PHONETIC ASPECTS OF NOOTKA PHARYNGEALS[1]

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0. The term *pharyngealized* can apply to non-distinctive or distinctive features of language-specific segments. Delattre (1971:129) identifies any pharyngealized segment as one in which

> the root of the tongue assumes the shape of a bulge and is drawn back toward the vertical back wall of the pharynx to form a stricture. This radical bulge generally divides the vocal tract into two cavities...

Pharyngealization is phonologically distinctive in Western Semitic, Caucasian, Ossetic, Interior Salishan and Nootkan.[2] Although articulatory descriptions exist for several languages with distinctive pharyngeal segments, acoustic or other experimental phonetic data on the nature of pharyngeals is restricted largely to Semitic. This paper describes the acoustic characteristics of pharyngealized segments in Ahousat Nootka, emphasizing their influence on their phonetic environment, and discussing the implications for both synchronic and diachronic Ahousat phonology.

Ahousat is a central dialect of Nootka, a branch of the Nootkan subdivision of Wakashan. Ahousat has the same phoneme inventory as Tseshaht Nootka (c.f. Sapir & Swadesh 1939): /p p̓ t t̓ c c̓ č č̓ λ ƛ̓ k k̓ kʷ k̓ʷ q qʷ s š ł x xʷ ḥ h m m̓ n n̓ y y̓ w w̓ ʔ ʕ a a· i i· u u· /. Uvular ejectives and fricatives are rare in Tseshaht, and are absent in Ahousat, at least for my consultants. The data set for this study consists of 131 Ahousat one-word, and 35 nonsense, disyllabic utterances, each recorded twice on an Ampex recorder at 19 cm/s. From these, 166 wideband linear-display spectrograms with superimposed amplitudes were

made, using each utterance's second repetition, which had more of a citation-style natural delivery than the first repetition[3]. For example, the response for *drifting* was t͡aʔak t͡aʔak.
Pharyngeals were analyzed first for associated features mentioned in research on Semitic pharyngeals.

1. Jakobson (1957) observes that in Arabic both 'emphatic' or pharyngealized phones and labialized phones have a low pitch. He argues for the "equivalence of pharyngealization and labialization" (Jakobson 1957:161), adding that

> often labialized consonants are substituted for the corresponding pharyngealized phonemes of Arabic words by Bantus..: ṭ→tʷ, ṣ→sʷ ... Instead of the back orifice, the front orifice is contracted. (ibid)

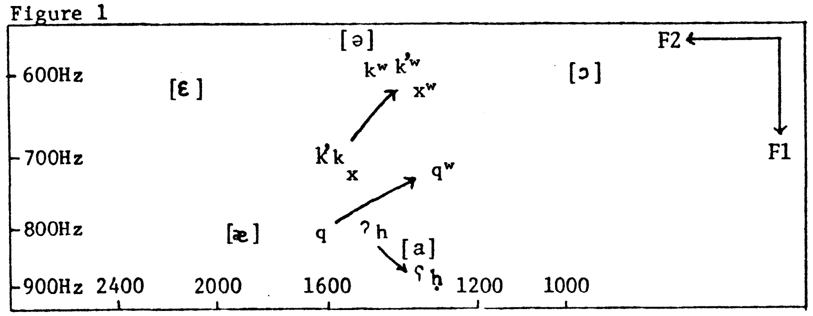
In Nootka, pharyngealization and labialization are both considered distinctive for consonants[4]. In order to compare the acoustic cues for these two articulations, the vowel formant values for first (F1) and second (F2) formants (measured in Hz 40 msec.[5] from onset) of the left-most vowel, and the amplitude ratios (x:1) of the initial consonants were obtained for the following:

Table 1	F1 of #C_	F2 of #C_	Amplitude of #_
kaƛ̓ḥšiƛ̓	700	1600	17
kʷaṫyi·k	600	1500	5-10
qatšiƛ̓	800	1650	13-15
qʷaƛ̓a·	700	1300	9
k̓ak̓a	700	1650	24
k̓ʷačiƛ̓	600	1500	24
ʔaƛ̓a	800	1500	25
ʕaƛ̓šiƛ̓	900	1350	3
xaxača	700	1550	'10
xʷaxʷakyumł	600	1300	10
hahapyumł	800	1500	24
ḥayu	900	1300	10

Labialized and pharyngealized consonants both have lower amplitude (and hence perceived lower pitch) than their plain counterparts.

The vowel formant values are plotted below on a mel-scale chart, the vowel position marked by its preceding consonant:

Figure 1



The bracketed vowels represent the formant values for the researcher's own non-high vowels. Vowel-lowering correlates with F1 raising; vowel-fronting correlates with F2 raising; manner has no significant influence on formant values. Therefore, averages of the F1 and F2 values (for all relevant vowels in the data, length being ignored) may be obtained for the following environments [6] (where X_ indicates that the vowel is preceded by a stop, ejective or fricative with X's place of articulation and degree of rounding, and is followed by any X or by silence, i.e. a word boundary):

Table 2		C_	k_	kʷ_	q_	qʷ_	ʔ_	ʕ_	č_
/a/	F1	750	650	600	750	700	800	900	650
	F2	1550	1650	1200	1600	1300	1550	1400	1800
/i/	F1	500	450	500	600	500	500	700	450
	F2	2250	2300	1900	2200	1500	2500	2100	2400
/u/	F1	550	550	-	650	-	500	700	-
	F2	1100	1200	-	1200	-	1000	950	-

/h ḥ/ are considered fricatives in Table 2.

Using the formant values for /a/ from Table 2, one observes that the averaged values match those from Table 1. Both labialized and pharyngealized consonants are followed by vowels

with lower F2's than those following plain consonants; but, whereas labialized consonants *lower* the following vowel's F1 (due to lip rounding), pharyngealized consonants *raise* the F1, due to the tongue root backing. Back and front orifice closures cannot therefore be acoustically cued by one feature. It is rather the rear constriction, due to pharynx stricture or to tongue body raising, which results in an acoustic cue (the lower F2) common to both labialization and pharyngealization (c.f. Fant 1962).

Labialization and pharyngealization must be seen as non-equivalent articulatory bundles, with lip rounding and root retraction mutually exclusive but rear constriction a shared articulation. This clarification of individual cues is crucial for finding acoustic correlates for 'rounding' in Interior Salish where a phonetic distinction between rounded and unrounded pharyngeals may exist.

2. Pharyngealization may influence the degree of opening of the velo-pharyngeal port. Hetzron (1969) notes that in East Gurage (Semitic) original pharyngeals have been replaced by nasals. He argues that any pharyngeal segment will have associated with it a movement of the uvula down along the tongue root to the radico-pharyngeal constriction site. He concludes that uvula lowering would force the velum to leave the rhyno-pharyngeal wall, causing nasalization, and more intriguingly, that

> phonetically, there are not really different possibilities of articulation for these laryngeals. (ibid, p.72)

Such a co-articulation is suspect in Ahousat, where nasals are discrete: vowels do not sound nasalized; nasals do not assimilate. Acoustic verification is however necessary.

Acoustically, nasalization is cued by F1 raising, F3 lowering and weakening, and presence of resonance bars *in addition* to the F1 and F2 bars. Therefore, the vowels /a/ and /i/, when adjacent to nasal, pharyngeal and plain consonants, were analyzed for F1 and F3 values, F3 amplitude (S = F2 amplitude for stressed vowels, M = medium, W = weak noise, e.g. that of /h/) and for presence of nasal bars. Examine the following:[7]

Table 3	F1	F3	AMP		F1	F3	AMP
#ʔat	750	27-28-2900	SW	#ʔa·m	850-950	2500	SM
tal#	650-750	28-26-2700	MWØ	#mam	750	2550	W
ka·#	500-800	24-24-2500	SMS	ma#	850	27-25-2500	MØ
#ʔak	700	26-25-2400	S	mak̓	700	27-26-2500	WS
#ʔaq	700	2600	MW	qaq	750	28-26-2700	SØ
ʕa#	900	29-28-2900	SØ	#maʕ	800-900	27-28-2700	MØ
#ʔaḥ	?	28-28-2700	SMØ				
#tiƛ	500	31-30-2800	M	ni·ƛ	500	2950	M
#hiḥ	650	2800	M	k̓in#	450	27-27-2900	MØ
#ʔiq	500	28-30-2700	S	qin#	700	27-29-3000	M
ḥiḥ	700	2600	M	#ʕin	700-750	28-28-2700	SWØ

Vowels adjacent to nasals or pharyngeals usually have stable F1's, and F1 shifts occurring are contradictory, e.g. in /maʕ-/ F1 is higher adjacent to the /ʕ/, but in /ʕin-/ F1 is higher adjacent to the /n/. If we compare the F1 values for vowels in specific consonant environments (including or excluding nasals) from Table 3 with the averaged values in Table 2, we find:

Table 4	/a/	*C	*k	*q	*ʕ	/i/	*C	*k	*q	*ʕ
Average		750	650	750	900		550	450	600	700
Table 3		725	675	725	900		500	-	500	700
+Nasal		850	700	-	850		500	450	700	725

There is some evidence that vowels' F1's do raise when the vowel is adjacent to a nasal. The stability of /i/ adjacent to a nasal *and a /k/* may be due to the use of a high F1 as a cue for */q/*. The contradictory behavior of /ʕ/ may be due to the extremely

high F1 value of any vowel adjacent to /ʕ/, allowing for some fluctuation in the F1 value independant of nasal influence. The facts that vowel F1's are not consistently higher in a /ʕ/ plus nasal environment as opposed to a non-nasal but /ʕ/ one, nor are the F1's stable (i.e. equivalent) in the two environments, suggest that nasalization is *not necessarily* a feature of pharyngealization.

The F3 transition values from Table 3 show that vowels may have a rising, falling or stable transition pattern *regardless* of their consonant environment, e.g. nasal or non-nasal:

Table 5	/a/	*C	*k	*q	*ʕ	/i/	*C	*k	*q	*ʕ
Other		2700	2450	2600	2800		3000	-	3000	2700
+Nasal		2525	2600	-	2800		2950	2700	2900	2800

The F3 of a vowel adjacent to a back consonant and a nasal may be either higher or lower than that of a vowel in a non-nasal but otherwise similar environment. The fact that /a/'s F3 value adjacent to /ʕ/ is <u>higher</u> than when adjacent to other consonants but /i/'s F3 value is generally <u>lower</u> adjacent to /ʕ/, regardless of whether a nasal is also present, again suggests that pharyngealization is not characterized by nasalization in Ahousat.

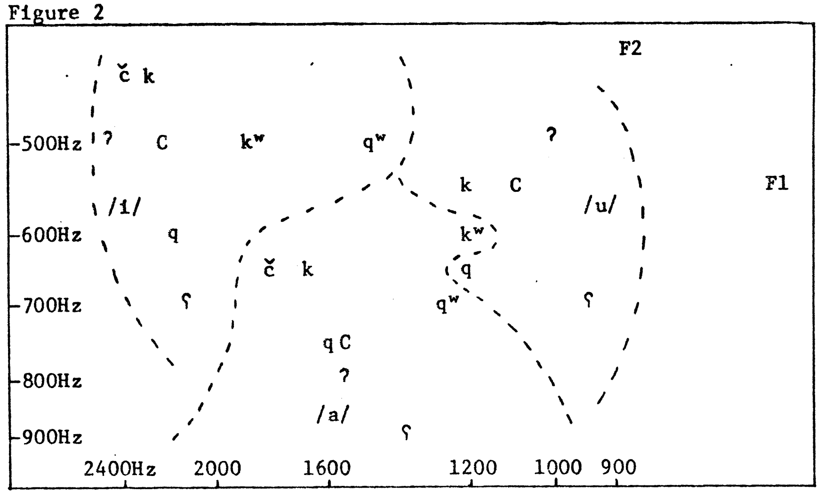
Examining F3 amplitude levels (in Table 3), we find that whereas amplitude tends to weaken for F3 adjacent to nasals, amplitude tends to <u>strengthen</u> adjacent to /ʕ/. Given that the information from F1 and F3 values is inconclusive, and that all vowels in Ahousat have an extra formant between 900 and 1200 Hz (site of the nasal resonance bar for /n/ and /m/), we conclude from the amplitude levels that pharyngeals *need not be nasalized*, and are not nasalized in Ahousat.

3. We turn now to the investigation of *velarization* as a secondary articulation of pharyngealization. Ladefoged (1975:208

defines velarization as "raising the back of the tongue", adding that there "is very little difference between velarized and pharyngealized sounds, and no language distinguishes between the two". However, a language may use both articulations to *jointly* distinguish a feature, e.g. the Arabic 'emphatic' feature.

In Ahousat, labialized variants of velars and uvulars complicates the function and identification of velarization, which is supposed to be cued by an adjacent vowel with lowered F2. Plotting the F1 and F2 values from Table 2 for all vowels, and identifying the vowels by their preceding consonant, we obtain the following mel-scale chart:

Figure 2



In order to determine what F2 is cueing in Ahousat, the difference of the F2 value of a vowel in a given environment from that of the F2 value of the same vowel following a plain non-back consonant (*C) was plotted for each vowel in all the environments given in Table 2, using a +/- distribution:

Figure 3 F2 Value Differences

	+200Hz		+100Hz		0Hz		-200Hz		-400Hz	
/i/	ʔ	č		k	C	q ʕ		k^w		q^w
/a/	č		k	q ʔ	C	ʕ	q^w	k^w		
/u/			k/q		C	ʔ ʕ				

We note first that /k/, which has a raised tongue body, does not cause velarization of adjacent vowels. In Ahousat, the /k/ is somewhat fronted or palatalized causing a raising and slight fronting of an adjacent vowel (i.e. F1 lowering and F2 raising). This F2 raising occurs in the environment of /č/ as well. In some Ahousat words, a /y/ off-glide is perceptible preceding /i/ or /a/, as in [ʔak^{y}a·] 'ouch'. This high front tongue position is associated with high pitch, which helps distinguish /k/ from other back consonants, all of which have low pitch. Such palatalization is common for languages with such large numbers of distinctive back consonants.

Secondly, whereas the F1 lip rounding cue distinguishes /k/-/k^w/ and /q/-/q^w/ from plain consonants by less than 100 Hz, the F2 'rear constriction' cue clearly distinguishes /k/, /q/ and plain consonants from /k^w/ and /q^w/ by at least 250 Hz for both /a/ and /i/. In the case of /u/, there must be lip rounding and rear constriction associated with the vowel onset in /ku/ and /qu/, but neither is marked, due to the neutralization of the 'rounded' and 'unrounded' series. Rather, the /u/ is centralized in these environments. Perhaps the general low F2 of /u/ prevents further F2 lowering in labio-velarized environments. We must conclude that in Ahousat <u>phonetic</u> labialization (F1 lowering) serves as a cue for neither pharyngealization nor labio-velarization. Rather, it is the *rear constriction* (F2 lowering) cue which is the common and crucial identifying cue for both articulations.

Thirdly, F2 raising (palatalization) and F2 lowering *combine* to yield a F2 distinction between vowels adjacent to /k/ versus /q/, at least for /i/ and /a/. However, it appears that labio-velarization's use of the F2 cue prevents F2 from also distinguishing /k/ from /q/. In addition, if /i/ and /a/ were to back more when adjacent to /q/, they would tend to sound like /u/, partly because /q/ tends to raise the Fl of /i/ so that it approximates the Fl of [ɔ].

The neutralization of labialization as a distinctive feature preceding /u/ seems inevitable, given that /u/ already has a very low Fl and F2. Thus the CV transition will reflect a [u]-like vowel whether or not the consonant is labialized phonologically.[8] The use of velarization, or rear cavity constriction, as the cue for labio-velarization may have contributed to the neutralization of labialization preceding /u/, due to the lack of *visibility* of the velarization cue in /Cu/ or /C^wu/ sequences, and to the *freedom of variation* in the F2 value for /u/ as opposed to the necessity of a low Fl for /u/ in order to maintain its distinction from /a/. Thus the F2 value of the transition preceding /u/ could vary between values signifying a preceding /C/ versus /C^w/ while still maintaining the /a/-/u/ distinction.

Lastly, we note that pharyngeals are cued by a *uniform* 150Hz drop in the F2 value of adjacent vowels. Given that F2 performs a triple function (at least), contributing to the identification of labio-velarized, pharyngealized or uvular (versus velar) consonants, we may question the function of Fl, or vowel *height*, in the distinguishing of consonants in Ahousat.

4. In 1962, Fant argued that Fl was used as a cue not only for labialization but also for *tongue root retraction*. Plotting the differences of Fl values of a vowel adjacent to a given consonant as opposed to the same vowel adjacent to a plain non-back consonant (*C), based on the data from Table 2, we obtain:

Figure 4 Fl Value Differences

	-200Hz		-100Hz		0Hz		+100Hz		+200Hz
/i/				k	ʔC k^w q^w		q		ʕ
/a/		k^w	k	q^w	C q	ʔ		ʕ	
/u/				ʔ	C k		q	ʕ	

If raised Fl signifies retracted root, then we must assume that uvulars share with pharyngeals this feature. As in the case of Fw, Fl is a multi-function cue. Not only does it distinguish the retracted root consonants from other consonants (by a difference of 100 to 200 Hz, except for /qa/ where the tongue position for /q/ and /a/ is almost the same). In addition, Fl is used to distinguish /k/-/q/, by a difference of 100 to 150 Hz. Vowel lowering, or tongue root retraction, distinguishes /k/-/q/ when adjacent to /i/ or /u/, and vowel raising distinguishes /k/-/q/ when adjacent to /i/ or /a/. Thus Fl raising and lowering *combine* to insure a large Fl difference between /kV/ and /qV/ for all Ahousat vowels, overcoming the articulatory limitations of Fl shifting.

In turn, the vowel always has an Fl value adjacent to /ʕ/ which is 50 to 100 Hz greater than if it were adjacent to /q/ and 150 to 200 Hz greater than if it were adjacent to a non-back consonant. This demonstrates that Fl height is a function of tongue frontness or backness (i.e. palatalization or root retraction), and helps to explain why, in Arabic, [q] has been described as a pharyngealized *k* (c.f. Delattre 1971). The reliance of the phonological system on F1 height as a cue for both a high consonant /k/ and the low consonants /q/ and /ʕ/ makes impossible the use of F1 as a cue for labialization. One hypothesizes that whenever a language has both rounded and unrounded consonants and a /k/-/q/ distinction, it must use cues other than F1 height (e.g. F2) to mark the rounding.

In fact, F1 can cue lip rounding or tongue root retraction, but not simulataneously. We find that /qu/ has a raised F1, /qʷi/ has a plain F1, and /qʷa/ has a lowered F1. Lip rounding thus has precedence over retraction as a cue if the vowel is low (high F1), but root retraction has precedence when the vowel is high (low F1) and back.

Based on the above findings, it should be clear that /kʷ/ and /qʷ/ cannot be consistently differentiated by one strategy for all vowel environments. For /i/, /kʷ/ and /qʷ/ are differentiated by the F2 value, which is 400 Hz less for an /i/ adjacent to /qʷ/ than for one adjacent to /kʷ/. If the /i/ adjacent to /qʷ/ were to lower (i.e. if its F1 were to raise), it could be misheard as /a/. For /a/, /kʷ/ and /qʷ/ are differentiated most effectively by a greater F1 lowering (by 100 Hz) of /a/ adjacent to /kʷ/ as opposed to that of /a/ adjacent to /qʷ/. These relations do not make a pattern, and it is no doubt due to the secondary priority of the /kʷ/-/qʷ/ distinction as opposed to the /k/-/q/ and /C/-/Cʷ/ ones which renders the /kʷ/-/qʷ/ distinction very difficult to perceive.

We conclude that in Ahousat pharyngealized phones are cued by a rear constriction feature, F2 lowering, which they share with labio-velarized phones, and a retracted root feature, F1 raising, which they share with plain uvulars.

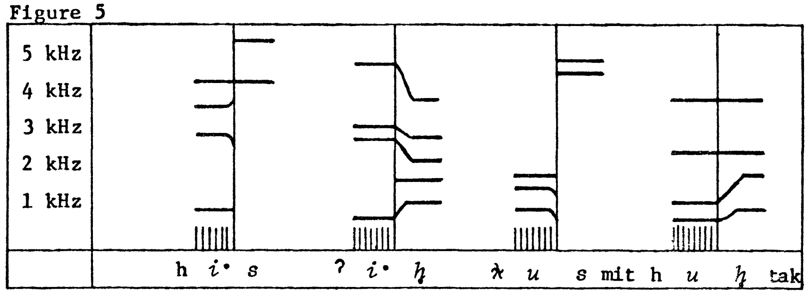
5. Another possible cue for pharyngeals could be *vowel transition*, known to cue at least some places of articulation (Fant 1962:14). In Ahousat, one perceives a [ə] between high vowels and an adjacent /ʕ/ (or /q/), as in ʕini·ƛ̓ [ˀə̰·ⁱni·tɬ] *dog*, or in ˀi·ḥ [ˀi·əḥ] *big* (˷ denotes laryngealization, and ˀ denotes a pharyngealized glottal). In order to examine the acoustic evidence for this [ə], vowel transitions and vowel durations for /i/ and /u/ adjacent to /ʕ/ (i.e. /ʕ/ or /ḥ/) were compared with those for /i/ and /u/ adjacent to /p/, due to its low F2 locus and lack of audible transition in adjacent vowels (e.g. *[pəⁱ]) and to /s/, due to its high amplitude:[9]

Table 6	F1	F2	DUR		F1	F2	DURmsec.
#pi	500-450	2100-2200	25	#ʕi	700-650	1900-2450	60
#si	450-500	2000-2150	25	#ḥi	700-500	1900-2600	88
#pu	500-450	1000- 900	50	#ʕu	700	1000	75
#su	500-550	1650-1500	40	#ḥu	650-600	1200-1100	75
it#	600-500	2200	45	iʕ	650	2200	50
i·s#	500	2650-2250	175	i·ḥ#	500-600	2500-2400	140
up#	500	1300-1000	75	uʕ	700	1150-1000	95
us	500-450	1350-1200	40	uḥ	750	1100	50

The stable transitions posited for /i/ and /u/ when adjacent to plain consonants, and the centralizing and lowering transitions when adjacent to pharyngeals, were not confirmed by the data. The averaged F1 and F2 transitions adjacent to plain consonants are 50 Hz and 150 Hz respectively; adjacent to pharyngeals, they are 50 Hz and 200 Hz respectively. In addition, there are more cases of stable vowels (with unchanging F1 and F2 values) adjacent to pharyngeals than to plain consonants. In fact, only vowels adjacent to pharyngeals can have both a nonchanging F1 and a non-changing F2 value, the /u/ in ʕuˀak *lake*. The transitions are contradictory: plain consonants and pharyngeals may be bounded by vowels with either stable or variable transitions. Because vowel transitions are no more likely to be variable when adjacent to /ʕ/ than when adjacent to plain consonants, we must conclude that pharyngeals are not flanked by [ə]-like transitions acoustically.

The *perception* of a [ə] transition adjacent to a pharyngeal must still be accounted for. The following are schematic diagrams of the main formants below 6000 Hz (= 6 kHz) for four words containing the sequences *us*, *uħ*, *is*, *iħ*. The vertical broken-line bar represents the end of voicing (the vowel) and the onset of random noise (the fricative). The short striations represent voicing. Horizontal lines are formants.

Figure 5



The formant transitions associated with pharyngeals occur *during* the pharyngeal articulation, not during the vowel. The high F1 and the relatively low F2 formants in the pharyngeal /ħ/ are possibly due to the superimposition of a low /a/ vowel on the pharyngeal fricative articulation. It must be these cues which one hears as a [ə] glide. Evidently linearization of two distinctive features, or sets of features, is taking place: the simultaneous /ħ/-/a/ articulation is perceived as a *sequence* of fricative and transition glide.

It is still necessary to explain the [ə] perceived to be

adjacent to /ʕ/. Hogan (1976:275) notes that ejectives have longer silent intervals (SI's) than their associated plain consonants, both for the SI preceding the consonant release, and for the SI between the consonant release and the vowel onset. He suggests that F2 and F3 transitions are not significant for distinguishing among ejectives, and that the SI durations may be of use in performing this task.

6. Hypothesizing that articulatory movements could occur during *silent intervals*, we compare the SI durations (in msec.) both preceding (PRE) and following (POST) a /ʕ/, /Cʼ/ or /C/ (/C/ here being any non-pharyngeal non-ejective consonant):[10]

Table 7	PRE SI	POST SI		PRE SI	POST SI
a_t_a	150	7.5	a_tʼ_a	277.5	30
a_k_a	187.5	0	a_kʼ_a	217.5	67.5
a_q_a	142.5	0	a_ʕ_a	75-90	15+
a_ʔ_a	202.5	0			
a_w_i	0	0	a_wʼ_i	165	0
č_a	NA	0	čʼ_a	NA	22-30

SI's are longer for ejectives than for non-ejectives in this data set. SI's for /q/ parallel those for the other non-ejective consonants. /ʕ/ patterns like an ejective in having a POST SI (due to the slowed rate of glottalic pulsing), but its PRE SI is shorter than for *any other* consonant, plain or ejective. We therefore cannot assume that the vowel positions for pharyngeals are approximated during extra-long pre-burst silent intervals, as Hogan has posited is the case for vowels adjacent to ejectives.

Some tongue position change may occur during the slowed bursts of the pharyngealized vowel, but this is not demonstrated in this study. There is an interesting relation between SI and vowel duration. Re-examining Table 6, we find that whereas a plain consonant is usually preceded by a medium length pre-burst SI, and a short vowel duration (about 160 and 85 msec. respectively), a pharyngeal consonant is preceded by a short pre-burst SI and a long vowel duration (around 75 and 130 msec. respectively). There are two possible explanations for this short pre-burst SI. One is that there is some kind of syllable duration constraint in Ahousat. This is difficult to accept, as the language has distinctive long and short vowels. The second explanation necessitates abandoning the Nootka constraint against syllable-final /ˀ/. There is some evidence that an /..XVCV../ sequence may be pronounced [..XVˀ : CV..] (where : represents a syllable boundary, and C must be /q/, /ˀ/ or /ˤ/). For example, /t̓iˤas/ *sitting outside* can be pronounced [t̓ɛ̰ʔ : ˤʌ̰s], with a syllable-final /ˀ/. The 'insertion' of [ˀ] results in a closed syllable, and therefore a shorter vowel duration than that for an open syllable.

7. The perceived syllable-final [ˀ] may be due to *laryngealization*, the slowing down of the glottal pulse to an aperiodic wave, identified auditorily as 'creaky voice'. Its spectrogrammic correlates are low amplitude (to be examined later) and spaced vertical striations, representing the individual glottal bursts, in contrast with the smooth horizontal formant bars found when the glottis is pulsing periodically and swiftly. If a syllable ends in a laryngealized vowel, the individual glottal pulses might be perceived as [ˀ] or a series of [ˀˀˀ] following the vowel.

In order to identify the presence of laryngealization, the consonants in this study (classed by place of articulation and by presence of glottalic activity) were investigated for spectrogrammic evidence for pre-consonantal laryngealization (PrCL) and amplitude (PrCA), length of SI (SI), consonantal amplitude (CA), post-consonantal laryngealization (PoCL) and amplitude (PoCA):

Table 8	C	C'	R	R̓	Front Fric	Back Fric	q	ˤ	ḥ	ʔ	h
PrCL	-	-	-	+	-	-	+/-	+	-	+	-
PrCA	Hi/Lo	Lo	Hi	Lo	Hi	Hi	Hi	Lo	Lo	Hi	Hi
SI	Ave	Long	-	Ave	-	-	Lo/Av	Short	-	Ave	-
CA	M/Hi	Hi	Dip	Hi	Mid	Lo	M/Hi	M/Lo	Lo	Hi	Very Lo
PoCL	-	+	-	+	-	-	+	+	-	+/-	-
PoCA	Hi	Hi	Hi	Hi	Hi	Hi	Hi	Lo	Hi	Hi	Hi

We observe first that laryngealization never occurs for vowels adjacent to non-ejective plain or velar consonants, or to any fricative, even the retracted root fricative /ḥ/. Although aperiodic noise characterizes fricatives, this does not constitute laryngealization or creaky voice, which is characterized by aperiodicity *at the glottis*.

On the other hand, vowels preceding and following the glottalized resonants (R̓) /m̓ n̓ y̓ w̓/ and /ˤ/ are necessarily laryngealized. Vowels are optionally laryngealized preceding /q/ and following /ˀ/. There seems to be a correlation between laryngealization and the production of a stop with constriction in the post-velar speech tract. Laryngealization occurs adjacent to a glottal closure, as in 'glottalized' resonants and stops (/C̓/ and /R̓/), /ˤ/ and /ˀ/, and optionally adjacent to a back consonant with retracted root, /q/.

Ejectives have laryngealization only following the burst, due perhaps to the long SI preceding ejectives, an interval during which the articulatory changes, anticipating glottal closure, can occur. The extra length of the SI may help to contrast the ejectives with the plain stops, which have an average-length SI. Glottalized resonants contrast with resonants, which have no SI at all. All other consonants with a closure and constriction in the extreme rear speech cavity have anticipatory laryngealization. Therefore, both for glottalized stops or resonants, the 'glottalization' feature can be cued either by the laryngealization plus /ˀ/, or by laryngealization alone, as in [ˀy̰ʌ̰ˀ m̰ʌ̰] or [ˀy̰ʌ̰m̰ʌ̰] for /y̓am̓a/ *salalberry*, or [ˀʌˀ tʌ̰] or [ˀʌ tʌ̰] for /ˀat̓a/ *thick*.

One reason laryngealization may serve as a primary cue is that Nootka has no syllable-initial phonological consonant sequences. If one attempted to apply this constraint to 'glottalized' consonants, the /ʔ/ would have to be assigned to the preceding syllable if it were perceived as discrete, i.e. separate from the 'glottalized' consonant segment. One hears this type of pronunciation in careful citation-style speech. However, there is also a phonological constraint against /ʔ/ occurring syllable-finally. Because the phonetic and auditory differences between [V̰ˀ] and [V̰] are negligible (laryngealization being a series of rapidly articulated /ˀ/'s: [V̰]=[Vˀˀˀ]), the language could maintain both constraints by replacing the distinctive cue of glottal closure, or /ˀ/, for glottalization by one of pre-consonantal and post-consonantal laryngealization.

Pre-consonantal laryngealization of /q/ suggests an explanation for a rather aberrant syllable-structure in Nootka, found in words such as /ˀiqḥuk/ [ˀɛ̰ˀ : qḥɔkʷ] or /taquqƛ̓i/ [tʾ:qɔ̰ˀ: qtɬɛ]. Recall that a syllable is supposed to have only one initial consonant followed by a vowel (affricates and ejectives are considered as single phoneme units). Therefore, a syllable could not start with a /ˀC/ sequence. Also, a syllable may not end with a /ʔC/

or a /CC/ sequence. Given the case of a /CVqV/ sequence, with expected shape [CV̰ : qV̰], if the pre-burst laryngealization is perceived as cueing a /ˀ/, this /ˀ/ could be understood as ending the pre-burst syllable: [CV̰ˀ : qV̰], thereby violating the syllable-final /ˀ/ constraint, but obeying the syllable-final /ˀC/, /C̓/ and syllable-initial /CC/ prohibitions in Ahousat phonology. Thus a non-distinctive feature, laryngealization, contributes to the reanalysis of syllable boundaries.

8. *Amplitude* is the maximum value of a periodically varying wave, e.g. the speech wave, or of a stretch of random noise. Amplitude bears some relation to intensity or loudness, and is affected by place, manner and phonation-type of an articulation. Re-examining Table 8, for the relative levels of amplitude for vowels preceding certain consonants (PrCA) or following certain consonants (PoCA), and for specific consonants (CA), we find that consonant amplitude is variable for stops and resonants, with glottalized stops generally higher than their plain counterparts. Resonants have high amplitudes in word-initial position (i.e. smooth rapid onset to the vowel), but intervocalically, their amplitude dips below that of the adjacent vowels. Fricatives, including /ḥ/, have lower and jagged (i.e. erratic) amplitudes, due to their aperiodicity, with the amplitudes of front fricatives generally higher than those of back fricatives.

In Ahousat, only /ʕ/, and very rarely /ḥ/, cause a following vowel to have a low or erratic onset, probably due to the *degree* of the laryngealization following /ʕ/ as compared to other consonants, resulting in the recording of individual glottal pulsings [ˀˀˀ] in the amplitude display. The amplitude of vowels tends to drop smoothly except prior to glottalized stops and resonants, /ˀ/ and pharyngeals, where the drop is erratic. This erratic amplitude drop may be due to associated laryngealization, because laryngealization does lower the pulse. However it cannot be due only to laryngealization, because glottalized stops do not have pre-burst laryngealization. Perhaps the erratic drop in amplitude prior to these consonants is also due to *larynx raising* (a known correlate for ejectives; c.f. Ladefoged 1975:114), which causes a compression of air in the pharynx. By visually and tactually exploring the front throat area during phonation, one finds that significant larynx raising occurs during either glottal closure or a pharyngealized articulation. One assume that, as with ejectives, larynx raising is used in the articulation of pharyngealized segments to create increased pharyngeal pressure.

9. Let us summarize the aspects of Ahousat pronunciation discussed in this paper. First, *labialization*, as a phonological feature, is actually composed of two articulations, lip rounding and velarization (tongue body raising). Plain velar and uvular consonants are also characterized by rear constriction and tongue body raising,[11] but they are distinguished from their 'labialized' counterparts by tongue fronting (palatalization) in the case of /k/ and root retraction in the case of /q/. The F1 and F2 cues used to identify the different articulatory movements of labialized and unlabialized consonants would not be sufficient to distinguish labialized and unlabialized *pharyngeal* consonants. Because both /ˁ/ and /ˁʷ/ have a retracted tongue root, the low F1 lip rounding cue would be lost. Because both /ˁ/ and /ˁʷ/ have a constricted pharyngeal region, the raised F2 cue for

phonological labialization (phonetic rear constriction) would also be lost. Perception confusion could result in the neutralization of labialization for pharyngeal segments. This theory of formant cue interaction suggests a partial explanation for the merger of *q̓ and *q̓ʷ (by way of /ˁ/ and /ˁʷ/) as /ˁ/, and the virtual merger of *x̣ and *x̣ʷ as /ḥ/ in Nootka.

The relatively high F1 of /q/ and low F2 of /qʷ/ and /q/ at least for /a/ and /i/ suggest that neutralization of labialization might occur for the /q/-/qʷ/ pair as well. This happens in Ahousat, at least for some cases of /qʷa/ where free or speech speed variants occur, as in /qʷam̓a/ or /qum̓a/ for *thus much*.

Pharyngeals share with labialized segments and uvular segments a constricted rear cavity, termed *velarization*, which contributes to the low amplitude of these segments. Velarization has been applied both to constriction in the rear oral tract, by tongue body raising, or to constriction in the upper pharynx. Pharyngealization shares with uvulars a *retracted tongue root* (higher F1 in adjacent vowels), again resulting in a lower amplitude than for plain consonants. Pharyngealized segments, /ˁ/ and /ḥ/, share with ejectives and /ˀ/ a *raised larynx*, associated with heightened pharyngeal pressure, and an erratic amplitude drop in the preceding vowel.

Pharyngeals are like resonants and /ˀ/ and /h/ in that they are not characterized by a burst, i.e. a discrete release separated by silence from a following vowel. In fact, aside from the vowel formant height cues, the only distinction between /ˀ/ and /ˁ/ is that /ˁ/ has a much more aperiodic and slowed rate of glottalic pulsing, resulting in a perceived 'cracking' or stop-like segment preceding the vowel, which is actually a series of [ˀˀˀ] bursts of articulation. /ˁ/ is like the glottalized resonants in that both preceding and following vowels *must* be laryngealized. Both for /ʕ/ and the glottalized resonants, this may be due to the absence of a stop cue, and the resulting absence of the post-consonantal silent interval cue which ejectives have as opposed to plain consonants. Apart from having a raised larynx, /ḥ/ resembles other back fricatives: it is characterized by aperiodic pulsing, relatively low amplitude, voicelessness, and smooth non-laryngealized adjacent vowels. There is, however, one way in which /ḥ/ is like the resonants, namely, its large transitions (due to the 'superimposed' /a/). It is interesting to note that the chief acoustic cue for glides, as opposed to stops, fricatives and vowels, is their long formant transitions (c.f. Gunnar M. Fant 1962:13), or in articulatory terms, the *perceptability* of the articulatory movements from a segment to a glide and back to another segment. /ḥ/ has this characteristic, one that no other fricative shares. We conclude that /ʕ/ and /ḥ/ are both resonants, although sharing features with ejectives and fricatives. /ʕ/ may be described as a pharyngealized glottal closure with raised larynx and retracted root, whereas /ḥ/ may be described as a pharyngealized fricative superimposed on a laryngeal glide, with raised larynx and retracted root.

10. The marked phonetic similarity of /ʕ/ and /ʔ/ suggest why, in contrast to /ḥ/ and /h/ which rarely overlap phonetically, /ʔ/ sporadically occurs as [ʕ], as in [ʔaḥʕa̰] for /ʔaḥʔa/ *that* or in [ʔʌyə̰ʕa̰tḥ] for /ʔayaʔatḥ/ *many inhabitants,* and /ʕ/ sporadically occurs as [ʔ], as in [ʔɔ̰ʔa̰k] for /ʕuʔak/ *flowing water*, or [ʔa̰ʕa̰shɛ] for /ʕaʕasḥi/ *planning.* The /ʔ/ to /ʕ/ change must be due to assimilation to another pharyngeal segment, usually adjacent, and in the same word. The /ʕ/ to /ʔ/ change can be

due either to anticipatory dissimilation, in the case of reduplicative sequences, and to assimilation possibly in cases such as /ʕuʔak/. There is only one example in the data set of an /h/ being pronounced as [ḥ]: [hiḥɛḥa] for /hihiḥa/ *breathing.* This change is one of anticipatory assimilation, encouraged by a phonological constraint against intervocalic /h/ (except by derivation). There are no examples of an /ḥ/ to /h/ change.

11. The reanalysis of syllable-boundaries due to the perceiving of laryngealization as laryngealization plus a /ʔ/ suggests a possible explanation for the historic uvular ejective to pharyngeal sound shift (c.f. Jacobsen 1969). Recalling the discussion on laryngealization (pp. 15-18) in the environment of uvulars and of pharyngeals, and noting that /q/ has a relatively short silent interval, one can hypothesize that historically, proto-Nootkan had *q̓ (and *q̓ʷ) as well as plain *q and *qʷ, and that /CVqV/ and /CVq̓V/ sequences could have been pronounced [CV̰ : qV̰] and [CV̰ : ʔqV̰] respectively, given that there was pre-burst and post-burst laryngealization as there is today. Applying laryngeal reanalysis and syllable reanalysis to these phonetic sequences, we obtain:

	CV̰ : qV̰	CV̰ : ʔqV̰
Laryngeal reanalysis	CV̰ʔ : qV̰	CV̰ʔ : ʔqV̰
Syllable reanalysis		CV̰ʔ : qV̰

The uvular ejectives /q̓ q̓ʷ/ would thus be in danger of merger with their plain uvular counterparts /q qʷ/.

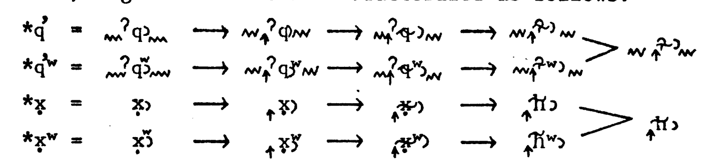
There is a second way in which the /q/-/q̓/ distinction could be indanger of merger. If the ejective were to use only the laryngealization feature to cue the glottal closure (i.e. if the /ʔ/ were absent) both the /CVqV/ and /CVq̓V/ sequences could be pronounced as [CV̰ : qV̰]. In either of the above reanalyses of /q/ and /q̓/, the only cue left for ejectives is a long silent interval. However, in Ahousat, /q/ has a relatively short silent interval, and /ʕ/ has a very short silent interval. It may be that /q̓/ also had a relatively short silent interval, in which case, the silent interval distinction between /q/ and /q̓/ would be absent, increasing the chance of a /q/-/q̓/ merger.

Such a merger could be prevented by re-intensifying the glottal closure feature for /q̓/. But this would differentiate all other ejectives or glottalized resonants from /q̓/, because glottal closure is 'downplayed' as a cue for phonemic glottalization. In any case, this strategy could work only if the distinctions between laryngealization patterns for /q/ and /q̓/ were re-intensified too. One could re-intensify this distinction by avoiding laryngealization in the environment of a plain /q/. But the constriction of the post-velar area, coupled with the retracted tongue root, makes laryngealization hard to avoid in that environment, especially in everyday speech. Having the ejective-marking /ʔ/ follow /q/ would not work either, because vowels are laryngealized following /q/ as well as /q̓/.

The final possible strategy would be to emphasize the rear constrictedness and ejective quality of /q̓/ by *larynx raising*. Although /q/ can also involve larynx raising, the larynx is raised more dramatically for ejectives. However, given that /q̓/ is characterized by retracted root, the raising of the larynx could well result in the /q̓/ gaining an upper pharynx constriction, i.e. [ʔqɔ]. Auditorily, this is very similar to [ʔɔ], i.e. a pharyngealized [ʔ] with retracted root (ɔ denotes that the previous segment is [+retracted root]), especially because uvulars and pharyngeals have a low pitch, and sound

somewhat muffled. By shifting the glottalized uvulars to pharyngealized glottal stop, the incipient merger of /q/ and /q/ could have been prevented.

In turn, consider the shift of *x̣ and *x̣ʷ to /ḥ/. If one wished to emphasize the rear constriction of /x̣/ and /x̣ʷ/ as opposed to /x/ and /xʷ/, one could do it without changing the articulatory place for the consonants, by *raising the larynx*. The resulting sound is auditorily indistinguishable from [ḥ], the larynx raising plus rear constriction plus retracted root combine to result in a necessarily *pharyngealized* frication. Possibly the retracted root is pushed up and back toward the upper pharyngeal wall. The two historical sound changes (of stops and of fricatives) might therefore be characterized as follows:



It is hypothesized that if a language's uvular ejectives and fricatives are not retracted root, but only retracted blade, then they will be more stable and less prone to a shift toward pharyngeal articulation. In the case of both /ḥ/ and /ʕ/, the historical sound change is due not only to the large number of consonants with a post-velar or velar place of articulation in the Nootkan language, but also to the retracted root quality of the Nootkan uvulars, which coupled with larynx raising, made pharyngealization a likely articulatory drift.

12. *In summary*, this work has, firstly, demonstrated one of the inadequacies of distinctive features. The features of /q̓/ which are necessary for describing the /q̓/ to /ʕ/ shift, i.e. laryngeal-

ization, retracted root and raised larynx, are not generally used as distinctive features, nor are they so used in Nootka. Yet non-distinctive features can play an important role in language change and therefore in synchronic phonology; for example, laryngealization may be crucial in explaining the Nootkan /q̓/ to /ʕ/ shift, although the Ahousat <u>morphophonemic</u> /q̓/ to /ʕ/ shift may be best described in terms of the raised larynx feature (for ejectives).

This work suggests that articulatory motions and states do have <u>acoustic correlates</u>, important both for phonetic and phonological descriptions. Areas of further research include the interaction, at phonetic and phonological levels, of auditory cues for all articulatory motions, including <u>different</u> parts of the tongue, and <u>other</u> articulators, e.g. the velum and the larynx. These latter motions (and resulting states) can play a central role in speech and a language's phonology, being phonetically independant and language-specific.[12]

Ahousat pharyngeals are characterized by retracted root, pharyngeal constriction, and raised larynx, but not by labialization or nasalization. Patterning like resonants, but also like fricatives or ejectives, they can lower and retract adjacent vowels. Also, vowels are laryngealized, and are erratic and low in amplitude when adjacent to a pharyngeal stop. The pharyngeal fricative is characterized by a superimposed /a/ and long transitions in the fricative's formant pattern.

The acoustic description of Ahousat pharyngeals makes possible certain explanations for the uvular ejective and fricative shift to pharyngeals, the merger of the historical *q̓/*q̓ʷ and of *x̣/*x̣ʷ, the allophonic overlap of pharyngeal and glottal consonants, and the aberrant reanalysis of syllable structure in words with /CVqCV/ sequences.

FOOTNOTES

1. I thank C. Dickson, M.J. Dick and Dr. H. Warkentyne for advice and interest. This work was supported by Humanities and Social Sciences Research Fellowship 452-782772.

Familiarity is assumed with Amerindian orthography, and some knowledge of spectrographic analysis is expected (as summarized in Ladefoged 1975:168-180).

2. See Delattre (1971:129) for a descussion of pharyngealization in Arabic, and Kinkade (1967:228) for one on uvular-pharyngeal resonants in Interior Salish.

3. Exceptions reflect Ahousat speech patterns, e.g. ʔaka· *ouch!*

4. If both labialization and pharyngealization were [+Flat], then such a feature could only account for the distinctive and exclusive features of pharyngealization on *consonants* and of rounding on *vowels*. The non-distinctive pharyngealization of vowels adjacent to pharyngeals would require a distinction between pharyngealization and rounding at the phonetic level.

5. In Kahn's analysis of pharyngealized segments in Arabic (1975:38), F1 and F2 were measured 80 msec. from vowel onset. In this Ahousat study, some vowels were not 80 msec. long. The 40 msec. point was chosen because in this sample it was usually situated in the final part of the CV transition, and thefore points up transition cues and vowel changes caused by adjacent consonants.

6. The number of values obtained for each environment is:

	C_	k_	kʷ_	q_	qʷ_	ʔ_	ʕ_	č_	Total
/a/	17	4	5	4	1	11	11	2	55
/i/	8	2	1	1	1	5	10	5	34
/u/	8	3	NA	1	NA	9	4	-	25
									114

7. Measurements were not made with /u/ because its F1 and F2 are close together, its F3 is very weak, and neutralization of rounded and unrounded consonants adjacent to /u/ complicates the findings.

The environments in Table 3 are taken from the following Ahousat words: ʔaʔataƚ, ʔaka·, ʔaqaqḥ, ʔahʕa, tiƚup, hiḥiḥa, ʔiqḥuk, ʔa·ma, mamak̓in, maʕas, ʕini·ƛ, ʔaqin.

8. Unless the consonant were palatalized.It is unclear why a palatalized /k/ would merge with /kʷ/, unless due to

analogy from the /q/-/qʷ/ merger.

9. For this experiment, /ʕ/ and /ḥ/ were considered as a stop and fricative respectively.

The environments in Table 6 were taken from the following Ahousat words: pisatuk, situp, p̓uˀi, susa·, ƛ̓usmit, hi·s, tiɬup, ʕini·ƛ̓, ḥiyi, ʕuˀak, ḥuƛ̓ḥuya, miʕat, ˀi·ḥ, ʕuʕupa, huḥtak.

The transition duration is half of the total vowel duration, and constitutes that part of the vowel whose F1 and F2's were measured to obtain the transition formant values.

10. The environments in Table 7 were taken from the following Ahousat words: ˀaˀataɬ, ˀaka·, ˀaqaqḥ, maˀas, hawiˀaƛ̓, čaˀak, ˀat̓a, k̓ak̓a, maʕas, haw̓i·k, č̓aˀak.

11. Jakobson (1957:164) assumes that the Arabic /q/ has a raised tongue body, and is at the same time pharyngealized.

12. For a discussion of the independance of tongue root and tongue blade movement, see Pike (1967:129). For a discussion of the importance of the larynx in phonological and phonetic description, see Henderson (1977:256).

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