Ejectives in Nez Perce

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Abstract
This paper discusses ejectives in Nez Perce, a Penutian language spoken in western Idaho, northeastern Oregon and eastern Washington. Using words collected in carrier phrases, VOT, burst amplitude, f0, intensity, and jitter are analyzed to provide a description of ejectives in Nez Perce. Kingston (1985, 2005) proposed a stiff/slack dichotomy for ejectives, however, researchers (Wright et al. 2002, Ingram & Rigsby 1987, Kingston 1985, Grossblatt 1997) using this typology have found great inter- and intra-speaker variation. The use of this dichotomy and a possible alternative are discussed.

1. Introduction
Ejectives are typologically common in the indigenous languages of North America (Maddieson 1984). Nez Perce, a Penutian language of western Idaho, northeastern Oregon and eastern Washington, is one such language. It is a highly endangered language with about 20 native speakers (A. Sobotta personal communication, August 30, 2010). Ejectives in Nez Perce and how Nez Perce ejectives fit into the ejective typology (Kingston 1985) is discussed. Statistical analysis will show that Nez Perce ejectives demonstrate more features of slack ejectives than stiff ejectives.

1.1 Previous Research
Current typological research on ejectives has led scholars to categorize these phones based on a stiff/slack distinction (Kingston 2005). Tense/lax (Ingram & Rigsby 1984) and fortis/lenis (Kohler 1984) are also terms that have been used. Kingston, however, uses the terms stiff/slack in his 2005 paper because the terms describe the state of the vocal folds during the production of the ejectives whereas tense/lax and fortis/lenis describe the muscular tension of the vocal tract rather than just the vocal folds. In an effort to describe how ejectives vary cross-linguistically the descriptions of Lindau (1984) and Kingston (1985; 2005) have been used to develop a typology to describe ejectives. Stiff ejectives are typified by a long VOT, intense burst amplitude, high f0, modal phonation, and fast (intensity) rise time[1] in the following vowel. Slack ejectives, however, have a short VOT, normal[2] burst amplitude, low f0, creaky phonation, and slow (intensity) rise time in the following vowel.

VOT, burst amplitude, f0, voice quality, and rise time (intensity) are all interconnected by the articulatory movement during the production of an ejective. The larynx raises, which also compresses the air during an ejective and causes the f0 of the following vowel to raise or lower (Kingston 1985). Slack ejectives can affect the phonation of the following vowel, causing it to become creaky (Lindau 1984: 154). Lindau saw this difference in creak between Navajo and Hausa. To measure creaky voice one uses a computer program, such as PRAAT (Boersma & Weenink 2010), to determine the jitter as described by Ladefoged (2003: 169-177). As will be mentioned in the results section, jitter measurements require sustained periods of voicing. Age can affect the amount of jitter which will be seen later (section 3.5). Wilcox & Horli (1980) studied twenty young adult males (mean age 23.3) and twenty older adult males (mean age 69.8). The older adults displayed greater jitter than the younger adults. Creaky phonation, measured using jitter, affects the intensity and fundamental frequency, lowering both of them (Gordon & Ladefoged 2001). All of these features -- creaky phonation, lowered f0, and slow rise time -- are associated with slack ejectives (Kingston 2005). Stiff ejectives, on the other hand, have modal or tense phonation and fast rise time (Kingston 2005). Modal voice has the most consistent vocal fold phonation and therefore less jitter and greater intensity (Ladefoged 2003: 179).

In both stiff and slack ejectives the vocal folds are held closed, however for a stiff ejective the oral cavity is “maximally contracted to compress the air inside it” (Kingston 2005: 146). The greater compression causes a more intense burst. There is also a long closure of the vocal folds. Slack ejectives on the other hand, do not occur with the oral cavity maximally contracted, the vocal folds are not closed for a long period of time (as compared to stiff ejectives), and the burst is not as intense as in stiff ejectives. (Kingston 2005)

All of the features discussed above are summarized in Table 1.

Table 1 This table shows how stiff and slack ejectives vary cross-linguistically. Based on Wright et al. (2002).

	Stiff	Slack	
VOT	Long	Short	Lindau (1984), Kingston (2005)
Burst Amplitude	Intense	Normal	Kingston (1985, 2005)
f0	High	Low	Kingston (1985, 2005)
Voice Quality	Modal or Tense	Creaky	Lindau (1984), Kingston (2005)
Rise Time (Intensity)	Fast	Slow	Lindau (1984), Kingston (2005)

Kingston (1985) was preceded by work by Lindau (1984). In her work Lindau discusses many of the same phonetic parameters of stiff and slack ejectives. Although Lindau does not posit any terminology or dichotomy as proposed by Kingston, her results do show that there are different types of ejectives. She discusses the individual aspects: VOT and aperiodicity of the vowel. Multiple researchers (Wright et al. (2002), Witsuwit’en; Kingston (1985), Tigrinya; Lindau (1984), Navajo and Hausa; Ingram & Rigsby (1987) Giksan) have used this typology or parts of the typology to study and describe ejectives in various languages.

Some researchers find that the ejectives in the languages of study fit the typology better than other ejectives. Lindau (1984) finds great inter-speaker variation in Hausa, a language that has been described as having slack ejectives. Four of the twelve speakers realize the velar ejective as a voiceless unaspirated velar and some realize it as a voiced velar. All Navajo speakers, however, realize the velar ejective as a velar ejective. Giksan ejectives (Ingram & Rigsby 1987) also display inter-speaker variation. This may, however, be due to language change as the two speakers in the study are mother and son.

Regardless, the ejectives produced by each speaker do not typify either the slack or the stiff ejectives. Giksan ejectives are more similar to slack ejectives than stiff ejectives. Sahaptin, the language most closely related to Nez Perce, has been described as having stiff ejectives (Grossblatt 1997). In a study of one speaker, Grossblatt finds that Sahaptin ejectives demonstrate long VOT, raised f0, and quick vowel onset (67). These are features that tend to group with stiff ejectives. He also points out, however, that there is a lot of variation. Kingston (1985) found in a study with three people, that Tigrinya displays stiff ejectives but there is also variation, especially in f0. Wright et al. (2002) also finds great inter-speaker variation in Witsuwit'en. In addition they question the use of a strict binary distinction (the ejective is either stiff or the ejective is slack) to describe ejectives.

Wright et al. (2002) are not the only researchers to discuss the fact that their data do not fit the typology well. Grossblatt (1999) also discusses the great variation in his data. The variation in data, seen in all the previously mentioned studies, is found both between speakers and within speakers. All of the researchers previously mentioned state that their data shows variation, however, only Wright et al. and Grossblatt question the stiff/slack typology. Grossblatt suggests that stiff and slack may be "best viewed as arbitrary complexes of phonetic characteristics, and not as sets of necessarily co-occurring features" (1999: 68). He then concludes that the there would be no true stiff or slack ejectives, just ejectives that exemplify more or less of the features of a stiff or a slack ejective. Wright et al. (2002) suggests a three dimensional continuum. The three dimensions would be longitudinal tension (cricothyroid muscle and vocalis), medial compression (interarytenoid, lateral cricoarytenoid, and lateralis), and larynx raising. Ejectives would fall along this continuum rather than using just the dichotomous stiff/slack distinction. This three dimensional system would account for the fact that people perceive ejectives as stiff or slack (Wright et al. 2002), but they are produced with a more complex underlying system. In addition it would be a useful tool for describing ejectives, however, it would also be difficult to measure and study as it would require more equipment than just an audio recorder, which is not feasible for all field recording situations.

1.2 Previous Research on Nez Perce Ejectives

Wright et al. (2002) suggest in their study that Nez Perce has stiff ejectives based on Aoki's (1970) study, however this must be viewed as a preliminary classification based on the limited information available in Aoki (1970). Aoki discusses the duration of silence after the release (about 0.1 seconds) and he states that the f0 of the following vowel is lowered. The long period of silence after the release is indicative of a stiff ejective, but the lowered f0 is indicative of a slack ejective. Based on these two factors no conclusion can be drawn about the typology of Nez Perce ejectives.

In their sketch grammar of Sahaptin, the most closely related language to Nez Perce, Rigsby and Rude (1996) describe Sahaptin ejectives as "relatively [stiff] as compared with Nez Perce. […] On the whole, the glottalized obstruents are strongly articulated and easily heard as compared with the more [slack] pronunciation of cognates among the Nez-Perce-speaking Cayuse around Pendleton, Oregon" (671). Their description leads one to believe Nez Perce does not have stiff ejectives but instead slack ejectives. As describing the differences between Nez Perce and Sahaptin was not the purpose of their paper they do not provide the acoustic data necessary to determine if Nez Perce does indeed have slack ejectives.

Phinney (1934) mentions ejectives and glottal stops in the introduction to his book *Nez Perce Texts*. He writes that "the glottalized sounds are not acoustically severe" (xi). This implies that Nez Perce ejectives may be slack. Phinney's comments may have been in comparison to Sahaptin. Both Grossblat (1999) and Rigsby and Rude (1996) state that Sahaptin ejectives are stiff.

The current paper examines Nez Perce ejectives using the features outlined in Table 1 to determine how they fit into the stiff or slack typology. The results will also be used to discuss the use of a binary stiff/slack distinction or the use of a more fine-grained description of ejectives.

2. Method

The research and recordings for this paper were conducted in Lewiston and Lapwai, Idaho in the summer of 2009. The word list used for this study was composed using Aoki's Nez Perce Dictionary (1994) and with the help of native speakers of Nez Perce. Three elders were recorded in quiet rooms using a Zoom H4n recorder with an AKG C555L head-mounted microphone with AKG MPA VL adapter. All three elders are women who are identified as FS1, FS2, and FS3 (FS=Female Speaker) ages 68, 73, and 75. All three speakers were used for every acoustic analysis except for jitter.

Words chosen to be recorded were those that exemplified each obstruent (ejective and aspirated) and vowel (all vowels, both regular and long length) combination ([p, p', t̪, t̪', ts, ts', k, k', q, q'], [i, æ, a, o, u]). Almost all combinations recorded were in stressed positions, however, to obtain as many combinations as possible some unstressed exemplars were used. All obstruent-vowel combinations were recorded in word-initial and word-medial positions. The word-initial and word-medial combinations were paired to form the within-subjects variables.

The word list, consisting of 172 words, was read in five parts, with a break in between each section. Before recording the word list each elder read over the list. Any unfamiliar words were removed from the list.

Following the methods of Wright et al. (2002) f0, jitter, and intensity were measured twice using thirty millisecond windows at 30 milliseconds into the vowel and at the vowel peak. The beginning of the vowel was measured at the first significant zero crossing.[3]

These recordings were recorded at 44.1 kHz 16 Bit. Praat was used to analyze all recordings. Statistical analysis was conducted using the statistics package PASW. Two-way repeated measures ANOVAs were used with an alpha level of 0.05. The independent variables were the location of the token, word-initial or word-medial. The dependent variables were: voice onset time, burst amplitude, rise time, f0 and jitter.

All data was checked for heteroscedasticity, or unequal variances, in accordance with the assumptions of the analysis of variance (ANOVA) approach. If any of the variances of the group were more than double the other variances O'Brian's R was used to check if the data was indeed heteroscedastic. If it was heteroscedastic then the data was corrected using the Welch method.[4] Unless otherwise stated in the below analysis the data was not heteroscedastic. As it is uncommon to correct for heteroscedasticity in linguistics analyses, the uncorrected results for all heteroscedatic variables are provided in Appendix 1 for comparison.

3. Results

This section presents the results for each of the three speakers organized by VOT, burst amplitude, rise time (intensity), f0, and voice quality (jitter).

3.1 VOT

As can be seen in Figure 1 all three speakers show a significant difference between ejectives and plain obstruents for VOT. All speakers show that the ejective has a longer VOT than the plain obstruent. [FS1: $F(1,61)=15078.69$, $p=.005$; FS2: $F(1,50)=376.17$, $p=.033$; FS3: $F(1,56)=391.40$, $p<.001$] Data points that are more than three inter quartile ranges from mean are considered outliers. The outliers were discarded because there is a clear mean, few outliers, and previous research (Aoki 1970), which provided a baseline.

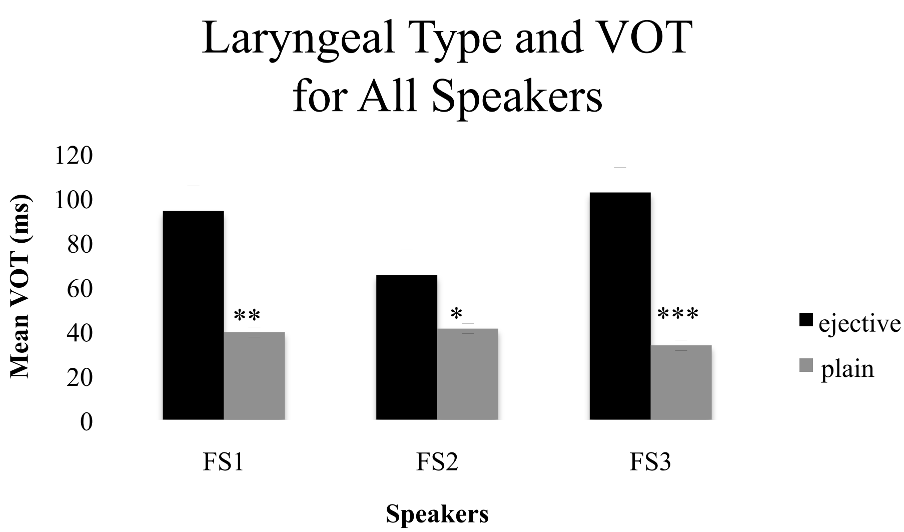

Figure 1 This figure shows the mean VOT for both ejectives and plain obstruents, collapsed across environment (word-initial and word-medial), for all three speakers. For FS1 the mean VOT for ejectives is 93.94ms and for plain obstruents is 39.39ms. For FS2 the mean VOT for ejectives is 65.07ms and for plain obstruents is 40.96ms. For FS3 the mean VOT for ejectives is 102.06ms and for plain obstruents is 33.43ms. Error bars show standard error.

The significantly longer VOT for the ejective, seen above, is indicative of a stiff ejective. This was demonstrated by all three speakers.

3.2 Burst Amplitude

The results for burst amplitude are indicative of slack ejectives for all three speakers, however, only the data, corrected of unequal variances, for FS1 and FS3 are statistically significant. [FS1: F''(1,59.0)=4.50, p=.038; FS3: F''(1,49.2)=18.95, p<.001] (For uncorrected results see Appendix 1.) The data for FS2 is not significant, however, these data followed the same pattern as FS1 and FS3.[5] [FS2: F(1,50)=2.33, p=.396] This data is detailed in Figure 2 following.

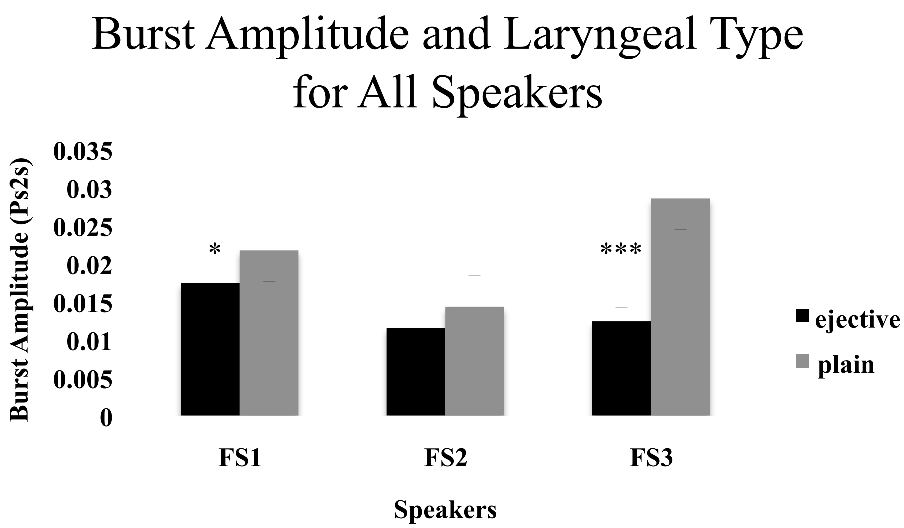

Figure 2 This figure shows the mean burst amplitude for both ejectives and plain obstruents, collapsed across environment (word-initial and word-medial), for all three speakers. For FS1 the mean burst amplitude for ejectives is 0.017Pa2s and for plain obstruents is 0.0217Pa2s. For FS2 the mean burst amplitude for ejectives is 0.011Pa2s and for plain obstruents is 0.014Pa2s. The results for these data are not significant, however, they follow the pattern of the other speakers. For FS3 the mean burst amplitude for ejectives is 0.012Pa2s and for plain obstruents is 0.029Pa2s. Error bars show standard error.

For slack ejectives the burst amplitude will be normal, or the same as the plain obstruents. FS2 demonstrated a burst amplitude for ejectives (mean=0.011Pa2s) very similar to the burst amplitude for plain obstruents (mean=0.014Pa2s). FS1 and FS3 displayed burst amplitudes that were significantly lower than those of the plain obstruents. This is indicative of slack ejectives.

3.3 Rise Time

The results for the three speakers are very different for rise time. The dependent variable is not significant for FS1; however, there is a significant interaction in the environment. (This is a difference between the word-initial and the word-medial environments.) This interaction was decomposed and the word-medial position for FS1 shows significant results. FS1 and FS3 pattern together and FS2 shows different results. FS1 and FS3 both show significant results only in the word-medial position. [FS1: F(1, 62)=183.17, p=.005; FS3: F(1, 59)=16.73, p=.015] As can be seen in Figure 3 and Figure 4 the intensity in the plain obstruents is rising faster than the intensity in the ejectives.

This is indicative of slack ejectives. FS2 does not show any significant results word initially or word medially or collapsed across those environments. [FS2: $F(1,50)=9.69$, $p=.198$] Figure 5 shows that the intensity is rising faster in ejectives than in plain obstruents for FS2. These non-significant results are indicative of a stiff ejective.

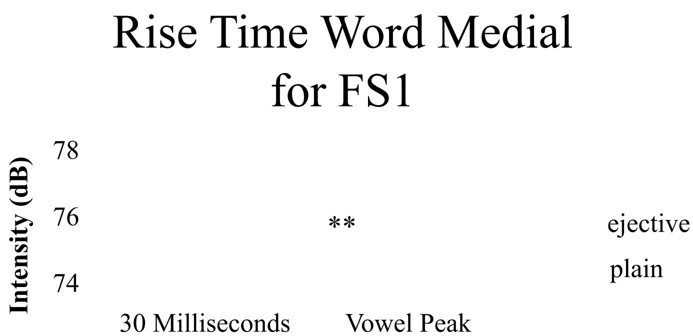

Figure 3 This figure shows the rise time or change in intensity for word-medial tokens for FS1. The horizontal axis shows the measurement locations: 30 milliseconds and at the vowel peak.

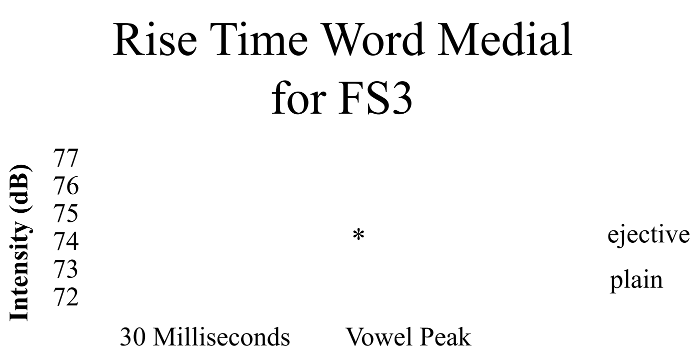

Figure 4 This figure shows the rise time or change in intensity for word-medial tokens for FS3. The horizontal axis shows the measurement locations: 30 milliseconds and at the vowel peak.

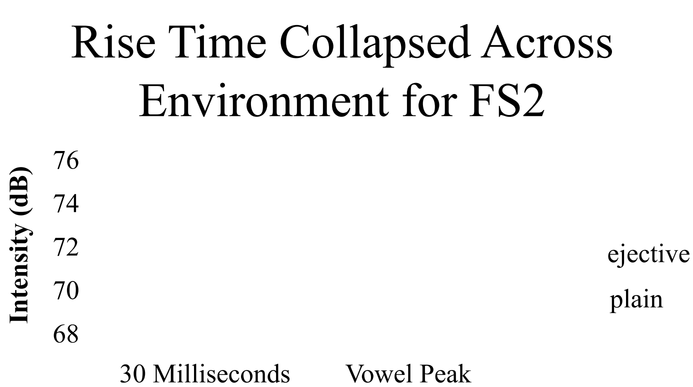

Figure 5 This figure shows the rise time or change in intensity for FS2 collapsed across environment (word-initial and word-medial). The horizontal axis shows the measurement locations: 30 milliseconds and at the vowel peak.

FS1 and FS3 both showed significant results with the intensity in the plain obstruent rising faster than that of the ejective. FS2, however, showed the intensity rising faster for the ejective than the plain obstruent indicating a stiff ejective, though these results were not significant.

3.4 Fundamental Frequency

Again FS1 and FS3 pattern together. The data for FS3 is significant (Figure 6), showing that the f0 of the vowel following the ejective is lower than the f0 following the plain obstruent. [FS3: F(1,59)=27.28, *p*=.006] FS1 patterns with FS3 and also shows that the f0 following an ejective is lower, word medially,[6] than the f0 following a plain obstruent (Figure 7). [FS1: F(1,62)=51.28, *p*=.019] These results point to a slack ejective. The results for FS2 (Figure 8) are not significant. The f0 following ejectives is, however, slightly lower than that of the f0 following the plain obstruents. This follows the pattern for slack ejectives, even though the results are not significant.

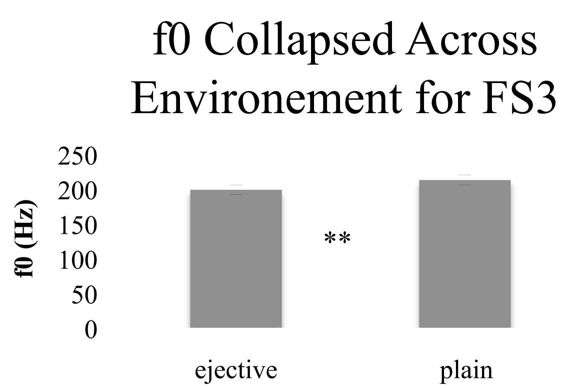

Figure 6 This figure shows the mean f0 collapsed across environment (word-initial and word-medial) for ejectives (mean=198.27Hz) and plain obstruents (mean=212.28Hz) for FS3. Error bars show standard error.

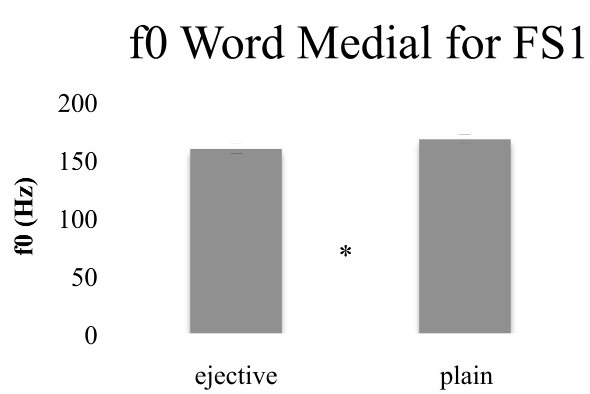

Figure 7 This figure shows the mean f0 for word-medial ejectives (mean=158.96Hz) and plain obstruents (mean=167.18Hz) for FS1. Error bars show standard error.

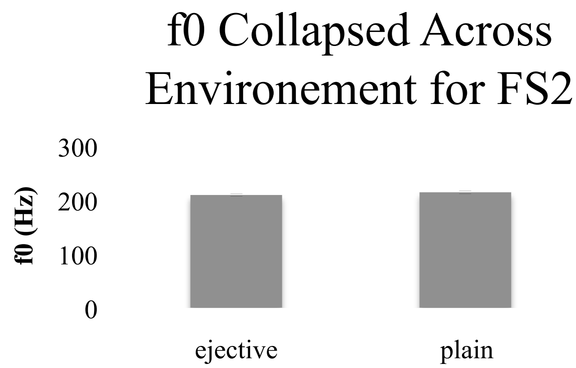

Figure 8 This figure shows the mean f0 for ejectives (mean=208.87Hz) and plain obstruents (mean=213.93Hz) for FS2. These results are not significant. Error bars show standard error.

The above results, both significant and not significant, follow the pattern for slack ejectives, with the f0 lower for ejectives.

3.5 Jitter

As was discussed in Section 1.1, jitter measurements require sustained periods of voicing. One of the participants, speaker FS2, age 75, typically dropped out of modal phonation when transitioning from a consonant of any kind to a vowel. These voice drop-outs could last for up to half the vowel. Data from FS2 will therefore be omitted from jitter analysis. As shown in Figure 9 these figures show that the ejectives for FS1 and FS3 both have more jitter than the plain obstruents.

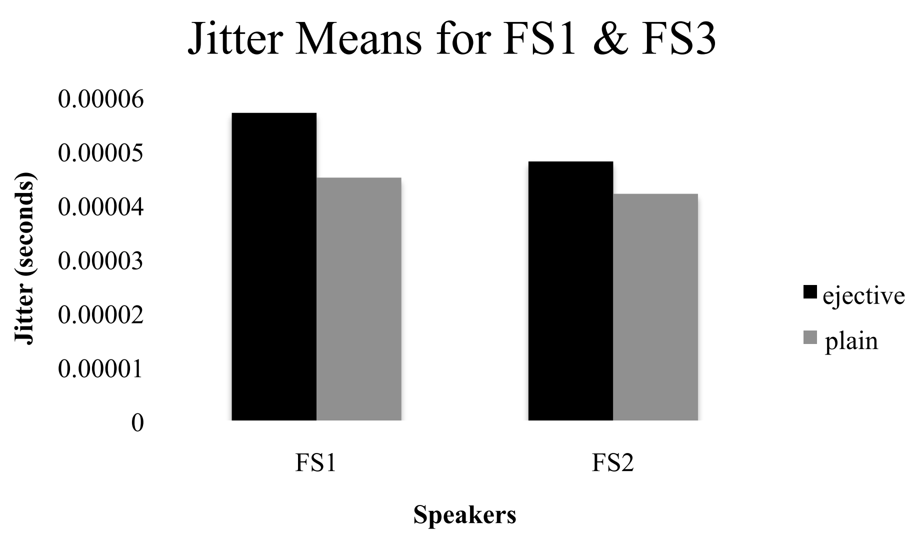

Figure 9 This figure shows the means for jitter for FS1 and FS3. For FS1 the mean for jitter for ejectives is 0.000057 seconds and for plain obstruents is 0.000045 seconds. For FS3 the mean for jitter for ejectives is 0.000048 seconds and for plain obstruents is 0.000042 seconds.

The descriptive statistics in these charts show that the data would be representative of slack ejectives because of the greater jitter in the vowels following the ejectives.

4. Discussion

The data examined in this study show that Nez Perce is a language with ejectives that demonstrate more features of slack ejectives than stiff ejectives. These results are summarized in Table 2.

Table 2 This table summarizes the features discussed in the results section. Bolded cells with * indicate $p<0.05$, ** indicate $p<0.01$, and *** indicate $p<0.001$. Cells with parenthesis indicate results that are only significant word medially. Jitter is italicized because the results in that row are based on descriptive statistics only.

	FS1	FS2	FS3
VOT	**Stiff****	**Stiff***	**Stiff*****
Burst Amplitude	**Slack***	**Slack**	**Slack*****
f0	**(Slack)***	Slack	**Slack****
Rise Time	**(Slack)****	Stiff	**(Slack)***
Voice Quality (jitter)	*Slack*	*N/A*	*Slack*

The speakers show mixed attributes of stiff and slack ejectives. It is therefore curious that these ejectives, as determined by an informal study of colleagues, are predominantly perceived as slack. This may indicate that the burst amplitudes of the ejectives, which are much lower than the plain obstruents, may override the stiff VOT and cause the ejectives to be heard as slack. All speakers display statistically significant stiff VOT. In contrast all speakers display slack burst amplitude. FS1 and FS3 show a burst amplitude for ejectives that is statistically shorter than the burst amplitude for plain obstruents. It is important to note that slack ejectives will show a burst amplitude that is normal (Kingston 1985, 2005) meaning the ejective burst amplitude will be same as the burst amplitude of plain obstruents, such as is shown by FS2. This is probably why these ejectives, despite their stiff VOT are heard as slack.

Rise time and f0 are both significant only in the word-medial position for FS1 and rise time is only significant word medially for FS3. These features are significant word medially because Nez Perce is a polysynthetic language (Aoki 1965), which would make the word-medial position a more natural position for the speakers, as polysynthetic languages have longer words. The f0 for FS2 and FS3 for ejectives is lower than for plain obstruents, however, it is only significant for FS3. FS2 deviates from the other speakers, though the statistics are not significant. The descriptives on jitter also show that ejectives for FS1 and FS3 are slack.

The above results add valuable data to the description of ejectives. As mentioned in the introduction, Kingston (1985, 2005) suggests a stiff/slack distinction to describe ejectives. Other researchers have used this dichotomy to describe ejectives in various languages. Grossblatt (1999) and Wright et al. (2002) question the use of a dichotomy both discussing the inter- and intra-speaker variation. The issue at hand is that ejectives are perceived as stiff or slack, however, they are produced with greater variation. Wright et al. (2002) propose a three dimensional continuum, however, the three dimensions (longitudinal tension (cricothyroid muscle and vocalis), medial compression (interarytenoid, lateral cricoarytenoid, and lateralis), and larynx raising) would be difficult to measure. Grossblatt (1999) writes "[stiff] and [slack] are perhaps best viewed as arbitrary complexes of phonetic characteristics, and not as sets of necessarily co-occurring features. […] Technically then, there are no [stiff] or [slack] ejectives. There are only ejectives which tend to exhibit more or fewer characteristics thought of as [stiff] or [slack]" (68). Grossblatt is correct in saying that stiff and slack are a "complex of phonetic characteristics", however, these characteristics could occur such that there could be a "truly" stiff or slack ejective.

Results of this study underscore the idea that acoustic descriptions for ejectives should recognize all of the features examined above (VOT, burst amplitude, f0, voice quality, and rise time) as they are all integral to understanding and describing ejectives. In keeping with this suggestion, I present Table 3 as an effective method to describe ejectives.

Table 3 This table is a remplate for ejective description generalized from Table 1 and Table 2.

	Speaker 1	Speaker 2
VOT	Stiff or Slack	Stiff or Slack
Burst Amplitude	Stiff or Slack	Stiff or Slack
f0	Stiff or Slack	Stiff or Slack
Voice Quality	Stiff or Slack	Stiff or Slack
Rise Time (Intensity)	Stiff or Slack	Stiff or Slack

This instrument would allow for a detailed description for each feature from Kingston (1985, 2005). After examining a language's ejectives for each feature listed in Table 1 to determine if the features represent stiff or slack ejectives, those results can be placed in a table such as Table 3. Rather than trying to collapse all of these individual results (VOT, burst amplitude, f0, voice quality, and rise time) all features are listed separately. This allows for a clearer understanding of the structure of the ejective. This will also allow for more fine-grained cross-language comparisons. Using this description will provide more phonetic information, especially due to the inter- and intra-speaker variation.

5. Conclusion

This paper discussed the ejectives of three speakers of Nez Perce using the research of Kingston (1985, 2005) to study the different features of ejectives (VOT, burst amplitude, f0, voice quality, and rise time). All three speakers were found to exhibit more features of slack ejectives than stiff ejectives. As none of the speakers showed all the attributes of either a slack or a stiff ejective, Table 3 was presented as a method to phonetically describe ejectives. This table allows the ejectives to be described by their individual features rather than a summary of the features. If an ejective shows more features of a slack ejective, but also displays some stiff features, as in the Nez Perce case, it does not have to be labeled as a slack ejective but can be described by all its individual features.

Notes

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[1] Fast and slow refer to the slope of the intensity, which is taken at 30 milliseconds into the vowel and at the vowel peak. The greater the slope the faster the rise time.
[2] The term normal is used in Kingston (1985, 2005). I understand it to mean that the burst amplitude is the same as the burst amplitude of a plain obstruent.
[3] One of the speakers, FS2, often devoiced the first part of vowels. This part of the vowel did not belong in the VOT and was therefore measured with the vowel.
[4] Howell (2010) discusses that one basic assumption of an ANOVA is homogeneity of variance or that each population in an ANOVA has the same variance (320-321). When this is not the case it can affect the results of a study, however, not correcting for heteroscedasticity does not invalidate the results of the study, it "protect[s] the analysis of variance on the means" (336). This may seem contradictory because "in practice […] the analysis of variance is a robust statistical procedure, and the assumptions frequently can be violated with relatively minor effects" (336). In other words, results that have been corrected for heteroschedasticity are more reliable.
[5] Slack burst amplitude will be normal or the same as the burst amplitude of the plain obstruents. Therefore is it not an issue that FS2 does not show a significant difference between the ejective and the plain obstruent burst amplitudes. She is also following the pattern of FS1 and FS3 because the mean for the ejective burst amplitude is lower than the mean for the burst amplitude of the plain obstruents.
[6] The between subjects variable is not significant, however, there is a significant interaction in the environment. (A difference between the word-initial and the word-medial environments.) When this interaction is decomposed, the word-medial position for FS1 shows significant results.

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Appendix 1

Uncorrected Burst Amplitude FS1: $F(1,62)=1.17$, $p=.475$
Uncorrected Burst Amplitude FS3: $F(1,57)=285.00$, $p<.000$