Acoustic evidence for ʕ as a glottalized pharyngeal glide in Nuu-chah-nulth [*]

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In this paper we study the acoustic properties of ʕ in Ahousaht Nuu-chah-nulth (Nootka) in order to refine its place within the larger picture of the phonology of the language. Although the phonological data largely favours an analysis of ʕ as a type of glottalized pharyngeal stop, impressionistic auditory evidence would suggest otherwise. We hypothesize that the phonetic characteristics of ʕ are more like those of a glottalized glide, and we test this by comparing its acoustic properties with glottalized resonants and glottalized stops in the language. We find that the timing of glottalization in the pharyngeal ʕ is like that of a glottalized resonant, rather than a glottalized stop. Moreover, we observe that in several tokens full closure is not achieved and that ʕ has the formant transition duration of a glide, further supporting the claim that it is a glottalized pharyngeal glide.

1 Introduction

The objective of this paper is to study the phonetic properties of the pharyngeal ʕ in Ahousaht Nuu-chah-nulth. Based on its impressionistic auditory properties, we hypothesize that, contrary to previous treatments (Sapir & Swadesh 1939, Rose 1976, Howe & Pulleyblank 2000), ʕ is in fact a glottalized pharyngeal glide and not a glottalized pharyngeal stop, and we test this acoustically.

The paper has the following structure. Section 2 of this paper gives an initial description of this sound and its place within the phonemic inventory of the language. It also reviews the phonological evidence supporting the analysis of ʕ as a glottalized pharyngeal stop, and possible reasons to doubt this interpretation. Section 3 presents the methodology and results of our acoustic study. Section 4 discusses the implications of our findings for the phonemic inventory of Ahousaht Nuu-chah-nulth. Section 5 concludes the paper.

2 Background

The place of the pharyngeal ʕ in the phonemic inventory of Nuu-chah-nulth is controversial. Although written with the same symbol normally used for a pharyngeal approximant, this is not an adequate characterization of this sound. This sound has been described in the past by Sapir and Swadesh (1939: 13) as "a glottal stop pronounced with the pharyngeal passage narrowed by the retraction of the tongue toward the back of the pharyngeal wall", by Swadesh (1939: 78) as a "glottal stop with pharyngeal constriction" and by Jacobsen (1969: 126) as a "pharyngealized glottal stop". Rose (1981: 15) gives a somewhat more detailed description:

> ʕ consists of a pharyngealized glottal closure which [...] is accompanied by a raised larynx and a retracted tongue root. ʕ is like a resonant in having no release burst (i.e. a stop release). However, associated laryngealization, perceived as a series of 'cracks', gives the impression of a series of stop bursts

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The glottal and stop-like nature of this pharyngeal always figure prominently in its description, and accordingly, it has traditionally been classified as a member of the glottalized stop series in the language. The following table shows the phonemic inventory of the Ahousaht dialect of Nuu-chah-nulth, and the conventional place of ʕ in it.

(1) *Ahousaht Nuu-chah-nulth consonant inventory* (Howe & Pulleyblank, 2000)

	Labial	Alveolar	Alveolar Affricates	Lateral	Alveo-palatal	Velar	Labio-velar	Uvular	Labio-uvular	Pharyngeal	Laryngeal
Voiceless stops	p	t	ts	tɬ	tʃ	k	k^w	q	q^w		
Glottalized stops	p’	t’	ts’	tɬ’	tʃ’	k’	$k’^w$			ʕ	
Fricatives		s		ɬ	ʃ	x	x^w	χ	$χ^w$	ħ	
Nasals	m	n									
Glottalized nasals	m’	n’									
Glides					j		w				h
Glottalized glides					j’		w’				ʔ

This classification of ʕ as a glottalized pharyngeal stop has also been supported by its phonological behaviour within the language. Its glottal nature can be observed in its phonotactic distribution. ʕ patterns with glottalized consonants, comprising *ʔ*, *h*, glottalized resonants and glottalized stops, in being banned from the syllable coda. This ban truly is restricted to glottalized sounds. The pharyngeal fricative, *ħ*, which has no laryngeal character, is free to occur in this position.

Stronger support for the status of ʕ in the phonemic inventory as a glottalized stop comes from the historical evolution of ʕ from a glottalized uvular stop in the proto-language (Jacobsen, 1969). This historical shift is still reflected in the modern language in the process of glottalization, whereby consonants become glottalized before glottalizing suffixes. In this context, where stops surface as ejectives and fricatives as glottalized glides, *q* and *q*^{w} regularly surface as ʕ.

(2) *Glottalization of non-uvular stops (Rose, 1976: 58-9)*

a.	/tɬup-’iːtʃħ/	[tɬup’iːtʃħ]	*summer*
b.	/m’itɬ-’iːtʃħ/	[m’itɬ’iːtʃħ]	*rainy time*
c.	/hupt-’atɬ/	[hupt’atɬ]	*they hid*
d.	/jats-’as/	[jats’as]	*walk outside*
e.	/wik-’as/	[wik’as]	*not outside*

(3) *Glottalization of fricatives (Rose, 1976: 59)*

a.	/his-’uːtɬ/	[hij’uːtɬ]	*on the rocks*
b.	/tɬuʃ-’atɬ/	[tɬuj’atɬ]	*dry inside*
c.	/hiɬ-’atɬ/	[hij’atɬ]	*Inside*
d.	/ts’ax^w-’atɬ/	[ts’aw’atɬ]	*speared inside*

(4) *Glottalization of uvular stops*

a.	/tsiq-’ik/	[tsiʕek]	*Fond of talking*
b.	/k’^{w}aq-’iːts/	[k’^{w}aʕeːts]	*eating spawned herring eggs*
c.	/ts’uq-’aqtɬ/	[ts’uʕaqtɬ]	*stabbed inside*
d.	/t’iq^w-’as/	[t’iʕas]	*sitting on the ground*

The limited amount of acoustic work previously done on Nuu-chah-nulth pharyngeals further supports this analysis. In a brief study, Bessell (1993: 7) found that the manner of articulation of ʕ is like that of a voiceless stop, with "a period of closure during which there is no energy in the spectrum and no indication of voicing". Furthermore, she notes that some tokens of ʕ contain what resembles a spike in the spectrogram, which she speculates may be indicative of a release burst.

Despite the phonological and small amount of phonetic evidence, there is good reason to doubt the analysis of ʕ as a member of the glottalized stop series. It is significant that the other members of the glottalized stop series are ejectives. ʕ lacks the characteristic popping release of these sounds, casting doubt on its status as a member of the glottalized stop series.

But it is possible that ʕ is some other type of stop with glottal closure, and thus should still be included in the glottalized stop series. Catford (1977: 163) discusses the "ventricular" or "strong glottal stop" [ʡʔ], also referred to as the "pharyngealized glottal stop" in the literature found in some Caucasian languages. Catford suggests that this sound is made when the ventricular bands are brought together with a simultaneous glottal closure. More recently, Esling (1996: 74) reanalyzes this sound, which the IPA represents as an epiglottal plosive *ʔ*, as "more properly aryepiglottic in origin and pharyngeal in general place of articulation". After listening to *ʔ* on the *Sounds of the World's Languages* database, we strongly doubt that this "pharyngeal stop" is the same as ʕ in Nuu-chah-nulth. Compared to *ʔ*, the Nuu-chah-nulth ʕ sounds much sharper, with a much clearer glottal closure.

Impressionistically, it is often difficult to tell ʕ apart from the regular glottal stop *ʔ*, the best cue to differentiate them being their effect on neighbouring vowels. Whereas *ʔ* often adds creakiness, ʕ adds not only creakiness, but adjacent vowels are normally somewhat pharyngealized and high vowels are regularly lowered to mid vowels, a typical effect of pharyngeals (Rose, 1996). Note, however, that contrary to Rose (1981), who was working on the Kyuquot dialect, we have not found that the low vowel *a* is retracted to *ɑ* in this environment in the Ahousaht dialect.

(5) *ʕ lowering vowels*

a.	/ʕiːtʃ.nʼuː/	[ʕɛːtʃ.nʼuː]	*bullhead fish*
b.	/ʕitʃ.ʃitɬ/	[ʕɛtʃ.ʃitɬ]	*to become rotten*
c.	/ʕu.jʼi/	[ʕo.jʼi]	*to augment, worsen*
d.	/ʕuː.kʷiɬ/	[ʕoː.kʷɪɬ]	*to augment, worsen*
e.	/ʕaː.ħuːs/	[ʕaː.ħəws]	*place name*
f.	/ʕaːtɬ.ʕaː.tɬa/	[ʕaːtɬ.ʕaː.tɬa]	*soften grass*

(6) *ʔ not affecting vowels*

a.	/ʔin.ku.wʼiɬ/	[ʔin.ku.wʼɪɬ]	*smoke house*
b.	/ʔiːts.kʷin/	[ʔiːts.kʷin]	*Mouse*
c.	/ʔu.ʔaː.ɬuk/	[ʔu.ʔaː.ɬuk]	*to look after*
d.	/ʔuː.kʷiɬ/	[ʔuː.kʷɪɬ]	*to*
e.	/ʔas.xʷaː/	[ʔas.xʷaː]	*to ask for something*
f.	/ʔap.piː/	[ʔap.piː]	*Back*

This suggests that the stop-like character of ʕ may be due to glottal closure alone, rather than any closure in the pharynx at all. Within Nuu-chah-nulth, the other series of sounds which have glottal closure but no stop closure are the glottalized resonants. If there is pharyngeal constriction without occlusion, then it seems reasonable to analyze this sound as a type of resonant as well. Our study, then, is an attempt to find acoustic evidence to support our claim that from the phonetic perspective, ʕ is better analyzed as a glottalized pharyngeal glide.

Our acoustic analysis addresses this question with a detailed study of waveforms and spectrograms. Specifically, the information gathered includes the following: the timing and duration of

glottal closures, the duration and direction of formant transitions, the presence or absence of creak associated with laryngeal activity and the presence or absence of release bursts.

3 Acoustic Study

3.1 Method

All of the data used in this paper was elicited from an adult female native speaker of the Ahousaht dialect of Nuu-chah-nulth. The data included for analysis in this paper was elicited over a four-month period during biweekly elicitation sessions. About half of the data was recorded using a Sony mini-disc MZ-R37 digital recorder. The other half of the data was recorded using various analog cassette recorders such as the Marantz PMD430. Although the recording room was not sound-proof, it did provide an environment relatively free from background noise. Data was digitized on an iMac computer sampling at 44kHz. Acoustic analysis was performed using *Praat 3.8.64*, a shareware program developed by Paul Boersma and David Weenink at the Phonetic Sciences department of the University of Amsterdam.[1] The results of our study are found at the end of the paper.

3.2 Results

When analyzing waveforms and spectrograms for glottal closure, the obvious thing to look for is a period of reduced acoustic energy (Kent & Read 1992: 142). Although it is possible to make a glottal closure without completely sealing the vocal folds, most of the energy in the waveform and spectrogram disappears. Depending on the speaking style of the speaker, leakage of air sometimes does occur (G. Carden, p.c.). As mentioned in Section 2, to test our claim that ʕ is a glottalized pharyngeal resonant and not an ejective, it is necessary to show that ʕ patterns phonetically with the other glottalized resonants. Kim (2000) shows that glottalized resonants are pre-glottalized whereas ejectives are post-glottalized. Figures 1 to 4 confirm these findings.

In Figure 1 (ʔunw'itɬɬ) it is very clear that *w'* is pre-glottalized. Immediately after the nasal consonant, there is a glottal closure that lasts approximately 80ms. Following the closure, the *w* glide is clearly evident in the formant transition from *w* to *i*. Figure 2 (tɬ'um'aɬsɬw'aːɬ) confirms that glottal closure occurs *before* the gesture for *w* glide. In this word, there is a closure lasting approximately 70-75ms for *w'*. In addition, the word contains another glottalized resonant, *m'*, which, despite some leakage before the *m* portion, shows an attenuation of energy (cf. the plain *m* in ʕumaːʔatɬukʔitsk in Figure 10). The word in Figure 2 also shows clearly that a glottalized stop (ejective) is post-glottalized. The release of the affricate *tɬ'* is separated from the start of the vowel *u* by about 50ms of glottal closure. In Figure 3 (n'ikj'ak) a glottal closure of about 100 ms is observed before the *j* glide. Likewise, in Figure 4 (sij'aʕaqatɬ'atɬs) the *j'* can be seen to be pre-glottalized.

Having confirmed that ejectives are post-glottalized and glottalized resonants are pre-glottalized, we now turn to ʕ to determine whether it is pre- or post-glottalized. Figure 5 (ʕaʕitɬ) shows a word with two occurrences of ʕ, one word-initial and the other intervocalic. The intervocalic ʕ is preceded by a silence of at least 40ms, which is consistent with pre-glottalization. After this period of closure, when ʕ becomes evident on the waveform, its F1 value is at a peak of 756 Hz. From this point, all the way through the following vowel *i*, the value for F1 steadily drops to a low of 393 Hz, a difference of 363 Hz. In pharyngeal environments, F1 is normally raised (Pickett, 1999: 42) so one would not expect such a high F1 throughout so much of the vowel *i* if the pharyngeal constriction preceded the glottal closure.

The ʕ in Figure 6 (p'aʕum) is similar to the intervocalic ʕ in Figure 5. In both cases, the preceding vowel *a* gradually dies out as complete glottal closure is attained. In Figure 6, after glottal closure, F1 is at a peak of 835 Hz, rather high for *u*, but consistent with a pharyngeal environment (Shank & Wilson, 2000) By contrast, for the vowel *a*, which precedes the pharyngeal, F1 and F2 maintain steady values at about 700-750 Hz and 1250-1300 Hz respectively right up to glottalization. This indicates that there is no

[1] For information see <http://www.fon.hum.uva.nl/praat/>.

pharyngeal influence *before* glottal closure, and thus is convincing evidence that the ʕ is indeed pre-glottalized.

A second issue to address is whether the pharyngeal exhibits glide-like behaviour. Glides differ from stops in having a longer transition period. Pickett (1999: 110) reports the F1 transitions for glides are in the range of 75 to 100 ms, whereas for stops, Kent & Read (1992: 116) report an average of 50 ms for transition to take place. In Figure 7 (ciʕik) the duration of the formant transition into the *i* following the pharyngeal is around 100 ms. In Figure 6 (p'aʕum) the formant transition after ʕ into *u* is about about 75 ms. A similar rather long transition is seen in Figure 5 (ʕaʕitɬ), with a transition from ʕ into *i* of ms 70. By comparison, in Figure 1 (ʔunw'iɬħ) *w'* has a formant transition of about of 75 ms, and in Figure 4 (sij'aʕaqtɬ'atɬs) *j'* has a transition duration of about 100 ms. Thus, the pharyngeal once again patterns with the glottalized glides.

Although ʕ is generally pre-glottalized, in some tokens full glottal closure is not achieved, but rather, the pharyngeal appears as a laryngealized. Laryngealization is indicated on the spectogram by an increased distance between glottal pulses. Figure 4 has an example of ʕ with no glottal closure. Likewise, Figure 9 (ʔaqaʕatɬukka) is another example where the pharyngeal fails to achieve full glottal closure and ʕ appears as a creaky transition between vowels.

One may wonder at the validity of calling ʕ a glottalized pharyngeal resonant if glottal closure does not always occur. However, even the glottal stop sometimes appears without full closure, instead appearing as a creaky glide. The first *ʔ* in Figure 10 (ʕumaːʔatɬukʔitsk) presents a good example of this kind of intervocalic glottal stop. Here, there is absolutely no sign of a prolonged glottal closure. In this word the laryngealization associated with the intervocalic glottal stop has a duration of over 100ms. Figure 11 (ʕujaːsʔap'aɬi) contains another example of a creaky *ʔ*.

The analysis to this point has focused on relative timing of glottal closure, formant transitions and laryngealization. One final issue is the occurrence of points of impulse (spikes) on the waveforms of ʕ, which Bessell (1993) notes might indicate a stop release. This is not the only interpretation, however. These spikes can sometimes represent the opening or closing of the glottis (G. Carden, p.c.). In this respect it is interesting to note that both *ʔ* and ʕ sometimes occur with a spike, and sometimes without. Figure 12 (ʔapw'in) shows an occurrence of *ʔ* with a clear spike before becoming creaky as it moves into *a*. On the other hand, Figure 8 shows that word-initial *ʔ* may not have a spike. In the same way, word-initial ʕ can have a spike as in Figure 5, but it can also appear without a spike as in Figure 10.

4 Discussion

The acoustic analysis is enlightening in several ways. First of all, it is amply clear that the impressionistic evidence was correct, and ʕ is in fact not an ejective. This is obvious from the relative timing data. Whereas ejectives are post-glottalized, ʕ is pre-glottalized. Furthermore, ʕ was found to have formant transitions more like glides than like stops. Therefore, analyzing this sound as a glottalized glide rather than a glottalized stop is very well motivated.

A further piece of evidence which suggests that ʕ is not a stop comes from the inconsistency of closure. In several tokens ʕ is not made with full closure. Rather, in these tokens, the pharyngeal appears as a creaky glide. It is certainly possible that a stop might have such a resonant-like allophone intervocalically, but when added to the evidence already discussed, it is much simpler just to say that we in fact are dealing with a glide.

As for the spike in the spectrogram, which Bessell speculated may be indicative of a stop release, it was found that the same sort of spike is observed in some tokens of the glottal stop. Thus, the spike is not very strong evidence for ʕ being regarded as a stop, since it can easily be attributed to the glottal release portion of its articulation.

To sum up our findings, we believe the acoustic evidence points to a reorganization of the phonemic inventory of Nuu-chah-nulth, with ʕ being moved from the glottalized stop series to the glottalized resonant series. We revise the phonemic inventory given in (1) in (7) below.

(7) *Revised Ahousaht Nuu-chah-nulth consonant inventory*

	Labial	Alveolar	Alveolar Affricates	Lateral	Alveo-palatal	Velar	Labio-velar	Uvular	Labio-uvular	Pharyngeal	Laryngeal
Voiceless stops	p	t	ts	tɬ	tʃ	k	k^w	q	q^w		
Glottalized stops	p’	t’	ts’	tɬ’	tʃ’	k’	$k’^w$				
Fricatives		s		ɬ	ʃ	x	x^w	χ	$χ^w$	ħ	
Nasals	m	n									
Glottalized nasals	m’	n’									
Glides					j		w				h
Glottalized glides					j’		w’			ʕ	ʔ

This analysis of ʕ raises several interesting questions. First of all, the reclassification of ʕ as a glottalized resonant has significant consequences for the overall balance of the phonemic inventory. While the received phonemic inventory as given in (1) above had gaps, in that there were no uvular or pharyngeal resonants, this revised one appears even more asymmetrical in lacking a glottalized counterpart to *q*, a role filled by ʕ in the previous inventory, and in lacking a plain (unglottalized) counterpart to ʕ. This asymmetry especially comes out in the glottalization data. As demonstrated in (4), before glottalizing suffixes, *q* becomes ʕ whereas other stops become ejectives and fricatives become glottalized resonants. The uvular stop is thus unique in being a stop which becomes a glottalized resonant after glottalization, patterning with the fricatives. Some of the answers may come to light after a more thorough study of the uvular stops, in order to find the motivation behind the *q* ~ ʕ alternation. A tentative proposal is that *q’* was reanalyzed as a ʕ because uvular ejectives and pharyngeals already share so many articulatory characteristics. Esling (1996: 80-1) suggests that pharyngeal articulations are normally made with a raised larynx, and where larynx height plays no role pharyngeal segments can be said to have the same manner of articulation as uvular segments. One can thus imagine that a uvular ejective, pronounced with a raised larynx, might be reanalyzed as a pharyngeal segment. The question of why this pharyngeal is realized as a glottalized resonant as opposed to a glottalized stop is then a question of why the timing of glottalization might change. The answer to this, in turn, might have something to do with the impossiblitly of producing an ejective at this point in the vocal tract. Pharyngeal ejectives are not documented in any natural language (B. Gick p.c.). At any rate, although the phonemic inventory given in (7) reflects phonetic reality better, for phonological reasons it may be that the inventory in (1) is ultimately preferable. If this is so, then Nuu-chah-nulth exhibits a fascinating mismatch between phonetics and phonology, and would be a strong case arguing in favour of a modular view of grammatical organization.

An alternative view to the one argued for here is that ʕ is not in fact a glottalized pharyngeal, but actually a pharyngealized glottal stop. Although this is certainly not an impossible situation, and the acoustic evidence given here does not really argue against such a claim, we are reluctant to adopt such an analysis. First of all, secondary pharyngealization would be rather restricted, only found on *ʔ* and *h*, and there are reasons to doubt that *ħ* should be reanalyzed as the pharyngealized counterpart of *h*. If *ħ* was the pharyngealized counterpart of *h*, then it too would be glottal. But then it would be difficult to explain why it is able to avoid the prohibition on syllable-final glottal elements. A second reservation to analyzing ʕ as a pharyngealized *ʔ* is that this implies a particularly strong relationship between *ʔ* and ʕ, but as seen by the *q* ~ ʕ alternation above, there appears to be stronger a case for the close relationship of pharyngeals to uvulars.

In future phonetic research, the next step in the study of ʕ is to observe it through direct physiological measures. An electroglottograph (EGG) detects changes in impedance across the vocal folds, indicating their degree of closure. A test using such a device would be useful in that it would be possible to make a more precise statement regarding the relative timing and degree of such closure. Perception tests could be designed to indicate whether the spikes in the spectrogram are necessary as cues for perception.

In addition, ultrasound may help indicate the degree of overlap in articulation between ʕ and the uvular stops.

5 Conclusion

To conclude, we have argued that the acoustic evidence points to a reclassification of ʕ as a glottalized resonant in Nuu-chah-nulth. This is well-motivated from a phonetic perspective, based on evidence such as the relative timing of glottal release and its tendency to fail to fully undergo stop closure. This conclusion conflicts with some phonological evidence, which points to the analysis of ʕ as a glottalized stop. Hopefully future phonetic and phonological work will help resolve these tensions.

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