DENE STOP CONTRASTS: DATA FROM DÉLĮNĘ SLAVEY

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ABSTRACT

This paper presents the results of an acoustic study of stop contrasts in Délı̨nę Slavey, a Dene (Athabaskan) language with a three-way laryngeal contrast. Stops in 8 speakers were measured. In addition to durational differences between the stops, burst intensity was found to be important for distinguishing aspirated stops from plain and ejective stops, and coarticulatory effects on the following vowel were found to be important for distinguishing ejective stops.

Délı̨nę Slavey has stop contrasts similar to those of a number of other Dene languages. The languages varied the most in their realization of ejective stops, but there were consistent patterns: ejectives were never longer than aspirated stops or shorter than plain stops and they were always, among the stops, followed by vowels with the most creaky voice and the slowest intensity rise.

Keywords: acoustic phonetics, Dene (Athabaskan), stop contrasts, ejectives

1. INTRODUCTION

Dene (Athabaskan) languages are known for their three-way laryngeal contrast between ejective, aspirated, and plain stops and affricates. Previous research on Dene stop contrasts [14] has primarily focused on durational properties of the stops.

The goal of this paper is twofold. The first goal is to provide a novel phonetic description of stop contrasts in Délı̨nę Slavey, the variety of North Slavey (Dene) spoken in Délı̨nę, Northwest Territories (NT), Canada, to determine how duration, intensity and coarticulation on a following vowel differentiate between aspirated, ejective, and plain stops in the language. The second goal is to situate these findings with those for other Dene languages in order to summarize what is known about Dene stop contrasts, not just in their durational properties but in their acoustic spectral properties as well. Given the cross-linguistic acoustic variation found in ejective stops [11, 18], determining what patterns emerge across the language family in how laryngeal stop contrasts are realized acoustically could provide important insights into whether there exists a prototypical Dene ejective.

2. METHODS

2.1. Participants

10 (6 male, 4 female) native speakers of North Slavey from Délı̨nę NT, were recorded for this study, but 2 speakers (1 male, 1 female) were excluded from the results due to background noise and small numbers of tokens. Participants were 54-69 years old (M = 62) and chosen as representative Délı̨nę speakers of their age group. All speakers also spoke English as a second language. No speech or hearing impairments were reported.

2.2. Procedures

A word list was created, containing at least three words for each stop and affricate (see Table 1) in word-initial and word-medial intervocalic positions. All of the consonants were in stem-initial position, either word-initial or following a prefix. Vowel quality was not controlled for; however, in general, there were equal numbers of front and back vowels following each consonant.

Table 1: North Slavey stops and affricates [15]

	Labial	Alveolar	Lateral	Post-alveolar	Velar	Labio-velar	Glottal
plain	p	t ts	tɬ	tʃ	k	(k^{w})	ʔ
aspirated		t^{h} ts^{h}	$tɬ^{h}$	$tʃ^{h}$	k^{h}	k^{wh}	
ejective		t’ ts’	tɬ’	tʃ’	k’	k^{w}’	

Participants were recorded in Délı̨nę by a native speaker interpreter and a research facilitator. They were given the English translation of each word on the word list and asked to say the Délı̨nę Slavey word. If a participant could not think of the translation of the word, it was given to them and if they were still unfamiliar with the word, it was skipped or replaced with another word containing the same sound in the same environment.

Each word was spoken between one and four times (five speakers had 1-2 repetitions and five speakers had 4 repetitions). The recordings were done using an Edirol R09 and a Zoom H4n digital recorder, both of which had built-in microphones.

2.3. Analysis

This study examined all alveolar and velar stops from the word list: /tʰ, t', t, kʰ, k', k/. Altogether 1,466 alveolar and velar stops (between 69 and 178 tokens for each consonant in each position) were annotated in Praat [2], and measurements of voice onset time (VOT), burst intensity, F0 perturbation, spectral tilt, and rise time were made.

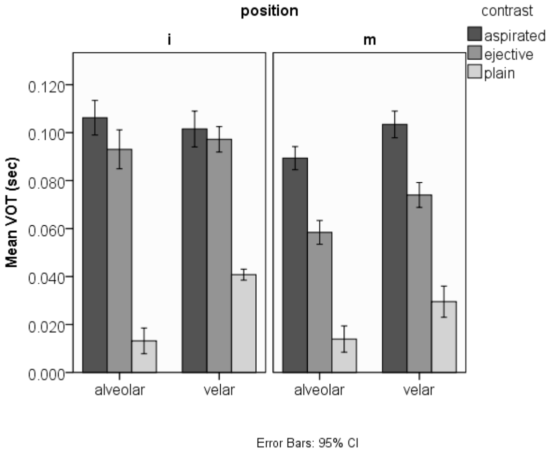
Statistics were done in SPSS [8] in the form of repeated measures ANOVAs for each of the measurements. Laryngeal contrast (aspirated, ejective, plain), place of articulation (alveolar and velar), and position (word-initial and word-medial) were set as within-subject factors, and gender (male and female) as a between-subject factor. Dependent variables were the acoustic measurements and each data point was an average of two or more tokens for each consonant in each position for each speaker. The p value was set to 0.05, and Bonferroni post-hoc tests were used for the three-way laryngeal contrast.

3. RESULTS

3.1. Duration

The duration of the stop releases was measured as VOT, the interval between the beginning of the stop burst and the onset of voicing. A significant effect of laryngeal contrast was found on VOT ($F[2, 12] = 88.781$, $p<.001$). Plain stops had shorter VOT than aspirated ($p<.001$) and ejective stops ($p<.001$). Their bursts led immediately into the following vowel, whereas ejective and aspirated stops both generally had a delay between the burst and vowel. For ejective stops, this delay consisted of a period of silence, but for aspirated stops, it was a period of aspiration, which for at least three speakers, was pronounced as a fricative release [x].

Figure 1: Mean VOT (sec) in word-initial and word-medial positions by laryngeal contrast



Délı̨nę Slavey stops were found to follow the universal tendency whereby velar stops have longer VOT than alveolar stops ($F[1, 6] = 7.830$, $p=.031$). This was especially true for plain stops ($F[2, 12] = 4.505$, $p=.035$).

Although aspirated stops had significantly longer VOT than ejective stops ($p=.005$), there was also an effect of position on VOT ($F[1, 6] = 45.637$, $p=.001$). Stops were longer in word-initial position, but, as seen in Figure 1, ejective stops in particular differed in length between word-initial and word-medial positions ($F[2, 12] =11.594$, $p=.002$).

3.2. Burst Intensity

Burst intensity was measured following [17] as the maximum intensity of the stop burst (relativized by subtracting against the maximum intensity of the following vowel). There was a significant effect of laryngeal contrast on relative burst intensity ($F[2, 12] = 27.516$, $p<.001$). Aspirated stops had quieter bursts than ejective ($p=.001$) and plain stops ($p<.001$) by about 4-7 dB. There was no significant difference in the intensity of ejective and plain stop bursts ($p=1.000$). However, a significant interaction between contrast and place of articulation ($F[2, 12] = 15.973$, $p<.001$) indicated that at the alveolar place of articulation ejective stops had quieter bursts than plain stops whereas at the velar place of articulation, plain stops had quieter bursts than ejective stops.

3.3. Effects on vowel

3.3.1 Pitch (F0)

F0 perturbation (mean F0 in the onset 30 ms - mean F0 in the mid 30 ms) was calculated following [19] in the vowels following the stops to measure the coarticulatory effects of the stops on pitch. Positive F0 perturbation values indicate raised F0 at the onset of the vowel whereas negative values indicate depressed F0 at the onset of the vowel.

A significant effect of laryngeal contrast on F0 perturbation was found ($F[2, 12] = 11.348$, $p=.002$). Although F0 perturbation values were generally all positive, F0 following ejective stops was not as raised as following aspirated stops ($p=.002$) and tended to be less raised than following plain stops as well, though this did not reach significance ($p=.089$). No significant difference in the F0 perturbation of aspirated and plain stops was found ($p=.539$).

An interaction between contrast and gender was also found to have a significant effect on F0 perturbation ($F[2, 12] = 6.230$, $p=.014$). As shown in Figure 2, aspirated and plain stops having higher initial pitch than ejectives is much more pronounced for female speakers and probably not significant for male speakers.

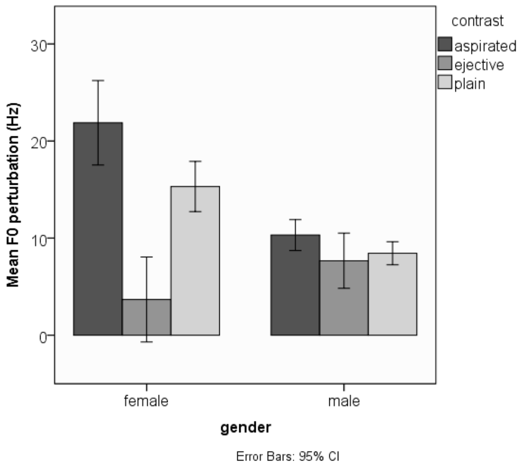


Figure 2: Mean F0 perturbation (Hz) in female and male speakers by laryngeal contrast

3.3.2. Phonation

Spectral tilt, measured as the difference in amplitude between the first (H1) and second (H2) harmonics of a vowel (H1-H2), was measured with a VoiceSauce imitator script [16] to determine the coarticulatory effect of the stops on vowel phonation. Creaky voice correlates with low H1-H2 values, breathy voice correlates with high H1-H2 values, while modal voice has intermediate values [5, 10].

Laryngeal contrast had a significant effect on H1-H2 values in the first third of the vowels (F[2, 12] = 11.709, p=.002). Ejective stops had negative H1-H2 values indicative of creaky voice that were significantly lower than those of aspirated stops (p=.001). Aspirated and plain stops did not differ significantly in H1-H2 (p=.577). They were both followed by vowels with positive H1-H2, suggesting that the vowels were produced with modal or breathy voice.

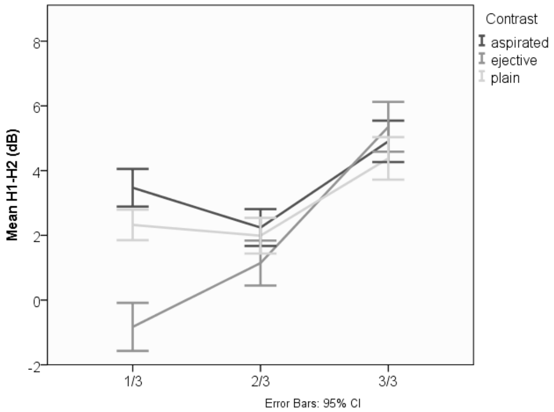


Figure 3: Mean spectral tilt (dB) in each third of the vowel by laryngeal contrast

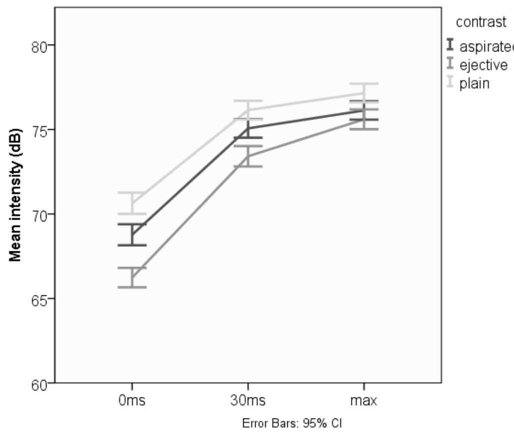
The difference between spectral tilt at the beginning of the vowel and in the middle of the vowel also proved to be significant (F[2, 12] = 6.296, p= .013). The spectral tilt of ejective stops, increased and those of aspirated and plain stops decreased so that the vowels differed little from one another in phonation, suggesting that they converged onto modal voice. This is illustrated in Figure 3.

3.3.3. Intensity rise time

Rise time was calculated in the vowels to determine the coarticulatory effect of laryngeal stop contrasts on vowel intensity. It was measured following [19] as the difference (in dB) between the intensity peak of the vowel and the intensity at 30 ms into the vowel (maximum intensity - intensity at 30 ms). The greater the difference between the intensity peak and the intensity at 30 ms, the slower the intensity rise in the vowel.

A significant effect of laryngeal contrast on rise time (F[2, 12] = 6.764, p=.011) was revealed by Bonferroni post-hoc tests not to be significant. However, there was still a trend towards ejective stops having a slower rise in intensity than aspirated (p=.070) and plain stops (p=.147). Examining individual results, two speakers may be responsible for the non significant post-hoc tests as, unlike the other speakers, their mean rise time values and error bars for all three laryngeal contrasts overlapped.

Figure 4: Mean intensity (dB) in vowels at 0 ms, 30 ms, and the point of maximum intensity by laryngeal contrast, averaged across all speakers



All speakers except for the two with overlapping rise time values had lower initial intensity following ejectives that nonetheless ended up reaching nearly as high of intensity peak as following aspirated and plain stops. Therefore, one explanation for the slightly slower intensity rise following ejectives is that intensity starts out lower and rises more slowly because it must rise slightly more in dB.

4. DISCUSSION

In Délı̨nę Slavey, plain stops are distinct from other stops in their short VOT, aspirated stops are distinct in their long VOT and quiet stop bursts, and ejective stops are distinct in that they elicit less raised pitch, slower intensity rise, and creaky voice on the vowels following them, and in that they are intermediate in length between aspirated and plain stops in word-medial position. This section will discuss how these patterns compare to findings in other Dene languages, as summarized in Table 2.

Plain and aspirated stops pattern similarly across Dene languages, including Délı̨nę Slavey, in being the shortest and longest stops in the languages, respectively. These results corroborate with the findings of [14], as does the finding that some Délı̨nę Slavey speakers pronounced aspirated stops with the [x] releases thought to be characteristic of Dene aspirated stops (see [14]).

Ejective stops vary across and within the languages in whether they are as short as plain stops, as long as aspirated stops, or somewhere in-between. [14] suggests that this is evidence that Dene languages have two types of ejectives, strong ejectives with long VOT and weak ones with short VOT. In Délı̨nę Slavey, these two types of ejectives appear to be conditioned by word position, since ejectives are shorter in word-medial position than word-initial position. [12] found a similar conditioning in Hän Athabaskan where ejectives are longer in stems than in prefixes. While prosodic and morphological conditioning of length differences in Dene ejectives should be investigated further to determine whether these patterns are language-specific or not, it is important to note that the length differences in ejectives do not seem to correlate with differences in vowel coarticulation and burst intensity, as claimed to be the case by [11].

The way F0 perturbation interacts with laryngeal stop contrasts varies across languages and speakers. It seems slightly more common for F0 following ejectives to be lower than following pulmonic stops, but so many patterns are attested that it cannot be said that F0 is a defining property of Dene laryngeal stop contrasts. Patterns seem to be speaker-specific, though Délı̨nę Slavey results suggest that gender can also be a factor.

In the languages in Table 2, ejective stops are always among those followed by vowels where the initial portion contains the most creaky voice. As [4] notes, this is the case even for ejectives that are not followed by vowels with visible creak. This may be a feature of Dene ejective stops or of ejective stops more generally, as a reflex of the closure of the vocal folds that occurs during the production of ejectives. Table 2 also suggests that slower rise time may be a feature of Dene ejectives, or at least Northern Dene ejectives, as Navajo ejectives have been reported to be followed by vowels with a fast intensity rise [18].

For lack of prior investigation, the importance of burst intensity in distinguishing Dene stop contrasts is still unknown; however, it may prove fruitful to examine burst properties in Dene stops more closely since Délı̨nę Slavey aspirated stop bursts were found to be quieter.

While aspirated and plain stops can be distinguished from one another by length alone, the variable length of Dene ejective stops suggests that the creaky voice and slow intensity rise time are important cues to Dene ejectives. This finding is significant given the cross-linguistic variability noted in ejectives: despite cross-linguistic differences, it seems that ejective stops in the same language family are realized similarly and contrast with pulmonic stops in similar ways.

Table 2: Acoustic properties of laryngeal stop contrasts in Dene languages (T’ = ejective, T = plain stop, T^h = aspirated stop, comma = not significantly different from; > = greater than)

	VOT	F0 at vowel onset	creaky phonation at vowel onset	intensity rise time of vowel
Navajo, Apachean [13]	T^h > T’ > T (V_V)	-	-	-
Western Apache, Apachean [4, 6]	T^h > T’ > T	T > T’	T’ > T	-
Hupa, Pacific Coast [3, 4]	T^h, T’ > T	T > T’ (1/2) T’ > T (1/2)	T’ > T	-
Witsuwit’en, Northern [19]	T^h > T’, T (7/11) T^h > T’ > T (1/11) T^h, T’ > T (3/11)	T^h, T > T’ (4/11) T^h, T, T’ (6/11) T’ > T^h, T (1/11)	T’ > T, T^h (3/11) T’, T, T^h (8/11)	T^h, T > T’ (9/11) T^h > T, T’ (2/11)
Tsilhqut’in, Northern [7]	T^h, T’> T	T^h, T > T’	T’ > T, T^h	T^h, T > T’
Deg Xinag, Northern [8]	T^h > T’ > T	T^h > T > T’ (3/7) T’, T > T^h (1/7) T > T’, T^h (3/7)	T’ > T, T^h	T^h, T > T’
Délı̨nę Slavey, Northern	T^h , T’ > T (#_) T^h > T’ > T (V_V)	T^h, T > T’	T’ > T, T^h	T^h, T,/> T’

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