Patterns and timing of glottalisation[*]

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1 Introduction

Edward Sapir remarked on several occasions that the relative intrasegmental timing of oral and glottal gestures varied according to segment type. Regarding 'glottalized stops and affricates (e.g. p̓, t̓, k̓, q̓, k̓ʷ, q̓ʷ, c̓, č̓)' he noted: 'In the overwhelming majority of cases the glottal release is posterior to the oral release' (1938:225). Then, regarding 'glottalized sonorant consonants (e.g. y̓, w̓, m̓, n̓, l̓)' he observed: 'In these consonants the glottal closure is synchronous with the momentarily voiceless initial phase of the continuant, its release being immediately followed by the voiced phase of the continuant' (1938:226). The same remark appeared in Sapir (1933:55). An earlier statement of these observations can be found in Sapir (1923:149):

> In the glottalized stops and affricates the closing of the glottis lasts during the whole articulation of the consonant and beyond. In the glottalized nasals, semivowels, and voiced lateral, however, the glottis is closed simultaneously with the oral contact but released instantly thereafter, the voiced continuant thereupon becoming fully audible.

Sapir reported this variation in the timing of glottalisation in languages belonging to several different language families: Haida, Tsimshian, Yowlumne ('Yawelmani'), Nuu-chah-nulth ('Nootka'), Kwak'wala ('Kwakiutl'), and Navajo.[1] In this article, we reconsider the timing of glottalisation in these languages, focusing on the issue of how this property fits into the theory of grammar. We begin (section 2) by showing that Sapir's observations regarding glottalisation were incomplete if astute, that perceptual factors influence the timing of glottalisation (Silverman 1997), and that this influence is part of the mapping of phonological structure into phonetic output, i.e. phonetic implementation (Pierrehumbert 1980).

We then concentrate on Yowlumne (section 3) to illustrate that the phasing asymmetry observed by Sapir – though phonetic in nature – may nonetheless affect the phonological distribution of glottalised segments. We interpret this as support for the grounding hypothesis

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[1] We will not discuss Navajo glottalised sonorants, as they are entirely derivative (from the "d-effect") and are generally not recognised in Athapaskan laryngeal phonology (e.g. Rice 1994); but see fn. 4 on Hupa.

(Archangeli & Pulleyblank 1994): that the phonological component of grammar includes a class of grounding conditions – formal implicational statements that are grounded in phonetic correlates (articulatory or perceptual). We show that grounding conditions properly belong to the phonological component of grammar, inasmuch as they abstract away from important complexities of the phonetics component, such as context-sensitive variation in the timing of glottalisation.

Next we introduce Nuu-chah-nulth (section 4) and Kashaya (section 5) as counterexamples to the claim that restrictions on the distribution of glottalised segments necessarily reflect perceptual factors associated with the timing of glottalisation (e.g., Steriade 1997). Indeed glottalised sonorants in these languages are distributed in exactly the opposite way of what would be expected if the phonology were sensitive to the timing and perception of glottalisation. Instead, the syllable – 'a phonological rather than a phonetic unit' (Ladefoged & Maddieson 1996:282) – fully determines the distribution of glottalised sonorants in Nuu-chah-nulth and Kashaya; they are syllable-initial in the former, syllable-final in the latter. We propose faithfulness constraints that are sensitive to prosodic prominence (cf. Beckman 1999, Lombardi 1999) to account for these patterns.

Our general finding, then, is that the facts of glottalisation argue for a modular approach to grammatical theory (Chomsky 1981, 1986) where a phonological component is distinguished from a phonetic component. This result leads us to question the validity of current efforts at integrating phonetics and phonology into a unified model (e.g. Steriade 1997, Flemming 1999).[2]

2 The timing of glottalisation as a phonetic property

While the patterns of asymmetric timing described by Sapir may be common, perhaps typical, they represent a pattern that is oversimplified. We present in this section a discussion of some of the complexities surrounding glottalisation, including cases in which stops and affricates are *pre*-glottalised and cases in which sonorants are *post*-glottalised.

2.1 The variable timing of glottalisation in stops

As mentioned above, glottalised stops and affricates are normally described as *post*-glottalised, i.e. glottal constriction persists beyond the oral constriction. For example, Sapir describes these segments as follows in Nuu-chah-nulth ('Nootka'): 'glottalized stops and affricates ... are pronounced with simultaneous closure of glottis, but with oral release prior to that of glottal release' (Sapir 1915:21). Similarly in Haida: 'the stop is released with the glottis closed, resulting in a sharp popping' (Lawrence 1977:23).

According to Kingston (1985, 1990) the usual late glottal release in stops and affricates follows from optimising the cues for interrupted airflow. The glottal articulation in such segments results in a build-up of air pressure, usually a function of raising the sealed larynx and constricting the pharyngeal walls. At the time of oral release, this results in a high level of acoustic energy. Kingston

[2] Blevins (to appear) makes a related argument against an integrated model of phonetics and phonology. Our proposals are rather different in two respects. Blevins suggests that perceptual factors play a role predominantly in the diachronic domain where we consider such factors to be one of several interacting components synchronically; Blevins argues against syllable-based phonotactics, while we maintain a role for featural reference to the syllable. A case bearing on these issues is discussed below.

argues that the glottal release follows the oral release because the ensuing high energy offers the best acoustic cues for the glottal gesture.

An interesting result of Kingston's explanation is that a late glottal release in sonorant consonants is not predicted. Because the airflow is never fully interrupted in these segments, the air is not strongly pressurised behind the oral constriction and so there is no salient acoustic burst at the release of the oral constriction. The absence of such a burst entails the absence of a late glottal release if, as Kingston argues, the acoustic burst is the sole motive for late timing of the glottal release. Beyond this, however, Kingston's account falls short of explaining why the glottal gesture is truncated with respect to the oral gesture and why it is sequenced before modal voicing in sonorant consonants.

The central point that we extract from Kingston's proposal is that the glottal gesture is timed so as to increase its perceptual salience. Far from being deterministic in its implications, this proposal predicts the possibility of variation in the phonetic implementation of glottalisation in stops. While the timing of the glottal release to produce a significant stop release provides a salient cue for the perception of glottalisation, other variables may interact to result in a different sequence of oral and glottal events. One example is Sm̓algyax (Coast Tsimshian) where the glottal gesture is not 'bound' by the oral release. Consider the following description from Dunn (1995:II.4):

> If a glottalized segment occurs before a vowel, the glottalic closure coincides with the consonant closure and the vocal cords are released after the consonant is released (k', k̲', p', t'). If the glottalized segment occurs after a vowel, the glottalic closure occurs before the consonant closure ('k, 'k̲, 'p, 't); if such a glottalized segment is word-final, the vocal cords are unreleased throughout the production of the consonant sound. When a glottalized segment occurs between vowels, it is of the former type (k', p', t') if the second of the two vowels has the greater stress; it is of the latter type ('k, 'p, 't) when the first of the two vowels has the greater stress.

Arguably, the timing of glottalisation in a Sm̓algyax stop is determined by perceptual salience, independently of the oral release, where glottalisation is timed so as to occur in a stressed vowel preferentially, an unstressed vowel second-best. The reason appears at least at first to be quite clear: a vowel, especially a stressed one, provides favourable acoustic cues for the perception and recoverability of glottalisation. We return to this explanation in our discussion of glottalised sonorants.

2.2 The variable timing of glottalisation in sonorants

Silverman (1997) attempts to broaden Kingston's approach in order to account for the gestural phasing of glottal constriction in sonorants. Silverman's fundamental assumption is that the oral and glottal gestures of stops would not be cued to the listener if their realisation were strictly simultaneous. On this assumption, the phonology must stagger the oral and glottal gestures of a segment so that each may be recovered in speech perception. For instance, the glottal gesture may either precede or follow the oral closure of stops and affricates. The unmarked oral-glottal sequencing reflects Kingston's observation that the glottal gesture is optimally cued in the period of high-energy burst which follows the low-energy oral closure portion of the segment.

In contrast to stops and affricates, sonorants have a high level of acoustic energy which renders gestural sequencing unnecessary. Nonetheless, glottal constriction reduces airflow (to zero when the glottal gesture is fully implemented) and Silverman claims that the reduced acoustic energy is insufficient to convey information about downstream constriction or velic lowering in the case of glottalised nasals. He argues that the phonology truncates the glottal constriction to a portion of the oral constriction in order to ensure the recoverability of the latter gesture: 'truncation of non-modal phonation is observed, so that all contrastive information is recoverable from the speech signal' (Silverman 1997:104, also p. 119).

Like Sapir, Silverman identifies the phasing of the glottal constriction to the *early* portion of the oral constriction as 'the canonical realization' (p. 104) for all glottalised sonorant consonants – nasals (p. 98), laterals (p. 102), and glides (p. 104). Silverman's explanation of this timing pattern is as follows. Recall that in glottalised stops and affricates the low acoustic energy of the oral closure precedes the high acoustic energy of the glottal release. In relative but parallel fashion, the low acoustic energy of the glottal constriction precedes the high acoustic energy of modal phonation in glottalised sonorants. According to Silverman, it is no accident that the variable timing of the glottal gesture in obstruents and sonorants results in an intrasegmental increase in acoustic energy. Rather, he interprets this increase as an imperative. It guarantees salient formant transitions into a following vowel.

Plauché (1998) and Plauché et al. (1998) point out, however, that Silverman fails to consider the case of glottalised sonorants in coda position. In this environment, there is no 'following vowel', only a preceding one. Still, they note a prediction made by Silverman's perception-based account:

> If preglottalisation is an effort to preserve as much information about the sonorant by keeping the inherently obscuring cues of glottalization (creaky voice and dip in amplitude) from compromising the crucial sonorant to vowel transition, then we would also predict that in coda position, where the crucial transition is not sonorant to vowel, but vowel to sonorant, we should find postglottalization. (Plauché et al. 1998:383)

This prediction holds true in many cases. In Yowlumne ('Yawelmani'), glottalised sonorants are preglottalised in onset position but postglottalised in coda position (Plauché 1998, Plauché et al. 1998, Suzanne Wertheim p.c.).[3]

(1) *Variable glottalisation in sonorants: Yowlumne* (Plauché et al. 1998:385)

	onset position			*_C (coda position)*			*_# (coda position)*	
a.	ʔa[ˀw]aṭ	*dislike*	e.	la[nˀ]ṫe	*left*	i.	haya[lˀ]	*day*
b.	taa[ˀm]uṭ	*whiskers*	f.	xo[lˀ]poyo	*lizard*	j.	ci[yˀ]	*bone*
c.	ti[ˀm]iṭ	*eyebrow*	g.	ċo[lˀ]lol	*white*	k.	nuku[mˀ]	*bend*
d.	no[ˀn]o	*man*	h.	bi[mˀ]tana	*stump*	l.	laṭa[wˀ]	*steep*

[3] Where desirable to indicate the timing of the glottal gesture in transcriptions, a raised glottal stop [ˀ] is marked preceding (ˀC: preglottalisation) or following (Cˀ: postglottalisation) the appropriate phonetic symbol.

In Kwak’wala too ‘the catch in the throat comes before the [sonorant] and sometimes afterwards’ (Grubb 1977:19-20). As Lincoln and Rath (1980) describe, glottalised sonorants are normally preglottalised [ˀm, ˀn, ˀl, ˀy, ˀw] (p. 19) but they have postglottalised [mˀ, nˀ, lˀ, yˀ, wˀ] ‘allophones’ pre-consonantally or word-finally (p. 23), i.e. syllable-finally.[4]

(2) *Variable glottalisation in sonorants: Kwak’wala*

	onset position			*coda position*	
a.	x̌i[ˀm]ala	*to creep sitting*	f.	x̌i[mˀ]xʔid	*to start to creep sitting*
b.	[ˀl]ax̌ʷʔid	*to stick tongue out*	g.	nə[lˀ]ʣi	*south, upriver*
c.	[ˀn]əqʷa	*to swallow*	h.	bə[nˀ]ǧəmáɬa	*looking face down*
d.	[ˀl]uqʷa	*halibut fishing*	i.	ɬə[lˀ]	*dead*
e.	[ˀy]əxʷa	*to dance*	j.	cə[yˀ]qa	*to dip among*

Postglottalised sonorants in coda position are also reported in Oowek’yala (Wakashan; Lincoln & Rath 1980, Howe in prep.), in Coatlán-Loxicha Zapotec (Uto-Aztecan, Plauché et al. 1998), in Kashaya (Pomoan, Buckley 1990, 1994), and in Kutenai (isolate, Larry Morgan p.c.).

As with glottalised obstruents, we observe interactions between stress and the timing of glottalisation on sonorants. The observed interactions are somewhat complex, however. Consider Caldecott’s (1999) comparison of glottalised sonorants in two Salish languages, Sənčáθən (Saanich) and St’át’imcets (Lillooet). Glottalisation in Sənčáθən is attracted to a stressed vowel, comparable to the case of Sm̓algyax discussed above. Montler (1986:1.1.2.1.3) gives the following rules: /R’/ → [ˀR] / v́_v; /R’/ → [Rˀ] / v_v́. In St’át’imcets, however, the exact opposite occurs: as characterised by van Eijk (1997:11), ‘...glottal stricture [in glottalised resonants] is strongest near the onset of the resonant before a stressed vowel, but near the outset in other positions.’

In other cases, however, glottalised sonorants are preglottalised in whatever context they happen to be. This is the case in Sm̓algyax (Dunn 1995), in Montana Salish (Flemming et al. 1994) and in Lai (Plauché et al. 1998), where glottalised sonorants are preglottalised whether they are syllable-initial or syllable-final. In a related vein, Silverman reports that glottalised vowels are realised as initially glottalised:

> [T]he optimal pattern of creakiness/silence and vowels consists of the early realization of a laryngeal constriction, followed by a modal vowel. That is, the constriction is truncated with respect to the vowel, phased to its initial portion. (Silverman 1997:119).

In brief, the variable timing of glottalisation in stops and sonorants, which Sapir (1938) described, may serve to assist the listener in recovering acoustic cues in the speech signal, as argued by Kingston (1985, 1990) and Silverman (1997). While numerous cases suggest that there exists an imperative for sonorants to be preglottalised, regardless of the formant transitions

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[4] Hupa (Athabaskan) and Klamath (Plateau Penutian) present different though arguably related patterns. According to Gordon (1996), glottalised sonorants are unitary phonemes in Hupa, and the timing of glottalisation is derived from the underlying position of consonants before a vowel (deleted at the surface) versus a word boundary or consonant. According to Blevins (1993:239), glottalised sonorants are preglottalised in onset position (prevocalically), but “[w]hen glottalized sonorants are followed by nonsyllabic segments, glottalization is nearly simultaneous with oral constriction” (ibid.).

associated with their position, other cases suggest the importance of additional variables such as syllable position and stress.

2.3 The interactions of timing with phonology

There are various models for the incorporation of phonetic information into a grammar. Since the recognition that "phonetics" is not determined by the automatic physical implementation of a set of abstract featural specifications (see, for example, Cohn 1990, Keating 1988, 1990, 1996, Liberman and Pierrehumbert 1984, Pierrehumbert 1980, 1990), two perspectives can be broadly distinguished. One possibility is to identify two distinct modules, a phonetic module and a phonological module, whose content may overlap to a certain degree (above references; also Kiparsky 1982, 1985, Mohanan 1986, Pulleyblank 1986, etc.). We will refer to this possibility as the "modular" theory. A second possibility is to postulate a single module which encodes the full range of properties required for "phonetic" and "phonological" interpretation (Steriade 1997, 1998ab, 1999, Flemming 1999, etc.). We will refer to this second approach as the "integrated" theory.

These two approaches to the phonetics/phonology interface define very different possibilities for the representation of information on glottalisation. According to the modular theory, there is no necessary relation between the details of phonetic implementation and the patterns of distribution and alternation observed in the phonology. For example, we could observe in some language that glottalisation on obstruents and sonorants patterns in a similar fashion phonologically in spite of significant differences in their phonetic realisation. According to the modular view, there is no reason to expect an exact correspondence between the phonetic timing of events and their phonological distribution. In contrast, the integrated theory incorporates properties of phonetic timing directly into the fabric of phonological encoding. As such, we expect to find phonetic distinctions manifesting themselves in distribution and alternation; we expect to find properties of phonetic timing determining the behaviour of the relevant segments.

In the following discussion, we present evidence in favour of the modular view. First, we discuss the case of Yowlumne which at first glance supports the integrated view. A closer examination of the phonetic facts, however, appears to cast doubt on such a view. Second, we discuss the case of Nuu-chah-nulth where the distribution of glottalised sonorants is exactly the opposite of what would be expected from an integrated view of phonetics and phonology. Finally, we discuss briefly the case of Kashaya which is similar to Yowlumne except for disallowing glottalisation in the context that would be the best context according to the integrated hypothesis.

3 The distribution of glottalisation in Yowlumne

On the face of it, the distribution of glottalised sonorants in Yowlumne appears to present a strong argument in favour of the integrated hypothesis. Glottalised sonorants are strongly preglottalised and may only occur in postvocalic position. This seems to argue for an analysis where their distribution is restricted to contexts that are optimal for the realisation of preglottalisation. We suggest, however, that this interpretation is based on an incomplete assessment of the phonetic data.

We begin by a brief discussion of the distributional differences between glottalised obstruents and sonorants. We then lay out the evidence for the integrated view, present problems for that view, and conclude that Yowlumne actually argues for modularity.

3.1 Patterns of glottalisation in Yowlumne

The full inventory of Yowlumne consonants is presented here (Newman 1944).

(3) *Yowlumne consonant inventory*

	Labial	Dental	Dental affricates	Alveolar	Alveolar affricates	Palato-alveolar	Palatal	Laryngeal
Voiceless unaspirated	b	d	z	ḍ	ẓ		g	
Voiceless aspirated	p	t	c	ṭ	ç		k	
Glottalised	p'	t'	c'	ṭ'	ç'		k'	
Fricatives		s		ṣ			x	
Nasals	m	n						
Glottalised nasals	m'	n'						
Liquids & glides	w			l		y		h
Glottalised liquids & glides	w'			l'		y'		ʔ

Newman describes Yowlumne ejectives as follows (1944:14): 'In all dialects the glottalised stops and affricates are articulated with a light degree of glottal plosion. Glottalised stops are pronounced with a simultaneous release of the glottis and stop closure'. As Steriade (1997:80) reasons, the release quality of ejectives appears to be sufficiently distinct for the Yowlumne listener to be able to identify these segments in any phonological context. As the following data show, ejectives in Yowlumne may be word-initial, word-final, intervocalic, postconsonantal, or preconsonantal. Data are also given to show that a glottal stop may appear adjacent to a stop, whether ejective or not. This is consistent with an analysis where both ejectives and glottal stop are true phonemes in Yowlumne, not derivative segments. Data below are from Newman (1944) and Gamble (1994).

(4) *Surface distribution of ejectives*

a.	*Word-initial*	c̓iy	*bone*
		t̓oy̓ix	*getting rusty*
		p̓axaat̓	*mourn*
	Word-final	yaw'lic̓	*wolf*
		taxak̓	*bring (it)!*
		duwweeʔiṭ̓	*butcher bird*
	Intervocalic	hit̓elni	*with ashes*
		meek̓en	*swallow will*
		wec̓oy	*birds*
	Postconsonantal	ṭunk̓a	*close the door!*
		sidk̓a	*get ready!*
		c̓omc̓umun	*destroy repeatedly*
	Preconsonantal	goṭ̓hotin	*desire to overtake*
		nuhak̓daa	*kneel repeatedly*
		picp̓ic̓xoonit	*is being counted repeatedly*
b.	*Contrasts between glottalised obstruents and clusters with [ʔ]*		
	VC'V	ṭook̓o	*strike, hit*
	VʔCV	yoʔgeexo	*he returns*
	VCʔV	ʔudʔal	*only*
	VʔCʔ'V	ʔoʔc̓axo	*he is watching*
	VC'ʔV	ṣudok̓ʔuy	*remove*-SUBJECTIVE

We now turn to the glottalised sonorant consonants and their distribution in Yowlumne. The basic facts are as follows:

> [E]ach of the simple nasals, semivowels, and laterals is balanced with a glottalized consonant which is treated as a distinct phoneme with the following limitation: it can never appear initially in a word or in a syllable that follows a closed syllable. (Newman 1944:15)

This restricted distribution may be interpreted as involving a preference of glottalised sonorants for coda position (Kingston 1985) – though note the VC'V cases – or a preference for postvocalic position (Archangeli and Pulleyblank 1994:348, Steriade 1997:79).

The postvocalic distribution is illustrated with the following data. As shown, glottalised sonorants in Yowlumne occur in all postvocalic postions, i.e. word-finally, intervocalically, and preconsonantally. Conversely, they do not occur in any non-postvocalic positions, i.e. word-initially and postconsonantally. The additional data provided show that a glottal stop may appear adjacent to a sonorant, without deriving a glottalised sonorant. This demonstrates that glottalised sonorants are treated as true Yowlumne phonemes (Newman 1944:15).

(5) *Surface distribution of glottalised sonorants*

a.	*Word-initial*	*not attested*	
	Word-final	ʔamaʔaxam̓	*and perhaps*
		bon̓yil̓	*twice*
	Intervocalic	c̓oow̓oo	*work*
		kay̓iw	*coyote*
		bowon̓iy	*trap*
	Postconsonantal	*not attested*	
	Preconsonantal	p̓um̓naʔ	*a full-blooded Indian*
		ʔil̓k̓in̓in	*water inhabitants*
		hew̓taxo	*walk about*
b.	*Contrasts between glottalised sonorants and clusters with [ʔ]*		
	VC'V	non̓oʔ	*man*
		daʔal̓ehin	*brought to life*
	VCʔV	gononʔon	*he alights*
		hilalʔan	*she is invisible*
	VʔCV	moyoʔneenit	*will be made tired*
		ʔaṭaʔlee	*cause to open*
	VʔC'V	*not attested*	
	VC'ʔV	sil̓ʔeexo	*are looking at*

The postvocalic restriction on glottalised sonorants is further evidenced by cases of neutralisation (Newman 1944, Steriade 1997). As shown in the following pairs of morphologically-related lexemes, contrastively glottalised sonorants have nonglottalised alternants when they occur in postconsonantal contexts.

(6) *Alternations between plain and glottalised sonorants*

a.	giy̓igyiisa	touch oneself/each other repeatedly
	giy̓igiy̓i	touch repeatedly
b.	dil̓laal	that which is in a sloping position
	dil̓il̓wiyi	becoming sloping

Finally, a morphological process of sonorant glottalisation provides additional evidence for the condition that glottalised sonorants be postvocalic. The forms below illustrate the fact that a morphologically provided glottalisation feature induces glottalisation on sonorants (Archangeli 1988, Archangeli & Pulleyblank 1994:346-350).[5] When a sonorant is postvocalic and immediately adjacent to the glottalising suffix, it is glottalised.

[5] Only sonorants are targeted by this feature, despite the fact that Yowlumne has a full range of both glottalised sonorants and obstruents. Various explanations are offered in Archangeli & Pulleyblank (1994:346-350), Steriade (1997:83-84), and Howe & Pulleyblank (in prep). For some discussion of these, see below.

(7) *Glottalisation of sonorants adjacent to suffix*

a.	caw-	caaw̓aahin	shout
b.	c̓um-	c̓oom̓aahin	devour
c.	nin-	neen̓aahin	quieten

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.

(8) *Glottalisation of sonorants over another consonant*

a.	ʔilk-	ʔel̓kaahin	sing
b.	dull-	dol̓laahin	climb
c.	yawl-	yaw̓laahin	follow

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

(9) *Glottalisation as a glottal stop*

a.	max-	maxʔaahin	procure
b.	dos-	dosʔoohin	report
c.	hot̓-	hot̓ʔoohin	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.

(10) *Deletion of glottalisation*

a.	hogn-	hognaahin	float
b.	ʔidl-	ʔedlaahin	hunger
c.	ʔagy-	ʔagyaahin	pull

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

3.2 An "integrated" account of glottalised sonorants

Stephen Anderson and Donca Steriade (1992 personal communication) have independently suggested that the postvocalic restriction of glottalised sonorants in Yowlumne derives from the fact that these segments are normally preglottalised (recall Sapir 1938, Kingston 1985, 1990, Silverman 1997). Indeed, Newman (1944) reported that the glottalised sonorant consonants in Yowlumne give a 'rasping effect' to adjacent vowels, 'especially to those which precede' (p. 19). For Steriade (1997:80), '[t]his indicates that the incomplete glottal closure responsible for the rasping or creaky quality of the sonorant begins and is most saliently noted during the preceding vowel' (p. 80).

That glottalisation is observed only in those sonorants which are preceded by a vowel in Yowlumne can be explained by the preglottalised nature of these segments. At issue, however, is the precise nature of that explanation. Both the modular and the integrated hypotheses of phonetics/phonology interaction provide potential accounts for the observed distribution, but with subtly different predictions.

Considering first the *integrated* approach, there are two main components to the analysis (Steriade 1997). First, features of “ejection” and “creak” are distinguished to account for the differences in the patterning of ejectives and glottalised sonorants. Second, by appealing to the differences in perceptual cues for the two glottal properties so distinguished, a grammar can then be constructed as follows. The free distribution of ejectives is the result of ranking faithfulness to [ejection] above constraints on the perceptibility of [ejection], ensuring that ejection is retained in all positions. In contrast, the restricted distribution of glottalised sonorants is the result of ranking faithfulness to [creak] below a constraint restricting [creak] to a particular position.

With regard to the first component of the integrated analysis, the separation of [ejection] and [creak] is possible for Yowlumne, and consistent with the fact that glottalising suffixes affect sonorants only, never obstruents (analysed by assigning glottalising suffixes the feature [creak]). Nevertheless, this proposal is problematic for the treatment of glottalising affixes in other languages. For instance, in his *Klamath Grammar*, Barker (1964:263) posits a ‘morphophoneme //’//, which is represented on the phonemic level by the glottalization of some neighboring consonant’, and which Blevins (1993:266) interprets as ‘a floating [constricted glottis] feature’. Crucially, stops as well as sonorants are affected by this feature, which accompanies the diminutive /-ˀaːk̓/ for example.

(11) *Klamath diminutive* (Barker 1964, Blevins 1993)

a.	RED + n̓epʰ + ˀaːk̓	→	n̓enp̓aːk	*distributive little hands*
b.	RED + pʰečʰ + ˀaːk̓	→	pʰepč̓aːk	*distributive little feet*
c.	RED + qčʰuːl + ˀaːk̓	→	qčʰuqčuːl̓aːk	*distributive little star*
d.	RED + ʔankʰu + ˀaːk̓	→	ʔaʔankw̓aːk	*distributive little sticks*

Similarly, Buckley (1990:9) reports that in Kashaya ‘the Assertive morpheme is a floating [+constricted glottis] feature which links to an immediately preceding consonant, thereby glottalizing it’. Stops and sonorants are both affected by the same glottalising feature.

(12) *Kashaya* (Buckley 1990)

a.	yahmot + ˀ	→	yahmot̓	*it’s a cougar*
b.	c̓iškan+ ˀ	→	c̓iškan̓	*it’s pretty*

Another process of glottalisation is caused by underlying glottalised sonorants, which regularly denasalise in syllable-onset position, e.g. can̓ ‘looked [FACTIVE]’ vs. cad-u ‘look!’ (see section 5 below). When the preceding segment is a consonant, ‘the nasal spreads its glottalization to the preceding segment before undergoing oralization’ (Buckley 1990:13). Again, obstruents and sonorants are both affected in this manner.

(13) *Kashaya* (Buckley 1990)

a.	cahnoc + m̓a	→	cahnoc̓ba	*after speaking*
b.	dahyuṭ + m̓a	→	dahyuṭ̓ba	*after rubbing*
c.	pʰanem + m̓a	→	pʰanem̓ba	*after punching*

d.	duhtay + m̓a	→	duhtay̓ba	*they say he touched*

Also in Kwak'wala (Wakashan) as well as in Nisga'a (Tsimshian) one finds numerous cases in which both sonorants and obstruents are glottalised by the same feature, presumably [constricted glottis].

(14) Kwak'wala *glottalising suffix:* /-ˀm/ 'really' (Boas 1947:302)

a. *Stops*	/RED-giq-m̓/	gəgiq̓əm	*really a chief*
	/RED-łakʷ-ˀm/	łəłak̓ʷəm	*really strong*
	/RED-glt-ˀm/	gəglt̓əm	*really long*
b. *Sonorants*	/RED-w̓n-m̓/	w̓əw̓ən̓əm	*really to hide*
	/RED-k̓n-ˀm-xʔid/	k̓ək̓ən̓əmxʔit	*to get really loose*
	/RED-ml-ˀm-xʔid/	məməl̓əmxʔit	*to get really twisted*
	/RED-qy̓-ˀm/	q̓əq̓əy̓əm	*really many*
	/RED-bw-ˀm/	bəbəw̓əm	*really to leave*

(15) *Nisga'a glottalising suffix: indefinite antipassive* /-ˀskʷ/ (Tarpent 1987)

a. *Stops*	/kíp-ˀskʷ/	gíp'iskʷ	*to eat berries while picking*
	/yúːłimq-ˀskʷ/	yúːłimq̓askʷ	*to give advice to, tell s.o. how to behave*
	/yac-ˀskʷ/	yac'iskʷ	*grass (lit. covering)*
	/cakʷ-ˀskʷ/	ʣak̓ʷiskʷ	*animal (lit. killing)*
b. *Sonorants*	/łimoːm-ˀskʷ/	łimoːm'iskʷ	*to help out (traditional requirement)*
	/siːlín-ˀskʷ/	siːlín̓skʷ	*to hunt*
	/swán-ˀskʷ/	swán̓skʷ	*to blow on sth. (shaman cure)*
	/sə-táːw-ˀskʷ/	sidáːw'iskʷ	*to freeze food*

In short, unless [creak] and [ejection] are the same feature, viz. [constricted glottis], there is no unified treatment of the glottalising suffixes in e.g. Klamath, Kashaya, Kwak'wala and Nisga'a (also Nuu-chah-nulth; see Rose 1976, Howe 1996, Kim 1999). More generally, if [creak] is defined independently of [ejection], as argued by Steriade (1997) for Yowlumne, then nothing prevents [creak] from appearing in languages without [ejection]. This is not the case, however. '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' (Maddieson 1984:116). And again: 'If a language has any laryngealised sonorants it also has glottalic or laryngealised stops. 19/20 95.0%' (Maddieson 1984:121).

Our proposal to account for the implicational relation between glottalisation on obstruents and sonorants, and for the languages where glottalisation specifically targets sonorants, is outlined in Howe and Pulleyblank (in preparation). The essential idea is that glottalisation on obstruents is more perceptually salient than on sonorants, hence the loss or addition of glottalisation with obstruents is more salient than with sonorants. The grammatical result is that modification of glottalisation on obstruents (loss/addition) incurs more significant violations of faithfulness constraints than with sonorants.

In the remainder of this section, we wish to consider the second component of Steriade's integrated analysis. To account for the restriction of glottalised sonorants to postvocalic position, two factors are crucial. First, the timing of oral and glottal gestures in glottalised sonorants must be fixed, with the glottal gesture timed before the oral gesture (SONTIMING). Second, the constraint requiring adherence to the presonorant perceptual cues (CONTEXTCUES[CREAK]) must outrank faithfulness to glottalisation (PRESERVE[CREAK]):

(16) *Licensing by cue*

SONTIMING, CONTEXTCUES[CREAK] >> PRESERVE[CREAK]

The effect of these constraints can be seen in tableaux such as (17) and (18). These tableaux consider the possible occurrence of a glottalised sonorant in an acceptable context (intervocalically: *kay'iw* 'coyote'), and in an unacceptable context (initially: putative **[n']iw'ow* (compare *niw̓ow* 'afternoon')).

(17) *Intervocalic glottalised sonorants*

	/kay̓iw/	SONTIMING	CONTEXTCUES [CREAK]	PRESERVE [CREAK]
a.	ka[yˀ]iw	*!		
b. ☞	ka[ˀy]iw			
c.	ka[y]iw			*!

SONTIMING requires preglottalisation of sonorants and will therefore be violated in any occurrence of [Cˀ] (17a). CONTEXTCUES[CREAK], on the other hand, will be satisfied intervocalically with either postglottalisation (17a) or preglottalisation (17b) since the adjacent vowel in either case provides a locus for perceptual cues. Combined, these constraints mean that in an intervocalic context, the optimal candidate respects preglottalisation.

Word-initially, the situation is different.

(18) *Impossibility of word-initial glottalised sonorants*

	/n̓iw̓ow/	SONTIMING	CONTEXTCUES [CREAK]	PRESERVE [CREAK]
a.	[nˀ]iw̓ow	*!		
b.	[ˀn]iw̓ow		*!	
c. ☞	[n]iw̓ow			*

If a glottalised sonorant were to occur word-initially, then a postglottalised surface form would violate SONTIMING (18a) and a preglottalised surface form would violate CONTEXTCUES[CREAK] since there is no vowel adjacent to the glottal portion of the segment to support glottal cues (18b). In word-initial position, therefore, the grammar makes it impossible for glottalisation to surface in an optimal candidate. It is important to stress the role of fixed timing in this integrated analysis. As noted by Steriade, 'Had timing been alterable, it would have been possible to generate *post*-glottalized sonorants' (1997:85). Postglottalised segments, if existent, would be properly cued in initial position.

This integrated account of the phonetics and phonology of Yowlumne provides an elegant explanation for the distribution of glottalised sonorants. Preglottalisation is fixed for the language by the high ranking of SONTIMING and the postvocalic distribution is guaranteed by the high ranking of CONTEXTCUES[CREAK]. There is an important context that has not been discussed yet, however, and it turns out that this context proves problematic for the integrated approach.

Let us consider the predictions of the integrated analysis for glottalised sonorants in word-final and preconsonantal positions. In both such positions, a glottalised sonorant should occur without difficulty. Provided that it is postvocalic, such a segment could be preglottalised, thereby respecting SONTIMING, and the presence of a preceding vowel would allow the configuration to respect CONTEXTCUES[CREAK]. Hence glottalised sonorants should occur both before consonants and word-finally – and they do. The problem is that such segments are *postglottalised*, not *preglottalised*.

Most work on Yowlumne, including Steriade (1997), has been based on Newman (1944). Newman explicitly discusses the preglottalised nature of glottalised sonorants (1944:14), and it has generally been assumed that *all* glottalised sonorants in Yowlumne are preglottalised. A careful reading of his text, however, leaves some question as to whether Newman is referring only to intervocalic position (note his rather suggestive remarks on p.17). As discussed in section 2 above, this issue is addressed in work by Plauché et al. (1998) where auditory and preliminary acoustic evidence is presented that glottalised sonorants in Yowlumne are preglottalised in onset position and postglottalised in coda position, that is, word-finally and preconsonantally.[6]

The impact of this phonetic research on the integrated proposal for Yowlumne is enormous. If the timing of glottalisation in Yowlumne is variable, then some constraint must outrank SONTIMING. Though not phrased in these terms, Plauché et al. (1998) follow Silverman (1997) in proposing that the relevant constraint relates to optimising the cues for place features. Silverman's basic proposal (recall section 2) is that the formant transitions from a consonant into a vowel provide the best cues to place, and glottalisation tends to obscure such cues. Hence by timing glottalisation away from the VC transitions, optimal place cues are achieved. Plauché et al. interpret this as meaning that a glottalised sonorant will optimally be preglottalised in onset position ([^{ʔ}CV]) and postglottalised in coda position ([VC^{ʔ}]).

Consider how the analysis of Yowlumne presented above would interact with a constraint requiring optimisation of the transitional cues for place (CONTEXTCUES[PLACE]). To guarantee that the constraint on place cues triggers a retiming of the glottal gesture, CONTEXTCUES[PLACE] would necessarily outrank both SONTIMING and CONTEXTCUES[CREAK] ("CONTEXTCUES" abbreviated here as "CONCUES").

[6] An anonymous reviewer suggests that glottalised sonorants may have been consistently preglottalised during the Newman research period, and that the patterns of glottalisation described by Plauché et al. in their work with current speakers of Yowlumne may be the result of language attrition. Newman (1944:14, 17) did not discuss the case of glottalised sonorants in coda position (as just mentioned), so there is no reason to think that glottalised sonorants were formerly preglottalised everywhere in Yowlumne. Moreover, recall from section 2.2 that many languages from diverse language families exhibit the tendency for glottalised sonorants to be preglottalised in onset position and postglottalised in coda position. The fact that current speakers of Yowlumne follow this "phonetic universal" (Plauché et al. 1998) does not constitute compelling evidence of "attrition".

(19) *Postglottalisation of word-final sonorant*

	/bon'yil'/ 'twice'	CONCUES [PLACE]	SON TIMING	CONCUES [CREAK]	PRESERVE [CREAK]
a. ☞	bon'yi[lˀ]		*	*	
b.	bon'yi[ˀl]	*!			

The problem is that PRESERVE[CREAK] would also have to be promoted above SONTIMING and CONTEXTCUES[CREAK] since otherwise deglottalisation in final position would be optimal (selection of a nonoptimal candidate is indicated by a "bomb": 💣):

(20) *Glottalisation in word-final sonorant should not be lost*

	/bon'yil'/ 'twice'	CONCUES [PLACE]	SON TIMING	CONCUES [CREAK]	PRESERVE [CREAK]
a.	bon'yi[lˀ]		*!	*!	
b.	bon'yi[ˀl]	*!			
c. 💣	bon'yi[l]				*

Promoting PRESERVE[CREAK] correctly results in postglottalisation in word-final or preconsonantal position:

(21) *Postglottalisation in word-final sonorants*

	/bon'yil'/ 'twice'	CONCUES [PLACE]	PRESERVE [CREAK]	SON TIMING	CONCUES [CREAK]
a. ☞	bon'yi[lˀ]			*	*
b.	bon'yi[ˀl]	*!			
c.	bon'yi[l]		*!		

The broader effects of this reranking, however, are to completely lose the basic generalisation that any analysis of Yowlumne must account for, namely that glottalised sonorants only appear postvocalically. If PRESERVE[CREAK] outranks the constraints on the timing and cueing of glottalisation on sonorants, then glottalisation should be preserved in *any environment*. For example, if glottalisation were to appear in a word-initial onset consonant, then it would (wrongly) be preserved. To see this, reconsider the case in (18) where we investigated the result of positing such a word-initial consonant.

(22) *Glottalisation in word-initial sonorant must not be retained*

	/n'iw'ow/	CONCUES [PLACE]	PRESERVE [CREAK]	SON TIMING	CONCUES [CREAK]
a.	[nˀ]iw'ow	*!		*	
b. 💣	[ˀn]iw'ow				*
c.	[n]iw'ow		*!		

The desired result is that glottalisation should be impossible in a word-initial context; the result of the seemingly necessary ranking is counter-factually that a word-initial preglottalised sonorant would be retained.

The problem is as follows. The integrated approach to the distribution of glottalised sonorants depends crucially on deriving the postvocalic distribution by requiring that all glottalised sonorants be preglottalised and by directly relating this putative fact to their distribution. Once it is recognised that the timing of glottalisation is variable in sonorants, and dependent on position, then one can no longer relate the position to the timing without invoking a completely circular analysis. That is, position cannot depend on timing when timing itself depends on position.

3.3 A "modular" account of glottalised sonorants

It is straightforward to produce an account of Yowlumne glottalised sonorants if the details of phonetic implementation are distinct from the phonological constraints governing distribution. Phonologically, glottalised sonorants must be restricted to postvocalic position (see Blevins 1999a):

(23) *Postvocalic condition for glottalised sonorants*
If R' then V_ : If a sonorant is glottalised, it must follow a vowel

Phonetically, the rules of implementation, whatever their precise nature, must result in preglottalisation intervocalically and postglottalisation word-finally and preconsonantally. The ranking of the postvocalic condition above faithfulness will guarantee that glottalisation is retained only when postvocalic; the inclusion of timing relations in the phonetics results in the phonology being sensitive only to the presence or absence of glottalisation, not to its precise timing with respect to an oral constriction.

At issue in a modular theory is the precise nature of a constraint such as that in (23). There are at least three possibilities. First, it could be that the implicational relation between the feature of glottalisation and the postvocalic position is completely arbitrary, subject to idiosyncratic cross-linguistic variation. Second, it could be that the relation is non-arbitrary, grounded in but semi-independent from phonetic properties governing the production and perception of glottalisation (Archangeli & Pulleyblank 1994). Third, it could be that the postvocalic constraint is due to diachronic developments (Blevins 1999ab, to appear). The constraint might be the result of phonologising phonetic properties[7] (relating it to the second possibility) but within a theory of phonology that imposes no strict grounding requirement (relating it to the first possibility). That is, according to the diachronic view, there could be a diachronic tendency to respect phonetically motivated distributions, but there would be no synchronic requirement for such.

It seems clear that the condition that glottalised sonorants must be prevocalic is grounded in phonetic properties: universally, sonorants tend to be preglottalised (Sapir 1938, Kingston 1985, 1990, Silverman 1997) so a preceding vowel favours the context cues for glottalisation in these segments. It also seems clear that the grounded condition is not a direct projection of the phonetic facts – at least, if projected from phonetic facts, then the facts are of a complexity that extend beyond the determination of position through reference to fixed glottal-oral timing. Hence a

[7] On the notion that the phonetic facts may have been simpler in the past, i.e. that glottalised sonorants may have been uniformly preglottalised in earlier Yowlumne, see fn. 6.

modular approach to disentangling the facts of Yowlumne glottalisation is required, either in the sense of grounding theory or through the phonologisation of phonetic effects.

4 The distribution of glottalisation in Nuu-chah-nulth

Unlike Yowlumne, glottalised sonorants in Nuu-chah-nulth (Nootka), a southern Wakashan language of Vancouver Island, do appear to have a fixed timing. While this might have made the language amenable to an analysis where the phonological distribution of glottalised segments were dependent on the nature of the oral-glottal timing, it turns out that the distribution continues to be independent of the pattern of timing.

In this section, we discuss the inventory of glottalised segments in Nuu-chah-nulth, focussing on the Ahousaht dialect. We discuss the distribution of both ejectives and glottalised sonorants. We show that their restricted distribution phonologically is independent of phonetic differences in the timing of the glottal gesture relative to the oral gesture.

4.1 The inventory of glottalised consonants

The consonant inventory of Nuu-chah-nulth is given in (24). Our focus here is on the Ahousaht dialect (Fraser & Howe 1996, Howe 1996, Nakayama 1997, Kim 1999, Dick et al. *in prep*) but some discussion will also be made of the Tseshaht dialect (Sapir & Swadesh 1939, Rose 1976, Stonham 1994).

(24) *Ahousaht Nuu-chah-nulth consonant inventory*

	Labial	Alveolar	Alveolar affricates	Lateral	Alveo-palatal	Velar	Rounded velar	Uvular	Rounded uvular	Pharyngeal	Laryngeal
Voiceless stops	p	t	c	ƛ	č	k	kʷ	q	qʷ		
Glottalised stops	p̓	t̓	c̓	ƛ̓	č̓	k̓	k̓ʷ			ʕ	
Fricatives		s		ł	š	x	xʷ	x̣	x̣ʷ	ḥ	
Nasals	n	m									
Glottalised nasals	n̓	m̓									
Glides					y		w				h
Glottalised glides					y̓		w̓				ʔ

Phonetically, glottalised obstruents are ejectives, involving glottal release after oral release. Glottalised sonorants are strongly pre-glottalised, with creaky voice shifting into modal voice during the production of the sonorant. Consider Sapir's (1933) description of the two segment types. (Recall that Nuu-chah-nulth was often referred to as "Nootka".)

> As a pure matter of phonetics, while the Nootka glottalized stops and affricates are roughly parallel in formation with glottalized sonantic consonants, they are not and

cannot be entirely so. In a glottalized *p*, for instance, ... there is a synchronous closure of the lips and glottal cords, a closed air chamber is thus produced between the two, there is a sudden release of the lip closure, a moment of pause, and then the release of the glottal closure. It is the release of the lip (or other oral closure) in advance of the glottal closure that gives consonants of this type their superficial "click-like" character. On the other hand, in a glottalized *m*, ... while the lip closure and glottal closure are synchronous as before, the glottal closure must be released at the point of initial sonancy of the *m*. Roughly speaking, therefore, p' may be analyzed into *p* + *'*, while 'm may be analyzed into *'* + *m*. (Sapir 1933:56)

The phonetics of the two segment-types are different enough that in early transcriptions Sapir employed two different methods of transcription for the two segment types. Following the practice of Franz Boas, Sapir (1906), for example, transcribed ejectives with an exclamation mark following the corresponding stop/affricate symbol (p!, t!, ts!, etc.) while glottalised sonorants were transcribed with a raised epsilon preceding the corresponding sonorant symbol ($^{\varepsilon}$m, $^{\varepsilon}$n, $^{\varepsilon}$l, etc.). Note that the raised epsilon is also used to indicate a glottal stop. This differentiated style of transcription was in spite of Sapir's clear recognition of the parallels between glottalisation on obstruents and on sonorants:

Kwakiutl and Nootka $^{\varepsilon}$*m,* $^{\varepsilon}$*n,* $^{\varepsilon}$*w,* $^{\varepsilon}$*y,* and Kwakiutl $^{\varepsilon}$*l* are undoubtedly related to ordinary Kwakiutl and Nootka *m, n, w, y,* and Kwakiutl *l* as are Kwakiutl and Nootka *p!, t!, k!, ʟ!, ts!, q!,* Kwakiutl *k·!,* and Nootka *tc!* to non-fortis Kwakiutl and Nootka *p, t, k, ʟ, ts, q,* Kwakiutl *k·,* and Nootka *tc*. (Sapir 1911:353).

Later, Sapir replaced both ! and $^{\varepsilon}$ by ' (apostrophe), but he continued to indicate glottalisation differently in sonorants and stops: 'When used for glottalization, the apostrophe is placed before resonants ('m 'n 'w 'y), after stops (p' t' k'), and internally for affricates (t's t'š)' (William Bright, *Phonetic key to publications of Edward Sapir*, in Golla 1991:523).

Our goals in focussing on Sapir's observations and proposals are twofold. First, auditorily based impressions of the timing relations between oral and glottal gestures are clear and consistent, and the language shows no evidence of significant change in this respect over the last 100 years. Second, though phonetically different, these two segment types show remarkable and consistent phonological patterning. Again, there is no evidence of a significant shift in this regard, and we turn now to some evidence for the claims regarding phonological patterning.

4.2 The distribution of glottalisation

Ejectives occur only prevocalically, in syllable-initial position. This is exemplified in the following table where examples are given of word-initial ejectives, intervocalic ejectives and postconsonantal but prevocalic ejectives. There are no examples of either word-final or preconsonantal ejectives in Nuu-chah-nulth.

(25) *Surface distribution of ejectives*

a.	*Word-initial*	p̓uuʔi	*halibut*
		t̓uḥc̓iti	*head*
		c̓aʔak	*river*
		ƛ̓upaa	*sunny*
		č̓aʔak	*water*
		k̓ašk^w^ay̓ap	*put things away*
		k̓^w^isaa	*snowing*
b.	*Intervocalic*	tup̓ał	*sea, ocean*
		ʔat̓a	*thick*
		q^w^ayac̓iik	*wolf*
		ʔič̓aʔap	*to lift*
		k̓^w^aƛ̓aq	*sea otter belt*
		wik̓aƛ	*not*
		t̓ak̓^w^as	*gills*
c.	*Postconsonantal*	łapḥsp̓at̓u	*bird wing*
		c̓imt̓uu	*squirrel*
		ƛułc̓uuʔiš	*it is clean (e.g. a cup)*
		ʔimč̓aap	*to play*
		hitaaq̓as	*woods, forest*
		ƛ̓ask̓asʔiš	*the surface is smooth*
		ʔink̓^w^aḥs	*lamp, ceiling light*

Ejectives contrast with sequences of a consonant followed by a glottal stop:

(26) *Contrasts between glottalised obstruents and clusters with [ʔ]*

VC’V	t̓ay̓ac̓u	*fish line (straight down fishing)*
VCʔV	ʕapcʔin	*abalone*

Other possible combinations of ejectives with a glottal stop are not possible because ejectives cannot occur preconsonantally (explaining the absence of *VC’ʔV*) and glottal stops cannot occur except syllable-initially/prevocalically (explaining the absence of *VʔCV* and *VʔC’V*).

The distribution of ejectives in Nuu-chah-nulth is faithfully repeated by the glottalised sonorants. As with ejectives, glottalised sonorants occur only in prevocalic/syllable-initial position. Examples are given in (27) of word-initial, intervocalic and postconsonantal but prevocalic glottalised sonorants. As with ejectives, there are no examples of either word-final or preconsonantal glottalised sonorants in Nuu-chah-nulth.

(27) *Surface distribution of glottalised sonorants*

a.	*Word-initial*	m'iƛaa	*raining*
		n'uw'iiqsuʔi	*the father*
		y'aʔisi	*butter clams*
		w'asaqšiʔ	*cough*
b.	*Intervocalic*	y'am'a	*salal berry*
		kin'ucak	*blue*
		k̓ʷiy'as	*snow on the ground*
		łiw'aḥmis	*cloud*
c.	*Postconsonantal*	łuučm'uup	*sister*
		mamałn'i	*European, white person*
		wiky'uʔaƛs	*I have not*
		ƛatw'aa	*paddle a canoe*

Again like the ejectives, a contrast is observed between glottalised sonorants and clusters with a glottal stop:

(28) *Contrasts between glottalised sonorants and clusters with [ʔ]*

VR'V	qinḥaam'a	*egg*
VRʔV	ʔumʔiiqsu	*mother*

Finally, it is important to focus on glottal stops themselves. It has been noted that glottal stops occur only syllable-initially/prevocalically. Some examples have been seen already, but here we add to those to show the full range of contexts for a glottal stop.

(29) *Surface distribution of glottal stop*

a.	*Word-initial*	ʔaḥkuu	*here*
		ʔiiḥ	*big*
		ʔučqak	*foggy*
		ʔuuštup	*something*
b.	*Intervocalic*	ʕaʔuk	*lake*
		naʔaa	*hear*
		huuʔiiʔatḥ	*Ohiaht tribe*
		hiʔiis	*there on ground*
c.	*Postconsonantal*	ƛ̓aačʔaał	*thimbleberry*
		čimʔił	*bed*
		ʔustʔił	*floor, downstairs*
		mušʔasum	*door*

As with both ejectives and glottalised sonorants, a glottal stop may not occur either word-finally or before a consonant.

4.3 Syllable-based distribution and positional faithfulness

General properties of Nuu-chah-nulth syllable structure are as follows (Sapir & Swadesh 1939, Stonham 1994). Every syllable has an onset; vowel nuclei may be either long or short; codas are possible and may contain up to three consonants. The effect of these constraints is that "syllable-initial" and "prevocalic" descriptors both refer to the same class of consonants. This means that ejectives and glottalised sonorants may be correctly described as occurring only syllable-initially, or as occurring only prevocalically. It is not the case, however, that these descriptors are equivalent. At issue is whether the appearance of glottalised segments in this particular position is due to properties of prosodic organisation or to featural properties of the consonant-vowel sequence.

Consider first the issue of timing. Unlike Yowlumne, Nuu-chah-nulth shows no variability in the timing of oral and glottal gestures. Glottalised obstruents are consistently ejectives, that is, post-glottalised; glottalised sonorants are consistently pre-glottalised. Hence constraints governing the relative timing of oral and glottal gestures would have to be highly ranked – inviolable as far as the Nuu-chah-nulth grammar is concerned.

The second issue concerns goodness of cues to glottalisation. If we assume that the optimal cues to the glottal component of an ejective are to be found *after* the ejective, and that cues to the glottal component of a pre-glottalised sonorant are to be found *before* the glottalised sonorant, and that cues to the presence of a glottal stop could be optimal either *before* or *after* the glottal stop, then we are left with a quandary. Since all three segment types show a uniform distribution, and since the optimal cues for the glottal component of the three segment types are located in different contexts, it cannot be the case that perceptual cues to glottalisation are the determining factor in the segments' distribution.

Turning to the potential role of place cues, we see a similar lack of explanation. Consider first the distribution of the glottal stop. Since there are no place features to be either optimally perceived or inhibited (at least, independent of the laryngeal articulation itself depending on whether it is considered a "place"), there can be no role for the perceptibility of place cues in glottal stop distribution – but the distribution of glottal stop is fully parallel to the distribution of ejectives and glottalised sonorants. With regard to ejectives, it is somewhat unclear whether ejection enhances or interferes with the perception of place features. If the heightened pressure and so on actually enhances the perception of place, then place cues are optimised pre-vocalically. But if ejection enhances place perception, then there should be no problem per se with a word-final or pre-consonantal ejective. Since plain obstruents freely occur in such contexts, there must be sufficient cues for the recoverability of place features; if ejection serves to enhance, not inhibit, the perception of place, then ejectives should be equally possible in such contexts as they are pre-vocalically.

We conclude that there are no plausible factors in terms of the perceptibility of creaky voice on pre-glottalised sonorants, the perceptibility of ejection on glottalised obstruents, and the perceptibility of glottal stops *tout court* that would explain the uniform pre-vocalic distribution of the three segment types.

At this point, it is worth noting that Blevins (to appear) attempts to interpret our description of the Nuu-chah-nulth facts in the framework of "[a] weaker version of Steriade's proposal." She claims that Nuu-chah-nulth is “amenable to cue-based phonetic explanations in the diachronic dimension” in the following way:

> Suppose that in pre-Ahousaht, laryngealized sonorants were the result of sonorant-glottal stop clusters, and were all post-laryngealized. Alternations in pre-Ahousaht resulted in pre-V and pre-C environments for ejectives and post-laryngealized sonorants, and the weaker release cues in pre-C environments resulted in laryngeal neutralization for obstruents and sonorants. Over time, sonorant laryngealization shifted to its optimal position (Kingston 1990), resulting in the current Ahousaht system. (Blevins to appear)

While it might be considered at first glance rather appealing, such a diachronic cue-based account does not seem satisfactory. First, like the synchronic cue-based account, it fails to explain the fact that glottal stops have the same distribution as ejectives and glottalised sonorants in Ahousaht, as discussed above.

Second, while it is quite plausible that some glottalised sonorants may have arisen historically from sonorant-glottal stop sequences (see Sapir 1938 for some potential examples), glottalised sonorants in general are of “Wakashan” age – perhaps 2900 (Swadesh 1953) or even 6099 (Embleton 1985) years old! Some examples of Proto-Wakashan glottalised sonorants are given here (Howe 1999):

(30) *Proto-Wakashan glottalised sonorants*

a. *n̓ak- ‘look’ > Haisla/Henaksiala *n’ak-*, Heiltsuk *n’ák-*, Oowek’yala *n’ak-*, Kwak’wala *n’ak-*, Nuu-chah-nulth (“Nootka”) *n’ač-*, Ditidaht *dač-*, Makah *dač-* (cf. *naq- ‘drink’ > Haisla/Henaksiala *naq-*, Heiltsuk *náq-*, Oowek’yala *naq-*, Kwak’wala *naq-*, Nuu-chah-nulth (“Nootka”) *naq-*, Ditidaht *daq-*, Makah *daq-*)

b. *n̓aː- ‘day’ > Heiltsuk *n’álà*, Oowek’yala *n’aːla*, Kwak’wala *n’ala*, Nuu-chah-nulth (“Nootka”) *n’aːs*

c. *n̓m-/m̓n- ‘one’ > Haisla/Henaksiala *m’ncx̌ʷ* ‘twenty (one score)’, Heiltsuk *m’ńsğm* ` ‘one silver doller’, Oowek’yala *m’nsğm* ibid., Kwak’wala *n’msğm* ibid., Nuu-chah-nulth (“Nootka”) *n’upu* ‘six (one left)’

Whatever their ultimate origin, the development of glottalised sonorants has been independent of cluster properties for thousands of years.

Third, Blevins’ proposition that glottalised sonorants were “all post-laryngealized” in “Pre-Ahousaht” cannot be substantiated. Glottalised sonorants are preglottalised in all Wakashan languages where these segments survive: Haisla/Henaksiala (2 dialects), Heiltsuk (2 dialects), Oowek’yala, Kwak’wala (at least six dialects), Nuu-chah-nulth (“Nootka”) (at least 12 dialects), and Ditidaht.[8] Some instances of postglottalised sonorants are attested in Kwak’wala and in Oowek’yala, but these are restricted to coda positions, in accordance with the “phonetic universal” (Plauché et al. 1998) discussed in section 2.2. In fact, to our knowledge no language exists in which glottalised sonorants are consistently postglottalised prevocalically. As mentioned in section 2.2., there are cases in which phonetically postglottalised sonorants appear intervocalically when the

[8] Ditidaht sonorants are being affected by a gradual loss of glottalisation. This loss results in the lengthening of an immediately preceding vowel (if any); see Gamble (1977).

following vowel is either stressed (Sənčáθən) or unstressed (St'at'imcets), but even in these languages, glottalised sonorants are otherwise preglottalised prevocalically.

This leaves us, then, with the prosodic option of accounting for the distribution of the three segment types with reference to syllable structure. Two points are central. First, to account for the parallel behaviour of ejection in obstruents, creak in sonorants and a plain glottal stop, a single unified feature of "[constricted glottis]" is to be preferred to more elaborated features such as "[creak]" and "[ejection]". That is, the Nuu-chah-nulth patterns favour the more abstract glottal features that have been posited in work such as Halle & Stevens 1971 (cf. more narrowly phonetic features such as suggested in work such as Steriade 1997); see discussion above. Second, since the segmental context does not seem to provide an explanatory account for the distribution of glottalised segments in Nuu-chah-nulth, we hypothesise instead that the crucial factor is syllabic position. We instantiate this hypothesis by the postulation of positionally dependent faithfulness constraints (Beckman 1999, Lombardi 1999). Specifically, we assume a constraint that uniformly prohibits the presence of a [Constricted Glottis] specification, *[CG], along with two faithfulness constraints requiring the retention of any lexically specified [Constricted Glottis] specification, one positionally dependent and one unrestricted.

(31) *CG — Specifications of the feature [Constricted Glottis] are prohibited.
MaxCG — If the feature [Constricted Glottis] is found in the input, then there is a corresponding feature [Constricted Glottis] in the output.
MaxCG/Ons — If the feature [Constricted Glottis] is found in the input, then there is a corresponding feature [Constricted Glottis] in Onset position in the output.

Under the assumption that ejectives, glottalised sonorants and glottal stop all involve specification for the feature [Constricted Glottis], these constraints will restrict glottalisation to onset position if ranked MaxCG/Ons >> *CG >> MaxCG. That lexically specified glottalisation is retained in onsets is illustrated in (32) with word-initial and intervocalic glottalised sonorants; the effect of the constraints will be the same for ejectives and glottal stop, and will be the same postconsonantally.

(32) *Retention of [Constricted Glottis] in onset position*

/y̓am̓a/	MaxCG/Ons	*CG	MaxCG
a. ☞ ˀyaˀma		**	
b. yaˀma	*!	*	*
c. ˀyama	*!	*	*
d. yama	*!*		**

That glottalisation is impossible in codas is illustrated schematically in (33).

(33) *Impossibility of [Constricted Glottis] in coda position*

/CVC'/		MAXCG/ONS	*CG	MAXCG
a.	CVCˀ		*!	
b. ☞	CVC			*

To summarise, the appearance of glottalisation in onsets but not in codas can straightforwardly be attributed to syllable-sensitive faithfulness constraints. Before speculating on the motivation for such syllable-based dependencies, it is important to consider an additional type of distributional pattern for glottalisation. For this we turn to the example of Kashaya.

5 The distribution of glottalisation in Kashaya

The pattern of glottalisation on sonorants in Kashaya (Buckley 1990, 1994) is in significant ways the mirror image of that seen for Nuu-chah-nulth both phonetically and phonologically. Phonetically, while the glottalised sonorants of Nuu-chah-nulth are systematically pre-glottalised, those of Kashaya are consistently post-glottalised. Phonologically, while the glottalised sonorants of Nuu-chah-nulth occur only in onset position, those of Kashaya appear only in codas.

As seen in (34), Kashaya presents a range of plain and glottalised consonants (Buckley 1990, 1994). As in the other languages discussed here, the glottalised obstruent stops are ejectives while the glottalised sonorants involve creaky voice.[9]

(34) *Kashaya consonant inventory*

		Labial	Dental	Alveolar	Palatal	Velar	Uvular	Glottal
Stops	plain	p	t	ṭ	c	k	q	
	aspirated	p^h	t^h	$ṭ^h$	c^h	k^h	q^h	
	glottalised	p'	t'	ṭ'	c'	k'	q'	
Fricatives	plain			s	š			
	glottalised			s'				
Nasals	plain	m	n					
	aspirated	m^h	n^h					
	glottalised	m'	n'					
Approximants	plain	w		l	y			h
	aspirated	w^h		l^h	y^h			ʔ
	glottalised	w'		l'	y'			

[9] The Kashaya inventory includes a glottalised fricative. The phonetics of this segment are not discussed in Buckley (1994).

Like Yowlumne, and unlike Nuu-chah-nulth, the distribution of ejectives is quite free. These segments occur initially (k̓anás ‘sickly’), medially (pʰiṭ̓em̓ṭ̓e ‘symphysis’), and finally (s̓ot̓ ‘lungs’). Of interest here, however, is the more limited distribution of the glottalised sonorants.

Consider first the phonetic realisation of the glottalised sonorants. Buckley is explicit about their being realised ‘with normal voicing at the beginning and creaky voice toward the end, sometimes followed by a glottal stop’ (Buckley 1994:40). Indeed, the timing is so clearly oral followed by glottal that earlier work by Robert Oswalt analysed these cases as involving phonological sequences of a sonorant followed by a glottal stop (see Buckley 1994 for discussion and references). Buckley argues convincingly, however, that these cases constitute unitary glottalised segments, not clusters. Hence Kashaya presents a class of glottalised segments that are phonetically post-glottalised.

Of interest in this regard is the patterning of these segments. Buckley demonstrates that glottalised sonorants may occur only in coda position:[10]

(35) *Surface distribution of glottalised sonorants*

a.	*Word-final*	mόm̓	*run across*
		diṭ̓án̓	*bruise by dropping*
		saw̓	*tight*
		hiʔbálʰmul̓	*turn around*
		kó꞉ltay̓	*mosquito*
b.	*Preconsonantal*	pʰaʔám̓so	*type of greens*
		mahsán̓qʰ	*must have taken it away*
		ʔihmín̓cay̓	*singer*
		šíw̓ši	*chick*
		wól̓wo	*badger*
		máy̓ma	*separate, apart*

Glottalised sonorants may not occur word-initially, nor may they occur intervocalically or postconsonantally.

This distribution is significant with regard to whether the distribution of glottalisation can be characterised prosodically or in terms of phonetic cues. In terms of prosody, this pattern is simply described: glottalised sonorants in Kashaya may only appear in coda position. In terms of phonetic cues, the distribution is problematic for two reasons. First, if distribution were to optimise the glottal component of post-glottalised segments, then such segments should appear *prevocalically*; in fact, Kashaya restricts glottalised sonorants to the exact opposite position. Second, were cues to be optimised for the glottal component or the oral (place) component, an intervocalic context should be optimal for the realisation of cues. Since glottalised sonorants in Kashaya may not appear in what would be the optimal context, this restriction cannot be explained with reference to phonetic cues.

The conclusion seems to be clear. The distribution of glottalised sonorants in Kashaya depends not on the goodness of the phonetic context but on their syllabic position. Buckley

[10] Ladefoged and Maddieson (1996:110) erroneously report Buckley as claiming that Kashaya ‘places the constriction at the beginning of the nasal when the consonant is syllable-initial, and at the end when it is syllable-final’ (as in Yowlumne).

suggests that glottalised sonorants are banned from onsets by the constraint *[$_\sigma$[+son, gl] (cf. Kingston 1985).[11] An alternative – still prosodic – explanation might run as follows: glottalised sonorants (but not ejectives) represent one of the most highly marked types of segments (Maddieson 1984) and as such, their phonological use may depend on their being licensed by prosodic structure. Suppose, in particular, that glottalised sonorants in Kashaya must be licensed by a mora (cf. Parker 1994 on Chamicuro). Their distributional pattern then follows: a mora dominates consonants in syllable coda position but not in the onset.

Note that weight-by-position is demonstrated in Kashaya by metrical stress patterns (e.g. (.qóm.)(.qa.sʼu.)(.wem.) 'keep peering around'), by closed-syllable shortening (e.g. diː+cʼw+acʼ+a+mu → dicʼ.wa.cʼa.mu 'what they say (is)'), and by compensatory lengthening after c-deletion (e.g. yoqʼoc+tʰ → yoqʼoːtʰ 'he isn't keeping it') (Buckley 1994, 1995).

We regard the "moraic licensing" of glottalised sonorants in Kashaya as an instance where prosodic prominence is what makes it possible to tolerate a marked segment type. We therefore postulate faithfulness constraints that are dependent on prosodic prominence. That is, paralleling our analysis of Nuu-chah-nulth (section 4) we assume a markedness constraint that prohibits the presence of a [Constricted Glottis] specification on sonorants, *CG/SON, along with two faithfulness constraints requiring the retention of any lexically specified [Constricted Glottis] specification, one prosodically dependent and one unrestricted.

(36)	*CG/SON	Specifications of the feature [Constricted Glottis] are prohibited on [Sonorant] segments.
	MAXCG	If the feature [Constricted Glottis] is found in the input, then there is a corresponding feature [Constricted Glottis] in the output.
	MAXCG/μ	If the feature [Constricted Glottis] is found in the input, then there is a corresponding feature [Constricted Glottis] in moraic position in the output.

If ranked MAXCG/μ >> *CG/SON >> MAXCG, these constraints will correctly restrict the distribution of glottalised sonorants to the syllable coda position, which is moraic. That lexically specified glottalisation on sonorants is preserved only in moraic position is illustrated here:

[11] This constraint is held responsible for at least two types of alternations: Postlexically, any glottalised sonorant which syllabifies as an onset simply loses its glottalisation (e.g., /manʼ+ʔe mu/ → [mané mu] 'that's her'; cf. [mánʼ] 'she'). Lexically, a glottalised nasal in onset position loses not only its glottalisation but also its nasality (e.g., /nʼu+hlunʼ+mʼa/ → [duhlunʼba] 'after picking'; /nʼu+hlunʼ+anʼ+in/ → [duhludaːdun] 'while continuing to pick').

(37) *“Moraic licensing” of glottalised sonorants in Kashaya*

		MAXCG/μ	*CG/SON	MAXCG
/R’V…/	a. σ μ R ’ V…		*!	
	b. ☝ σ μ R V…			*
/…VR’/	c. ☝ σ μ μ …V R ’		*	
	d. σ μ μ …V R	*!		*

6 Implications and discussion

The phonologist and the phonetician have overlapping mandates inasmuch as each is charged with the description and explanation of speech production and perception. The difference between them, it is sometimes assumed, is that the former is primarily a cognitive scientist, concerned with sound patterns that are unconsciously controlled by the human mind, while the latter is above all a physical scientist, concerned with the acoustic and physiological bases of speech. Under such a view, the former specialises in the manipulation of discrete symbolic elements which are frequently gross idealisations of the physical reality investigated by the latter. For instance, phonological representations are categorical while phonetic representations are gradient. (Phonetic models with categories represent gradiency by ‘interpolation’; see Keating 1996).

Reliance on such a distinction between ‘cognitive’ and ‘physical’ has decreased in cognitive science over the last decade, however, as there has been a dramatic increase in our understanding of how the brain may uncover the structure of the physical world – including linguistic structure – via its sensory receptors, and how it may perform cognitive functions with neurons instantiating parallel distributed representations (see McLeod, Plunkett & Rolls 1998 for an introduction to connectionist modelling of cognitive processes, including speech). These recent developments in cognitive science have had an important impact on phonology. Examples include (Connectionist) Cognitive Phonology (Touretzky & Wheeler 1990, Wheeler & Touretzky 1993), Harmonic Phonology (Goldsmith 1993), Harmonic Grammar (Smolensky 1986), and its successor Optimality Theory (Prince & Smolensky 1993, 1997).

Significantly, these new models are especially useful for researchers attempting to incorporate phonetic substance directly into accounts of phonological patterns. There is, accordingly, growing acceptance of the view that phonetics has a direct effect on phonology. In its extreme form, this view says that ALL phonology is phonetically-motivated. (Sound patterns that appear to have no explanation in speech production or perception are relegated to the morphological module of grammar.) For example, models of stress assignment which make direct reference to the acoustic wave rhythm have been developed by Wheeler and Touretzky (1991) in Connectionist Cognitive Phonology and by Laks (1997) in Harmonic Phonology. Crucially, these models avoid all reference to phonology-proper notions such as (metrical) constituency and compositionality. In Optimality Theory, phonotactic patterns have been analysed with constraints and constraint hierarchies that directly encode the physical perspectives of the speaker/listener, such as relative ease of articulation (e.g. Kirchner 1997) or relative ease of perception (e.g. Flemming 1995).

Such phonetic reductionism in phonology is vividly illustrated in recent work by Donca Steriade (1997, 1998ab, 1999). Steriade argues that perceptual constraints and constraint hierarchies fully eliminate the role of the syllable in the explanation of the distributional patterns of features. Wide-currency statements such as “feature X is restricted to syllable onset position” or “feature X is not permitted in syllable coda position” are thus replaced by apparently more explanatory ones such as “feature X occurs where perceptual cues to it are maximized” or “feature X is avoided where perceptual cues to it are weak”. Steriade’s discussion focuses on the distribution of retroflexion and laryngeal features, but her claim is general: features are licensed by perceptual cues, not by prosody.

We have found compelling evidence against this view as it pertains to the patterning and timing of glottalisation. Indeed, an interesting pattern emerges from the three cases discussed in this paper. As can be seen in (38), there is a correlation between syllabic position and the pattern of glottal timing.

(38) *Syllabic position and glottal timing*

Language	*Syllable position*	*Timing of glottal component*
Nuu-chah-nulth	Onset	Pre-glottalised
Yowlumne	Onset	Pre-glottalised
Yowlumne	Coda	Post-glottalised
Kashaya	Coda	Post-glottalised

Of interest, the observed correlation is exactly the opposite of that predicted by an analysis seeking to optimise for phonetic cues to glottalisation – at least if cues to glottalisation are optimal in a vocalic environment. Our conclusion is that the timing and the perception of glottalisation, which have been discussed at length by Sapir, Kingston and Silverman among others, have no direct effect on the phonological component of grammar. They are part of the mapping of phonological structure into phonetic output – a language-particular operation of the phonetics (Keating 1988).

It is true that the observed tendency for glottalised sonorants to be preglottalised may inspire a grammatical constraint (a perceptually-grounded condition) restricting glottalised sonorants to postvocalic position, as in Yowlumne. But the constraint in question turns out to be a gross abstraction of phonetic facts: phonologically, it restricts glottalised sonorants to postvocalic position even when they are postglottalised phonetically (section 3). In Nuu-chah-nulth (section 4) and in Kashaya (section 5) we argued that syllable-based faithfulness constraints caused glottalised sonorants to be distributed in these languages in exactly the opposite way of what would be expected if the phonology were sensitive to the timing and perception of glottalisation. Crucially, the syllable is a purely phonological construct for which there is no obvious phonetic motivation (see discussion in Ladefoged & Maddieson 1996:282).

Such blatant mismatches between the phonology and the phonetics bode ill for the emergence of a 'unified model that allows a direct and economical account of parallelism according to which parallel 'phonetic' and 'phonological' phenomena are motivated by the same constraints' (Flemming 1999:23; cf. Steriade 1997, 1998ab, 1999). Instead, the glottalisation facts support the modularity hypothesis, under which phonology and phonetics are different modules, each independently motivated and empirically supported. In this approach, phonological patterns such as the distribution of glottalisation result from the interaction of several largely-independent submodules, e.g. grounded conditions, constraints on syllable structure, and faithfulness constraints.

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