (Dravidian: Bright 1975:13).

Back [ɨ] is also favoured for epenthesis in many languages. In Chukot (Chukotko-Kamchatkan: Blevins 1995:226, 242), for instance, [u] is used when flanked by two velars, by a labial and a velar, or by [w], else [ɨ] is preferred.

(79) *Epenthesis in Chukot*

	stem	*aorist (-hin)*	*gloss*
[ɨ]	/pnl/	[pɨnɨl]	'news'
	/tke-rkin/	[tɨkerkin]	'thou smellest of'
	/n-np-qin/	[nɨnpɨqin]	'the old one'
[u]	/kkl/	[kukɨl]	'one-eyed man'
	/mk-icin/	[mukicin]	'more numerous'
	/iwl-walat/	[iwluwalat]	'long knives'

Back [ɨ] is also the default epenthetic vowel in Korean (Ahn 1991:13-4). Front [i] is inserted after palatals only.[33]

(80) *Epenthesis in Korean*

kʰɨɾisɨmasɨ	'Christmas'	*cf.*	oɾendʒi	'orange'
tʰɨɾəmpʰɨ	'trump'		codʒibuʃi	'George Bush'
pʰɨɾei	'play'		pʰɨɾencʰi	'French'
sɨmogɨ	'smog'		apʰacʰi	'Apache'

In Kashmiri (Indo-Aryan: Koul 2003), too, only back [ɨ] is inserted between consonants: obligatorily in compounds, e.g, *nuːn + dəːn'* → *nuːnɨdəːn'* 'salt pot', *caːj + dəːn'* 'pot' → *caːjɨdəːn'* 'tea pot' (p. 16), and optionally inside noncompound words, e.g., *ʃab-nam* → *ʃabɨnam* 'dew' (p. 8).

The epenthetic vowel in Tigrinya (South Semitic: Buckley 2003) is also back [ɨ]:

(81) *Epenthesis in Tigrinya*

/kəlb-na/	[kəlbɨna]	'our dog'	/dngl/	[dɨngɨl]	'virgin'
/m-rkab/	[mɨrkab]	'to find'	/sm/	[sɨm]	'name'

In our faithfulness approach all such cases are suggestive of the ranking DEPHIFR ≫ DEPHIBK, as illustrated in the following tableau; cf. (77).

33 Back [u] is not used for epenthesis, perhaps due to DEP[+ROUND] (cf. fn. 29).

(82) *[ɨ]-epenthesis in Tigrinya*

/kəlb-na/	*CCC	DEPNONHI	DEPHIFR	DEPHIBK
a. kəlbna	*!			
b. ☞ kəlbɨna				*
c. kəlbina			*!	

Finally, the ranking LINHIBK ≫ LINHIFR is apparently required for Huallaga (Quechuan: Weber 1989), in which only high front vowels metathesise (with [k]), e.g., *atʃki* 'light' + *-jaː* 'become' → *atʃikjaː-* 'to shine'. On the other hand, the fact that metathesis occurs only with high back [ɨ, u] in Hixkaryana (Carib: Derbyshire 1979) argues for the opposite ranking LINHIFR ≫ LINHIBK.

To conclude, we have argued that the faithfulness constraints FAITHNONHI and FAITHHI have a fixed ranking because their relation encapsulates a genuine sonority-based harmonic scale: LOW ≻ MID ≻ HIGH (8). In contrast, the diversity of ways in which vowel backness is involved in phonological processes (deletion, insertion, metathesis) suggests that FAITHHIFR and FAITHHIBK are freely rankable. In our approach this is precisely because the latter are not bound by a sonority-based harmonic relation. Indeed, unlike with vowel height, there is no consensus among phonologists for a front-back distinction in sonority. On the one hand, Jones (1918) and Pike (1943) consider [i] as less sonorous than [u], while Hooper (1976) and Foley (1977) consider back round vowels to be more sonorous than front vowels. On the other hand, Arab grammarians (Bohas 1979, 1982) consider [u] as less sonorous than [i],[34] while Kiparsky (1979) considers front vowels to be more sonorous than back vowels. Instead, we agree with Angoujard (1990:24) that "[a]ny language may interpret the sonority hierarchy, but it cannot reconstruct it", that at least for vowels this hierarchy is based on height (p. 15), and that "the sounds /i/ and /u/ … are subjected to specific processes" (p. 16).

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[34] Arab grammarians give the hierarchy of "weight": a > i > u. As Angoujard (1990:9) states: "It is evident that they did not do so for the sake of strange metaphoric notions but that they all understood the importance of an "explanation" in terms of the sonority hierarchy."

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Darin Howe (howed@ucalgary.ca)
Department of Linguistics
University of Calgary
2500 University Drive N.W.
Calgary, Alberta
Canada T2N 1N4

Douglas Pulleyblank (Douglas.Pulleyblank@UBC.ca)
Department of Linguistics
University of British Columbia
E270-1866 Main Mall
Vancouver, BC
Canada V6T 1Z1