Production and perception of ejective stops in Hul'q'umi'num' and Q'anjob'al

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INTRODUCTION: This study presents production and perception experiments from two languages, Hul'q'umi'num' (Coast Salish) and Q'anjob'al (Mayan), which have been impressionistically associated with typologically different strong and weak ejectives, respectively, as described in [1] and [2]. No other research has systematically investigated the perceptual cues to ejectives, and so a major contribution of this work is to examine how the acoustic dimensions which characterize ejectives in production are used by listeners in perception of the ejective – plain stop contrast. The findings also address whether there are differences across the languages in production or perception which may pattern along [1] and [2]'s typological classification of languages' ejectives as strong and weak.

PRODUCTION: Acoustic analysis was done for each language separately to determine how ejectives are characterized as opposed to plain stops in each language and the extent to which their acoustics aligns them as strong or weak.

Methodology: 9 L1 speakers of Hul'q'umi'num' (aged 65-87), and 25 of Q'anjob'al (aged 21-61) were recorded reading a word list of plain - ejective (near-)minimal pairs in their language covering all stop places of articulation across three word positions (word-initial, intervocalic, word-final). Annotations were made in Praat (2717 stop tokens for Hul'q'umi'num' and 4754 for Q'anjob'al) and measurements taken based on [3]. Linear mixed effects models were done in R to determine for each acoustic measurement whether ejectives significantly differed from plain stops.

Results*:* As summarized in Table 1, Hul'q'umi'num' ejectives typically had long releases with a period of silence after loud bursts, characteristics of strong ejectives. Plain stops were aspirated and followed by vowels with more raised onset F0 and higher onset H1-H2 than ejectives', but a similar amount of jitter suggesting breathy voice on them more so than the creaky voice following ejectives that is characteristic of weak ejectives. Q'anjob'al ejectives were equally likely to have or not have a period of silence following the burst (characteristics of strong vs. weak ejectives), and except word-finally were longer than plain stops, which were unaspirated. Ejective bursts were similar in intensity to plain bursts and following vowel onsets had lower H1-H2, greater jitter, and lower F0 for ejectives which suggests the presence of creaky voice, a characteristic of weak ejectives. Neither language's ejectives fit perfectly into the strong – weak typology, but on average Hul'q'umi'num' ejectives had more strong characteristics and Q'anjob'al more weak.

PERCEPTION: Forced choice identification tasks with language-specific stimuli were given to listeners of each language. Q'anjob'al listeners had an additional task, one of the Hul'q'umi'num' stimulus sets, to more directly compare perception without differences in stimuli acoustics.

Methodology*:* Participants were 25 L1 listeners of Q'anjob'al and 26 listeners of Hul'q'umi'num', of which 7 were L1 – Hul'q'umi'num' only has about 35 L1 speakers and so for this reason L2 speakers were included. The stimuli were minimal pairs manipulated along acoustic dimensions found to characterize ejectives in production and cross-spliced to make all combinations: for Hul'q'umi'num' there were 4 bursts (2 burst types: baseline ejective and baseline plain and 2 intensities: 40 dB and 50 dB), 5 releases (0 ms/burst only, 50 ms silence, 50 aspiration, 120 ms silence, 120 ms aspiration), and 4 vowels (2 vowel types: baseline ejective and plain and 2 F0 patterns: onset raised and onset lowered by 0.286 barks). Q'anjob'al stimuli had the same manipulations except no aspirated releases. Logistic mixed-effects regression models were performed in R on the 6160 responses from Hul'q'umi'num' listeners, 4008 responses from Q'anjob'al listeners to their own language stimuli and an additional 2000 Q'anjob'al responses to Hul'q'umi'num' stimuli to determine whether listeners' percent of ejective responses differed across levels of the dimensions.

***Results**:* Listeners from both languages were very similar in perception: they used as primary cue to the perception of ejectives the presence of silence after the burst. 75% of Hul'q'umi'num' stimuli with silence were perceived as ejective by Hul'q'umi'num' listeners, 95% of Q'anjob'al stimuli by Q'anjob'al listeners, and 94% of Hul'q'umi'num' stimuli by Q'anjob'al listeners. In contrast, about 50% of stimuli with no silence or 0 ms of post-burst release duration were perceived as ejective for each. Properties of the stop burst and coarticulation in the following vowel were secondary cues in both languages, that listeners relied on more in the stimuli with 0 ms of post-burst release duration, the results for which are presented in Table 2. One difference between the languages is that Q'anjob'al listeners seemed more sensitive to baseline burst type and vowel type.

DISCUSSION: The results did not find complete correspondence between production and perception. Q'anjob'al listeners used silence in the release as a cue to ejectives slightly more despite having a lesser percent of releases with silence in production. Both languages used burst intensity to a similarly small extent in perception despite Hul'q'umi'num' but not Q'anjob'al's ejectives' bursts being louder than plain bursts in production. Neither language used lowered vowel onset F0 as a cue to ejectives even though ejectives differed from plain stops in this in production.

The overall similarities in perception suggest that differences in ejective stop production may not relate straightforwardly to any typological differences across languages. One explanation which contextualizes the findings is sociolinguistic factors related to language context: Hul'q'umi'num' participants were teachers and students with varying levels of fluency at a language school aimed at language revitalization. Strong ejective characteristics in production may reflect a shift in the stop system due to hyperarticulation in the context of language teaching [4] and less robust perceptual cue usage may reflect variation in production in this language context.

Table 1. Summary of acoustic results. > = "significantly greater than"; , = "not significantly greater than"; ej = ejective; pl = plain; #_ = word-initial; V_V = intervocalic; _# = word-final, asp = aspiration, sil = silence, w/ = with, w/o = without

Acoustic dimension		**Hul'q'umi'num'**	**Q'anjob'al**
Release type (% of tokens by stop type with post-burst release content)	Plain	60% w/ asp, 37% w/o	13% w/ asp, 69% w/o
	Ejective	62% w/ sil, 28% w/o	43% w/ sil, 45% w/o
Release duration (from onset of burst to onset of voicing or offset of release for _#)		ej > pl (#_) ej, pl (V_V, _#)	ej > pl (#_ and V_V) pl > ej (_#)
Burst intensity (maximum intensity in dB)		ej > pl	pl, ej
Following vowel onset phonation (normalized against midpoint)	H1-H2	pl > ej	pl > ej
	Jitter	ej, pl	ej > pl
Following vowel F0 perturbation		pl > ej	pl > ej

Table 2. Summary of % ejective responses for Hul'q'umi'num' and Q'anjob'al listeners for each manipulated dimension in stimuli with 0 ms of post-burst release duration. > = "significantly greater % ejective responses than"; , = "not significantly greater % ejective responses than"; (%) is the difference in % ejective response between the first and second level (a higher % = more cue usage)

Dimension	**Own-language stimuli**		**Shared Hul'q'umi'num' stimulus set**	
	Hul'q'umi'num'	**Q'anjob'al**	**Hul'q'umi'num'**	**Q'anjob'al**
Burst type	ej > pl (10%)	ej > pl (35%)	ej > pl (13%)	ej > pl (32%)
Burst intensity	loud > quiet (9%)	loud, quiet (4%)	loud > quiet (9%)	loud > quiet (10%)
Vowel type	ej > pl (19%)	ej > pl (21%)	ej > pl (15%)	ej > pl (33%)
Vowel F0	raised, lowered (1%)	raised > lowered (5%)	lowered, raised (3%)	lowered, raised (6%)

References

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