ACOUSTIC CHARACTERISTICS OF AYMARA EJECTIVES: A PILOT STUDY

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ABSTRACT

This study investigates acoustic characteristics of Aymara ejectives. Acoustic measurements of the Aymara ejectives were conducted in terms of the durations of the release burst, the vowel, and the intervening gap (VOT), the intensity and spectral centroid of the release burst, and H1-H2 of the initial part of the vowel. Results showed that ejectives vary with place of articulation in the duration, intensity, and centroid of the release burst but commonly have a lower H1-H2 irrespective of place of articulation.

Keywords: Aymara, ejective, VOT, release burst, H1-H2.

1. INTRODUCTION

1.1. Ejectives

Ejectives are sounds which are produced with a glottalic egressive airstream mechanism [26]. They are usually articulated with the vocal tract momentarily blocked by the tongue or the lips at some location in the oral cavity and with airstream through the nasal cavity blocked by the velum. An abrupt raise of the larynx with the glottis closed compresses the air in the vocal tract. If the vocal tract is completely closed to articulate stops, the compressed air bursts out at the release of the closure.

Ejectives occur in about 20 percent of the world's languages [24]. They are reported to be found in many languages in Africa, America, and Asia [25]. Typologically, velar ejectives are the most favored among the places of articulation [13, 17, 21, 28]. Uvular ejectives are also quite common [25]. They are reported to occur in many North American languages, such as Haida [35], Wintu [7], South Eastern Pomo [31], and most of the Salishan languages, as well as in Caucasian languages, such as Georgian [34, 37, 39, 40] and Kabardian [23]. Palatal ejectives, on the other hand, are comparatively rare when compared with the palatal plosives [25]. They are reported to occur in Kwakwala [2, 3, 14], Acoma [30], Bella Coola, and Jaqaru [15]. Bilabial ejectives are not as favored as bilabial plosives.

Comparison of velar ejectives in Hausa [18, 19, 22] and Navajo [36] showed significant cross-linguistic variation and some notable inter-speaker differences [27]. It was found that the two languages differ in the relative durations of the different parts of the ejectives, such that Navajo stops are greater in the duration of the glottal closure than Hausa ones. In Hausa, the glottal closure is probably released very soon after the oral closure and it is followed by a period of voiceless airflow. In Navajo, it is released into a creaky voice which continues from several periods into the beginning of the vowel. It was also found that the long glottal closure in Navajo could not be attributed to the overall speech rate, which was similar in both cases [27].

1.2. Aymara ejectives

Ejectives occur in Aymara, which is one of the Ande an languages spoken by the Aymara people who live around the Lake Titicaca region of southern Peru an d western Bolivia and in some communities in north ern Chile [1]. Aymara is an official language in Boli via as well as Spanish and Quechua. Some studies di scussed specific dialectal differences [5, 6], which is known to be minor. However, some differences are r eported to cause difficulty in understanding [8, 9]. Aymara shows a three way contrast in stops and affricates, as shown in Table 1.

Table 1: Three series of occlusives in Aymara.

	Bilabial	Alveolar	Palatal	Velar	Uvular
plain	p	t	tɕ	k	q
aspirated	pʰ	tʰ	tɕʰ	kʰ	qʰ
ejective	p'	t'	tɕ'	k'	q'

As shown in Table 1, Aymara has three series of occlusives (plain, aspirated, and ejective) in 5 different places of articulation (bilabial, alveolar, palatal, velar, and uvular) and three vowels /a, i, u/. Stress is fixed on the penultimate in Aymara, as in S panish. It is not clear whether the Aymara stress patt ern is due to the influence of Spanish or independent of it. Aymara also has a contrast in vowel length [16].

Ejectives are characterized by the coordination of the occlusion in the oral cavity and the glottal closure. The relative timing of the oral occlusion and the glottal closure can be best investigated in terms of change in the air pressure build-up in the pharyngeal cavity. It is known that the pressure behind the oral occlusion is often increased to about double the normal pulmonic pressure (i.e. from about 8 to about 16 cm H_2O) [25]. The onset and offset of both the oral occlusion and the glottal closure can be fixed by a fiberscope or aerodynamic devices. However, they can be intrusive in the sense that subjects are hard to keep a stable state during the experiment and the fiberscope or air pressure measuring devices inserted through the nasal cavity may keep the passage partially open, causing air leakage. A rapid upward movement of the larynx can be recorded by camera. The intensity and duration of the release burst can also give us a holistic view of ejectives. It is expected that there is a greater intensity in the stop burst at the moment of oral release due to the greater glottal pressure [25]. The stop burst seems to be a sole carrier of the acoustic information about place of articulation in word-initial positions, since the release burst are separated from the vowel by the gap and the following vowel uniformly begins with a glottal closure regardless of place of articulation.

The relative timing of vocal fold vibration to the release of the oral occlusion may shed lights on the characteristics of ejectives, as was tried in most previous studies. The complete closure of the glottis suggests a voice quality close to creaky voice in the initial part of the following vowels [12]. In this regard, ejectives can be acoustically investigated in terms of temporal parameters of VOT, durations of the release burst, and in terms of spectral parameters of the intensity of the release burst and H1-H2 of the initial part of the following vowels.

1.3. Objectives and significance

Aymara has not been investigated in terms of acoustic measures of temporal and spectral characteristics, such as VOT, the duration of the release burst, the intensity and spectral centroid of the release burst, and the intensity difference between the first two harmonics (H1-H2). This study is significant in that important acoustic characteristics of the Aymara ejectives are newly reported. However, it should be noted that this study has a limitation in that it only provides a limited amount of preliminary data about Aymara ejectives.

2. METHODS

2.1. Materials

Speech materials used in this study are part of the Aymara Project conducted by a joint group of the Department of Linguistics and the Institute of the Latin American Studies at Seoul National University, Korea. This study provides acoustic measurements of only one Aymara subject’s responses. The subject is a native Aymara male in his forties who is living in El Alto and teaching Aymara at the Universidad Mayor de San Andrés (UMSA). He was asked to provide Aymara words for given Spanish lexical items, which amount to 2,960. The subject was paid for his service. Materials used in this study are part of his responses. They are listed in Table 2.

Table 2: Aymara materials with English and Spanish glosses.

Aymara	English	Spanish
/p’axla/	bald	calvo
/t’alp’a/	plain	plano
/tɕ’aʎa/	sand	arena
/k’ara/	salty	salado
/q’aɲu/	turbid	turbio

The materials were bisyllabic words in the form of CV(C)CV where the word initial consonant is an ejective and is followed by /a/. They are in the same prosodic environment in the sense that stress falls on the penultimate syllable.

2.2. Recording and digitization

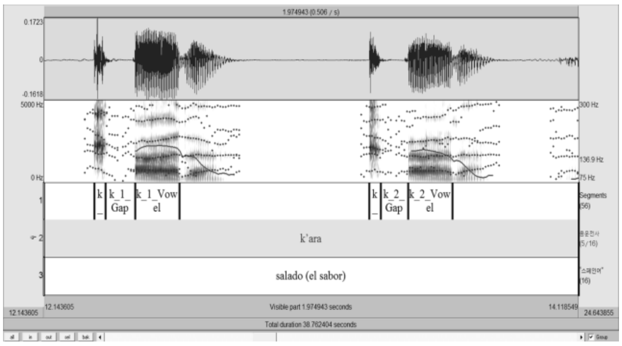
Recording was conducted in a quiet room without outstanding noise at Hotel Calacoto, La Paz, Bolivia. Two types of microphones were used to record the subject’s responses: one for the questioner and the other for the subject. The one for the questioner is a unidirectional pin microphone, AT831b Audio Technica, which is known to be excellent in absorbing sound. The other for the subject is a unidirectional headset microphone, AKG C520 AKG, which was fixed to the subject’s head to secure consistence in recording. The subject’s audio responses were put on digital audio tapes by Sound Devices 722. Audio recordings were stored in two channels in a .wav format. They were digitized at a sampling rate of 44.1 kHz and a quantization bit of 16. In addition, video recording was also conducted to record lip shape, lip opening, and the movement of the larynx by which ejectives are known to be accompanied. Video recordings were stored in an .avi format. Audio track signals were digitized at a sampling of 48 kHz and video track signals were digitized at a resolution of NTSC 720*480 pixels.

Recording was monitored to secure quality output in audio and video before, during, and after the subject provides responses to the questions. The subject was given instructions to provide a pair of identical lexical items in the same intonation pattern with a short pause between them. The subject could take a break for refreshing their mind and clearing throat over a cup of water. The subject’s responses were transcribed in IPA at the recording by one of the authors. It should be noted that vowel lowering occurred when vowels are preceded or followed by uvulars, as noted in previous studies [16].

2.3. Measurements

Praat was used to measure acoustic parameters of temporal and spectral characteristics [4]. Temporal characteristics, such as the durations of the release burst, the vowel, and the intervening gap were measured in milisecond by calculating the interval between the two time points showing a remarkable change in the waveforms and spectrograms, as shown in Figure 1. Boundaries were set at 4 points: the onset and offset of the release burst and the onset and offset of the vowel. Durations of the release burst, the vowel, and the intervening gap were determined by measuring the interval duration between the boundaries in order. It should be noted that the sum of the durations of the release burst and the immediately following gap corresponds to the notion of VOT. An example of segmentation and labelling of a word is illustrated in Figure 1.

Figure 1: Segmentation and labelling of a word.



Spectral characteristics, such as the intensity and centroid of the release burst and H1-H2, were measured by referring to the spectrum of the relevant intervals. The intensity of the release burst was measured in dB by getting the value of intensity for the interval of the release burst. The centroid of the release burst was measured in Hz by getting the value of centre of gravity (centroid) for the spectrum of the interval of the release burst which was band-pass filtered up to 11,025 Hz. H1-H2 was measured in dB by subtracting the intensity of the second harmonic from that of the fundamental component for the spectrum of a 25.6 ms Hamming windowed sample of the initial part of the vowel.

3. RESULTS

Results of the acoustic measurement of the Aymara ejectives are provided in Table 3.

Table 3: Results of the acoustic measurement of the Aymara ejectives.

	p’	t’	tɕ’	k’	q’
Duration of RB	12 (20)	14 (10)	70 (75)	43 (42)	58 (60)
Gap	65 (81)	93 (64)	118 (144)	107 (102)	80 (105)
VOT	77 (101)	107 (74)	188 (219)	150 (144)	138 (165)
Duration of Vowel	123 (130)	94 (78)	105 (117)	163 (163)	144 (106)
Intensity of RB	48.8 (51.14)	48.86 (48.09)	60.90 (59.76)	62.38 (60.08)	59.31 (60.52)
Centroid of RB	826 (989)	3207 (2384)	6022 (5838)	2382 (2256)	1654 (1037)
H1-H2	0.89 (1.41)	0.35 (-0.80)	-1.25 (-1.25)	-0.94 (-0.16)	0.75 (-2.16)

In Table 2, the value in parentheses indicates the one measured for the second trial of a word. As shown in Table 2, prevocalic temporal parameters, such as the duration of the release burst (RB), the gap (Gap), and VOT (the sum of the durations of the release burst and the gap) commonly shows that velar, palatal, and uvular ejectives have longer interval than the others with a minor variation between two trials. It should be noted that the release burst is the longest with palatal one. It seems to be due to a widest contact area around the palatal region, which is followed by the uvular and velar regions. A wide contact area may be helpful to build up air pressure and a characteristic explosion of the release burst. These results are in line with the typological pattern noted earlier in that velar and uvular ejectives are the most preferred and commonest in the world’s language. On the other hand, such a pattern is not observed with the duration of the vowel.

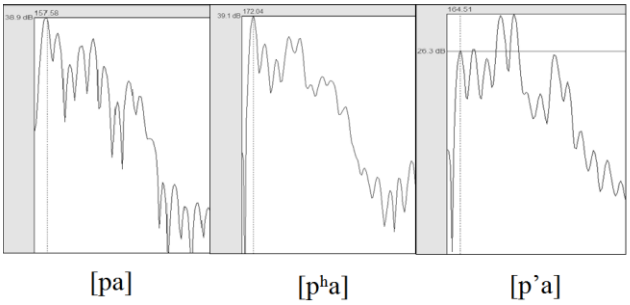
The same pattern is observed with prevocalic spectral parameters of the intensity of the release burst across places of articulation, such that velar, uvular, and palatal ejectives are greater in intensity than the other places of articulation. However, centroid of the release burst varies with places of articulation, such that palatal has the highest frequency, followed by alveolar, velar, uvular, and bilabial, from the highest to the lowest. The centroid of the release burst seems to be a sole acoustic carrier of the spectral information about place of articulation in word-initial positions, since it is separated from the gap and the vowel and the vowel commonly begins with a glottal closure across places of articulation. Results showed a very low, even negative, value of H1-H2 for all places of articulation, which seems to be a typical feature of a glottalized or creaky voice. There was no substantial difference in H1-H2 across places of articulation.

4. CONCLUSION

This study investigated acoustic characteristics of Aymara ejectives in terms of temporal and spectral parameters. Among temporal parameters, the duration of the release burst and the gap showed that velar, alveolar, and uvular ejectives have a longer duration than bilabial and alveolar ejectives. Among spectral parameters, the centroid of the release burst demonstrated a characteristic feature of ejectives with place of articulation while H1-H2 revealed a unique feature of ejectives with voice quality irrespective of place of articulation.

As a follow-up study of ejectives, H1-H2 was compared across phonation types. Spectral slices of the vowel following bilabial stops are given in Figure 2.

Figure 2: Spectral slices of the vowel following bilabial stops: [pa], [pʰa], and [p’a].



In Figure 2, the leftmost spectrum stands for the plain bilabial stop /pa/, the middle one for the aspirated bilabial stop /p^{h}a/, and the rightmost one for the ejective bilabial stop /p’a/. As shown in Figure 2, the vowel following /p^h/ is greater than the one following /p/, which, in turn, is greater than the one following /p’/. It seems that acoustic parameters of phonation types could be a reliable indicator of the characteristics of which are present in the initial part of the vowel.

Acoustic data provided in this study are limited to ejective stops and affricates in 5 places of articulation. The method of this study could be extended to the plain and aspirated series of stops and affricates, so that three series can be compared to each other within or across speakers. Positional variation could be a matter of concern. Although this study is focused on the ejective stops and affricates occurring in word-initial positions, those occurring in intervocalic positions may show a different picture of acoustic measures with additional information about the duration of stop closure. A cross-linguistic comparison, in particular, between Aymara and Korean, which commonly have a three way contrast of voiceless occlusive, also gives us a wider view of the consonant types in the world’s languages. Perception tests could confirm perceptual differences of phonation types or consonant types within Aymara and between Aymara and other languages. Those studies remain to be studied.

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