CONTEXTUAL VARIATION IN THE ACOUSTICS OF HUL’Q’UMI’NUM’ EJECTIVE STOPS

Maida Percival

University of Toronto
maida.percival@mail.utoronto.ca

ABSTRACT

This paper examines the acoustic properties of ejective stops across different word contexts in Hul’q’umi’num’, a dialect of Halkomelem (Salish). It seeks to determine what characterizes Hul’q’umi’num’ ejectives, and to contribute towards answering the question of how much variation can be present within a language’s ejective category. Measurements of duration, intensity, and adjacent vowel quality in ejective [p’, t’, kw’, q’, qw’] and plain [p, t, kw, q, qw] stops across word-initial, intervocalic, and word-final positions were made. Results found that ejectives had longer releases than plain stops, especially in word-final position which included a visible glottal release following the oral one. Prevocalic ejectives also elicited correlates of creaky voice in following vowels. The results have implications to learners acquiring the sound categories, and are also of interest in light of considerable cross-linguistic variation in ejectives ([5]; [7]; [14]), which has less frequently been examined in relation to position.

Keywords: Hul’q’umi’num’, acoustic phonetics, ejective stops, phonetic variation

1. INTRODUCTION

Hul’q’umi’num’ is the dialect of Halkomelem (Salish) spoken on Vancouver Island. The dialect currently has about 40 native speakers and a number of second language speakers. Because the native speakers are all community Elders, and minimally in their late sixties, documentation of the sounds of the language is of interest.

Ejective stops are produced with a closure of the glottis accompanied by a raising larynx gesture, which increases the air pressure in the intra-oral cavity and leads to a distinctive “poppy” sounding burst upon the stop’s release [6]. Although ejectives occur in about 17% of the world’s languages [8], Hul’q’umi’num’ is somewhat unusual in allowing these sounds to occur unrestricted across a number of positions, including not only word-initial and word-medial, but also word-final ([10], [3]).

Most studies of ejectives have concentrated on pre-vocalic ejectives. They have found considerable cross-linguistic variation across a number of acoustic dimensions, leading some to propose different types of ejectives based on the clustering of these acoustic characteristics in the languages they examined [5], [7]. For example, [5] suggests that “strong” ejectives are produced with a loud burst, a long release with a period of silence between the burst and the vowel, which has raised pitch, modal phonation, and a quick rise in intensity. “Weak” ejectives, on the other hand, are produced with a quieter, shorter burst, and no silent portion between the burst and the vowel– instead the glottal release of the ejective occurs during the vowel, producing correlates of creaky voice, such as lowered F0, aperiodicity, lower H1-H2, and a slow rise to maximum intensity on the vowel. Others have also found that various clusterings of these and similar acoustic characteristics can differentiate ejectives from other stop types [14], [13] (inter alia).

Using these previous studies as guidance, one research goal of the present study is to determine how Hul’q’umi’num’ ejectives are distinct from plain stops in the language. A second goal is to investigate variation within the ejective category by examining differences in the contrast across word-position.

2. METHODOLOGY

2.1. Participants

Five Hul’q’umi’num’ first language speakers (3 female, 2 male) were recorded for this study. All were between the ages of 65 and 86, and were bilingual in English, having heard and used the language with family, but done their schooling in English. Given the nature of the population, some participants had dentures and/or hearing loss.

2.2. Material

80 minimal or near-minimal pairs of plain versus ejective stops were selected and arranged into a word list. The list contained each pair of ejective and plain stops found in the stop inventory in Table 1 paired

with 2-3 different vowel qualities ([i], [e], [a], or [ə]) and in word-initial, intervocalic, and word-final positions. Table 2 displays some sample (near-) minimal pairs for the consonant pair [t] vs. [t’]. Altogether across all words and speakers, there were 981 stop tokens (a small number of tokens were discarded due to reading errors).

Table 1: Hul’qumi’num’ stop inventory.

	bilabial	alveolar	velar	labialized velar	uvular	labialized uvular	glottal
plain	p	t	k	kw	q	qw	ʔ
ejective	p’	t’		kw’	q’	qw’	

Table 2: Sample minimal pair words

	word-initial	intervocalic	word-final
plain	[ten]	[ʔitət]	[mit]
	‘mother’	*‘sleep’*	*‘dime’*
ejective	[t’en]	[ʔit’əst]	[mit’]
	‘go out of sight’	*‘pack a baby by the middle’*	*‘get splayed (a fish)’*

2.3. Procedure

Participants were seated at a table in a quiet room, given a printed copy of the wordlist, and asked to read each word twice in a carrier phrase *kwun’s thut* __ (‘*you say* __’). It was not possible to find a carrier that participants accepted where the target word was not the last word in the phrase. Distractors were not included, as this would have lengthened the recording time, which was already long for some participants. Recordings were done in Audacity 2.1.1 [11] with a Yeti microphone.

2.4. Analysis

Annotations and measurements were made in Praat 6.0.33 [2]. The measurements were exported to R 3.3.3 [12], where linear mixed effects models using the lmer function [1] were fitted with the measurements as the dependent variable. Fixed effects were stop laryngeal type (ejective, plain), word position (initial, medial, final), and place (bilabial, alveolar, velar, uvular). Random effects were participant, word, and vowel. Note that the labialized and non-labialized phonemes are treated as one group to simplify the analysis and because there are no simple velar phonemes. Following vowel phonatory measures and analyses did not apply to word-final stops.

3. RESULTS

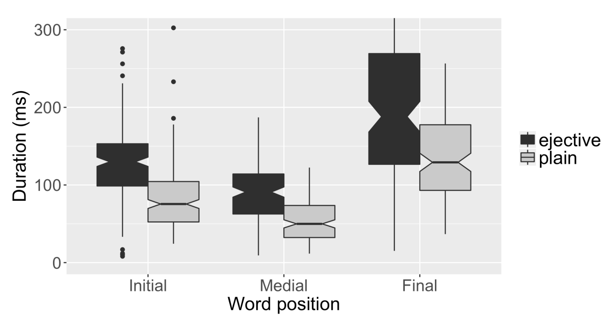
3.1. Release duration

Release duration was measured as the length of time from the onset of the stop burst to the first zero-crossing of the vowel for word-initial and intervocalic stops. For word-final stops, it was from the onset of the stop burst to the point at which noise of the stop release was no longer audible or visible in Praat.

Results of the linear mixed effects model found a significant effect of laryngeal type on release duration: ejectives had longer releases than plain stops (t=8.078, p<0.001, df=923.1). There was also a significant effect of position: word-medial stops were the shortest (t=4.374, p<0.001, df=163.3), word-initial stops where intermediate, and word-final stops were the longest (t=5.955, p<0.001, df=5.5). A significant interaction between laryngeal type and position indicated that word-final ejective releases were significantly longer compared to all other stops (t=2.718, p=0.007, df = 944.1). These patterns can be seen in Figure 1.

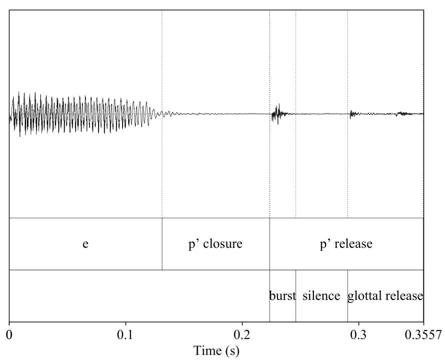
Significant effects and interactions with place of articulation were also found. Bilabial stops had the shortest releases, which were significantly shorter than velar stops’ (t=2.646, p=0.009, df=188.2). Uvular stop releases were quite variable, especially in word-final position where they were the longest (t=2.864, p=0.004, df=204.6), but the ejective and plain overlapped. This may be because uvulars were sometimes pronounced as affricates and because the analysis is grouping together the labialized and non-labialized uvular phonemes.

Figure 1: Release duration.



Part of the reason word-final ejective releases were so long is that many of them had a glottal release portion, which appeared on the waveform and spectrogram as a glottal burst (or series of 1-3 bursts) and a period of aspiration (see Figure 2 for an example). 76% of the final ejective tokens had an audible (and visible) glottal release while this feature was seldom found in word-initial and word-medial stops. The final glottal release in ejectives was partially speaker-dependent with two speakers consistently producing it, one speaker consistently not producing it, and two speakers varying.

Figure 2: Word-final ejective in *squqep'*.

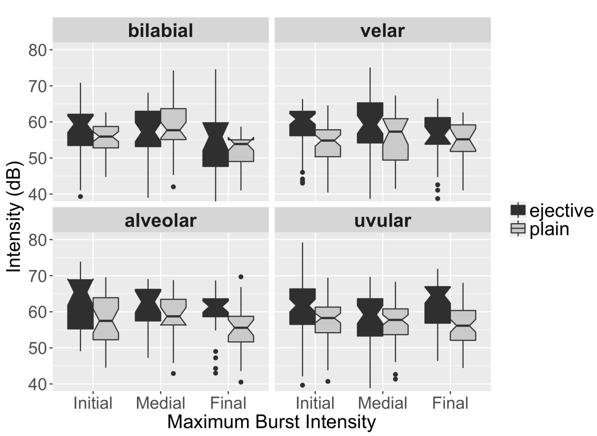


3.2. Burst intensity

Burst intensity was measured as the mean intensity in dB from the beginning of the stop burst to its offset (i.e., the onset of either aspiration, a period of silence, or a vowel).

There was no significant effect of laryngeal category on mean burst intensity. However, intensity of [t'] was found to be significantly greater than [t] (t=2.204, p=0.028, df=315.1), and [kw'] was also marginally greater than [kw]. In addition, a significant interaction between uvular place of articulation, position, and laryngeal category suggests that uvular stop bursts have significantly greater intensity than plain stop bursts in word-initial (t=3.593, p<0.001, df=349.2) and word-final position (t=3.496, p<0.001, df=348.8). Figure 3 illustrates these patterns.

Figure 3: Mean burst intensity.



There was also an effect of position. Word-medial bursts were significantly quieter by about 4 dB than those in word-initial (t=3.353, p<0.001, df=359) and word-final position (t=2.591,p=0.013, df=49.1.

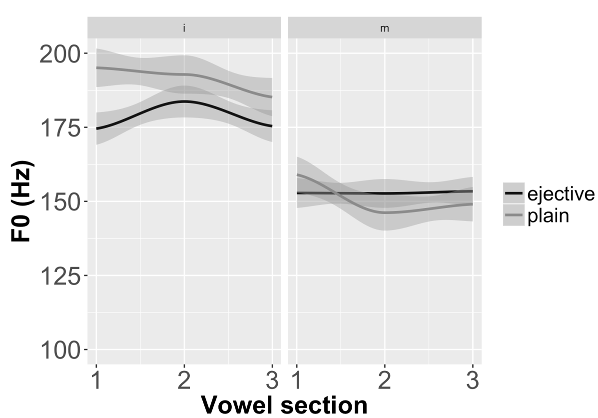
3.3. Following vowel

3.3.1. F0 perturbation

F0 perturbation measures the degree to which F0 is raised or depressed at the beginning of a vowel. It was measured by taking the mean F0 in the first 30 ms of the vowel and subtracting the mean F0 from the middle 30 ms of the vowel, following [14].

The results of the linear mixed effects model revealed a significant effect of laryngeal type on F0 perturbation (t=2.194, p=0.028, df=612). Ejectives were followed by vowels with low F0 perturbation (around or just blow zero), whereas plain stops were followed by vowels with high F0 perturbation (above zero). Place of articulation and position were not significant. Figure 4 illustrates, however, that while F0 perturbation did not differ across positions, raw F0 did seem to differ, being overall higher in word-initial position.

Figure 4: Mean F0 across the beginning (1), middle (2), and end (3) portions of the following vowel. left panel = word-initial stops, right panel = word-medial stops.

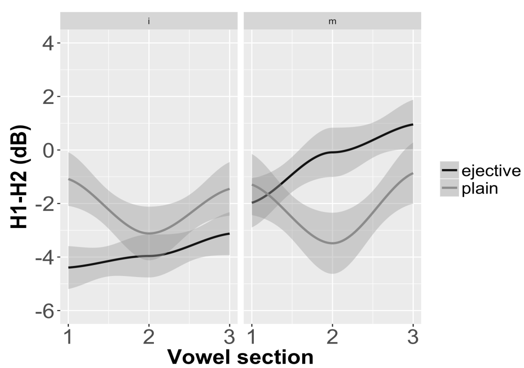


3.3.2. H2-H1

H1-H2 is the difference in amplitude between the first and second harmonics. A negative H1-H2 value is one of the acoustic correlates of creaky phonation [4]. As with F0, it was measured as a perturbation, by subtracting the initial mean H1-H2 by the mid mean H1-H2, except that in this case the vowel was divided into equal thirds using a VoiceSauce Imitator Praat script from the UCLA Phonetics Lab.

The linear mixed effects model found a significant effect of laryngeal type on H1-H2 (t=2.763, p=0.006, df=428), but no other significant effects were found. Figure 5 displays the change in H1-H2 across three sections of the vowel. The ejectives always start out with lower H1-H2 that rises throughout the vowel, whereas the plain stops H1-H2 start out high, then drop towards the middle of the vowel before raising again. Although position was not found to affect the shape of H1-H2 contour, there does seem to be a difference in raw H1-H2 in that ejectives in word-medial position have very high mean values, even more so than plain stops.

Figure 5: Mean H1-H2 across the first (1), second (2), and third (3) thirds of the following vowel. left panel = word-initial stops, right panel = word-medial stops.



4. DISCUSSION

The first research goal was investigating what acoustic characteristics distinguish plain and ejective stops. As summarized in Table 3, the findings indicated that these include release duration and vowel phonatory measures, but not necessarily burst intensity. This is similar to what [13] found for word-initial and word-medial stops in Georgian, where release duration, F0 perturbation, and H1-H2 but not burst intensity significantly distinguished ejective from aspirated and voiced stops. Similar results were also found in other studies [9].

Table 3: Summary of findings

	Initial	Medial	Final
Release dur.	T’>T	T’>T	T’>T
Burst int.	T’=T	T’=T	T’=T
F0 pert.	T’>T	T’>T	–
H1-H2 pert.	T’<T	T’<T	–

As for burst intensity, it may be that there is a difference between ejective and plain stops, but that it is not be captured by measures of mean (or max) intensity. Learners of Hul’q’umi’num’ impressionistically report that ejectives sound ”louder”, but perhaps a more dynamic measure such as change in intensity over time, would better capture the characteristic ejective burst that they attempt to describe.

The second research goal was to look at variation across different positional contexts. Findings indicated that ejectives were longer in word-initial position than word-medial ejectives, and suggested they were followed by higher F0 and lower H1-H2. Some of these differences may be associated with stress, as word-initial vowels are often stressed in Hul’q’umi’num’. More data would be needed to tease this apart, but given that higher F0 and greater duration are common correlates to stress across the world’s languages, it is not unreasonable to hypothesize that stress is playing a role.

Word-final ejectives were interesting in that they were essentially only captured by release duration within the measurements examined in this paper. Their very long releases in which the glottal release is often audible were quite distinctive, but were inconsistently present in some speakers, and it remains to be seen whether they would persist in running speech. Perhaps other correlates such as closure duration, burst spectral measures, or differences of phonation or formants in the preceding vowel may help distinguish word-final ejectives.

Overall this study found that the acoustic correlates of ejectives are not necessarily the same across speakers or word positions. These differences can be attributed to the timing of the glottal and oral events, which is what motivated [5]’s “strong” vs. “weak” ejectives where the creaky characteristics of vowels following ejectives are due to a delayed glottal release into the vowel onset. Word-finally, the creaky voice correlates are missing, but the glottal release may be present. This leads to the questions of which correlates are essential in which contexts, and how people can learn to produce these sounds in a native-like way across contexts. This is something very important in a population with few speakers, where the learners are the future speakers and teachers of the next generation. Future research will use this study’s recordings to conduct perception experiments to attempt to determine which acoustic correlates L1 and L2 speakers use as perceptual cues to distinguish the sounds.

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