

Characteristics of non-pre-vocalic ejectives in Northwest Sahaptin¹

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Abstract

Northwest Sahaptin, like many languages of the Pacific Northwest, has a contrast between ejective and non-ejective stops and affricates before voiceless consonants and word-finally. This article presents the results of an instrumental study of how the contrast is signaled in these contexts. Word-finally, ejectives are often realized as creaky voice on the vowel immediately before the ejective, which may in fact be realized as a fricative. Pre-consonantly, for ejective stops, the salient phonetic characteristic of the contrast is heightened burst amplitude. For ejective affricates, frication amplitude is not a reliable correlate of ejectivity. Instead, the only reliable phonetic correlate of ejectivity for ejective affricates is a silent period when the following segment is a fricative. The same characteristics hold for pre-vocalic ejectives. Neither pre-vocalic nor pre-consonantal ejectives are marked by preceding jitter, as in the word-final case.

keywords: ejective, creaky voice, intensity, amplitude

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1 Non-pre-vocalic ejectives.

There are by now many instrumental studies of ejectives in various languages and language families. These studies include the following:²

- Tsimshianic family: Gitksan: Ingram and Rigsby 1987
- Semitic family: Tigrinya: Shosted and Rose 2011
- Caucasian family
 - ❖ Ingush: Warner 1996
 - ❖ Turkish Kabardian: Gordon and Applebaum 2006
 - ❖ Georgian: Vicenik 2010, Beguš 2017
- Salishan family: Lushootseed: Kye 2021
- Athabaskan (Dene) family
 - ❖ Chipewyan: Hogan 1976
 - ❖ Navajo: Lindau 1984
 - ❖ Western Apache: Gordon, Potter et al. 2001
 - ❖ Witsuwit'en: Hargus 2007; Wright, Hargus et al. 2002
 - ❖ Deg Xinag: Hargus 2008, Hargus 2011
 - ❖ Chilcotin: Ham 2007

In these instrumental studies, a variety of measures have been employed to determine how ejectives differ acoustically from phonetically similar sounds. Some measures report on purely consonantal characteristics such as VOT (Lindau 1984), intensity of ejective release burst (Ingram and Rigsby 1987), or duration of the silent period (Hogan 1976) which often occurs between the release of the supralaryngeal and laryngeal portions of an ejective articulation. Other measures used in some studies assess the effect of the ejective on a following vowel. Ejectives are known to perturb the fundamental frequency of a vowel up or down (Lindau 1984), so the effect on f_0 at the beginning of the vowel, sometimes relative to vowel midpoint, is reported in many of the above studies. Another such measure is rise time, the time it takes a vowel to obtain peak amplitude. Due to the glottal closure of an ejective, rise time can be

²Although instrumental and reporting numerical results, some of these studies provide inferential statistical testing of hypotheses and some do not.

relatively “slow”, i.e. the amplitude profile of a vowel after an ejective can be relatively flat compared to that of a vowel following a corresponding non-ejective (Wright, Hargus et al. 2002).

Ejectives have generally been studied instrumentally only in pre-vocalic contexts. Probably the main reason for this is that ejectives are limited in distribution to pre-vocalic position in many languages, as is, for example, the case in the Athabaskan languages listed above. However, in some languages, ejectives also occur word-finally and/or before voiceless consonants, where there is no possibility of detecting an ejective via its modification of some aspect of the periodicity of the following segment. Such languages include Ahtna (Kari 1990, Tuttle 2015) and Dena’ina (Kari 2007) (both Athabaskan family); Tlingit (Maddieson, Smith et al. 2001) (Na-Dene family); Gitksan (Ingram and Rigsby 1987) and Coast Tsimshian (Dunn 1995) (Tsimshianic family); and Montana Salish (Flemming, Ladefoged et al. 1994) (Salishan family).

Properties of ejectives word-finally and/or before a voiceless consonant are much less studied than pre-vocalic ejectives. In the remainder of this introduction, I summarize the small literature on this topic.

In Tlingit (Maddieson, Smith et al. 2001), the inventory of ejectives consists of ejective stops, fricatives and affricates. Word-initial, pre-vocalic stops are post-glottalized, as expected, with a silent period and glottal release following the supralaryngeal release. However, the silent period did not always occur after an ejective fricative. Instead, “ejective fricatives often have a more “scrapy” quality, with the noise broken into a series of pulses...due to intermittent closures of the articulatory channel.” (p. 159).³ Word-finally, ejective stops contrast with voiceless unaspirated stops, but they are “ejective” only phonologically. Phonetically, they are pre-glottalized stops, described in this study as follows: “frequently a separate release of the glottal closure can be heard, and detected on spectrograms, some 50-100 ms

³This study does not provide instrumental data on the affricates.

[before] the oral release” (p. 151). Ejective fricatives are described as “flanked by glottal closures” (p. 171), pre-glottalized word-finally but often with a post-frication glottal release.

This Tlingit study also collected and analyzed aerodynamic data on a subset of the ejective and non-ejective fricatives. Specifically, they collected data on air pressure in the oral cavity behind the constriction for /s s' ʔ ʔ'/. They found that “intra-oral pressure reaches a considerably higher maximum during the ejective fricative and remains elevated for a shorter duration than for the pulmonic fricative” (p. 166). Another finding was that the pulmonic, but not the ejective, fricatives were subject to word-final lengthening.

In Ahtna, Tuttle 2015:53 reports that “in all dialects of Ahtna except Mentasta, ejectives occur finally in some form---usually, however, not as canonical ejectives with a glottal release.” Correspondences for four dialects of Ahtna are shown in Table 1, with transcriptions modelled after descriptions of each dialect provided by Kari 1990. The Western dialect is the most conservative,⁴ with final ejective stops and affricates allowed. (However, no information is provided about the phonetics of the final ejectives in Western Ahtna.) The Central dialect is the next most conservative. Word-final ejective affricates are produced with creaky voice on the preceding vowel (and the affricate is spirantized). Word-final ejective stops similarly have creaky voice on the preceding stop. Tuttle provides qualitative, instrumental evidence confirming the transcription of preceding creaky voice in Central Ahtna. The Lower dialect is like the Central dialect with the additional innovation of the ejective stop being turned into a fricative with no phonetic ejective or laryngealized characteristics. The Mentasta dialect is the most innovative. In this dialect, word-final ejectives do not occur, having been replaced by their pulmonic equivalents.

⁴‘liver’ and ‘mittens’ are reconstructed with word-final ejectives by Leer 2006-2010.

	Western	Central	Lower	Mentasta
'liver' /c'ezet'/	[c'ezet']	[c'ezɛt]	[c'ezɛt]	[c'ezɛt]
'mittens' /cets'/	[cets']	[cɛs]	[cɛs]	[cets]

Table 1. Dialectal allophones of Ahtna word-final ejectives.

The phonetic inversion of the supraglottal and glottal components of the ejective in Central Ahtna is reminiscent of the Tlingit realization of word-final ejectives. In fact, the two languages are distantly related and Leer 1979 reconstructs this inversion as a phonological rule ('Constriction') of Proto-Athabaskan.

In Coast Tsimshian (Dunn 1995) post-vocalic ejective stops and affricates are pre-glottalized and even written as such in the orthography (<'k, 'k̲, 'p, 't, 'ts>, e.g. *hanaa'k̲* 'woman'), whereas pre-vocalic ejectives are post-glottalized (like canonical ejectives) and written <k', k̲', p', t', ts'>. Dunn (grammar p. 4) provides the following additional description of the phonetics of ejectives:

If a glottalized segment occurs before a vowel, the glottalic closure coincides with the consonant closure and the vocal cords are released after the consonant is released (k', k̲', p', t'). If the glottalized segment occurs after a vowel, the glottalic closure occurs before the consonant closure ('k, 'k̲, 'p, 't); if such a glottalized segment is word final, the vocal cords are unreleased thruout the production of the consonant sound.

The pre-glottalized pronunciations <'k, 'k̲, 'p, 't> also occur intervocalically after a stressed vowel. When the preceding vowel is long, post-vocalic pre-glottalization is so prominent that Dunn notes that "the glottalization often 'bleeds' into the vowel, changing it into an interrupted vowel. Sometimes the following consonant is also deleted" (grammar p. 11). Thus *hanaa'k̲*, *hana'a* are listed as variants of 'woman'.

There is thus instrumental and impressionistic evidence that ejectives in one non-pre-vocalic environment, word-final, are pre-glottalized in some languages, either

with preceding silent interval as in Tlingit or preceding creaky voice as in Central Ahtna and Coast Tsimshian (apparently). However, the nature of the contrast between ejective and pulmonic stops before voiceless consonants remains undescribed in the instrumental phonetic literature. The goal of this article is to provide an instrumental description of the non-pre-vocalic ejectives of Northwest Sahaptin.⁵

2 Sahaptin.

2.1 *Background.*

In an overview of Northwest Sahaptin phonetics and phonology, Hargus and Beavert 2014 note that Sahaptin has a generous inventory of ejective stops and affricates, as shown in Table 2:

⁵The second author of this article is a native speaker of the Yakama (a.k.a. Yakima) subdialect.

	labial	alveolar	palato- alveolar	palatal	velar		uvular		glottal
					plain	labial	plain	labial	
plosive	p	t			k	k ^w	q	q ^w	ʔ
affricate		ts	tʃ						
lateral affricate		tɬ							
ejective stop	p'	t'			k'	k ^{w'}	q'	q ^{w'}	
ejective affricate		ts'	tʃ'						
lateral ejective affricate		tɬ'							
nasal	m	n							
fricative		s	ʃ		x	x ^w	χ	χ ^w	h
lateral fricative		ɬ							
approximant				j		w	(ɣ)		
lateral approx.		l							

Table 2. Northwest Sahaptin consonant phonemes.

Grossblatt 1997 studied properties of pre-vocalic ejective stops in Sahaptin, also working with data from Virginia Beavert. His main findings are summarized in Table 3. Generalizing across /p p'/, /t t'/, /k k'/, /q q'/, /k^w k^w'/, /q^w q^w'/, ejectives have significantly longer VOT and significantly higher f0 at vowel onset, as well as a silent period not found with voiceless unaspirated stops:

	VOT	post-release silent duration	f0 at vowel onset
stops	38 ms.	--	211 Hz
ejectives	103 ms.	43 ms.	224 Hz

Table 3. Characteristics of Sahaptin pre-vocalic ejective stops (Grossblatt 1997).

Ejective stops not only occur before vowels in Sahaptin, but also occur before consonants, voiced ([^lq'miḥ] *k'miḥ* 'rock'⁶) as well as voiceless ([^lq'já:] *k'sháash* 'curly'). In this context, they contrast with voiceless unaspirated stops (e.g. [^lk'sit] *k'sít* 'cold', [^lksik] *ksík* 'stink'). But at the same time there are also word-final ejective stops: [huq'huq'] *huk'húk'* 'pig'. However, there are also restrictions on the distribution of ejective stops. Although Sahaptin allows geminate consonants (e.g. [ttú:] *ttúush* 'some', [k'átt] *k'átt* 'steep'), there are no geminate ejective stops except for one onomatopoeic word (see §3). And while ejective stops can occur before voiceless consonants, they do not occur before affricates, another ejective, or glottal stop. The attested ejective stop + voiceless obstruent combinations are shown in Table 4-Table 5, with word lists exemplifying each combination below each table:⁷

⁶We include orthographic representations of all Sahaptin data (in italics) in this article, to make this article accessible to the widest possible audience.

⁷This statement of attested combinations is based on data we have collected in the course of lexicography (a second edition underway of Beavert and Hargus 2009; see fn. 8).

	p	t	k	k ^w	q	q ^w
p'					p'q	p'q ^w
t'			t'k	t'k ^w	t'q	
k'	k'p	k't				
k ^w '	k ^w 'p		k ^w 'k			
q'	q'p	q't				
q ^w '	q ^w 'p	q ^w 't	q ^w 'k			

Table 4. Ejective stops before stops.

(1) Words containing ejective stops before stops

'pap'q <i>páp'k</i>	'burst'
wi:'p'q ^w i <i>wiip'kwí</i>	'choke, cough out, regurgitate'
'i:t'k <i>íit'k</i>	'mucus, snot'
'la:t'k ^w <i>lát'kw</i>	'end, stop'
'pat'q <i>pát'k</i>	'slap, clap'
'k'pís <i>k'pís</i>	'cold (weather)'
'k'tít <i>k'tít</i>	'hard, solid (smaller object)'
ta'mak ^w 'p <i>tamákw'p</i>	'behead, knock top or head off'
'itk ^w 'k <i>ítkw'k</i>	'straighten, organize'
'aq'pa:ʃ <i>ák'paash</i>	'stomach, tripe, large intestine'
'q'ta:t <i>k'táat</i>	'hard, solid (larger object)'
ta'maq ^w 'p <i>tamákw'p</i>	'fold in half, fold over'
ti'naq ^w 'tk <i>tinákw'tk</i>	'sprain'
'nuq ^w 'k <i>núkw'k</i>	'swallow' (v.)

	s	ʃ	ʃ	x ^w	χ	χ ^w
p'	p's	p'ʃ	p'ʃ		p'χ	
t'			t'ʃ	t'x ^w	t'χ	t'χ ^w
k'	k's		k'ʃ			
k ^w	k ^w s		k ^w ʃ			
q'	q's		q'ʃ		q'χ	q'χ ^w
q ^w		q ^w ʃ	q ^w ʃ			

Table 5. Ejective stops before fricatives.

(2) Words containing ejective stops before fricatives

'sup'sk <i>súp'sk</i>	'string up'
'pap'ʃk <i>páp'ʃk</i>	'pierce'
'χap'ʃnak <i>χáp'ʃnak</i>	'deflate and fall down, collapse, break apart, sprain'
'ti:p'χ <i>típ'χ</i>	'remind'
'it'ʃk <i>ít'shk</i>	'extinguish'
a't'x ^w i <i>at'xwí</i>	'sneeze'
'sut'χs <i>sút'χs</i>	'fool's onion' (<i>Brodiaea hyacinthina</i>)
'lat'χ ^w <i>lát'χw</i>	'pop, explode from heat, erupt, glow from heat'
'k'sit <i>k'sít</i>	'cold (object)'
'wi:k'ʃk <i>wík'shk</i>	'run over'
'k ^w sti <i>kw'stí</i>	'act_up, throw a tantrum'
'k ^w ʃti <i>kw'shtí</i>	'ignore, give cold shoulder to, be stubborn, spoiled, difficult, irrational'
'tuq'sk <i>túk'sk</i>	'stomp, step on to pieces'
'tʃaq'χ <i>chák'χ</i>	'tear, pull apart'
'ʃq'uχʃq'χ ^w ni <i>ʃk'úχʃk'χwni</i> ,	'scraped up'
'ʃq'χ ^w ʃq'uχni <i>ʃk'χwʃk'úχni</i>	
'q ^w ʃtíp <i>kw'ʃtíp</i>	'strong, physically fit, capable, powerful'
'q ^w ʃim <i>kw'shím</i>	'disruptive, mischievous, unruly, stubborn, wild (person)'

Like ejective stops, ejective affricates are found before a vowel ([^hts'a:] *ts'áa* 'near'), before a voiced consonant ([^hts'míst] *ts'míst* '9'), and before a voiceless consonant ([^hts'xwí:] *ts'xwí* 'conical'). Also similar to ejective stops, ejective affricates are restricted in distribution. An ejective affricate cannot be followed by another ejective or another affricate. However, unlike ejective stops, there are no geminate ejective affricates (although there are geminate affricates, e.g. [tʃtʃú:] *chchúu* 'quiet'), and there are no word-final ejective affricates. In general, ejective affricates are rarer and more restricted than ejective stops in Sahaptin. The attested ejective affricate + obstruent combinations are provided in Table 6-Table 7, with word lists exemplifying each combination below each table:

	p	k	k ^w	q
ts'	ts'p	ts'k	ts'k ^w	
tʃ'	tʃ'p	tʃ'k		tʃ'q
tʃ'		tʃ'k		

Table 6. Ejective affricates before stops.

(3) Words containing ejective affricates before stops

'ts'pís <i>ts'pís</i>	'release, free (up)'
'kuts'k <i>kúts'k</i>	'little piece'
'ts'k ^w i:t <i>ts'kwít</i>	'corner, angle'
'jatʃ'pi <i>yátʃ'pi</i>	'be wet'
'kutʃ'k <i>kútʃ'k</i>	'piece, part'
'χatʃ'q <i>xátʃ'k</i>	'fall and break'
'χwitʃ'k <i>xwích'k</i>	'quickly removing'

	x ^w	χ	χ ^w
ts'	ts'x ^w	ts'χ	ts'χ ^w
tʃ'			tʃ'χ ^w
tʃ'		tʃ'χ	

Table 7. Ejective affricates before fricatives.

(4) Words containing ejective affricates before fricatives

'ts'x ^w i: ts'x ^w ī	'conical, cone-shaped, peaked'
ta ^l mats'χ tamáts'χ	'soil the bed, defecate at night'
'ts'uχts'χ ^w ts'úχts'χ ^w	'suck on'
'wi:tʃ'χ ^w wíitʃ'χ ^w	'run out of, finish'
'tʃatʃ'χ chách'χ	'split'

2.2 Questions about Sahaptin ejectives.

The current study is designed to answer the following questions about Sahaptin ejectives:

1. As compared with (non-ejective) plosives and affricates, what are the phonetic properties of ejectives (a) before voiceless consonants? (b) word-finally?
2. Given the distributional rarity of ejective affricates in Sahaptin, are there differences in the phonetic characteristics of ejective affricates and ejective stops before voiceless obstruents?
3. Are ejectives before voiceless consonants produced in a different way than they are before vowels?

We will start by answering the question about word-final ejectives with a qualitative study in §3, since there are actually not many word-final ejective stops, not enough for a quantitative study. More specific versions of these research questions (and hypotheses) will be provided in the subsequent quantitative sections of this article.

3 Sahaptin word-final ejectives.

An exhaustive inventory of word-final ejective stops is shown in Table 8, along with a word-final voiceless unaspirated stop for contrast when one exists. All of the instances of word-final ejective stops in Table 8 appear to be onomatopoeic.

	C'	C
q	jiq'jiq' <u>yik'yik</u> ' (especially creaky sound)	jiq'jiq' <u>yikyik</u> ' (creaky sound)
	huq'huq' <u>huk'huk</u> ' 'pig'	
	juq'juq' <u>yuk'yuk</u> ' 'unstable, wobbly'	
	'χi:q' <u>xik</u> ' 'hoot' (by owl)	
t	t't't' t't't' (noise of rain)	'k'att <u>k'att</u> ' 'steep'

Table 8. Word-final ejective stops.

Next we provide a set of waveforms of the words containing word-final [q']. What is common across all realizations is a creaky voiced uvular fricative before a stop release, if any.⁸

⁸The recordings analyzed in this study were made over a period of years to accompany a dictionary, Beavert and Hargus 2009. mp3 versions of these recordings were distributed on a CD with the published dictionary. We are currently working on a revised version of the dictionary.

The creaky voice associated with the word-final ejective can extend some way into the preceding vowel, as can be seen in both syllables of Figure 1.

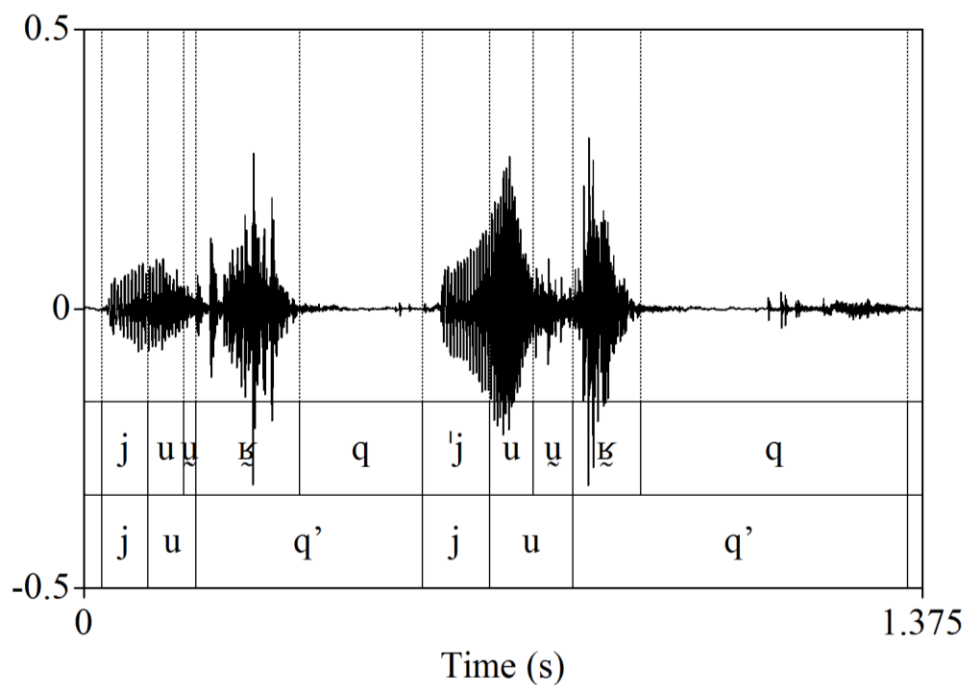


Figure 1. Waveform, narrow and broad transcriptions of [juq'juq'] yuk'yúk' 'unstable, wobbly'.⁹

⁹The vertical axis of the figures in this section shows sound pressure in Pascals. When two transcription tiers are provided with these waveforms, the top tier is a narrow phonetic transcription and the bottom tier is a phonemic transcription.

In Figure 2, a uvular stop closure precedes and follows the [ɣ] in the first syllable but only precedes it in the second. Also note that creaky voice on the vowel preceding the final ejective stop occurs in the second syllable (only) of Figure 2:

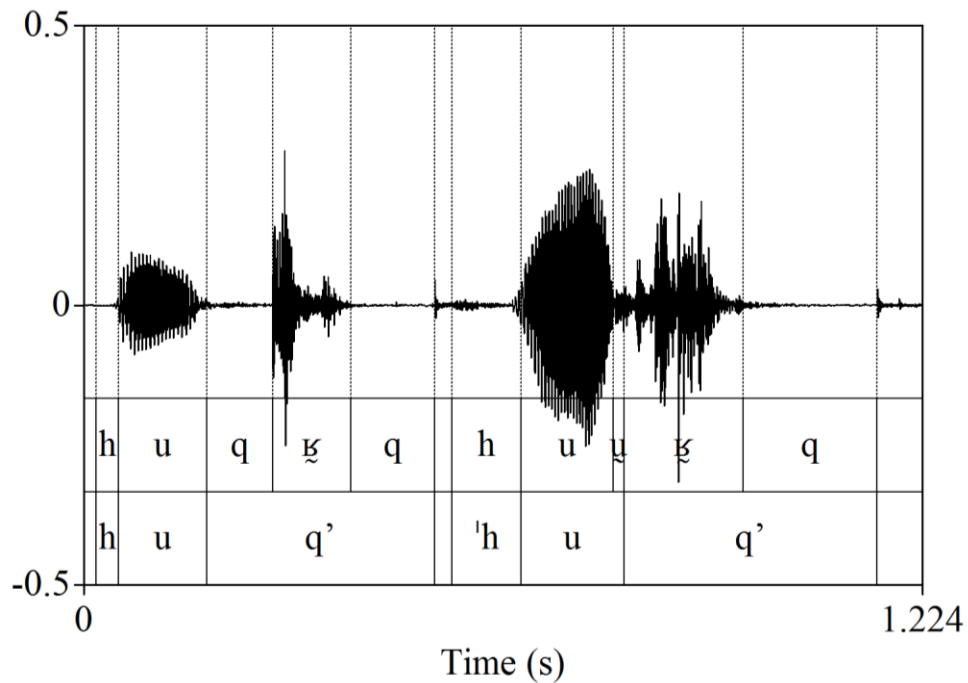


Figure 2. Waveform, narrow and broad transcriptions of [huq'hɣq'] *huk'húk'* 'pig'.

Figure 3 is taken from a textual recording by Ellen Saluskin, late mother of the second author. The two syllables are taken from the middle of a sentence.¹⁰ There is no audible or visual uvular stop release for the second instance of [q']. There is also no creaky voice on the preceding vowel.

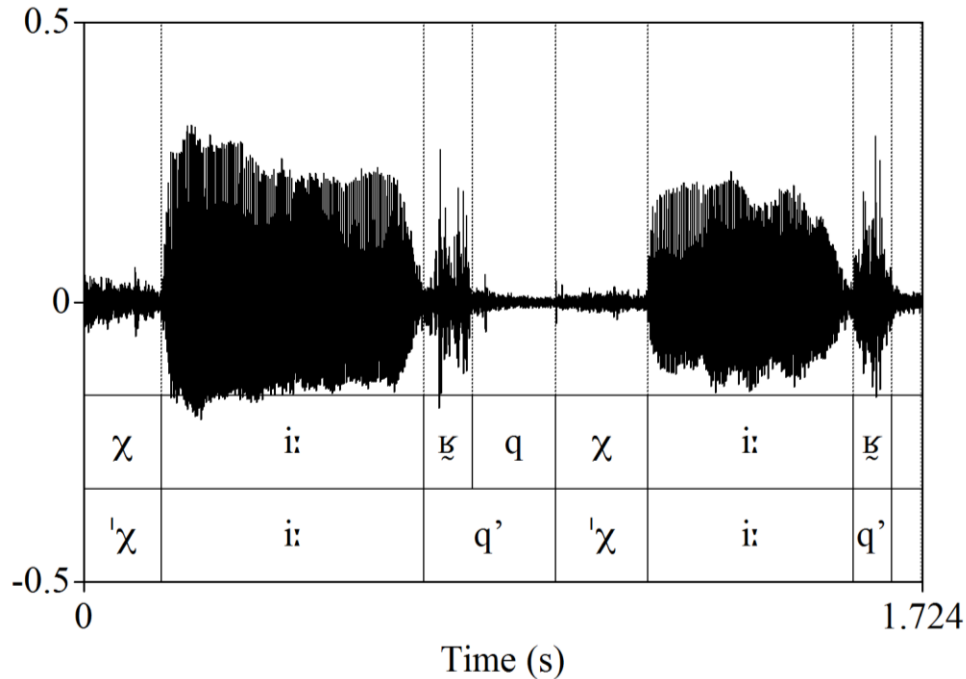


Figure 3. Waveform, broad and narrow transcriptions of [^hχi:q'] χiik' 'hoot' (by owl).

¹⁰The sentence is:

<i>Awkú</i>	<i>awkłáw</i>	<i>awkú</i>	<i>χiik'</i>	<i>χiik'</i>	<i>ánatχanaχana.</i>
aw'ku	awkław	aw'ku	'χiiq'	'χiiq'	'a-natχana-χa-na.
then	just	then	(hoot)	(hoot)	3OBV-utter-HAB-PST

'Then it (owl) would just hoot at him.'

In Figure 4, there is creaky voicing on the vowel preceding [q'] in both syllables. A relatively long silent interval within the creaky voicing is transcribed (narrowly) as glottal stop. (The first syllable is also effectively word-final in this token, as there is a 150 ms. pause between the syllables in this production of the word.)

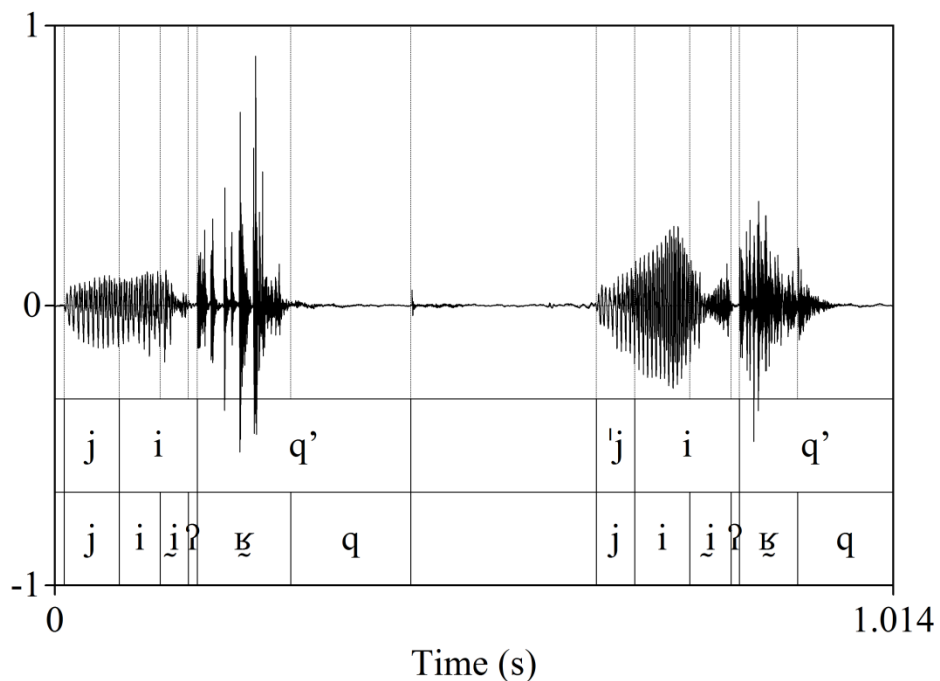


Figure 4. Waveform, broad and narrow transcriptions of [jɪq'jɪq'] *yik'yik'* (especially creaky sound).

Compare Figure 4 with Figure 5, which contains final [q]. Note the absence of creaky voicing and the voiced uvular fricative. Note also the much quieter uvular components in Figure 5 as compared to Figure 4.

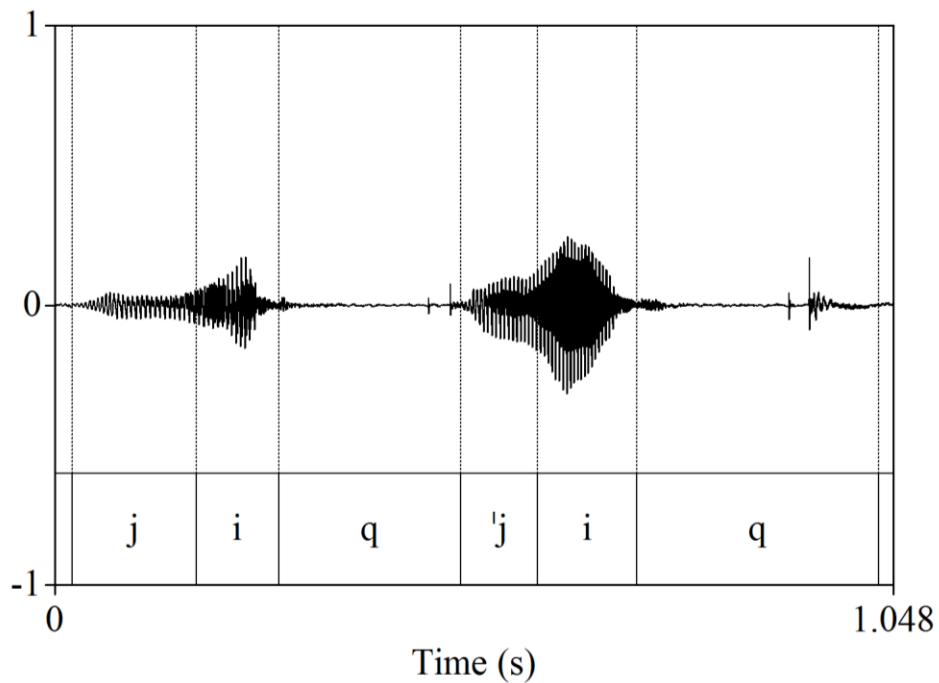


Figure 5. Waveform and transcription of [j i q 'j i q] yikʏk (creaky sound).

The other attested word-final ejective, also onomatopoeic, consists of a string of alveolar ejectives [t't't't'] t't't't (noise of rain), shown in Figure 6:

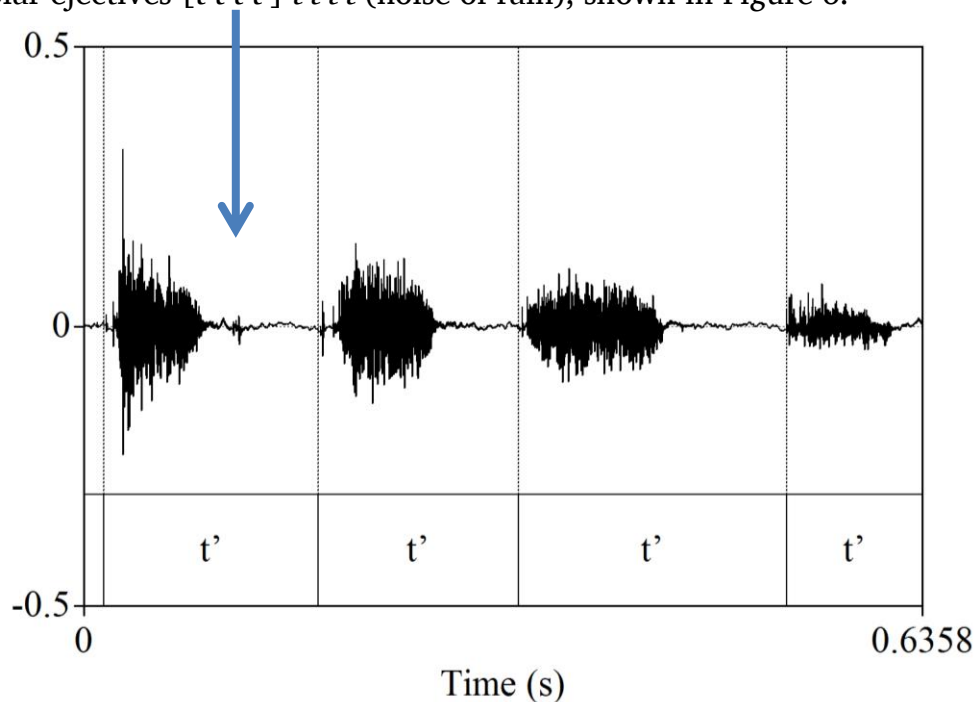


Figure 6. Waveform and transcription of [t't't't'] t't't't (noise of rain).

Figure 6 was produced on a single breath, and it can be seen that the intensity of the supralaryngeal release decreases over the four instances of [t']. The release of the first glottal closure, marked by the arrow, can also be seen within the first interval transcribed [t'].

Compare Figure 6 with Figure 7, which contains an ordinary geminate word-final [tt]:

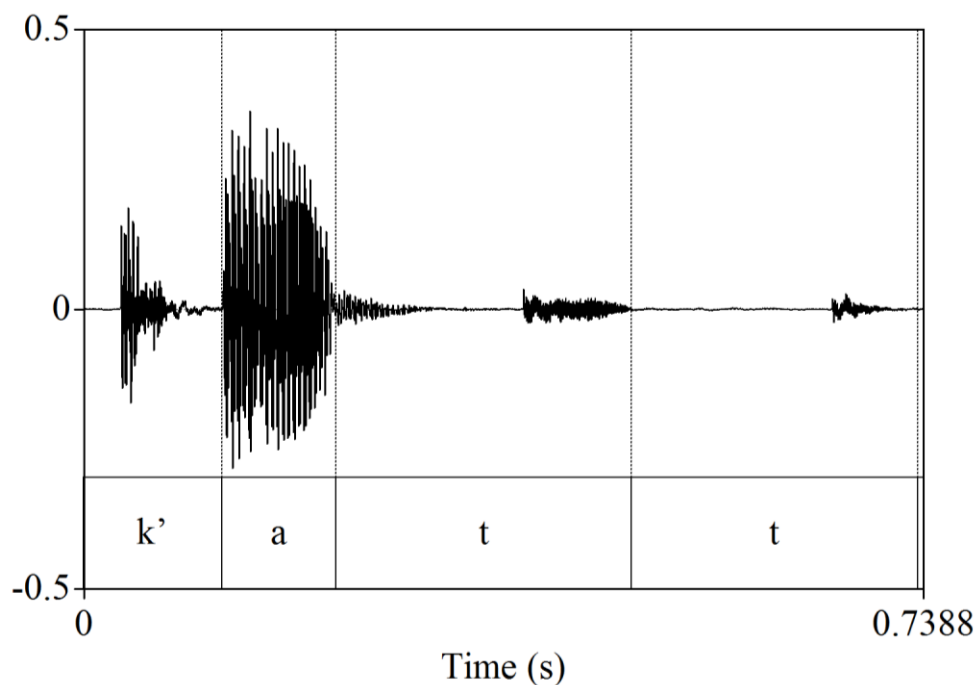


Figure 7. Waveform and transcription of [k'att] *k'átt* 'steep'.

It can be observed that the amplitude of the final voiceless unaspirated [t] is less than even the quietest of the consonants in the string of [t'] in Figure 6.

To summarize, word-final ejective stops have two consistent features. (1) A high amplitude stop release occurs, or instead of a full stop closure, a high-amplitude fricative may be produced. Since ejectives are produced by releasing compressed air trapped between a supralaryngeal closure and the closed glottis, it is not surprising that the release of the supralaryngeal ejective stop closure is relatively high in intensity, compared to non-ejective stops. (2) If preceded by a vowel, there can be creaky voice on the second half of the vowel, indicating that the glottis is closing before the stop closure is made.

4 Sahaptin pre-consonantal ejectives.

4.1 Observations.

The supralaryngeal release bursts of phonemic word-final ejective stops seen in §3 seem to be higher in amplitude than the corresponding voiceless unaspirated stops. Qualitative inspection of contrasts between ejective and non-ejective stops before a voiceless consonant leads to the hypothesis that the supralaryngeal releases differ in amplitude in this environment as well.

Compare Figure 8 and Figure 9, which contrast word-initial [kʰ] and [k] before fricatives. It can be seen that the release of the ejective [kʰ] in Figure 8 is of higher amplitude than the fricative, whereas the release of [k] is roughly equal in amplitude to the following fricative in Figure 9. In Figure 8, note the “silent period” (onset marked with arrow) between the release of the stop and the onset of the fricative. The silent period measures 22 ms. in this token. Although the silent period in Figure 8 is not completely silent, it contrasts with the absence of a silent period between the stop release and the fricative in Figure 9.

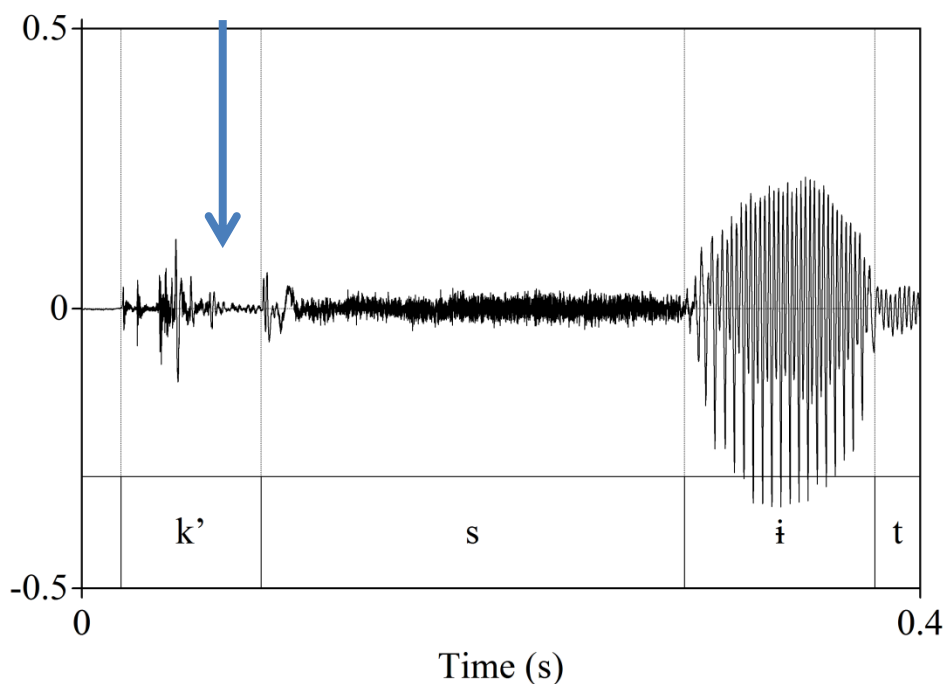


Figure 8. Waveform and transcription of [kʰsít] *kʰsít* ‘cold’.

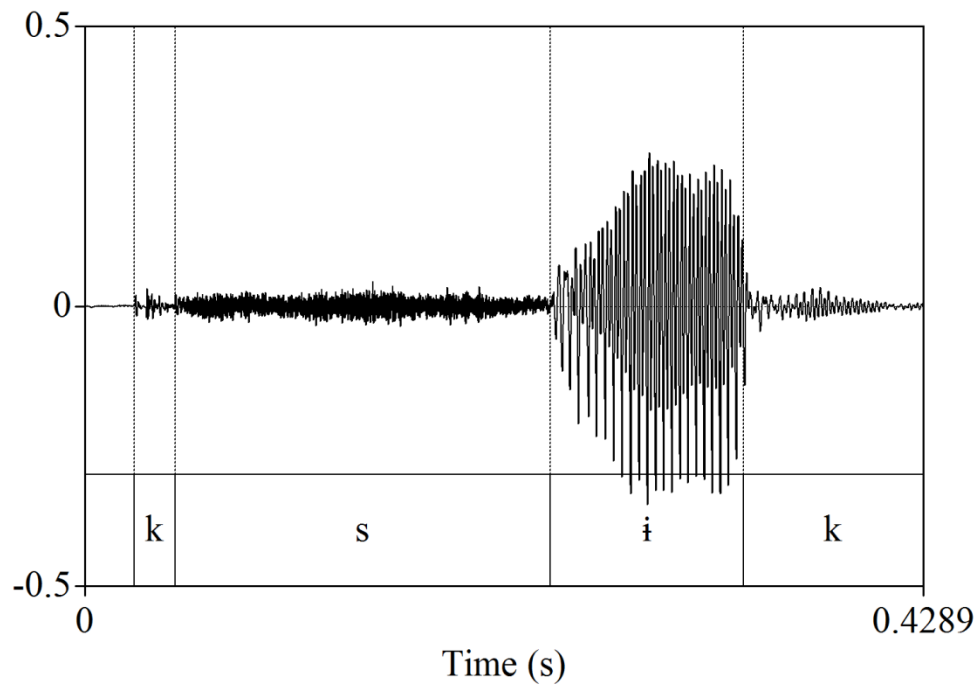


Figure 9. Waveform and transcription of ['ksik] *ksɪk* 'stink'.

Next, compare Figure 10 and Figure 11, which contain post-vocalic [k^w] and [k^w], respectively, before stops. Note the relatively high amplitude release of the labial velar ejective stop in Figure 10 compared to the voiceless unaspirated stop in Figure 11. Unlike the word-final ejectives discussed in §3, the vowel before the pre-consonantal ejective in Figure 10 does not appear to contain any creaky voice.

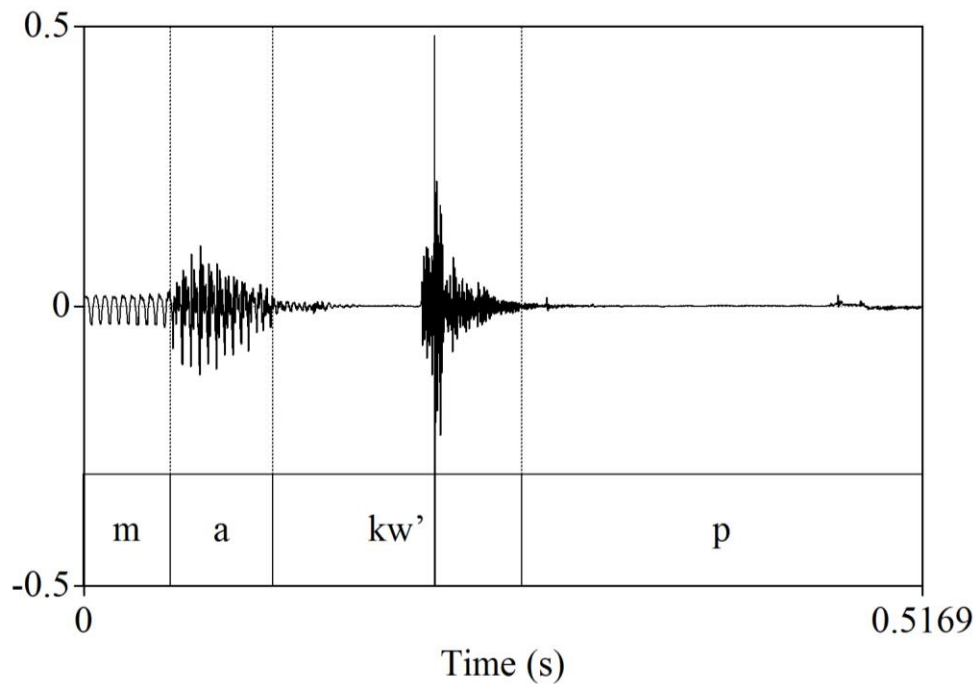


Figure 10. Waveform and transcription of [ta'mak^w'p] *tamákw'p* 'behead, knock top off'.

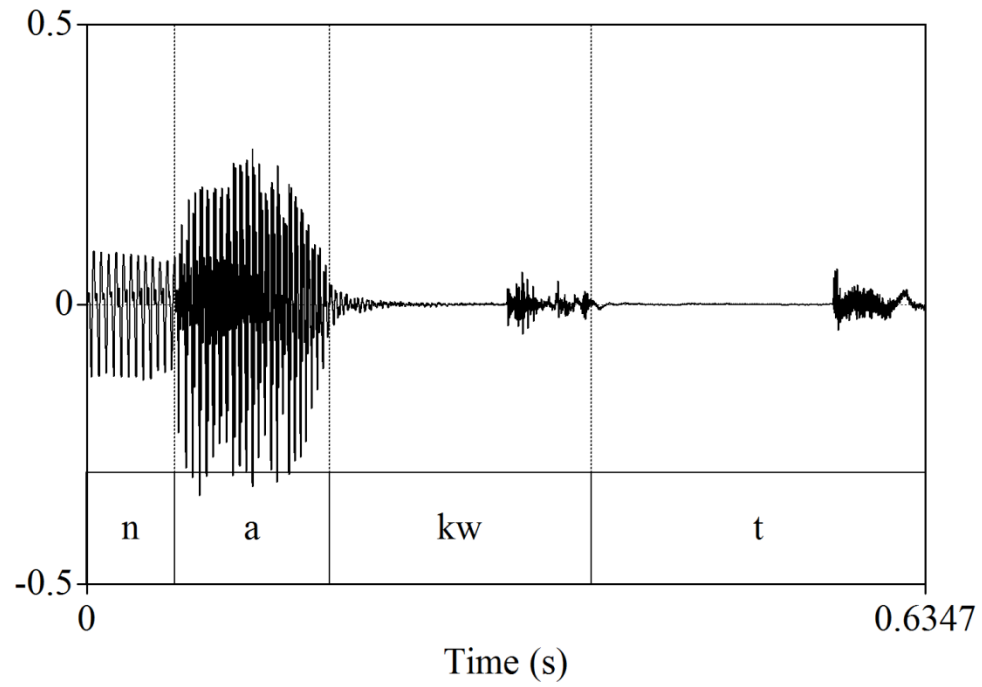


Figure 11. Waveform and transcription of [a'nak^wt] *anákw* 'separated, divorced'.

Turning now to impressions of the difference between ejective and voiceless unaspirated affricates, compare the ejective affricate in Figure 12 with the voiceless unaspirated affricate in Figure 13. Both are post-vocalic. In Figure 12, the amplitude of the fricative portion of [ts'] is nearly as great as the preceding vowel, considerably greater than the release of [q]. As with the pre-consonantal ejective stop in Figure 10, the vowel before the ejective affricate in Figure 12 does not appear to be creaky.

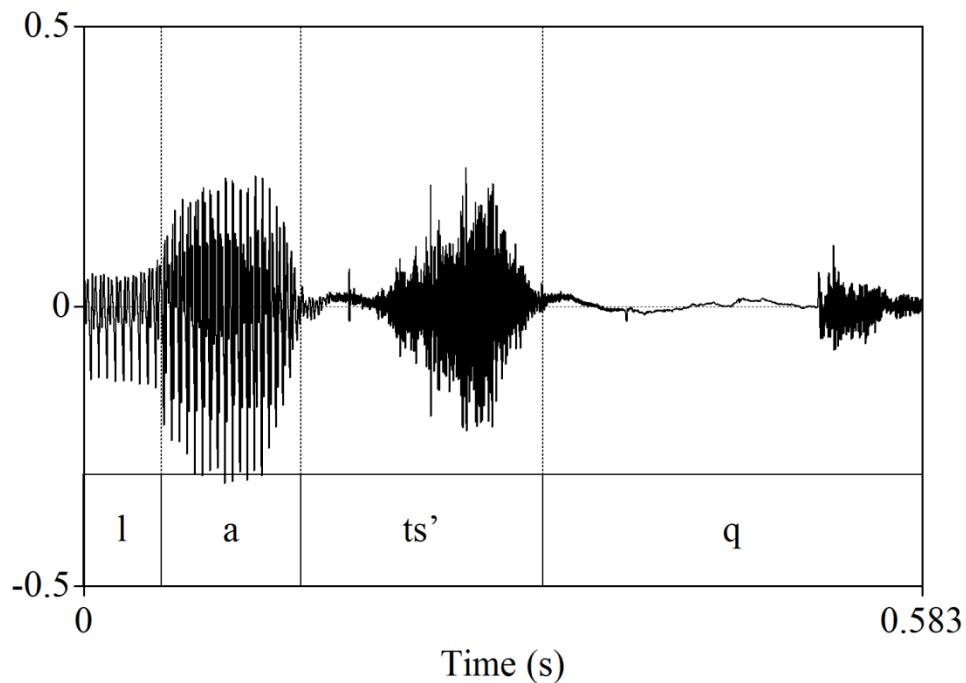


Figure 12. Waveform and transcription of [lats'q] *lats'k* 'snap, crack, spark'.

In contrast, in Figure 13, the amplitude of the fricative portion of non-ejective [ts] is much less than the vowel, less even than the maximum amplitude of the [q] release:

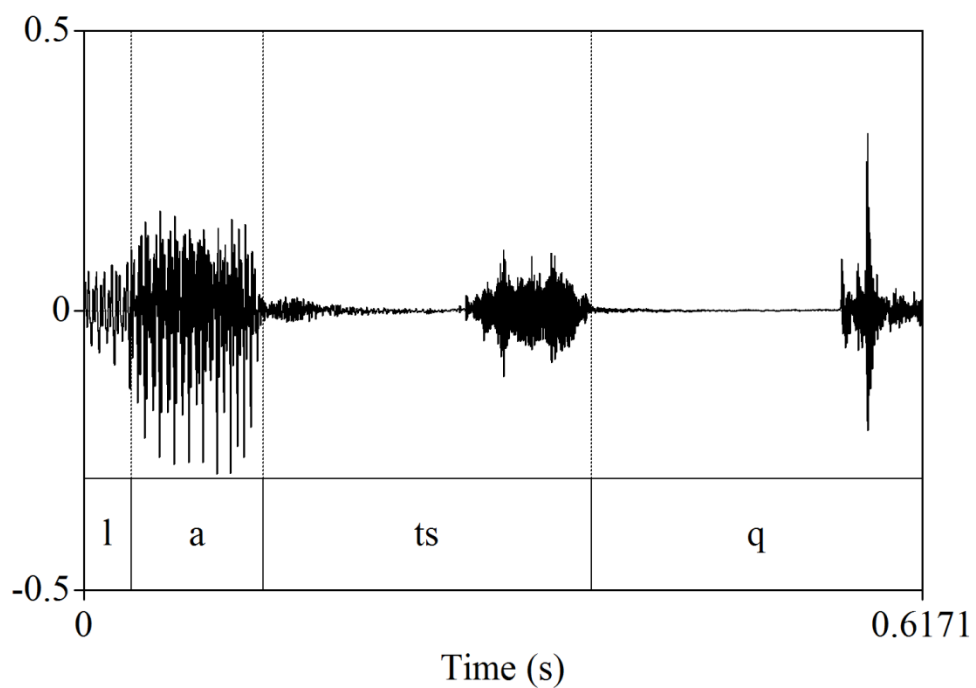


Figure 13. Waveform and transcription of [latsq] *látsk* 'daydream'.

In Figure 12 above, in which [ts'] is followed by a stop, there is no segmentable silent period. However, when the following segment is a fricative, a short silent period is visible in the waveform after the noise of the ejective affricate before the following fricative. Figure 14 provides one example, with the beginning of the silent period, 67 ms. long, marked by the arrow. In this token too, notice the absence of creaky voice on the preceding vowel.

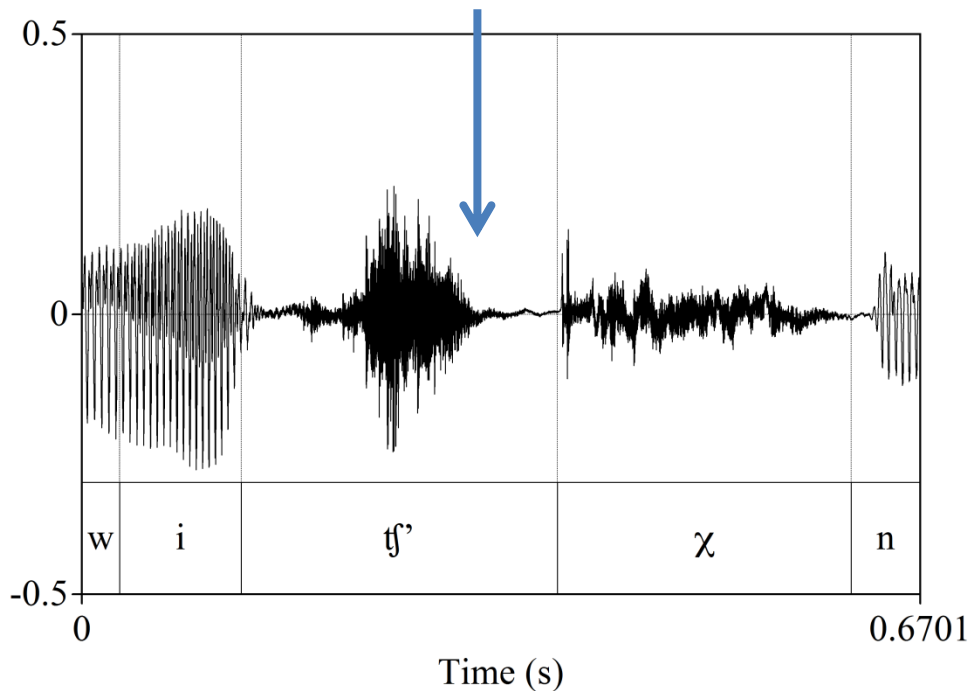


Figure 14. Waveform and transcription of [i'witʃ'χna] *iwích'χna* '(3sg) stripped, shredded it'.

In contrast to Figure 14, there is no silent period after the non-ejective affricate followed by a fricative in Figure 15:

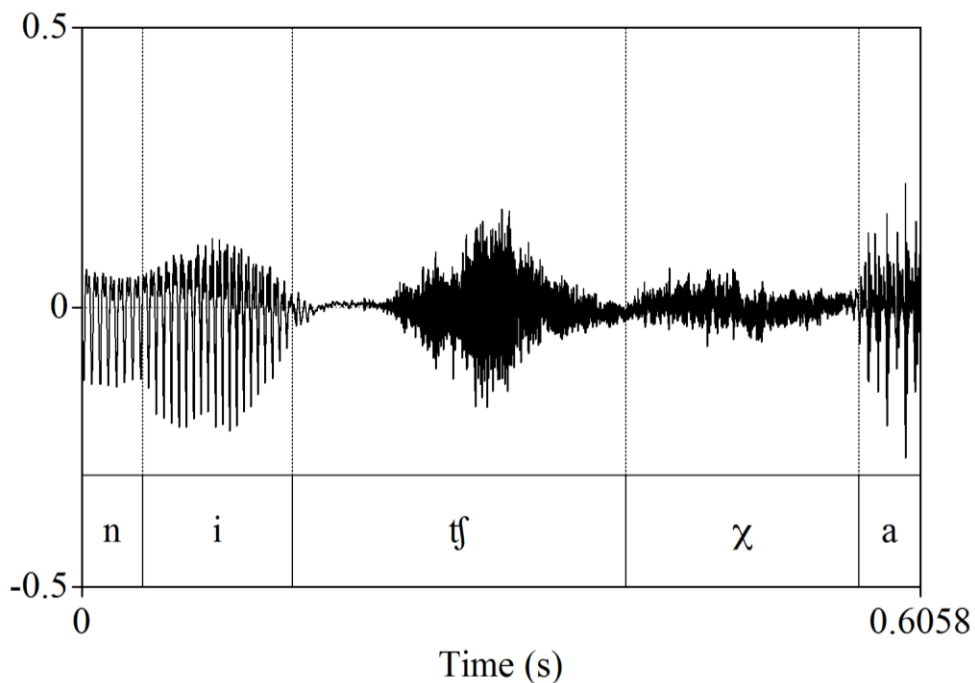


Figure 15. Waveform and transcription of [i'niʃχa] *iníχxa* '(3sg) places (habitually)'.

The preceding observations gave rise to the hypotheses in Table 9 about the phonetic differences between pre-consonantal ejective stops and affricates, relative to voiceless unaspirated stops and affricates:

	__stop	__fricative
ejective stop	high intensity burst	high intensity burst
		silent interval
ejective affricate	high intensity fricative	high intensity fricative
		silent interval

Table 9. Hypotheses about pre-consonantal phonetic differences between ejectives and non-ejectives.

In addition, it was hypothesized that unlike the word-final ejectives, pre-consonantal ejective stops and affricates were *not* characterized by creaky voice on a preceding vowel.

As contrasts such as those exemplified above in this section are not rare in Sahaptin, there is sufficient data for a quantitative study to test these hypotheses.

4.2 *Measures and materials.*

As mentioned in §1, some instrumental studies of ejectives have measured intensity of the release bursts of ejectives and compared this to non-ejectives: Ingram and Rigsby 1987 for Gitksan, Warner 1996 for Ingush, Maddieson, Smith et al. 2001 for Tlingit fricatives, Gordon and Applebaum 2006 for Turkish Kabardian (ejective fricatives but not stops), Hargus 2008 for Deg Xinag, Vicenik 2010 for Georgian.

The intensity measure used here was a normalized measure of intensity, where the maximum intensity of the stop release or fricative noise was subtracted from the maximum intensity of a vowel in the word to better control for differences in speaking volume during the recording of the stimulus words. Figure 16 shows a spectrogram with superimposed intensity contour for an ejective token. The maximum intensity of the consonant and the vowel were measured roughly where the arrows are placed.

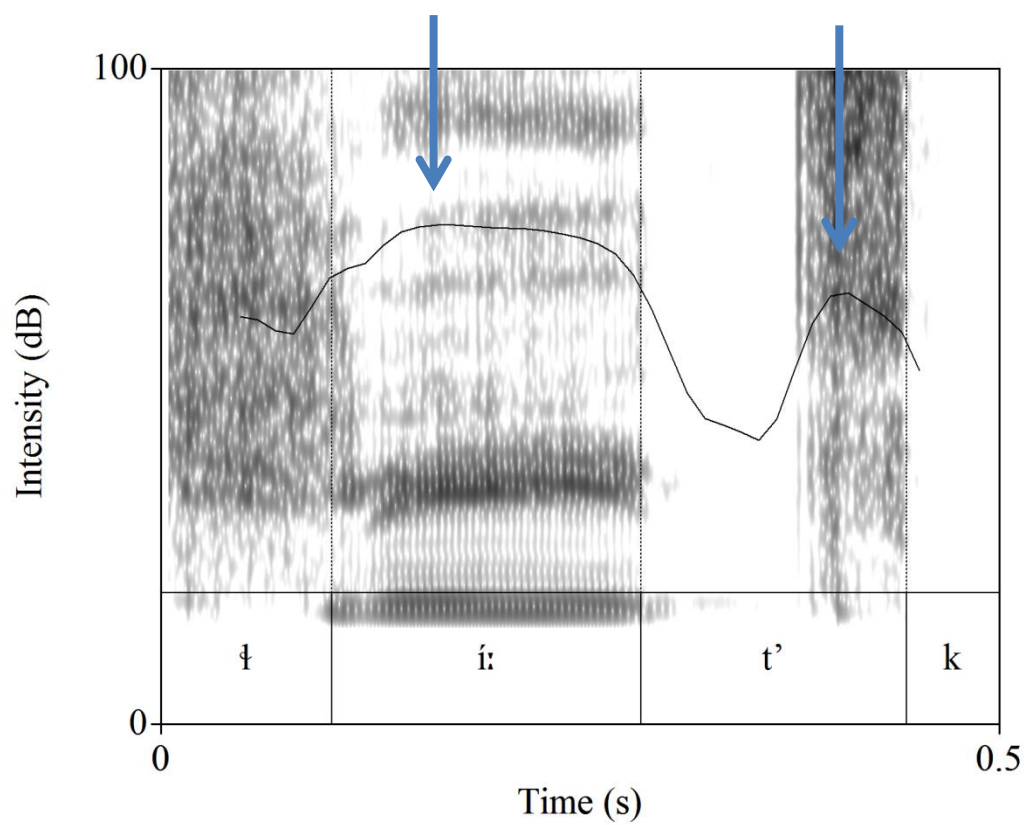


Figure 16. Spectrogram and intensity contour of [ʎi:t'k] *ʎit'k* 'mucus'.

The difference between the intensity peaks in words like [ʔi:tʔk] *títʔk* was compared with the difference between the intensity peaks for a pre-consonantal non-ejective, as shown in Figure 17:

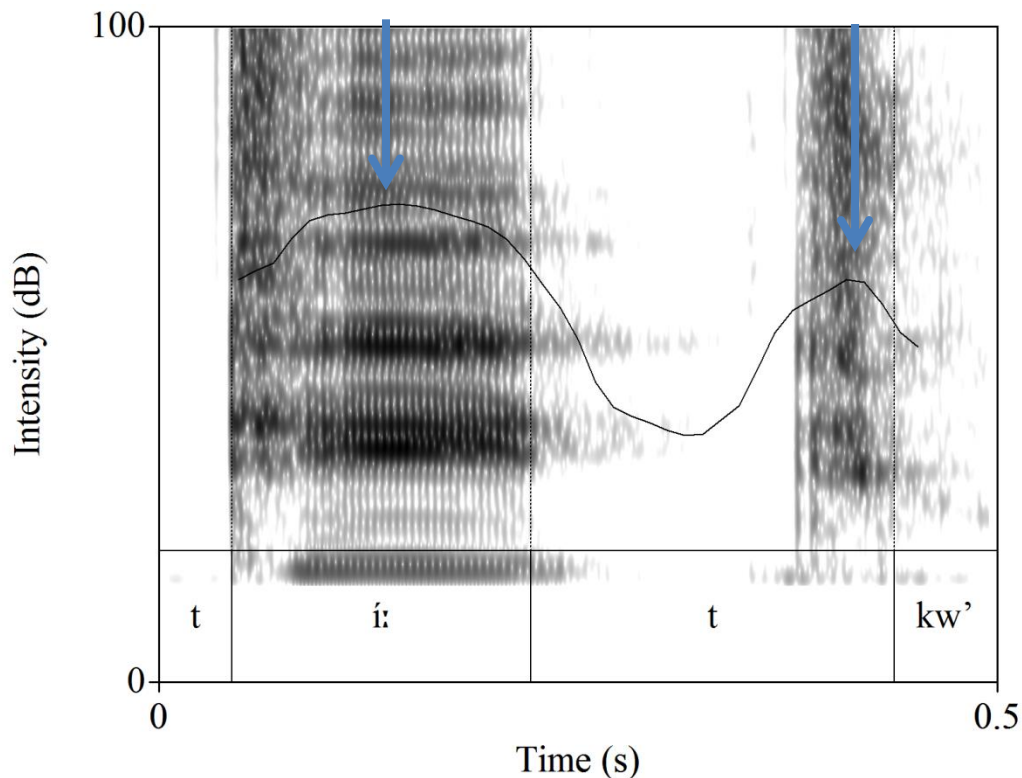


Figure 17. Spectrogram and intensity contour of [ʔi:tʔkʷk] *títkwʔk* ‘advise, set straight’.

A word list was selected in which the reference vowel in both ejective and non-ejective tokens was balanced for vowel quality and stress. Table 10 gives an overview of the design of the word list used with the intensity measure. The consonants and vowels which were measured for intensity are in bold. The reference vowel was usually the stressed vowel of the word unless the vowel qualities were different. The complete word list is provided in 8.1.

release		pairs	Cʔ	C
stop	p	7	' χap 'ʃnak <u>χá</u> p'shnak 'collapse'	' χap ʃanajk <u>χá</u> pshanayk 'pile up'

	t	8	ʃa'pat'ki <i>shapát'ki</i> 'snapped, clicked, bolted'	ʃa'patk'i <i>shapátk'i</i> 'movie'
	k	5	'k'sít k'sít 'cold'	'ksík ksík 'stink'
	q	9	'tʃa ^q p <i>chá^kp</i> 'tie down'	'tʃa ^q pt <i>chá^kpt</i> 'pull tight'
	k ^w	8	sa'pak ^w stik <i>sapákw'stik</i> 'wipe'	wa'pak ^w ʃtik <i>wapákwshatik</i> 'grab at and miss'
	q ^w	6	ti'naq ^w tk <i>tinákw'tk</i> 'sprain'	ʃa'paq ^w tk <i>shapákw'tk</i> 'join together'
affricate	ts	5	'lats'q <i>láts'k</i> 'crack, snap, spark'	'latsq <i>látsk</i> 'daydream'
	tʃ	5	iw'jatʃ'χ ^a <i>iwýátʃ'χ^a</i> 'it ended'	'qatʃχatk <i>kátʃχatk</i> 'get used to'
	tʃ	5	i'witʃ'χ ^{na} <i>iwích'χ^{na}</i> '(3sg) stripped, shredded it'	i'nitʃχ ^a <i>iníchχ^a</i> '(3sg) places it'

Table 10. Sample comparison pairs for study of pre-consonantal ejective intensity.

Stops from all four places, including the secondary articulation of labialization, were included, along with the three types of affricates. There were more stop pairs (44) than affricate pairs (15) in the measurement set, reflecting the lower type frequency of ejective affricates in Sahaptin.

For tokens in which the following consonant was a fricative, the duration of the silent interval was measured.¹¹ This measure was used by Hogan 1976 in his study of Chipewyan (Dene Sų́liné) ejectives, by Grossblatt 1997 (Sahaptin), and by Maddieson, Smith et al. 2001 (Tlingit ejective and non-ejective fricatives) but otherwise is not common in ejective studies. There were 22 pairs of C vs. C' where the following consonant was a fricative. See Appendix 8.1.

A smaller set of words (34 pairs) in which the contrasting consonants were preceded by a vowel was measured for jitter (specifically, Relative Average

¹¹When the following segment is a stop, a possible silent interval cannot be reliably distinguished from the stop since both have very similar amplitudes.

Perturbation jitter, Koike 1973). As it had been observed with word-final ejectives (§3) that jitter was only found on the second half of the vowel, the vowel preceding the ejective was segmented into two halves and jitter was measured over the second half of the vowel. The consonant preceding the vowel on the jitter wordlist was not an ejective or glottal stop since it is known from studies of ejectives and glottal stop (e.g. Hargus 2016) that such consonants can induce increases of jitter on a following vowel. Appendix 8.2 provides the complete word list for the study of jitter.

4.3 *Results and discussion.*

The measurements were subjected to two-way ANOVA, with Type (ejective, non-ejective) and Release (stop, affricate) as independent variables.

4.3.1 *Jitter.*

The lack of jitter hypothesis was upheld. There were no significant differences in the amount of jitter in the second half of the preceding vowel before ejective vs. non-ejective consonants. There were also no significant differences in jitter before stops vs. affricates, and no significant interactions between Type and Release. Thus, pre-consonantal ejectivity does not appear to be signalled by jitter on the preceding vowel.

4.3.2 *Intensity.*

There was significantly less normalized intensity following an ejective than non-ejective consonant ($F[1,112] = 28.237, p < .0001$), showing a significant effect of Type (affricates and stops pooled together). A graphical representation of this result is provided in Figure 18 (error bars represent one standard deviation):

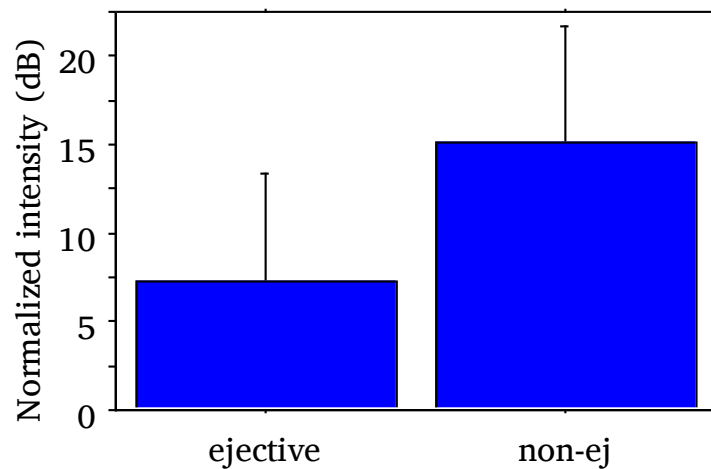


Figure 18. Effect of Type on normalized intensity.

There was also significantly less normalized intensity following an affricate than a stop ($F[1,112] = 30.011, p < .0001$), showing a significant effect of Release. A graphical representation of this result is provided in Figure 19, which shows lower normalized intensity for affricates (whether ejective or not); i.e. the intensity of affricate releases is closer to that of the reference vowel than it is for stops:

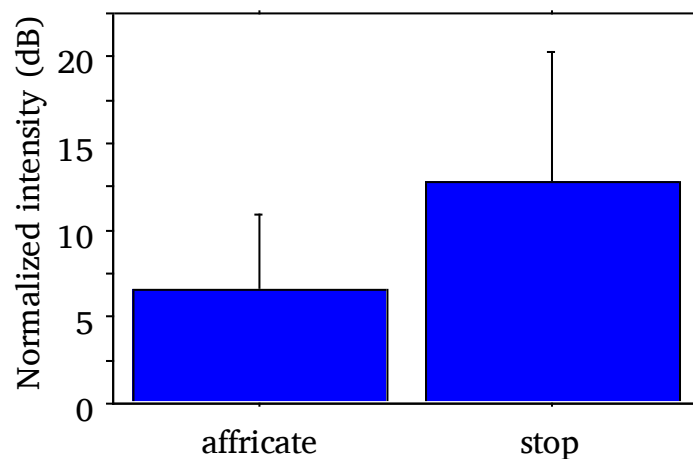


Figure 19. Effect of Release on normalized intensity.

The interaction of Type and Release was also significant ($F[1,112] = 11.385, p = .0010$), as shown in Figure 20. Normalized intensity is low after affricates, whether

ejective or not, but for stops, normalized intensity varies according to whether a stop is ejective or not:

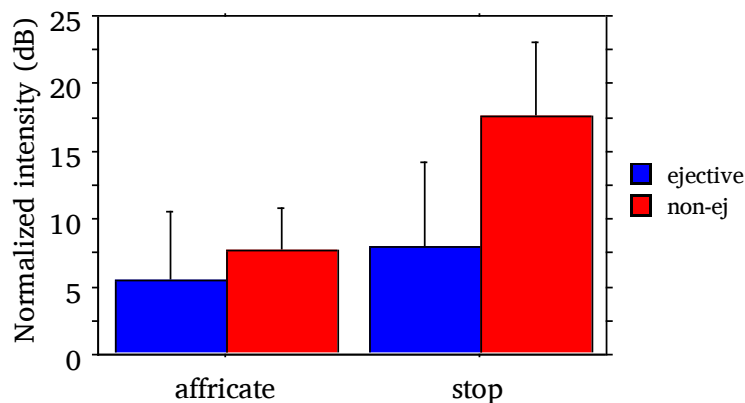


Figure 20. Effects of Type and Release on normalized intensity.

Normalized intensity results were thus as predicted for stops but not for affricates. Figure 21 provides a closer look at the normalized intensities of each of the ejective affricates in the measured set of tokens. Recall that normalized intensity was calculated by subtracting release intensity from reference vowel intensity (4.2). It can be seen from Figure 21 that the majority of the ejective affricates, those numbered 5-15, behaved in accordance with the stops, in that the maximum intensity of the fricative was only slightly less than that of the reference vowel. However, for ejective affricates numbered 1-4 the reference vowel intensity was quite a bit greater than the fricative release intensity.

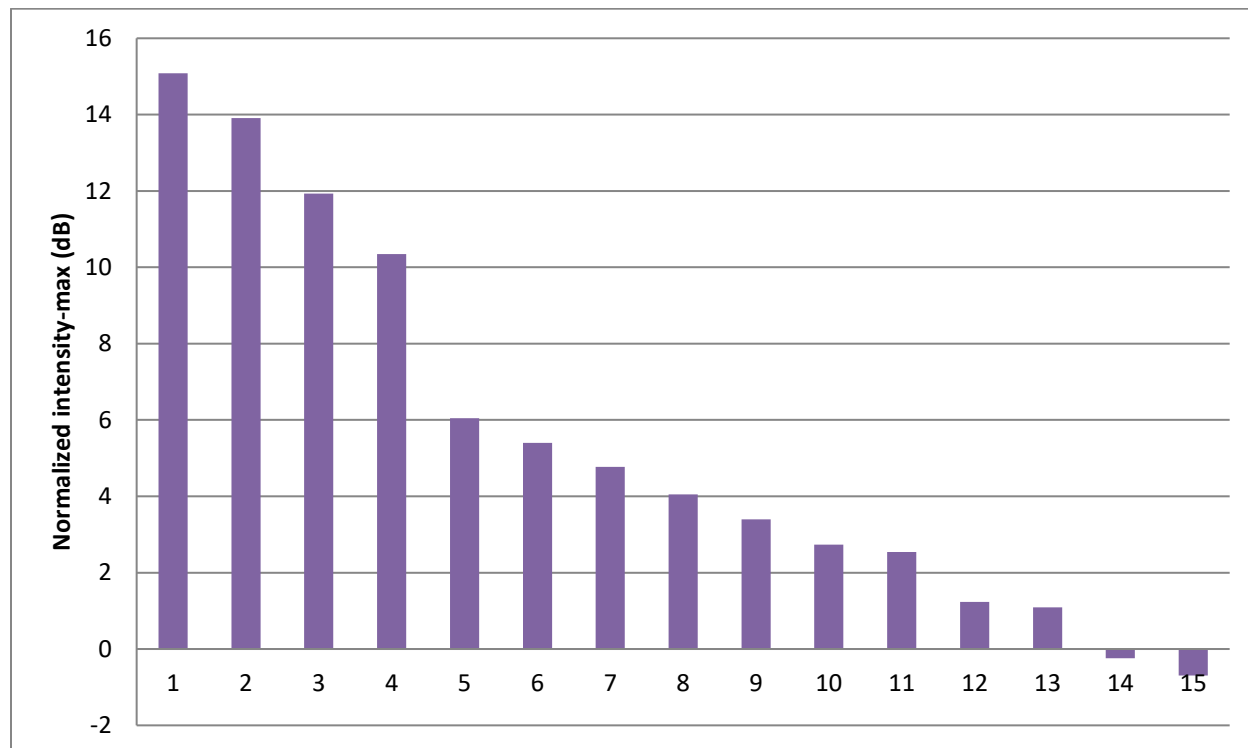


Figure 21. Normalized intensity of each ejective affricate release.

In previous studies of ejectives which used an intensity measure, intensity was not always a significant difference between ejectives. Burst intensity did not distinguish ejective and non-ejective stops in Gitksan, Ingush or Georgian, but in Tlingit, ejective fricatives had higher peak pressure than non-ejective fricatives, and in Deg Xinag, the fricative portion of lateral ejective affricates had higher fricative intensity than the fricative portion of either voiceless unaspirated or voiceless aspirated lateral affricates.

In Turkish Kabardian, there was a mixed result for stops vs. fricatives similar to the current findings for Sahaptin. The ejective fricatives of Turkish Kabardian had less intensity compared to non-ejective fricatives (Gordon and Applebaum 2006). The reason Gordon and Applegaum gave for this is that in the articulation of ejective fricatives there is both a narrower supralaryngeal constriction and a narrower glottal constriction. The narrower glottal constriction will reduce airflow but the narrower supralaryngeal constriction will increase noise. There is thus a delicate balancing act between pressure, airflow and noise generation for fricatives which may be resolved in

different ways in particular productions, which was seen in current study of Sahaptin in Figure 21. Whatever the underlying reason, ejective affricate releases behaved differently from ejective stop releases in the current study.

4.3.3 Silent interval.

For the 22 ejective stops or affricates followed by a fricative, all but one was followed by a silent interval. Of these 22, 18 were ejective stops and 4 were ejective affricates. The mean duration of the silent interval was .030 seconds ($s = .019$). An example of the pre-fricative silent period following an ejective affricate was provided in Figure 14, and an example for an ejective stop was provided in Figure 8. None of the non-ejective stops or affricates was followed by a silent period. The effect of Type on silent interval duration was therefore significant ($F[1,40] = 48.533, p < .0001$), but there was no effect of Release, nor any interaction Release x Type effect.

4.3.4 Summary.

As predicted from qualitative observations (4.1), unlike the word-final ejectives seen in §3, there was no creaky voice on the preceding vowel for a pre-consonantal ejective as determined by the RAP jitter measure.

Also as predicted, pre-consonantal ejective stops had significantly higher intensity bursts than non-ejective stops. However, not as predicted, ejective affricates did not have higher intensity fricative noise than non-ejective affricates. Both ejective stops and affricates are followed by a silent interval when the following segment is one where sound is otherwise expected (i.e. a fricative, not a stop). Thus the only reliable distinguishing acoustic characteristic of ejective affricates is the following silent period, but this cannot be discerned when the following segment is a stop. In such cases we have relied on the second author, who can feel the difference between an ejective and non-ejective when she produces these sounds. Her judgement is that ['lats'q] *láts'k* 'crack, snap, spark' contains an ejective affricate ("hard" consonant) whereas ['latsq] *látsk* 'daydream' does not. Moreover, some of the time the fricative portion of the ejective affricate may have relatively high intensity and thus produce an audible

difference between such tokens. A larger sample thus might have resulted in a significant difference in fricative intensity between ejective and non-ejective affricates.

5 Comparison with Sahaptin pre-vocalic ejectives.

We have seen that the characteristics of ejectives can vary depending on context. Post-vocalic word-final ejective stops are often preceded by creaky voice but pre-consonantal ones are not. The question then arises, do pre-vocalic ejective and non-ejective stops and affricates differ in intensity of the release?¹² Although Grossblatt studied ejectives pre-vocalically, intensity was not one of his measures. Moreover, he didn't include affricates in his sample.

5.1 *Materials and measures.*

A word list was prepared from which ejective and non-ejective stops and affricates could be measured for maximum intensity of release relative to a vowel of the same quality and prosodic characteristics (stressed or not). Table 11 provides an overview of the words on the pre-vocalic list. The consonant and reference vowel are in bold. Appendix 8.3 provides the complete word list. There were 58 stop pairs and 29 affricate pairs on the list.

¹²The impression of word-final ejective stops is that they too have high intensity release bursts but as mentioned in §3, intensity wasn't measured because there weren't enough word-final tokens for a quantitative study.

release		pairs	C'	C
stop	p	10	'sp'itsp'it sp'ítsp'it 'stroke, brush with hand'	'spilja spílya 'coyote'
	t	10	't'a:ʃ t'áash 'slowly extinguished'	ta:ʃ'ta:ʃ taashtáash 'muted, speckled'
	k	10	'pak'u pák'u 'council'	'paku páku 'have sex'
	q	10	'q'awχ k'áwχ 'bald'	'qawχ káwχ 'light-colored'
	k ^w	9	'k ^w 'ap kw'áp 'sprained'	'k ^w ata kwáta 'quarter'
	q ^w	9	'q ^w 'aʃq ^w 'aʃ kw'áshkw'ash 'sandhill crane'	'q ^w alq ^w al kwáلكwal 'turkey'
affricate	ts	10	'ts'ix ts'íx 'defecate'	'tsix tsíx 'sting'
	tʃ	9	'tʃ'a:k tʃ'áak 'in one layer'	'qtʃa:k ktʃáak 'forked, gapped, jagged, agape'
	tʃ	10	'tʃ'ij ch'ísh 'lying (telling a lie)'	'ptʃij pchísh 'door'

Table 11. Sample comparison pairs for study of prevocalic ejective intensity.

5.2 Results and discussion.

Analysis of variance for the normalized intensity measure was performed as in the pre-consonantal context. There was a significant effect of Type ($F[1,170] = 11.778, p = .0008$). As shown graphically in Figure 22, ejectives had significantly less normalized intensity than non-ejectives, meaning that the amplitude of ejective release was closer to that of the reference vowel than it was for the quieter, non-ejective releases.

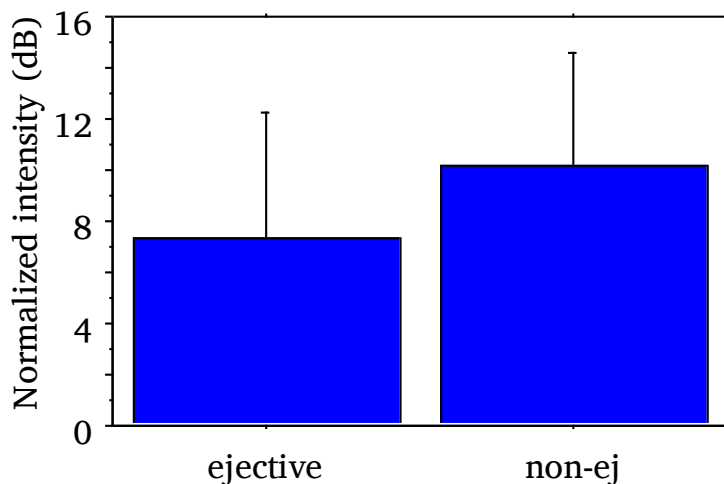


Figure 22. Effect of Type on normalized intensity (pre-vocalic context).

There was also a significant effect of Release: affricates, whether ejective or not, had significantly less normalized intensity than stops, as seen in Figure 23:

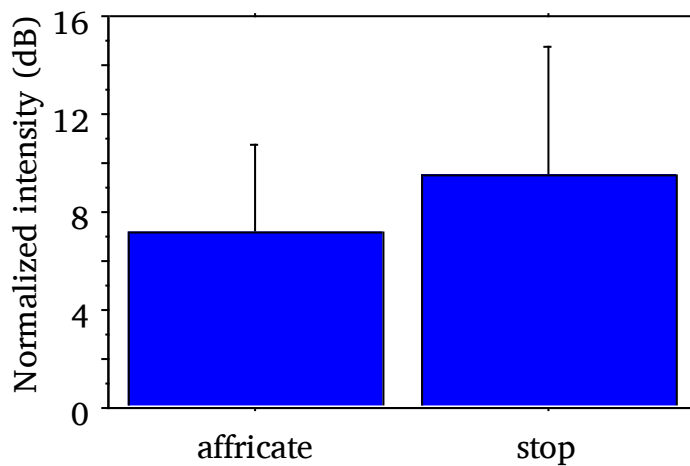


Figure 23. Effect of Release on normalized intensity (pre-vocalic context).

The interaction of Type and Release was not significant, as in the pre-consonantal context, although the data were trending in that direction. As seen in Figure 24, ejective stops but not affricates tended to have less normalized intensity (meaning that their releases were louder, closer to the reference vowel) than respective non-ejectives:

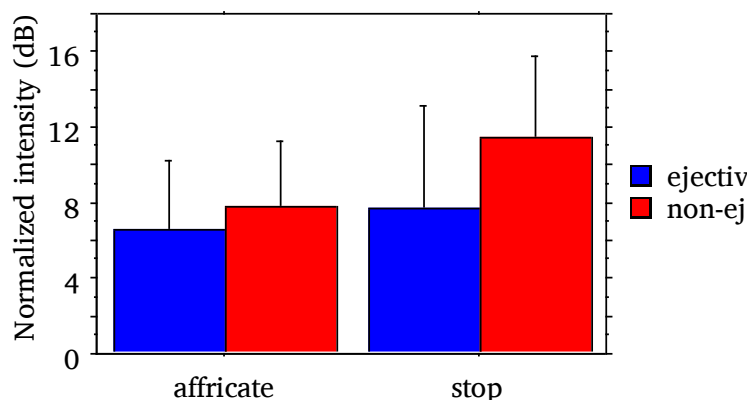


Figure 24. Non-significant interaction of Type and Release (pre-vocalic context).

Thus normalized intensity is a phonetic correlate of ejectives in Sahaptin in both pre-vocalic and pre-consonantal context. Moreover, we cautiously conclude that it is a phonetic correlate of stops only, and not affricates, in both contexts. Effect size has not been systematically investigated, but it appears that there are larger differences in normalized intensity for stops in the pre-consonantal than pre-vocalic context. This would make sense, as this appears to be the sole cue to ejectivity before stops, and one of only two cues before fricatives (the other being silent period duration), whereas pre-vocalically there is also VOT and f_0 perturbation.¹³

6 Conclusions.

Sahaptin, like many other indigenous languages of the Pacific Northwest, allows a striking array of consonant clusters (Hargus and Beavert 2002). This characteristic, along with ejectives in the consonant inventory, puts Sahaptin in a small group of languages in which ejectives contrast with non-ejective stops and affricates before voiceless consonants and word-finally, positions where ejective characteristics cannot be encoded on a following voiced segment. This article has investigated some of the

¹³Rise time has not been investigated.

ways in which the contrast between ejective and non-ejective consonant is signalled in the pre-consonantal and word-final contexts.

Word-final ejectives could not be studied quantitatively as there are only a few lexical items with ejective stops and none with ejective affricates. All word-final ejectives in Sahaptin are post-vocalic. We suggest that the typical word-final ejective stop is produced with creaky voicing on the second half of the preceding vowel. Instead of a stop, a fricative may be produced.¹⁴ When a stop is produced, the release burst appears to have high amplitude.

Pre-consonantal ejective stops are produced with significantly higher intensity release bursts than non-ejective stops. Pre-consonantal ejective affricates were not significantly different in intensity of the fricative noise than non-ejective affricates, but variation in the intensity of the fricative release was observed. Ejective affricates can be identified by a silent period following the fricative release, except when followed by a stop (because the silent period cannot be distinguished from stop closure).

We thus learn from this study that the characteristics of ejectives may not be uniform across contexts within a particular language. Before a vowel or consonant, ejective stop releases are high in amplitude, but word-final ejective stops are generally pre-glottalized consonants (if post-vocalic) rather than ejective, as in Tlingit. This study has also revealed that there may be systematic differences between subclasses of ejectives (here, stops vs. affricates). Future instrumental studies of ejectives should thus be conservative in their conclusions about the phonetic characteristics of ejectives if they do not investigate all kinds of ejectives and sample from all of the contexts in which they occur.

¹⁴These two findings are interesting in light of suggestions in Leer 1979 about what the phonetics of Athabaskan tonogenesis must have been like. Simplifying somewhat, Leer suggested that the glottal component of syllable-final ejective stops and affricates is phonetically realized on the preceding vowel (there are complications with ejective type and vowel quantity).

Finally, this study was able to investigate ejectives vs. non-ejectives across a large number of lexical items, creating balanced word lists (§8). This is a result of having performed painstaking lexicography for many years, resulting in ample lexical resources to draw on for this phonetic study.

7 Post-script.

This study has had one practical application for Sahaptin linguistics: the transcription of ejective affricates. Given the fact that normalized intensity is not a reliable phonetic correlate of ejective affricates pre-consonantly, we took a closer look at “geminate ejective affricate” tokens transcribed as such by previous sources, including Beavert and Hargus 2009. These turned out to fall into one of two types, listed in (5): (a) a non-ejective affricate followed by an ejective affricate or (b) an ejective affricate separated from an ejective affricate by an epenthetic [ɨ], thus adding to the list of contexts where epenthetic [ɨ] is required (Hargus and Beavert 2002).

(5) “Geminate ejective affricates”, recategorized

a. only second part ejective

'tsts'u:p *tsts'úup* ‘thaw, melt, defrost’

'itʃtʃ'ɪlk *íchch'ilk* ‘cause to make noise’

'tʃtʃ'a:l *chch'áal* ‘(gradually becoming) noisy’

'tʃtʃ'iw *chch'íw* ‘cattail’

mits'ts'íp *mitsts'íp* ‘very scary, frightening; itch’

b. epenthetic [ɨ]

tʃ'itʃ'umχ *tʃ'itʃ'úmχ* ‘red-wing blackbird’

8 Appendices.

8.1 Appendix 1: Pre-consonantal word list for intensity measurement.

The measured consonant and reference vowel are in bold.

8.1.1 p' vs. p.

'pap'qi páp'ki 'burst'

i'wap'qa iwáp'ka 'it broke open'

'pap'iki páp'iki 'pierced (larger object)'

'tʃawp'χ cháwp'χ 'mentally unsound'

'pap'ski páp'ski 'pierced (smaller object)'

'sup'ski súp'ski 'strung'

'χap'ʃnak χáp'shnak 'collapse' (v.)

'sapqitwani sápkítwani 'carefully'

'wapqalu:k wápkaluuk 'tilt head up'

'napłk^wi Nápłkw'i 'Tuesday'

'ajpχ áypχ 'mouth of river; plain, plateau'

'sapsik^wa sápsikw'a 'teach'

'stupsa stúpsa 'wild onion'

'χapʃanajk χápshanayk 'pile up'

8.1.2 t' vs. t.

ʃa'pat'ki shapát'ki 'snapped, clicked, bolted'

'la:t'k^w láat'kw 'end, stop'

'wawt'k^wk wáwt'kwk 'smash, shatter, break'

wa'past'k^w wapást'kw 'show, reveal bones (in bone game)'

wit'k'wit'k wít'k-wít'k 'nod' (v.)

'pit'χanuk pít'χanuk 'high country'

sut'χ'ła sut'χlá 'whale'

i'pat'qa ipát'ka '(3sg) slapped (3sg)'

t'χapta'nuwa:s t'χaptanúwaas 'spur'

ʃa'patk'i shapátk'i 'movie'

wi'q'a:tk'a wík'áatk'a 'too cooled off'

'wawtk^wt wáwtkw't 'overnight stay'

sa'pastk sapástk 'tie small knot'

'witk 'witk 'half'

'pitχanuk 'pítχanuk 'place pl. under'

wiiłtχ'ła wiiłtχlá 'one that goes up fast' (e.g. air balloon)

wa'latkawa walátkawa 'bundle' (v.)

tχana'nu: tχananúu 'lie in wait for, ambush'

8.1.3 k' vs. k.

k'piti'ma k'pitímá 'beadwork'

'k'sit k'sít 'cold'

'k'tit k'tít 'hard, solid'

'lik'p lík'p 'blink' (v.)

'k'pa:s k'páas 'cooled off'

kpajli'ma kpaylimá 'recently'

'ksik ksík 'stink'

'ktiχknik ktíχknik 'side, beside'

likp'likp líkplík'p 'fast, quickly'

'kpajlk kpaylk 'recent'

8.1.4 q' vs. q.

'q'ta:t k'táat 'flat and hard'
 'tʃaɪp chák'p 'tie down'
 'q'pu:ʃ k'púuʃ 'short'
 'paq'pʃ pák'psh 'pin'
 sha'paq'p shapák'p 'fasten, clamp'
 'q'ʃq'ʃli k'shk'shlí 'dry cereal'
 chaq'pawa:s chak'páwaas 'eyelet,
 grommet'
 'tʃawq'χ cháwk'x 'hang, strangle'
 ʃa'paq'ʃk shapák'shk 'make curl'

8.1.5 k^w vs. kw.

ta'mak^w'p tamákw'p 'behead, knock
 top off'
 a'k^w'iʃ'ak^w'ʃ akw'ish'akw'sh 'vein,
 artery'
 k'upk^w'ppa'ma tawt'nuk k'upkw'ppamá
 tawtnúk 'medicine for the back'
 'watχalk^w'k wátχalkw'k 'catch
 offguard, catch by surprise'
 'ik^w'stik ikw'stik 'wipe'
 sa'pak^w'stik sapákw'stik 'wipe'
 sapak^w'sti'kawa:s sapakw'stikáwaas
 'napkin'
 'tʃak^w'k chák'k 'pull straight,
 straighten by pulling'

8.1.6 q^w vs. q^w.

ʃa'paq^w'ʃk shapák'w'shk 'slather, smear'
 pi'naq^w'ʃtaj pinák'w'ʃtay 'take back,
 win back'
 ti'naq^w'tk tinák'w'tk 'sprain' (v.)

'qtʃa:k ktʃáak 'forked'
 'tʃaɪpt chákpt 'pull tight'
 'qpnu: kpnúu 'shoot at'
 'aɪpta i'pap ákpta ipáp '(3sg)'s hand got stuck'
 sha'paɪpt shapákpt 'stick/hold under arm'
 miq'ʃli mik'ʃlí 'gold'
 'ʃp'a:naɪpa ʃp'áanaɪpa 'in a Sally bag'
 iw'jawɪʃ iwýáwksʃ '(3sg) has had an accident'
 'tʃaɪsqʃ chákksʃ 'crunchy'

a'nak^w't anákwt 'separated, divorced'
 'ʃa'anak^w'ʃ shá'anakwsh 'cutting'
 χaχayk^w'pa'ma χaχaykwpmá 'cash box'
 'χatamat'k^w'k χátamat'kwk 'fall and break up,
 shatter'
 'ik^w'stimi ikwstimi 'arrange, rearrange'
 wa'pak^w'ʃtik wapákwshtik 'grab at and miss'
 'wawnak^w'ʃaʃ wáwnakwshash 'body'
 'wawt'k^w'k wáwt'kwk 'smash, shatter, break'

aq'ʃ'aq'ʃ akwsh'ák'wsh 'strutting'
 i'tʃaɪq'ʃkta ichák'w'ʃkta '(3sg) will get divorced'
 ʃa'paq^w'tk shapák'wtk 'join together, plug in,
 insert, attach'

'witq^wpʃk 'wítkw'pshk 'cramp' (v.)

ti'naq^wtka tinákw'tka 'sprained'

panuq^w'k'la panukw'klá 'monster'

8.1.7 ʈ' vs. ʈ.

'lats'q láts'k 'crack, snap, spark' (v.)

lats'q'la lats'klá 'sparker'

'lats'qi láts'ki 'sparking, sparked'

sa'pats'psk sapáts'psk 'snap off, open'

'ʈ'k^wi:t ts'kwíit 'corner, angle'

8.1.8 ʈʃ vs. ʈʃ.

'tatʃ'k tách'k 'pull out by top'

'wiχ^wʈʃ'k 'wíχwch'k 'take off, remove pl., undress'

tapʈʃ'kipa'ma 'si:l tapch'kipamá síl 'cloth for house dress'

i'witʃ'χna iwích'χna '(3sg) stripped, shredded it' (2 productions)

8.1.9 tʃ' vs. tʃ.

'tʃatʃ'ki chátʃ'ki 'broken off'

iw'jatʃ'χ^wa iwýátʃ'χwa 'it ended'

'tʃ'pi:p tʃ'píp 'wingdress'

wi:tʃ'χ^wnaʃ wíitʃ'χwnáʃ 'never runs out'

'ma:tʃ'k máatʃ'k 'dig up, out'

'tiq^wtk tíkwtk 'sit on sharp object, stall going backwards'

i'tiq^wtka itíkwtka '(3sg) sat on it (sharp object)'

q^wtq^witʃi'ma kwtkwítʃimá 'covered in thorns'

'latsq látsq 'daydream' (v.)

latsq'la latsq'lá 'daydreamer'

'majtsqi máytsqi 'morning'

i'juujuuna 'atspa iyúuyuuna átspa 'he called his younger sister'

ʈχʈχ'ni:ki tsxtsxnúiki 'crunchily'

'latʃqu láchku 'have smoke in the eye'

'qitʃk kíchk 'pay attention to'

njatʃpa'ma 'si:l nyachpamá síl 'cloth for pants'

i'nitʃ'χa iníchxa '(3sg) places (habitually)' (2 productions)

'tʃaq^wtʃki 'k'usi chákwtʃki k'úsi 'loose horse'

'qatʃχatk kátʃχatk 'get used to'

'wi:tʃq^wt wíitʃkw 'catch moving object'

wi:tʃq^wtpa'ma wíitʃkwtpamá playing field, outfield

'tʃχa:t tʃχáat 'tame, gentle'

8.2 Appendix 2: Pre-consonantal word list for jitter measurement.

The measured vowel is in bold>.

8.2.1 Vowels before p' vs. p.

'pap'ʔki 'páp'ʔki 'pierced (larger object)	'napʔk ^w i 'Náp'ʔk ^w i 'Tuesday'
'pap'ski 'páp'ski 'pierced (smaller object)	'sapsik ^w a 'sápsik ^w a 'teach'
'sup'ski 'súp'ski 'strung'	'stupsa 'stúpsa 'wild onion'
'χap'ʃnak 'xáp'shnak 'collapse' (v.)	'χapʃanajk 'xápshanayk 'pile up'

8.2.2 Vowels before t' vs. t.

ʃa'pat'ki 'shapát'ki 'snapped, clicked, bolted'	ʃa'patk'i 'shapátk'i 'movie'
wit'k'wít'k 'wít'k-wít'k 'nod' (v.)	'wítk 'wítk 'half'
'pít'χanuk 'pít'χanuk 'high country'	'pítχanuk 'pítχanuk 'place pl. under'
i'pat'qa 'ipát'ka '(3sg) slapped (3sg)'	wa'latkawa 'walátkawa 'bundle' (v.)
'tít'k 'tít'k 'mucus'	'títk ^w k 'tútk ^w k 'advise'
'χat'χw 'xát'χw 'drip' (v.)	'χatχat 'xátχat 'duck'
ʃa'pat'ʃk 'shapát'shk 'extinguish'	'watquki 'wátquki 'water pump'

8.2.3 Vowels before k' vs. k.

'lìk'p 'lìk'p 'blink'	lìkp'lìkp 'lìkplìkp 'fast, quickly'
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8.2.4 Vowels before q' vs. q.

'tʃaq'p 'chák'p 'tie down'	'tʃaqpt 'chákpt 'pull tight'
'paq'pʃ 'pák'pʃh 'pin'	'aqpta i'pap 'ákpta 'ipáp '(3sg)'s hand got stuck'
sha'paq'p 'shapák'p 'fasten, clamp'	sha'paqpt 'shapákpt 'stick/hold under arm'
chaq'pawa:s 'chak'páwaas 'eyelet, grommet'	'tʃp'a:naqpa 'tʃp'áanakpa 'in a Sally bag'
'tʃawq'χ 'cháwk'χ 'hang, strangle'	iw'jawqʃ 'iwýáwksh '(3sg) has had an accident'
ʃa'paq'ʃk 'shapák'shk 'make curl'	'tʃaqsqs 'chákks 'crunchy'

8.2.5 Vowels before k^w' vs. k^w.

ta'mak ^w p 'tamák ^w p 'behead, knock top off'	a'nak ^w t 'anákw ^t 'separated, divorced'
'ik ^w stik 'íkw'stik 'wipe'	'ik ^w stimi 'íkwstimi 'arrange, rearrange'
sa'pak ^w stik 'sapák ^w stik 'wipe'	wa'pak ^w ʃtik 'wapák ^w stik 'grab at and miss'

sapak^wsti'kawa:s *sapakw'stikáwaas*
'napkin'

'wawnak^wʃaʃ *wáwnakwshash* 'body'

8.2.6 Vowels before q^w vs. q^w.

pi'naq^wʔtaj *pinákw'ʔtay* 'take back,
win back'

i'ʔjaq^wʔkta *ichákwʔkta* '(3sg) will get divorced'

ti'naq^wtk *tinákw'tk* 'sprain' (v.)

ʃa'paq^wtk *shapákwtk* 'join together, plug in,
insert, attach'

8.2.7 Vowels before ts' vs. ts.

'lats'q *láts'k* 'crack, snap, spark',

'latsq *látsk* 'daydream'

lats'q'ʔá *lats'kʔá* 'sparker'

latsq'ʔá *latskʔá* 'daydreamer'

8.2.8 Vowels before tʃ' vs. tʃ.

'tatʃ'k *tách'k* 'pull out by top'

'latʃqu *láchku* 'have smoke in the eye'

i'witʃ'χna *iwích'χna* '(3sg) stripped,
shredded it'

i'nitʃχa *iníchχa* '(3sg) places (habitually)'

8.2.9 Vowels before tʃ' vs. tʃ.

iw'jatʃ'χ^wa *iwýát'χwa* 'it ended'

'qatʃχatk *kátʃχatk* 'get used to'

wi:tʃ'χ^wnaʔ *wiit'χwnáʔ* 'never runs out'

wi:tʃq^wtta^wma *wiit'kwtttamá* playing field,
outfield

8.3 Appendix 3: Pre-vocalic word list for intensity measurement.

The measured consonant and reference vowel are in bold.

8.3.1 p' vs. p.

'sp'itʃp'it *sp'ítʃp'it* 'stroke, brush with
hand'

'spilya *spílya* 'coyote'

'p'ip'i *p'íp'i* 'intestines'

k'u'pipi *k'upípi* 'dance circle dance'

a'p'u:s *ap'úus* 'cat'

k'a'pu:s *k'apúus* 'straight pin'

la'p'alʃ *lap'álsh* 'handle of root-digger'

sa'palwit *sapálwit* 'week, Sunday'

'p'ula *p'úla* 'blow up, expand'

'puʔa *púʔa* 'wild turnip'

'ʔp'a:naq *ʔp'áanak* 'sally bag'

sha'panak^w *shapáanakw* 'run off with, cause to
separate'

'p'ix *p'íχ* 'mentally sound'

a'p'ix *ap'íχ* 'untanned hide'

'p'ink p'ínk 'too close to'
 'p'uʃim p'úshim 'foam, beer'
 'p'a:χ p'áax 'gradually remembering'

8.3.2 t' vs. t.

't'a:ʃ t'áash 'slowly extinguished'
 mi't'ula mit'úla 'dog salmon, spawning
 salmon'
 ata't'awa:s atat'áwaas 'outhouse'
 't'i:χ t'íxw 'rain drop'
 i't'uk it'úk 'difficult'
 miʃ't'ipni misht'ipni 'stupid'
 patwa't'ikt patwat'íkt 'lacrosse'
 si't'aχs sit'áxs 'liver'
 'st'i:χ st'íx 'pop'
 't'alpt t'álp't 'shell bead'

8.3.3 k' vs. k.

'pak'u pák'u 'council'
 'k'up k'úp 'spillway'
 'k'a:nk k'áank 'blocking, in the way'
 'k'a:ʃ k'áaʃ 'begging'
 'k'alak k'áalak 'pack on back'
 'k'ask'as k'ásk'as 'small and cute'
 'k'a:tni k'áatni 'discarded'
 'k'u:lil k'úulil 'bowl-shaped'
 la'k'it lak'ít 'end'
 'k'i: k'í 'peek'

8.3.4 q' vs. q.

'q'awχ k'áwx 'bald'
 'q'a:p k'áap 'closed tight, secure'
 'q'a:w k'áaw 'burp'

'pink pínk 'he, she'
 'puʃa púsha 'paternal grandfather'
 'pa:χw páaxw 'loose, scattered'

ta:ʃ'ta:ʃ taashtáash 'muted, speckled'
 pa'tulpatul patúl-patul 'things'
 a'tawa:s atáwaas 'outhouse' (variant)
 'tuχ túb 'return'
 'tuktu túktu hurry up
 'qw'ítip kw'ítip 'physically fit'
 wa'tikʃ watíksh 'footprint'
 'taχʃ táxsh willow'
 'stít'a:s stít'aas 'rattlesnake rattle'
 'talpʃ tálpsh 'scalp'

'paku páku 'have sex'
 'kuks kúks 'your (man's) younger brother'
 'ka:m káam 'miss, feel short-changed'
 'k'as káas 'train' (n.)
 'kala kála 'color'
 'kasa kása 'maternal grandmother'
 (affectionate term)
 'ka:tnam káatnam 'long, tall'
 'sku:li skúuli 'attend school'
 napa'kink napakínk 'you 2'
 'ki:χ kíx 'loose'

'qawχ káwx 'light-colored'
 'qa:pt káapt 'crowded'
 'qa:w káaw 'separate'

'q'a:ɣ k'áax 'torn, level'

'q'ínu k'ínu 'see'

'q'ija k'íya 'fish hook'

'q'íp k'íp 'shut'

'q'is k'ís 'crunchy'

'q'uɣɬ k'úxɬ 'knee'

'q'ujɣ k'úyɣ 'elongated'

'qas káas 'tightly'

'qiluf kíluf 'chicken hawk'

'qija kíya 'red-tailed hawk'

'qíp k'íp 'shoot'

'qis k'ís 'tight'

'quɣ kúx 'thump'

'qujɣ kúyɣ 'white'

8.3.5 k^w vs. k^w.

'k^wap kw'áp 'sprained'

'k^wajk^waj kw'áykw'ay 'unidentified wren'

'k^wa:n kw'áan 'be spoiled, overindulged'

'k^wa:p kw'áap 'breaking'

'k^wa:ɟ kw'áash 'overcoming'

'k^wi kw'í 'waist'

'k^w:ink kw'ínk 'that aforementioned'

'k^w:íp kw'íp 'sprained'

'ik^w:a:nk íkwaank 'spoil' (v.)

'k^wata kwáta 'quarter'

'k^wajsim kwáysim 'simultaneously'

'k^wa:l kwáal 'that long'

'k^wa:k kwáak 'I don't know'

'k^wa:s kwáas 'last, remaining'

'k^wi kwí 'be deprived'

'k^w:ik kwíik 'so much, many'

'k^w:it kwít 'fast asleep'

'ik^w:a:k íkwaak 'smooth, clear off'

8.3.6 q^w vs. q^w.

'q^waɟq^waɟ kw'áshkw'ash 'sandhill crane'

'q^wa:ɟtp kw'áashtp 'slowing opening (eyes)'

'q^w:il kw'íl 'muddy (water)'

jɨ'q^w:il yík'w'íl 'muddy water'

'q^w:in kw'ín 'rot, spoil'

q^waɟ'q^wa:ɟja Kw'ashkw'áashya 'Crane'

'q^w:it kw'ít 'visible, clear'

wa'q^w:iti wakw'íti 'hoe' (v.)

lu'q^w:a lukw'á 'chub'

'q^walq^wal kwáalkwal 'turkey'

'q^wa:ɟ kwáash 'exhausted, worn out'

'q^w:it kwít 'stuck, stopped'

'q^wtq^w:it kwtkwít 'thorn'

'tɬq^w:it tɬkwít 'snatch, grab'

'q^wa:t kwáat 'firmly affixed'

jɨ'q^w:it yík'w'ít 'narrow'

'q^w:itɬ kwítɬ 'loose, untied'

'q^wa:ɟɟin Kwáɬchin 'Qualchin' (personal name)

8.3.7 tʃ vs. tʃ.

'tʃiʃ *ch'ísh* 'lying'
 'ntʃi *nch'í* 'big, old'
 'ptʃiwi *pch'íwi* 'become wealthy'
 'ntʃiwi *nch'íwi* 'become old'
 wi'tʃa:k *wich'áak* 'open, agape'
 'tʃa:χ *ch'áax* 'cracking'
 'tʃajtʃaj *ch'áych'ay* 'ringworm'
 tʃi'lu *ch'ilú* 'glance, look sideways at'
 'tʃija *ch'íya* 'woodpecker, flicker'
 'tʃim *ch'ím* 'sharp'

'ptʃiʃ *pch'ísh* 'door'
 wil'tʃi *wilch'í* 'root cellar'
 pa'tʃiwi *pach'íwi* 'be mean, grouchy'
 'ntʃiwi *nch'íwi* 'disagree about'
 'qtʃa:k *kcháak* 'forked, gapped'
 'tʃa:ʃwi *cháashwi* 'flirt'
 'tʃajtʃaj *ch'áychay* 'filthy'
 tʃi'nuki *chinúki* 'have venereal disease'
 'tʃiwa *ch'íwa* 'Dolly Varden'
 'tʃimti *ch'ímti* 'new'

8.3.8 ts' vs. ts.

'ts'apχ *ts'ápχ* 'cedar'
 'ts'i:χ *ts'íχ* 'consider easy'
 'ts'im *ts'ím* 'sharp'
 'ts'iχ *ts'íχ* 'defecate'
 'ts'uχts'χw *ts'úχts'χw* 'suck on'
 'ts'i:lil *ts'ílil* 'round, circular'
 'sts'at *sts'át* 'night'
 ja'ts'a:m *yats'ám* 'softly'
 'ts'u:p *ts'úp* 'melt, thaw'
 'wjats'a:k *wyáts'aak* 'approach'

'tsawk *tsáwk* 'red hot'
 'tsi:s *tsís* 'cheese'
 'tsimti *tsímti* 'brand-new'
 'tsiχ *tsíχ* 'sting'
 'tsu:im *tsúim* 'buffalo'
 'tsi:sas *Tsísas* 'Jesus'
 'tsastk *tsástk* 'tie knot'
 'tsxtsa:x *tsxtsáax* 'lukewarm'
 'tsu:ts *Tsúuts* George
 'atsa:s?atsa:sji *átsaas'atsaasyi* 'potato' (lit. having little eyes)

8.3.9 tʃ' vs. tʃ.

'tʃ'a:k *tʃ'áak* 'in one layer'
 'tʃ'a:q *tʃ'áak* 'broken'
 'tʃ'a:χ^w *tʃ'áax^w* 'all'
 'tʃ'anχ *tʃ'ánχ* 'on the other hand'
 'tʃ'i:ʃ *tʃ'ísh* 'generous'
 'tʃ'iks *tʃ'íks* 'soon'
 'tʃ'iqni *tʃ'íkni* 'broken'

'qtʃ'a:k *ktʃ'áak* 'forked, gapped, jagged, agape'
 'ptʃ'a:q *ptʃ'áak* 'spicy, peppery'
 'tʃ'a:χat *tʃ'áaxat* 'gradually becoming peaceful'
 'qtʃ'ani *ktʃ'áni* 'forked, gapped, jagged, agape'
 at'tʃ'i:χ *at'tʃ'íχ* 'porous, worn'
 'tʃipat *waʃat tʃ'ípat wáshat* 'dancing half-time'
 'tʃi *tʃ'í* 'scary sound'

'tʰiχ^w tʰɛχ^w 'end' (v.) atʰtʰiχ atʰtʰiχ 'rough, bumpy'
 'tʰuχ tʰúχ 'end' (v.) 'tʰup tʰúp 'jump' (v.)

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