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Glottalized Sonorants: A Phonetic Universal?

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1. Introduction

It has previously been argued that the glottalization of sonorants should be free to surface anywhere and that they tend to be preglottalized in the world's languages (Kingston, 1983). We have found in our preliminary phonetic investigation of Lai,[1] Coatlàn-Loxicha Zapotec,[2] and Yowlumne,[3] as well as a survey of detailed phonetic descriptions of the segments in other languages, that for those languages that rely mainly on creaky voice, full glottal stop, and amplitude as phonetic cues for glottalization, these segments will surface as preglottalized in onset and postglottalized in coda. This pattern is thought to be the result of the obscuring nature of these particular cues, in which segments preserve the most information if the glottalization does not co-occur with the crucial sonorant to vowel or vowel to sonorant transition.

This paper begins by predicting a universal tendency for the phonetic structure of glottalized sonorants based on previous analyses and data on the perception of sonorant-vowel (NV) and vowel-sonorant (VN) sequences (Section 2). A preliminary acoustic analysis of both Yowlumne and Coatlàn-Loxicha Zapotec are shown to support these predictions (Section 3.1, 3.2), but Lai is found to work contrary to our claim (Section 3.3). The paper concludes with a discussion of how knowledge of universal physical and acoustic constraints can predict what we actually find in the phonology of the world's languages (Section 4).

2. A universal phonetic structure of glottalized sonorants

Glottalized sonorants are phonetically sonorants (usually nasals, rhotics, laterals, or glides) accompanied by a constriction of the glottis caused by tightening the cricoarytenoid, found, for example, in a variation of the word 'couldn't' in English: [kʌdˀn̩]. Although relatively rare in the world's languages as a distinct phoneme (Maddieson 1984), the glottalized sonorant surfaces with various salient acoustic cues to mark its distinction from plain sonorants. The main structure is a sonorant produced with creaky voice, an irregular voicing modality, 'in which the arytenoid cartilages are much closer together than in modal voice. Creaky voice also involves a great deal of tension in the intrinsic laryngeal musculature, so that the vocal folds no longer vibrate as a whole.' (Ladefoged et al. 1996:53). Sometimes this constriction is complete, yielding a phonetic glottal stop. Other secondary acoustic domains may cue the perception of glottalized sonorants in a variety of languages as well. These include pitch, preceding vowel duration, sonorant duration, and bandwidth.

In his study of articulatory binding of glottalization, Kingston (1983) found that the complete oral closure of stops allowed a build-up of pressure in the oral cavity, causing a high-energy, salient acoustic event at the release of stops. Stops with a secondary laryngeal constriction tend to be postglottalized as a result of glottalization fixing itself to the salient stop release. In the case of sonorants, however, as a result of oral or nasal leakage, no equivalent air pressure build-up occurs. Thus, unlike stops, they do not have an equivalent asymmetrical design; their onset is much like a mirror image of their offset. Therefore, they should be free to have glottalization show up anywhere during the oral closure[4]. This paper will show, however, that many languages exhibit glottalized sonorants that are strictly preglottalized, but some show an even more specific structure: preglottalized in onset position, but postglottalized in coda.

In a study of voiceless nasals in Burmese and the Hmar dialect Mizo, Ladefoged and Maddieson found that voiceless nasals in initial position had substantial voicing in the last part of the oral closure.

> 'Ladefoged (1971) and Ohala (1975) suggest that an early onset of voicing helps to distinguish one voiceless nasal from another by making the place of articulation more apparent. This is because the voiced offglide from the nasal into the vowel displays formant transitions that are characteristic of each place of articulation.' (Ladefoged and Maddieson 1996:113).

Based on the behaviour of the voiceless nasals, Silverman (1995) then argued that because the CV transitions are primary in conveying information about the place and manner of nasals (Fujimura 1962), and

> 'a heavy glottal constriction may result in sufficient aperiodicity, or jitter, to disrupt the acoustic encoding of a salient nasal formant structure. ... if glottal pulse (quasi-periodicity) is markedly slow—a common result of creakiness—insufficient energy is present during the crucial transition period; transitions may take place during the relatively long periods of glottal closure. Consequently, formant transitions may be rendered unrecoverable.' (Silverman 1995:70)

By extending this argument to glides, he explains the tendency for languages to have preglottalized sonorants. This argument works well for sonorants in onset, but Silverman's concluding remarks of this argument reveal that it misses an entire set of sonorants: those in the coda: 'to optimize recoverability, sonorant consonants are realized with laryngeal gestures phased to the early portion of the

supralaryngeal configurations, ... in order to mitigate the potential non-salience of formant transitions into a following vowel.'(Silverman 1995:78)

The present paper extends this reasoning to those sonorants occurring in the coda and takes a closer look at the acoustic cues involved in glottalization of sonorants. Silverman mentions the irregular glottal pulses, the low amplitude, and lower F_0, but we have found in Lai, for example, that secondary cues may include vowel length and sonorant length. If preglottalization 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.

Note that this analysis suggests that glottalized sonorants are likely candidates for sound change, as cues for either place or glottalization may be compromised, since they work antagonistically. If creaky voice obscures the cues for sonorants, we expect to find cases of de-glottalization or de-sonorization historically; below are two compelling examples.[5] This is not to say that there is a universal tendency for glottalized sonorants to disappear; the creation of these segments from, say, a glottal stop and sonorant sequence is equally productive.

In Wakashan, 'glottalization floats off sonorants under certain circumstances, while remaining stably linked to stops under the same circumstances.'(Kingston 1983:320) Both loss of glottalization and loss of sonorancy are found in Kashaya: Glottalized sonorants de-sonorize (surface as [b] and [d]) word-initially and de-glottalize: 'if a glottalized sonorant at the end of a word resyllabifies as the onset, it loses its glottalization' (Buckley 1988:49):

/maˀne·mu/	→	mané·mu	'it's her'
/doloˀme·mu/	→	do lo mé·mu	'it's a wildcat''

3. Preglottalized in onset, postglottalized in coda.

3.1. Zapotec: postglottalized in coda position.[6]

Coatlán-Loxicha Zapotec (CLZ) follows our first prediction: the glottalized sonorants [nˀ, wˀ, lˀ, jˀ], which only surface in word-final position, consistently surface postglottalized. We find them only word-finally, the result of a historical vowel deletion which caused previously-medial sonorants to become word-final. Only when these sonorants became part of the rime could suprasegmental features such as tone and glottalization map onto them. Glottalized sonorants in CLZ are cued by either irregular F_0 and/or by a full phonetic glottal stop[7]. Even though historically the glottal feature may have come from either a preceding or following syllable, these segments are always postglottalized, with the irregular voicing modality starting 50ms after the onset of the sonorant and persisting to the end of the sonorant, often with a glottal release marking the end of the word. In the table below, note that whether the glottalized sonorant arose from a plain sonorant combined with a preceding, a following, or a surrounding pair of glottal stops, they consistently surface as postglottalized segments in CLZ today.

Original sequence	Proto-Zapotec (Kaufman, 1995)	Coatlán-Loxicha Zapotec	English gloss
*ʔS	*p+e: ʔlla	mbæ̌ l	'snake'
* SVʔ	* ʂilaʔ	ʂil	'cotton'
*ʔ SVʔ	*pe: ʔlaʔ	bæ̌ l	'meat'

Table 1. Historical origin of glottalized sonorants in CLZ.[8]

Creaky voice is produced by tightening the cricoarytenoid which causes the vocal cords to increase in mass at the point where the air mass passes through. This causes not only an irregularity in the vocal pulse, but a general drop in the rate of vibration. Speakers of CLZ and other languages[9] consistently produce glottalized sonorants in VN sequences with an associated high pitch on the preceding vowel, presumably as a re-interpretation of the contrasting drop in pitch on the sonorant itself when produced with glottalization. In CLZ, glottalized sonorants are found to cause pitch patterns to play out in higher frequencies on the preceding vowel, consistently enough to have developed into a fixed allotony in some cases. In the case of the rising tone, for example, this perturbation produces a regular allotony, conditioned by glottalization on either vowels or sonorants, such that the low-to-high rising tone surfaces as a mid-to-high rising tone in the Loxicha dialect, and a high-to-very high rising tone in the Coatlán dialect.

	VN (Average frequency)		$VN^{ʔ}$ (Average frequency)	
Loxicha	120>180 Hz.	Low to High	140>180 Hz.	Mid to High
Coatlán	130>170 Hz.	Low to High	190>220 Hz.	High to Very High

Table 2. The frequencies of the beginning and end of 100 rimes for each dialect were measured from a pitch extraction and averaged. In both dialects, the phonemic rising tone, low-to-high rising in non-glottalized environments, surfaces with a higher allotone when preceding glottalized sonorants or glottal stop.

Despite the variety of acoustic cues available to these segments in CLZ, the glottalized sonorants consistently surface with either irregular glottal pulses or a full glottal stop, compromising the communication of any brief formant structure, such as that found in the transition from vowel to the word-final sonorant. By consistently surfacing as postglottalized, these glottalized sonorants preserve the maximum acoustic cues about the place and manner of the sonorant itself.

3.2. Yowlumne: preglottalized in onset, postglottalized in coda.

A preliminary phonetic investigation of Yowlumne shows it complies to our prediction to the fullest extent: Glottalized sonorants in this language are consistently produced with preglottalization in onset position, but postglottalization in coda position. Unlike CLZ, Yowlumne has glottalized sonorants in onset (do not occur word-initially), where they are preglottalized, and in coda position (both preconsonantally and word-finally), where they are postglottalized. These segments are acoustically distinct from plain sonorants in their irregular F_0 and dip in amplitude, those cues previously discussed as being responsible for obscuring the place of the sonorant.

VNC		VN#		VNV	
Yowlumne	Gloss	Yowlumne	Gloss	Yowlumne	Gloss
lanˀtʼe	'left'	hajalˀ	'day'	ʔaˀwat͡ʃ	'dislike'
xolˀpojo	'lizard'	t͡sijˀ	'bone'	taaˀmut͡ʃ	'whiskers'
t͡sʼolˀlol	'white'	nukumˀ	'bend'	tiˀmit͡ʃ	'eyebrow'
bimˀtʰana	'stump'	lat͡ʃawˀ	'steep'	noˀno	'man'

Table 3. Glottalized sonorants in Yowlumne: preglottalized in onset, postglottalized in coda (as determined by visual inspection of spectrograms (Figure 1)).

In Yowlumne, the most consistent and prevalent acoustic cue for glottalized sonorants versus plain sonorants is the presence of creaky voice. Creaky voice, or jitter, is not the only acoustic cue for glottalized sonorants: these segments often surface with no sign of creaky voice, but with a drop in amplitude across the onset of the sonorant in VN sequences and across the offset in NV sequences. As previously noted, creaky voice is not only characterized by irregular glottal pulses, but often by long and irregular intervals of time in between each pulse. This has the overall affect of dropping the amplitude during the constriction. In Yowlumne, the dip in amplitude may have become a primary cue for glottalization on sonorants: On average, glottalized sonorants exhibit a drop in amplitude of 10- 20 decibels for nasals and laterals (5-10 dB for glides) compared to the drop in amplitude from a vowel to a plain sonorant which is 1-5 dB for plain sonorants.

As we observed in CLZ, the glottalized sonorants in Yowlumne are found to devoice when in coda position. Devoicing happens after, not instead of, glottalization. This was noted by Newman for Yowlumne and other Yokuts languages: 'The glottalized consonants, ẁ, j̀, l̀, m̀, ǹ, and ŋ̀, when they occur finally in a word or in a closed syllable, are heard as -w̓ʰʷ or even as -ʼʰʷ, etc.' (Newman 1944:17)[10] The tendency for voicelessness and glottalization to co-occur, is certainly related to the fact that voiceless glottalized sonorants do not exist distinctively in any language. (Maddieson 1984) This is to be expected, since the articulators needed to produce both of these voicing modalities are the vocal cords: it is physically impossible to constrict the glottis, causing the vocal cords to be closer together than in modal voice, while at the same time holding the vocal cords apart for true voicelessness. It is interesting to note that some of the overall acoustic effects for these two voicing modalities are similar: namely drop in amplitude and irregular output of energy.

3.3. Lai: an apparent exception.

Lai appears to contradict the principles discussed so far in this paper. Although this language only has glottalized sonorants [ˀm, ˀn, ˀŋ, ˀw, ˀr, ˀl, ˀj] in coda position, they show variation of phonetic production, but are mainly preglottalized. This phenomenon cannot be fully explained by the obscuring nature of jitter on the NV transition, as explained by Silverman, as there is no 'following vowel,' not even historically: these segments were derived from a final -s suffix (Proto-Tibeto-Burman *zey-smans > zey-hmanˀ 'whatever' (J. Matisoff p.c.)), presumably with an intermediate stage of glottal stop followed by a sonorant (cf. Roengpitya 1998). The sequence of a sonorant followed by a glottal stop was probably re-interpreted as a glottalized sonorant, which now surfaces as either preglottalized, simultaneously glottalized, or postglottalized.

	Form I	Form II	Gloss
Verbal Forms:	kaaŋ	kaˀŋ	'burn'
	ʔaj	ʔaˀj	'eat'
	hŋal	hŋaˀl	'know'
	saaw	saˀw	'prolong'
Nominal Form:		hŋeˀr-tee	'ants'

Table 4. Synchronic pattern of glottalized sonorants in Lai. The position of the glottalization relative to the sonorant varies, but it is most often preglottalized.

To understand the exception of Lai and other languages[11] to our prediction that languages should prefer postglottalized sonorants in the coda, we must look further at the phonetic and phonological structure of this language specifically. The phonetic structure of the glottalized sonorants differed from both CLZ and Yowlumne in that vowel and sonorant length varied consistently with glottalization. Also, a look at the phonology of Lai shows that stops are unreleased in word final and word medial codas, suggesting a different structure for sonorants as well.

Although creaky voice, and often full glottal closure preceding, simultaneous to, and following the sonorant are found as acoustic cues for glottalization in Lai sonorants, other secondary cues may be involved. We found that both the length of the preceding vowel (The average vowel length across 10 minimal pairs for the three nasals were 135msec before plain and 102msec before glottalized nasals) and the length of the sonorant itself (The average sonorant length across 30 minimal pairs including all sonorant types were 268msec for plain and 77msec for glottalized sonorants) greatly differ depending on the absence or presence of glottalization on the sonorant. This was found both word-finally and in word-medial coda positions. If vowel and sonorant length are used by listeners to identify plain and glottalized sonorants, cues such as jitter and amplitude drop might be less essential to the production of glottalized sonorants. Jitter and amplitude are found in the acoustic signal of Lai glottalized sonorants, however, and so the problem of these cues masking those for place when they occur at the VN transition remains.

Another relevant fact about Lai is that all codas are unreleased for stops and sonorants. This suggests that although the production of preglottalized sonorants in the coda may obscure the place of articulation, the glottalization itself is more likely to be perceived if it occurs at the beginning of the sonorant than at the end, since there is no equivalent dynamic transition after the sonorant.

4. Conclusion.

Although the simultaneous oral and laryngeal constrictions for glottalized sonorant are not bound by production to surface with a certain temporal restriction relative to one another, and indeed in Lai and other languages they do exhibit large variations in production from speaker to speaker and utterance to utterance, Yowlumne, Coatlàn-Loxicha Zapotec, and other languages exhibit a particular phonetic structure for glottalized sonorants: preglottalization in the onset and postglottalization in the coda. The main acoustic cues for glottalization (creaky voice, amplitude, and bandwidth) may obscure those for the place of the sonorant itself. The pattern discussed here is perhaps an effort to preserve the most information about the sonorant by restricting the obscuring secondary cues to the non-essential part of the speech signal: the vowel-to-sonorant or sonorant-to-vowel transition.

In Lai, however, facts about possible secondary cues and the way stops and sonorants behave in the coda in general suggests that for this language, the tendency need not be followed. Although the phonetic structure discussed may preserve the most information about the segments involved, it does not predict a phonological universal. It can only explain the cross-linguistic *tendency* for languages to preglottalize sonorants in the onset and postglottalize them in the onset. However, facts about the way specific languages function, including extra-phonetic facts (phonological, morphological, etc…), must be considered to determine whether this tendency is borne out on a case by case basis.

This paper is truly a preliminary look at the phonetic structure of glottalized sonorants in these languages. To determin what acoustic cues are used by listeners to identify these segments, it would be useful to run a series of perceptual studies, especially cross-linguistically. Also, as much of this and previous studies have mainly focused on glottalized nasals, more work should be done specific to laterals, glides, and rhotics.

Spectrogram.

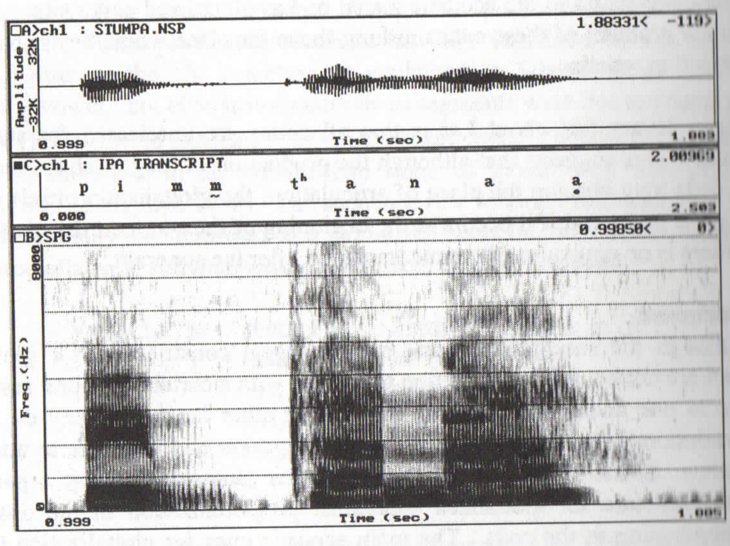

Figure 1. Yowlumne: pimˀtʰana 'stump'. The irregular F_0 starts after the onset of the sonorant. This word is consistently postglottalized.

…tes

A Tibeto-Burman language spoken in Northwestern Burma.

A Southern Zapotec language spoken in Miahuatlán and Pochutla in the state of Oaxaca, Mexico.

A language of the Yokuts family, spoken in the foothills of the Sierra Nevada. Referred to in previous …rature as Yawelmani.

In Montana Salish, we find true variation in the timing of the laryngeal constriction: 'Pronunciations of … word for 'soft' include [ɬəˀmˀmˀmóts], [ɬəmˀm:óts], and [ɬəˀm:ˀmóts], suggesting an underlying …presentation with three glottalized nasals, ɬəˀmˀmˀmóts, not all of which are realized.'(Flemming et … 1994:16)

Also, glottalized sonorants de-glottalize or do not occur in postconsonantal position in Yowlumne and …uswap. (Kingston 1983). In Klamath, sonorants de-glottalize word-finally (Barker 1964).

Other languages that follow this pattern(cf also Kraft 1973, Samarin 1966, Sapir et al. 1955, and Smith …968): In Klamath, glottalized sonorants are mainly preglottalized. In coda position, however, …lottalized sonorants 'are distinguished by a simultaneous glottal stricture instead of preglottalization.' …arker 1964:27). 'Kashaya places the glottal constriction at the beginning of the nasal when the …nsonant is syllable-initial, and at the end when it is syllable-final.'(Ladefoged et al. 1996:110; Buckley …990, 1993). In Logbara, the glottalized sonorants are preglottalized and only occur word initially …razzolara 1960).

Although historically the glottalization from both the first and second syllable of Zapotec roots was …apped onto the now-coda sonorant, synchronically suffixes such as [-m] and [-n] do not glottalize when …dded to roots whose vowels are checked.

Forms have been retranscribed to IPA.

In Acoma, 'the high accent on single vowels is usually realized as a high pitch with a slight fall if (1) …e following syllable is unaccented and starts with a glottalized sonorant (…)' (Miller 1965:17). The …ød in Standard Danish is a constriction of the vocal cords that is morphologically determined. When it …ccurs on a root that ends in a sonorant, a phonetic glottalized sonorant is the result, in which, 'the first …art of the syllable is characterized acoustically by a higher pitch level and often a higher intensity level …an syllables without stød (…). In the second part, the stød phase proper, there is a considerable …ecrease in intensity (…) and a noticeable decrease in fundamental frequency, and/or aperiodicity' …ischer-Jørgensen 1989). In Kammu, glottalized sonorants only occur with high tone (Svantesson …983).

This phenomenon has also been observed in Montana Salish: 'Glottalized nasals are preglottalized …ven in final position or before a voiceless consonant, as in sts'óˀm 'bone'. In these cases, the nasal …ortion is devoiced or creaky… In final position, the glide portion (of a glottalized sonorant) is realized …s a voiceless, or very creaky, version of the equivalent vowel.' (Flemming et al. 1994:16)

Gitksan has preglottalized sonorants in both word-initial and word-final position. (Wickstrom 1974). Montana Salish glottalized sonorants are typically preglottalized, even in final position (Flemming et al. 1994).

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VOWEL HEIGHT: Reconsidering Distinctive Features

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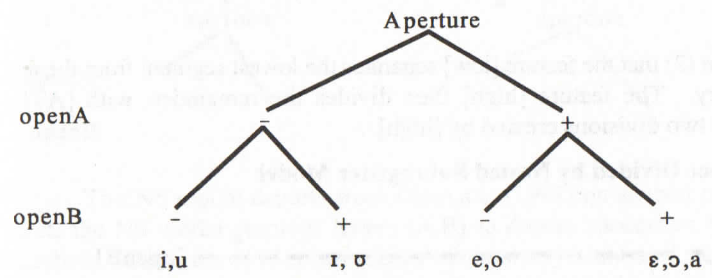
1. Introduction

A model of vowel height consisting of a two-tiered, symmetrical hierarchy of autonomous nodes is presented as a descriptor of the segmental organization for languages which exhibit [ATR] type harmonies. This model is called the Nested Subregister model, and is illustrated in (1) below as it would describe a typical nine-vowel inventory.

(1) The Nested Subregister Model



In the Nested Subregister model, the feature [openA] divides the height dimension in half. The [-openA] half is the less open, and thus the higher half, and the [+openA] half is the more open, and thus, the lower half. The feature [openB] represents a subregister, or subdivision of [openA]. As we will see in the two languages examined in this paper, the segmental makeup of the terminal nodes can vary, determined by the vowel inventory of the specific language. Following Clements (1991), a phonetic constant is that the leftmost (least open) vowels will always be the highest in the inventory, and the rightmost (most open) will be the lowest, with the remaining vowels arrayed by relative height.

The notion of an inventory-driven division of vowel features is contrary to the notions regarding distinctive features put forth in SPE. The traditional features as put forth in SPE are articulatorily based. They reference raising or lowering of the tongue body in relation to a "neutral" position defined as that in the English word 'bed' (Chomsky and Halle 1968:304). The assumption is that all languages divide the vowel space along the same parameters of musculature. It may be that the need for cooccurrence constraints and cleanup rules in so many harmony analyses stems from this assumption. In contrast, Archangeli & Pulleyblank (1994:135) cite evidence for cross-linguistic variability in the phonetic realization of F-elements. The Nested Subregister model allows for this sort of phonetic variability within the framework of a highly constrained hierarchy.