A Preliminary Phonetic Study of Glottalized Resonants in Sənčaeən*

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Glottalized resonants are rare segments cross-linguistically, occurring in only 20 of the 317 languages in a balanced study by Maddieson (1984). Because of the limited number of sources that serve as a basis for the study of these segments, they are not well understood. It is also the case that theories of glottalized resonants will be based on a narrow subset of possible data. Thus, it is important to demonstrate that current theories can accurately account for data outside this limited set. This paper will test one such theory, namely Steriade's (1997) Licensing by Cue, which proposes that the distribution of glottalized resonants is dictated by the timing of their glottal events, on Sənčaeən (Saanich), a Salish language.

The languages of the Northwest Coast, and Salish in particular, are rich in glottalized resonants, and are not commonly a part of the standard corpus. This paper will give a brief background on the phonetics of glottalized resonants (Sec. 1), show preliminary phonetic evidence for the timing of glottal events in Sənčaeən (2), introduce the Licensing by Cue hypothesis (3), and apply it to the Sənčaeən data in Section 4. Section 5 will be a modification of the Licensing by Cue hypothesis.

It will be shown that while the concepts that underlie the Licensing by Cue hypothesis are intuitively appealing, in its basic form it cannot account for the Sənčaeən data. Phonetic timing cannot explain the distribution of glottalized resonants in the way Licensing by Cue predicts.

0. Background

Sənčaeən is a North Straits, Coast Salish language, spoken on the East Coast of Vancouver Island, near Victoria. It is more commonly referred to as Saanich in the literature, but my consultant strongly prefers the name Sənčaeən. I will refer to the language using the phonetic transcription of its name. The two major treatments of Sənčaeən are Montler (1986) *An Outline of the Morphology and Phonology of Saanich, North Straits Salish* and Montler (991) *Saanich, North Straits Classified Word List.* Below is the consonant inventory:

(1) Sənčaeən Consonant Inventory

Lab	Dent	Alv	Lat	Alveo-palat		Lab-vel	Uvular	Lab-uvular	Laryngeal
p		t		č	(k)	kʷ	q	qʷ	
p'	tθ'	t'	tl'	č'		kʷ'	q'	qʷ'	ʔ
	θ	s	ɬ	š		xʷ	X	Xʷ	h
m		n	l	y		w	ŋ		
m'		n'	l'	y'		w'	ŋ'		

As can be seen above, both obstruents and resonants oppose plain vs. glottalized segments (ejectives and glottalized resonants)[1] Ejectives are free in their distribution, while glottalized resonants are restricted to post-vocalic positions, as shown in the following chart:

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(2)

	ejectives	glottalized resonants
#__	t'thə́ŋ'əɬ/ chest	unattested
C__V	pq'ə́l'qən "mountain goat wool" (Montler 1991)	unattested
V__V	t'ət'íl'əm' someone singing	sk'ʷəy'échən 'grizzly bear' kʷ'él'əs 'it's hot'
__C	st'et'čiʔ "snag" (Montler 1991)	ʔán'xstsxʷ 'you are groaning'
__#	láp' "eat with a spoon" (Montler 1991)	kʷə́n'ən' 'dolphin'

ʔ is considered to be a resonant, but stands apart from other glottalized resonants in that it may occur word initially: /ʔáy'ənkʷəs/ 'you are afraid'. This is not an uncommon occurrence cross-linguistically, but raises the question of the relationship between ʔ and other glottalized resonants. This issue will not be considered at this point.

One question that must be asked at this point is why is there a distribution asymmetry between glottalized resonants and ejectives? Is there something inherent in their phonetic nature that causes this? According to Steriade (1997) Licensing by Cue hypothesis, this is indeed the case. The first step in applying this theory will be to examine the phonetic evidence.

1. Auditory/impressionistic descriptions

Auditory descriptions of Sənčaeən glottalized resonants are given in Montler (1986: 13). "The glottalized resonants are usually realized phonetically as voiced resonants with accompanying laryngeal constriction, creaky voice". He claims with respect to glottal timing, that glottalization is attracted in to the stressed vowel (i.e. post-glottalized before stress, pre-glottalized following stress). This author supports this description with the modification that glottalized resonants in coda position, followed by a C (i.e., not word finally) are post-glottalized.[2] To facilitate between the representation of pre- and post-glottalized resonants, pre-glottalized will be written 'R and post-glottalized R'. Examples in the text will be in broad transcription (written post-glottalization for reasons of convention). Thus, a more accurate representation of glottalized resonants in Sən could be given as follows:

(3)

word initial	post-C	pre-stress intervocalic	post-stress intervocalic	post-stress pre-C	word-final
N/A	N/A	VR'V	V'RV	VR'C	V'R#

[1] Also note the presence of ŋ, a relatively unusual segment in Salish languages.
[2] Montler (p.c.) confirms this.

To summarize, resonants are post-glottalized immediately preceding the stressed vowel (R'V́) and immediately following the stressed vowel in coda position when followed by a C (V́R'C). They are pre-glottalized following the stressed vowel (V́'RC) and in word-final position. (V'R#).

The first issue that must be addressed by acoustic analysis is if these perceptions of glottal timing are indeed accurate. Glottal timing is perceived to be variable. This predicts that acoustic analysis should show glottal stricture in two positions relative to the resonant: towards the beginning of resonants in post-stress and word-final position, and at the end of resonants in pre-stress and pre-consonantal resonants in coda position.

The auditory descriptions also predict that glottalized resonants in coda positions will have two distinct timing relations, dependent on whether they are followed by a consonant or word final. This is unusual given that one would expect codas to function uniformly. In order to confirm both predictions, phonetic evidence must be examined.

1.1 Phonetic Background

Glottalized resonants are complex segments, consisting of primary oral closure with secondary glottalic constriction. Modal voicing, used in the production of plain voiced segments, is achieved through uniform vibration of the vocal folds, with the arytenoid cartilages in neutral position (Ladefoged and Maddieson 1996:50). The glottal constriction accompanying glottalized resonants is often referred to as 'creaky voice'. Creaky voice occurs when "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."(53) This tension can result in complete glottal closure or irregular vibration. The timing of this glottal constriction with respect to the oral closure gives us the descriptive terms pre- or post-glottalized.

Common acoustic correlates to what is perceived as creakiness or glottalization on resonants are decreased amplitude, irregular pitch pulses, which can surface as irregularities in the wave form, slower pitch pulses, more energy per pitch pulse, more energy in the higher frequencies, or even full glottal closure[3].

While ejectives are considered to be the obstruent counterparts of glottalized resonants, phonetically, they are very different. Kingston (1985,1990) claims this difference is a result of the timing of glottal events and the different natures of the oral closures of resonants and obstruents. Ejectives, he claims, will be consistently post-glottalized i.e. glottalic articulation will occur at the release of the stop. Plain stops are formed with complete occlusion in the oral cavity, which causes a build up of intraoral pressure. When the occlusion is released, a particularly salient burst containing cues to place occurs. In this sense, the change in intraoral pressure is the articulatory goal of stops.

In ejectives, a second closure is added, namely that of the glottis. The larynx raises and compresses the air above the glottal closure, sometimes up to doubling the amount. (Ladefoged and Maddieson 1996:78). Since any glottalic movement affects the articulatory goal, namely the release burst (pressure change), glottalic closure must be coordinated with the latter half of the ejective, meaning that ejectives are consistently post-glottalized. Continuants (for him, resonants and fricatives) never have a complete build up of intraoral oral pressure, since there is always a flow of air. Thus, the rapid change in intraoral pressure (burst) that is the articulatory goal in stops, is not an articulatory goal for continuants, and the glottal articulations need not be coordinated. As a result, glottal closure accompanying these segments will be have more variable timing, and will modify voice quality and the fundamental frequency of the sonorant and neighbouring vowels instead. (Kingston1985:247).

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[3] Maddieson p.c., Silverman (1995), Guy Carden (p.c.)

Silverman (1997) explains why languages have a tendency to have pre-glottalized resonants. He claims that 'heavy glottal constriction may result in sufficient aperiodicity, or jitter, to disrupt transmission of a salient nasal formant structure'. (97) As a result 'contrastive laryngeal gestures are optimally phased such that the laryngeal gesture is truncated with respect to the supralaryngeal gesture, and sequenced with respect to voicing: non-modal phonation is followed by modal phonation. In this fashion, cues are optimally transmitted to the listener. 83). In other words, the transition formants that are cues to place and manner for sonorants could be obscured by clues to glottalization if they were to overlap.

2. Phonetic Evidence

Data was collected from one 83-year-old female native speaker over a period of three months in three 2-hour sessions in the consultant's home. Approximately 120 words were collected and recorded on a Marantz tape recorder and analyzed using Signalize 3.1. But, before discussing the findings, two problems arose during the analysis of the collected data.

The first is that the consultant has naturally creaky voice due to her age. As discussed above, "phonological" or phonemic creakiness (where creakiness is a feature, which contrasts from plain segments) is caused by tightening and compressing the vocal folds in such a way so that they do not vibrate uniformly. As we age, our membranes become thicker, and our vocal folds less flexible, often causing them to vibrate irregularly, resulting in 'accidental' or phonetic creakiness, playing no role in the phonology. Thus, it is difficult to distinguish between the phonetic creakiness in my consultant's speech and the feature [creak] associated with particular segments or processes.

The second difficulty is that several cues are used in the production of phonological creaky or glottalized resonants, but not consistently, and often in conjunction with other cues. It is difficult to define a distinct acoustic correlate for glottalized resonants in Sənčaθən, since there is as yet no generalization governing which cues are used by which resonants, in which contexts or even if cues are used consistently across tokens. A much more in-depth phonetic study, outside the realm of this paper, is required. However, it will be shown that it is possible to use aperiodicity, slower pitch pulses, more energy per pitch pulse, more energy in the higher frequencies and full glottal closure as cues to distinguish plain vs. phonologically glottalized resonants.

Given that the timing descriptions of glottalized resonants varies dependent on stress, this paper examines four contexts in which glottalized resonants occur: intervocalic immediately preceding the stressed vowel, intervocalic immediately following the stressed vowel, pre-consonantal immediately following the stressed vowel, and word finally following an unstressed vowel. Word final glottalized resonants in monosyllabic roots are not considered due to a lack of appropriate data. Contexts that are not relevant (i.e. not involving a stressed vowel) are also not considered.

In order to confirm the timing relations perceived by both Montler and this author, consider Figure 1, a comparison of the words /k'ʷél'əs/ 'warm' and /čən qʷáləxʷ/ 'the dogsalmon month'. The waveform of /l/ in a) shows a marked decrease in amplitude compared to the one in b), suggestive of glottalization. Very narrow band spectra of glottalized and plain /l/ are given in c) and d) respectively. The large energy peak at 1300 Hz present in c) but not d) is also indicative of glottalization. However, neither determines whether the resonant is pre- or post- glottalized. To establish this, consider the wide band spectrograms in e) and f).

In f), the plain /l/ shows regular pitch pulses with a continuous F0. The glottalized /l/ on the other hand, shows an interrupted F0 with pitch pulses that are spread very far apart in the transition from vowel to resonant, i.e. the beginning of the resonant. The vertical striations associated with these pitch pulses are another indication of glottalization. It is clear from this example that glottalization occurs at the beginning of the resonant, even at the end of the preceding vowel. Note the space between glottal pulses, the vertical striations and the greater amount of energy in the higher frequencies during the latter half of the preceding vowel, into the transition. Based on Figure 1, it is clear that post-stress glottalized resonants are indeed pre-glottalized.

Turning to Figure 2, consider post-stress, pre-consonantal coda resonants. Recall that perceived timings predicted that these resonants should be post-glottalized. a) and b) are expanded versions of the waveforms of c) and d), the words /ʔán'xstsxʷ/ 'you are groaning' and /sə́nti/ 'from Sunday to Sunday'. In a) the irregularity and marked decrease in amplitude of the waveform of the resonant again indicates glottalization. Notice the periodicity throughout the plain resonant in b).

Considering the broad band spectrograms in e) and f), the irregularities in the waveform are apparent as irregular pitch pulses at the end of the glottalized resonant in f). In comparison, the plain resonant in e) shows a smooth gradual transition into the following consonant. These diagrams confirm the perceived timing relations: post-stress, pre-consonantal resonants are indeed post-glottalized.

But what about word final resonants? Will they be pre-glottalized as predicted? Consider Figure 3, the comparison of the words /kʷán'ən'/ 'dolphin' and /kʷásən/ 'star'. Given in a) and b) are the expanded versions of the waveforms in g) and h). Notice the unusual shape of the waveform of the /ə/ in b), becomes 'hairier' towards the end, as compared to that of the plain ə in a) as well as the irregularly shaped and widely spaced waveform of the glottalized resonant. This suggests that both the preceding ə and the final resonant are glottalized.

Further evidence that the preceding vowel is glottalized is given in the comparison of c) and d) (glottalized) vs. e) and f) (plain). Very narrow spectra were taken at the beginning(c,e) and end(d,f) of both /ə/s. The energy peaks at 800 and 1800 Hz in the glottalized /ə/ are not present in the unglottalized one.

From this, it is clear that the ə between the two glottalized resonants of /kʷan'ən'/ is indeed glottalized. But how does one know that it is pre-glottalization of the following resonant, rather than post-glottalization of the preceding resonant? Recall that a glottalized resonant immediately following a stressed vowel will be PRE-glottalized, suggesting that the creakiness of this vowel is mainly derived from the word-final resonant.

Unfortunately, a problem arises. As seen in the broad band spectrogram in i), the glottal pulses of the word final /n'/ slow down considerably, appearing quite spread apart. It is also the case that the speaker has an audible release following most word-final glottalized resonants, whereas this never occurs following plain resonants word finally. This is suggestive to the author of post-glottalization, but due to the lack of appropriate data, it is difficult to make judgements at this time. It appears that reference to pre- or post- glottalized may not be relevant in this case, since the resonant may be both, or better said, glottalized throughout. The implications of this may mean that discussion of cues to glottalization at vowel/resonant transitions may not be relevant. However, these implications cannot be meaningfully discussed without better understanding of what is actually occurring. For now, it will assumed, based on the evidence of pre-glottalization perceived and seen in Figure 3, that word final, pre-consonantal glottalized resonants are indeed pre-glottalized.

In Figure 4 a) and b) are the waveforms for two words containing pre-stress glottalized resonants: /skʷəy'ə́čən/ 'grizzly bear' and /sčuw'áəən/ 'Tsawassen'. Glottalized resonants are not common in this position for the following reason. Based on Montler's description of stress[4], as well as the author's own experience, I will suggest that Sənčothən has a mainly trochaic stress system (i.e. stress usually occurs on the first vowel of the word). Since word initial glottalized resonants are not licensed in this language, pre-stress R' are difficult to find. However, here are the only two examples in the collected data, with the expanded

[4] " the first /i, /e/, or /a/ (i.e., non-schwa) takes the main stress, and if there are only schwas, then the penultimate takes the main stress " (1991:viii)

waveforms given in e) and f). e) shows that the vowel preceding the resonant is very periodic. In f) we can see that the same is true. In both cases, the vowel following the resonants is very aperiodic, indicative of heavy glottalization, and suggestive of a post-glottalized resonant.

Considering c) and d), the broad band spectrograms clearly show that the glottalization takes place at the end of the resonant. In c) the transition from ə to a high front position has already occurred before the glottal stricture takes place. Until this point, there has been a continuous F0, but there is a break in it at this point, marking the glottal stricture. The following vowel shows the now familiar vertical striations and greater energy in the higher frequencies. d) clearly shows the irregular pitch pulses occurring after the steady state vowel/resonant. Unfortunately, there are no corresponding plain examples for either, but the spectrograms show correlations to glottalization present in the diagrams already seen, supporting the perceived timing of post-glottalization on resonants preceding stress.

Figures 1-4 confirm the auditory predictions of both Montler and this author: pre-stress and pre-consonantal resonants are post-glottalized R': (_V́, _C), and post-stress and word-final resonants are pre-glottalized ('R: V́_, _#).

From this evidence, stress seems to be a major conditioning factor on the timing of glottal events in Sənčaəən. This is not unreasonable, given that stressed vowels are often more prominent, and thus amplify any acoustic cues. Silverman (1997) confirms this, "...stress plays the functional role of increasing acoustic energy through increased aerodynamic force, as well as overall lengthening and sometimes hyperarticulation..."(97). How would a theory based on cues and glottal timing account for the distribution of glottalized resonants in Sənčaəən? The next section introduces such a theory, namely Steriade's (1997) Licensing by Cue to the phonetic data above.

3. Licensing by Cue

Steriade's (1997) Licensing by Cue hypothesis seeks to explain the distribution of glottalized segments as a result of 'phonetic implementation factors'. She argues that perceptual cues, and their salience in particular contexts are what license features in certain positions. Absence of a supportive context for cues results in neutralisation. Thus, she proposed Licensing by Cue, as opposed to Licensing by Prosody, in which laryngeal features are licensed due to their position in the syllable (i.e. onset vs. coda). "The general idea pursued here its that phonological grammars incorporate knowledge of the conditions under which feature contrasts are physically implemented" (1997:1). Thus, phonetics, in the guise of 'implementational constraints' play a vital role in the grammar

Under the Licensing by Cue hypothesis featural contrasts will only surface in environments supportive of the 'cues' to that particular feature. Acoustic cues in the speech signal to what we perceive as voicing, for example, might be voice onset time, burst and closure duration. Steriade distinguishes between two kinds of cues, internal (cues present during the oral closure) and transitional (onset or offset). Voiced stops then would contrast with voiceless stops only in contexts where these cues are salient or perceptible enough, as judged on a relative scale of the feature [voice].

What governs which contexts are acceptable are phonetic implementation factors. "Phonetic implementation factors involve gestural timing, gestural magnitude and contrast perceptibility, i.e. the nature and relative duration of cues available in a given context for the identification of a specific contrast." (1997:61). Speakers are aware that certain contrasts are more salient in certain contexts (i.e. k/g contrast is easier intervocalically than between obstruents) and this awareness of phonetic implementation factors is active in the phonology as 'implementational constraints'. These constraints represent the knowledge of physical implementation of contrast.

Steriade frames her hypothesis in Optimality Theory (OT) (Prince and Smolensky 1993). In OT it is the interaction of universal and violable constraints on phonological well-formedness that select the surface forms we see. The more highly ranked the constraint, the more important it is in the language. Implementational constraints, then, interact with more familiar constraints on identity (faithfulness) and the different ranking of these constraints with respect to each other should give us cross-linguistic variation.

The Licensing by Cue hypothesis is used by Steriade to explain laryngeal neutralization and the distribution asymmetries between ejectives and glottalized resonants. Recall that glottal timing between ejectives and R' varied, with ejective having the glottal closure aligned with the release burst. This means that the cues to glottalization for obstruents will be at the right edge. The opposite is true for resonants. Glottal constriction, while thought to be more variable, was found to be timed to the onset of oral stricture, in other words, glottalized resonants will be pre-glottalized (Silverman 1997).

Since the differences in distribution between ejectives and R may depend on auditory or articulatory properties or this difference in glottal timing, Steriade suggests that the relevant features that should be used in this analysis are two auditory features [ejective release] and [creak].[5] Steriade's evidence that two different features are needed comes from Yokuts, where certain morphologically governed processes glottalize sonorants, but not obstruents. The main implementational constraint used is Context Cues. While not explicitly stated, this could be generally characterized as Context Cues [F]: *[F] / in positions lacking contextual cues where [F] is the feature in question.

To analyze glottalized resonants in particular, Steriade posits Context Cues [creak]

(4) Context Cues [creak] *[creak] in positions where context cues to [creak] are absent

This constraint represents a perceptibility scale for the cues to [creak]. Vowel-resonant transitions represent the most optimal environment for the support of glottal cues, which is why glottalized resonants occur post-vocalically. For pre-glottalized resonants (with cues at the onset of the segment), the most optimal environment is after a sonorant ([+son]_) and less optimal elsewhere (#_,[-son]_). Translated into constraints, *[creak]/[-son]_,*[creak]/#_ will outrank *[creak]/[+son]_, Thus, Context Cues is a way of ensuring that pre-glottalized resonants will be post-vocalic.

Constraints formalizing the timing relations described previously are abbreviated SonTiming (Obst Timing for ejectives)

(5) Son Timing: The onset of glottal constriction must precede the onset of oral closure
The peak of glottal constriction must precede the oral release

This constraint rules out variable timing, ensuring that glottalized resonants will be consistently pre-glottalized. A third constraint, Preserve [creak] penalizes loss of the feature [creak].

One of the case studies for Licensing by Cue is Yokuts, where all glottalized resonants are pre-glottalized. They neutralised anywhere but post-vocalically, so we have the following ranking:

(6) SonTiming, Context Cues >>Preserve [creak]

[5] The articulatory feature [constricted glottis], normally applied to both, (cf. Howe and Pulleyblank 1999) does not play an active role in this analysis. The implication here is a distinction between production and perception. Use of [cg] supposes that it is articulation or production features that are relevant in an analysis. Steriade, while still suggesting that glottalized segments have the feature [cg], theorises that it is the perceptual or auditory features that play the active role here.

SonTiming is an unalterable characteristic of the language and therefore must be very highly ranked. Context Cues [creak] must outrank Preserve [creak] in order to insure that an initial or post-consonantal R' will never surface. Either cues are present for that particular timing in that context, or neutralisation occurs. An example of how the constraints work can be seen in example (40).

(7)

/lihm/ creak	SonTiming	Context Cues [creak] >>	Preserve [creak]
lihm-			*
‘lihm- (pre-glott)		*!	
l’ihm- (post-glott)	*!		

This ranking ensures that i) only post-vocalic glottalized resonants will surface and ii) timing is invariable. Neutralization is preferable to a shift in the timing relations of the glottal events.

If we consider briefly again ejectives, we can see the different distribution of ejectives and glottalized resonants as a result of different ranking of constraints. For ejectives, Preserve [ejective] and Obst timing, outrank Context Cues [ejective] so that ejectives will surface regardless of their distribution. Since the focus of this paper is on glottalized resonants, no more will be said about ejectives. In the next section Licensing by Cue will be applied to the Sənchothən glottalized resonants we saw above.

4. Applying Licensing by Cue

If we apply Steriade's Licensing by Cue hypothesis, we are not very successful. Recall that glottalized resonants in Sənchothən are also only found post-vocalically. In order for Sənchothən to fit Licensing by Cue, all glottalized resonants would have to be pre-glottalized. As seen above, this is not the case. To summarise the matches and mismatches between the predictions of Licensing by Cue and My Acoustic Findings(MAF), consider the table below:

(8) **Matches:**	LbC	MAF	
-Post-stress	V́’RV	V́‘RV	kʷ’é’ləs
-Word finally	V’R#	V‘R#	kʷə́n’ə’n
Mismatches			
-pre-stress	V’RV́	VR’V́	skʷ’əy’échə
-pre-C	‘RC	V́R’C	ʔán’xstsxʷ

As shown in the above table, Licensing by Cue predicts only fifty percent of actual glottal timings that surface in Sənčaəən. The Sənchothən data poses a number of problems for the Licensing by Cue hypothesis. First, Sənčaəən seems to have variable timing, which is not predicted under Licensing by Cue. It is clear from both perceived and acoustic evidence that stress governs the variation in timing. Without reference to stress, it is impossible to predict when a resonant will surface as pre- or post- glottalized. However, it is still theoretically possible to achieve variable timing by subordinating SonTiming to another constraint which will dictate when each timing variation will occur, or by altering Context Cues to be sensitive to stress, since it is stress that seems to dictate the timing of glottal events. In an account of Shuswap Steriade does latter.

In Shuswap (Interior Salish), a glottalization feature of suffixes is always attracted to the resonant following the stressed vowel. Steriade explains this as "Stress is an enhancer of glottalization cues. I attribute this to the fact that the stressed vowel is longer, louder and thus better able to carry the contextual cues for creak" (86). She formalizes this by introducing a new level to the perceptual scale of [creak]: a stressed vowel (V') is a more optimal environment than an unstressed vowel (V), and by adding a new constraint to Context Cues: creak/V[-stress] >>*creak/V[+stress]. Thus, after adding the stress constraints to Context Cues, glottalization not adjacent to the stressed vowel will violate Context cues. We can see this below.

The question of the relevance of SonTiming in Sənčaəən comes up. The constraint proposed by Steriade in (5) is a markedness constraint. Since timing relations of glottal constriction with regards to oral closure is predicted to be variable by Kingston (1985,1990), SonTiming is irrelevant and will not be included in this analysis[6] The following tableaux represent the timing relations and environments in Sənčaəən. Context Cues (including the new optimal context V') outranks Preserve Creak (penalizing loss of [creak].

Tableau 1

V́RV creak	Context Cues>>	Preserve Creak
1. V́'RV (pre-glott)		
2. V́R'V	*!	
3. V́RV		*!

The first candidate is the winning candidate, because glottalization immediately adjacent to the stressed vowel is the most optimal context for cues to creak. A post-glottalized resonant (candidate 2) violates Context Cues, and the third candidate which is neutralized, violates Preserve Creak. A similar tableau, but with the resonant in pre-stress position can be seen below:

Tableau 2

/VRV́/ creak	Context Cues>>	Preserve Creak
1. **VR'V́** (post-glott)		
2. V'RV́ (pre-glott)	*!	
3. VRV́		*!

If the glottalized resonant precedes the stressed vowel, the optimal context for cues to glottalization will be adjacent to that stressed vowel i.e. post-glottalized. Candidate 1 satisfies all constraints because it is post-glottalized. Candidate 2. violates Context Cues because [creak] is not adjacent to the stressed vowel. The third candidate violates Preserve Creak. The next tableau shows a problem for this analysis.

Tableau 3

/V́RC/ creak	Context Cues >>	Preserve Creak
1. V́R'C (post-glott)	*!	
→2. V́'RC (pre-glott)		
3. V́RC		*!

Candidate 1, is the intended winner, but Candidate 2 surfaces as the actual winner. Candidate 1, which is post-glottalized, has the cues for creak in a less optimal environment (not adjacent to the stressed vowel) than it should. Thus it violates Context Cues. Candidate 2, with its cues adjacent to the stressed vowel incurs no violations.

[6] SonTiming is a markedness constraint which says that pre-glottalized resonants are the unmarked form. If this is the case, then the implications of this are i) languages with only pre-glottalized resonants exist ii) no languages will have just post-glottalized resonants iii) languages with post-glottalized resonants must also have pre-glottalized resonants. At this point, I am unsure whether these hold true, and thus do not include the constraint in this analysis.

As we can see, even with this new addition to Context Cues, one case, that of post-glottalized pre-consonantal resonants cannot be accounted for. Clearly, these two constraints alone are incapable of accounting for everything. Another explanation must exist.

5. Possible Solution: Silverman (1997) / Plauche, de Azcona, Roengpitya, Weigel (1999):

Recall that Silverman (1997) claimed there was a tendency for resonants to be pre-glottalized, also based on cues. He hypothesizes that sonorants will be preglottalized, to keep from obscuring the place/manner cues in the consonant vowel transition. Under this hypothesis it seems that cues can be in competition with each other.

Plauché et al (1999) note that Silverman fails to consider resonants in coda position. The authors extend Silverman's hypothesis to glottalized resonants in codas, reasoning that by the same logic, glottalized resonants in coda position will be post glottalized. If the vowel-resonant transition is the primary locus for cues to place and manner, and if cues to glottalization risk rendering these 'unrecoverable', then coda glottalized resonants should be post-glottalized. The authors come to the conclusion that 'glottalized resonant that rely mainly on creaky voice, full glottal stop and amplitude as phonetic cues to glottalization... will surface as pre-glottalized in onset and post-glottalized in coda. (381)

This other cue-based theory, comes to slightly different conclusions from Licensing by Cue, and makes different predictions. If cues to glottalization work antagonistically against cues to place/manner, resonants should be pre-glottalized in onset position, and post-glottalized in coda-position. Below is a chart comparing the predictions made by Silverman/Plauché et al. and my acoustic findings:

(9) **matches**:	S/P	MAF
-pre-C	V́R'C	V́R'C
-post-stress	V́'RV	V́'RV
mismatches		
-pre-stress	V'RV́	VR'V́
-word final	VR'#	V'R#

This theory also only accounts for fifty percent of the contexts. This theory fails because it makes generalization based on onsets and codas without making a distinction based on stress, and also fails to take into account whether the resonant is followed by a consonant or not. But, if we take the idea of glottal cues obscuring place/manner cues, and also the idea that stress is what motivates the timing of glottal events in Sənchothən, we may be able to modify Licensing by Cue constraints somewhat and produce a comprehensive account.

Let's hypothesize for the moment that there is competition between place/manner and glottalization cues for the vowel-resonant (coda) or resonant-vowel (onset) transitions. In inter-vocalic positions, which have two such transitions, competition will not be that fierce. The cues to glottalization will surface adjacent to the stressed vowel, possibly because they are the marked cues, and the stressed vowel is acoustically strong enough to support both cues.

However, in a case where the glottalized resonant is post-vocalic, but preceding another consonant, there is only one vowel-resonant transition, and two competing sets of cues. In this case, faithfulness to the place/manner cues is more important, leading to a shift in glottal timing. Importantly, this does not lead to neutralization, so Preserve [creak] must be ranked higher than Context Cues [creak], since [creak] surfaces in a less optimal environment. Since place cues play a role in this analysis, they must have a constraint which outranks Preserve [creak]

(10) Preserve [place/manner] Place/manner cues present in the input must be present in the output

Independent evidence for this can be seen in the fact that Sənčaθən does not have place assimilation. The constraints can be seen below.

Tableau 4

skʷəy'écha	Preserve [place]	Preserve Creak	Context Cues creak
1. skʷə'yécha			*!
2. **skʷəy'écha**			
3. skʷəyécha		*!	

The bolded candidate is the intended output, and indeed is the actual winner. This is the straightforward case, where the first candidate is ruled out by the fact that glottalization is not adjacent to the stressed vowel, and the third candidate is ruled out because it violates Preserve creak. This does not show any crucial rankings however. These are shown in the next tableau:

Tableau 5

ʔán'xstsxʷ	Preserve [place] >>	Preserve Creak>>	Context Cues creak
ʔán'xstsxʷ (place cues unobscured)			*
ʔá'Nxstsxʷ (place cues obscured)	*!		
3. ʔánxstsxʷ		*!	

The winning candidate is the first candidate, which salvages place/manner at the expense of violating Context Cues. Following Silverman, pre-glottalized resonants in this position would obscure place/manner cues, thus violating Preserve Place. However, since faithfulness to place / manner cues is ranked higher, this will allow the correct candidate to win. The third candidate, who eliminates [creak] if it cannot be in its optimal environment, is ruled out due to a higher ranking of Preserve Creak over Context Cues.

Unfortunately, while we are now able to account for the distribution of glottal timing, we are unable to explain the distribution asymmetries which Steriade set out to explain. If one imagines a word with an underlying word-initial resonant, with stress on the immediately following vowel, our constraints cannot secure that this glottalized resonant not surface:

Tableau 6

/R'V́C/	Preserve place>>	Preserve Creak>>	Context Cues creak
R'V́C (post-glott)	*!		
→ 'RV́C (pre-glott)			*
RVC		*!	

The third candidate is the intended winner, but loses due to the Preserve Creak violation. A pre-glottalized resonant violates Context Cues Creak, and a post-glottalized resonant violates Preserve Place. Recall that Preserve Creak had to outrank Context Cues Creak, as we saw in Tableau 5, while it seems the opposite ranking is necessary here. Post-consonantal glottalized resonants cannot be ruled out either. Thus, while we can account for the timing of glottalized resonants in Sənčaθən, we cannot explain the neutralization that occurs word initially or post-consonantally. Part of the answer lies in a language specific phonotactic constraint against CR initial roots ("there are no root initial obstruent-resonant sequences in Saanich" (Montler 1986: 127)), which ipso facto rules out C'R clusters. Why no word initial glottalized resonants occur remains unsolved.

6. Conclusion

The goal of this paper was to apply the Licensing by Cue hypothesis to Sənčaθən, and evaluate its success in accounting for this language, rich in glottalized resonants, but not part of the standard corpus. Sənčaθən glottalized resonants were shown to have variable timing, being pre-glottalized following the stressed vowel and word-finally, and being post-glottalized pre-stress and following stress in a coda position. Licensing by Cue sought to base the distribution of laryngeal segments on their phonetic implementation factors, i.e. types of cues and glottal timing. Word initial and post-consonantal glottalized resonants do not surface due to a lack of cues. However, in Sənčaθən it was demonstrated that these phonetic implementation constraints could not rule out word initial or post-consonantal glottalized resonants, and that they were not enough to explain the variable timing of glottalization, even after taking stress into account.

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Figure (1)

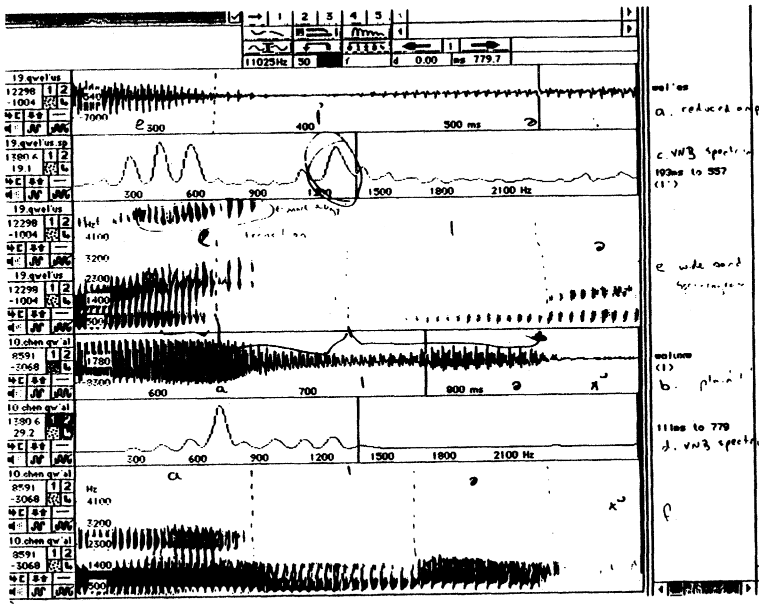
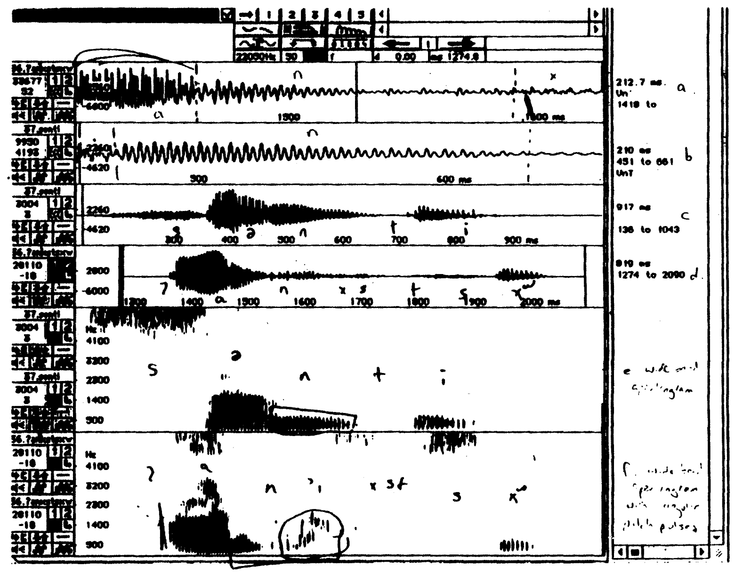


Figure 2



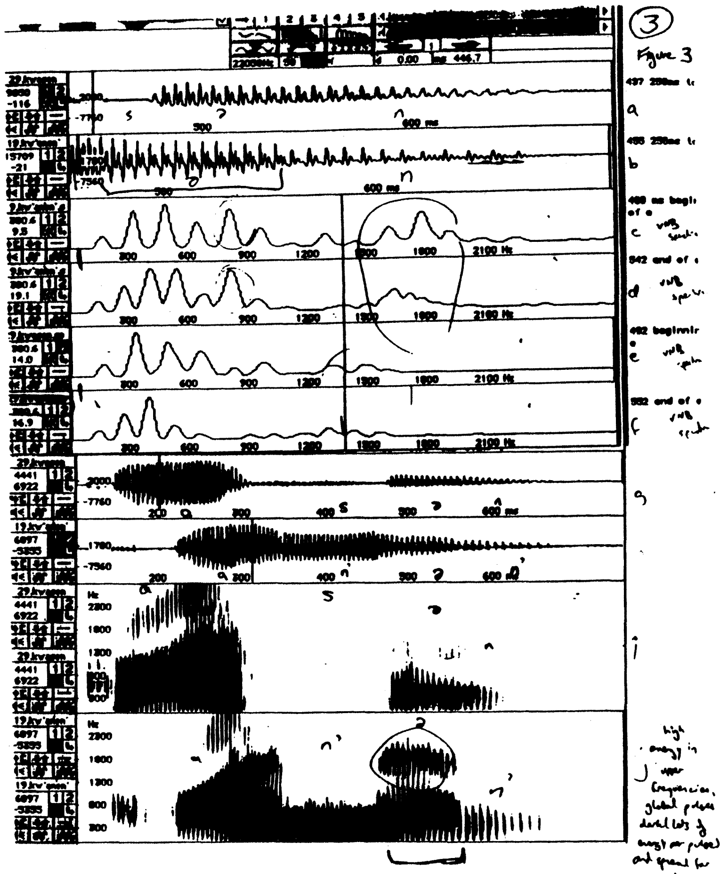


Figure 3

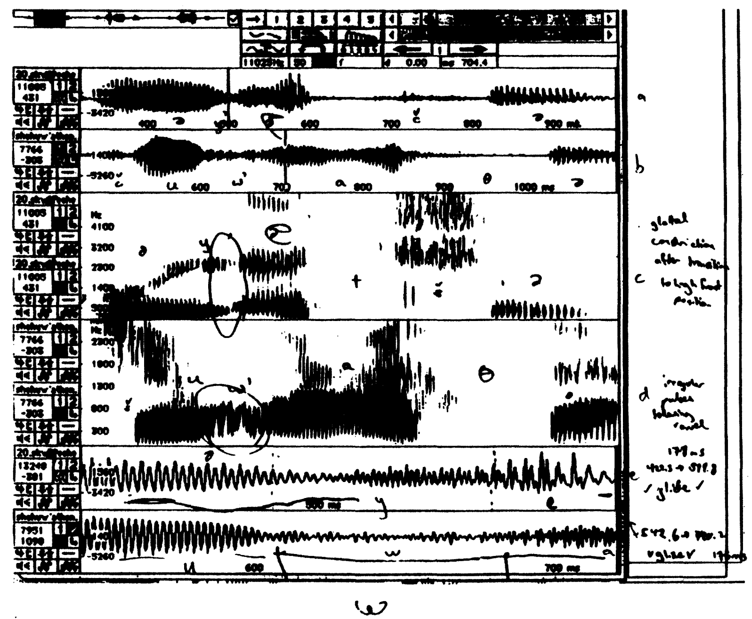


Figure 4.