An Acoustic Analysis Of Oromo And Amharic Ejective Stops

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Résumé

Les études acoustiques antérieures des éjectifs semblent s'être concentrées sur la comparaison des arrêts éjectifs avec les arrêts sans voix pulmonaires. La présente étude examine les arrêts éjectifs de l'oromo et de l'amharique afin d'examiner s'il existe des variations significatives au sein des sons et entre les deux langues. Les données audios de l'étude ont été recueillies auprès de 36 étudiants de premier cycle qui sont des locuteurs natifs de leurs langues respectives. Neuf mesures acoustiques, qui incluent des paramètres temporels et spectraux, ont été extraites des données. Une analyse statistique des mesures acoustiques révèle une variation significative au sein des arrêts d'éjection par rapport à la plupart des variables acoustiques étudiées. Il existe une variation significative entre les langues dans le seul mode de phonation tel que mesuré par h1-h2. La plupart des témoins des sons sont correctement classés avec les moments spectraux de leurs éclats de bruit. Typologiquement, les arrêts éjectifs des langues ne peuvent pas être catégoriquement classés comme faibles ou forts et diffus ou compacts en fonction de leurs propriétés acoustiques. Dans l'ensemble, il est conclu que plus de différences sont observées au sein des sons qu'entre les langues.

Mots clefs : Oromo, Amharique, éjectifs, arrêts

Abstract

Previous acoustic studies of ejectives seem to have concentrated on the comparison of ejective stops with pulmonic voiceless stops. The current study investigates ejective stops of Oromo and Amharic in order to examine if there are significant variations within the sounds and between the two languages. The audio data for the study were collected from 36 undergraduate students who are native speakers of their respective languages. Nine acoustic measures, which included temporal and spectral parameters, were extracted from the data. A statistical analysis of the acoustic measures reveals a significant variation within ejective stops with respect to most acoustic variables under investigation. There is a significant variation between languages in only mode of phonation as measured by h1-h2. Most tokens of the sounds are correctly classified with the spectral moments of their noise bursts. Typologically, ejective stops of the languages cannot be categorically classified as weak or strong and diffuse or compact based on their acoustic properties. Overall, it is concluded that more differences are observed within the sounds than between the languages.

Keywords: Oromo, Amharic, ejective, stops

1. Introduction

Ejective stops are found in the sound systems of Oromo and Amharic, Afroasiatic languages widely spoken in the Horn of Africa [1, 2]. The articulation of ejective stops is aerodynamically complex, involving oral (or pharyngeal) and glottal constrictions [3]. To describe ejective stops, various acoustic measures such as VOT, duration of closure, intensity of burst release and pitch pattern of the following vowel are often used [4]. These measures are known to vary within a class of ejective stops and across languages [5]. The survey of previous studies reveals that most of them have mainly focused on acoustic features of ejective stops of a single language or on acoustic comparison of ejective stops of a single language with their corresponding pulmonic voiceless stops [6]. The current study will examine ejective stops of Amharic and Oromo to find out if there are significant variations within the sounds and between the two languages.

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1.1. Acoustic study of ejective stops

The articulation of ejective stops is aerodynamically a complex process, involving a closure in the oral cavity and at the glottis [7]. During the process, the larynx rises, compressing the air in the oral cavity. Then, air pressure builds up in the cavity behind the closure, and ultimately, the sudden release of the oral closure produces sounds with various phonetic features [8]. Depending on the timing of the release of oral and glottal constrictions, two types of ejective stops are often identified. If the glottal closure is released before the oral closure, a strong ejective with a large burst and a long VOT will be produced. On the other hand, the simultaneous release of both closures will lead to the production of weak ejective stops with a weak burst and short VOT [3]. These cases seem to be the two possible timings for the production of the sounds as the oral closure is not expected to be released before the glottal closure.

Acoustic criteria such as total duration, burst intensity, VOT, F0, and intensity rise time are used to classify ejective stops [4]. Long duration, intense burst, long VOT, high F0 onset, modal phonation and fast intensity rise time are said to be features of strong ejective stops. On the other hand, short segmental duration, normal burst, short VOT, low F0 onset, creaky phonation and slow intensity rise, are believed to be characteristics of weak ejective stops [9, 10]. A binary division of ejective stops into strong or weak is debatable. It may be argued that the two categories represent only two ends of a continuum as ejective stops of the same language can be realised more as strong than as weak or vice-versa when one or more acoustic criteria are satisfied [11]. Other binary division of ejective stops is also possible based on their overall spectral shape of noise bursts. Past studies used standard deviation and kurtosis to classify plain stops into diffuse or compact based on place of articulation [12-15]. One of the objectives of the current study is to determine if these acoustic features could classify ejective stops into diffuse or compact.

Previous studies have largely focused on the comparison of acoustic features of ejective stops with those of pulmonic voiceless stops in a word-initial or a word-medial position [7, 9, 11, 16]. The comparison indicated that ejective stops significantly differed from pulmonic voiceless stops, having longer VOT, slower intensity rise time, and lower F0 in the following vowel [4, 9]. For instance, Georgian aspirated stops have longer VOT than ejective stops while ejective stops have shorter VOT than voiced stops [9]. The comparison also showed that acoustic properties of ejective stops exhibit variations with their place of articulation and position in a word. For example, VOT tends to decrease from anterior to posterior of the vocal tract, with velar ejective stops having the longest VOT [5, 9]. The VOT of ejective stops is longer at a word-initial position than at a word-medial position [10, 11]. Acoustic data from a study of ejective stops are useful to understand the association between a complex articulation and its acoustic correlates. However, enough published acoustic data on ejective stops of different languages seems to be lacking on ejective stops.

Similarly, enough attention does not seem to be paid to the investigation of acoustic features of ejective stops across languages. A couple of studies compared acoustic features of ejective stops in different languages, reporting significant acoustic variations cross-linguistically. One of such studies compared ejective stops in Hausa and Navajo, and reported that the sounds significantly differed in terms of total duration and closure duration ratio. Another study revealed significant contrasts between Tigrigna and Quiche ejective stops [17, 18]. Nevertheless, some other studies have compared the acoustic properties of ejective stops in their studies with published data from ejective stops of other languages [4, 10, 16]. Such comparisons may be problematic given the lack of standardisation in methods across studies. If researchers followed similar methods, valid generalisations could be drawn and such generalisations are useful for understanding ejective typology. Lack of data is also noted in the classification of ejective stops though enough data may be available on the classification of vowels and fricatives [19-21].

1.2. Amharic and Oromo ejective stops

Ethiopia is one of the linguistically diverse countries being home for speakers of over 81 languages [22]. Among these languages are Oromo and Amharic, which belong to the Cushitic and Semitic branches of the Afroasiatic language phylum respectively. These languages share many consonants, and one class of these consonants are ejective stops (TABLE 1). Oromo has ejective stops and affricate, but Amharic has an ejective fricative in addition to those which it shares with Oromo.

Table1: An inventory of Oromo and Amharic consonant phonemes [2, 1].

Manner	Voicing	Labial	Alveolar	Palatal	Velar	Glottal
Stop	Vl	P*	t		k	ʔ
	Vd	b	d		g	
	Ejective	p’	t’		k’	
Affricate	Vl			ʧ		
	Vd			ʤ		
	Ejective			ʧ’		
Fricative						
	Vl	f	s	ʃ		h
	Vd	v*	z*	ʒ*		
	Ejective		s’ *			
Nasal		m	n	ɲ		
Liquid			l r			
Glide		w		j		

*These phonemes are found only in Amharic.

The current study focuses only on ejective stops, which can be geminated in Oromo [1] and labialised in Amharic [2]. Investigating acoustic correlates of gemination and labialisation in ejective stops of different languages is an interesting area of study but geminated and labialised ejective stops lie out of the scope of the current study. It is believed that these sounds warrant a separate study, which will thoroughly investigate their acoustic properties. As far as the knowledge of the researcher is concerned, there is not enough acoustic study on ejective stops of Ethiopian languages except some on Amharic, Tigrigna and Oromo [10, 23, 24]. The number of participants in these studies is very small. The data were collected from a single speaker in [25], from five speakers in [10] and from eight speakers in [23, 24]. Similarly, the number of speakers participated in other previous studies is small, ranging from one [16] to eleven [4]. With small number of speakers, it may be difficult to capture acoustic features of speech sounds, known to be variable [4]. These studies did not set out to compare acoustic features of ejectives of two or more languages, but they focused on an acoustic description of ejectives of a single language. The current study, therefore, aims to determine (a) if there is a significant variation within ejective stops of Amharic and Oromo, and between the two languages with respect to acoustic characteristics of their ejective stops, (b) to classify ejective stops of the language using different sets of acoustic parameters and (c) to investigate how the two languages behave typologically as regards their ejective stops.

2. Method

2.1. Participants

Participants of the study are 36 speakers (Amharic=18; Oromo=18, with gender balanced in each language) who were doing their first degrees at a university at the time of the research. The Amharic speakers were born and brought up in Addis Ababa, having acquired the standard dialect of the language [26]. The Oromo speakers were born and brought up in the countryside of Wollega, where the Macha or the Western dialect of the language is spoken [1]. The Oromo speakers learned Amharic at school as a subject starting from grade five. It is assumed that their Amharic may not be good enough to qualify them as proficient bilingual speakers since Amharic is hardly used in the countryside of the region [22]. The average age of all participants was 23 years and the range was four years. None of the participants reported hearing and speech difficulties, and their consents were sought before they took part in the study.

2.2. Stimuli and procedures

The target sounds were embedded in a monosyllable (CV) and produced in a carrier phrase of each language. The syllable was used because real words which have the target sounds in the same or in even a similar phonetic environment could not be found. It was created following the syllabic structures of the languages. For example, CV forms Amharic words such as /k'ata/, which means a 'trigger'. Oromo words also have the syllable (CV) in words like / k'ara/, which means a 'sharp edge' [1]. The syllable contains the target sound at an initial position in the context of the vowel sound /a/. For instance, one of the stimuli for Amharic is /t'a bəl/, which means 'say t'a' and the Oromo version is /t'a ʤedi/, which also means 'Say t'a'. The initial position was chosen for VOT, burst release and post-burst silence are clearly exhibited at this position (See FIG. 1) though it did not allow for the measurement of closure duration and total segmental duration.

The stimuli were randomised and presented to participants of the study on a laptop's screen (MacBook Air 2017) in Keynote. Instructions were written in each language and the participants could only proceed to the recording session when they read and understood the instructions. The recording took place in a quiet room with Computerised Speech Lab (CSL, Kay 4400). The participants held a microphone (Sennheiser e865) 10 cm away from their mouths. Before the actual recording, the participants were familiarised with the recording procedures. The familiarisation session was intended to adjust the presentation pace of the stimuli so that it could match the habitual speech rate of each participant. In the actual recording session, the participants repeated each stimulus three times in a random order at their habitual speech rates, and one session produced nine stimuli (three tokens for each ejective) for one participant. All recording sessions produced (36 speakers x 3 ejective stops x 3 repetitions) 324 tokens, which means 162 tokens per language. The stimuli were sampled at 44.1k Hz and digitised at 16 bit.

2.3. Measurements

As stated earlier, this study compares Oromo and Amharic ejective stops with respect to nine acoustic measures, namely VOT, h1-h2, F0 in 30 ms into the onset of the following vowel, relative intensity, intensity rise time and four spectral moments. VOT was measured from the beginning of the burst as indicated by 'B' up to the end of the glottal closure as indicated by 'G'. It is the sum of the duration of 'B'and 'G' as indicated in Figure 1 Glottal closure duration is the length of the silent gap (a post-burst lag) between the burst release and the onset of the following vowel as indicated by 'P' [10]. A phonation pattern of the vowel onset (as measured by h1-h2) was measured over 30ms portion of the following vowel onset designated by 'P'. Fundamental frequency was computed in the 30 ms portion of the vowel onset and normalised by subtracting it from F0 at the midpoint of the vowel [13]. Maximum of intensity of ejective burst (in dB) was subtracted from maximum intensity of the following vowel (in dB) to obtain relative intensity [9]. Intensity rise time was computed by subtracting the time at the maximum intensity from the time at the onset of the vowel [27]. The spectral moments were computed from power spectra over the entire burst, which is over the portion indicated by 'B' in FIG 1 [9]. PRAAT [28] was used to extract the acoustic measures from the stimuli and the extraction was done manually.

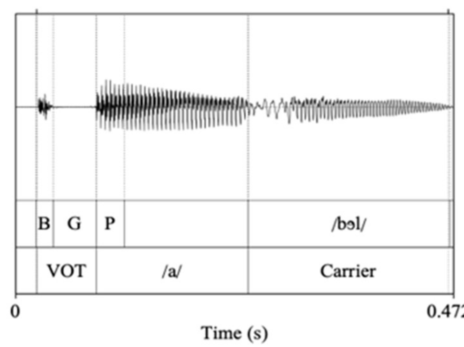

Figure 1: 'k'a bəl' (meaning 'Say k'a') as produced by an Amharic female speaker.

2.4. Statistical analysis

Linear mixed effects regression in R (R Core Team 2019), with the lme4 package [29] was used for the data analysis. Language (with two levels) and sound (with three levels) were modelled as fixed factors, and speakers as a random factor. The sounds were compared with respect to the nine acoustic measures, collapsed across languages because the study is interested in acoustic variations within stop ejective stops. Multiple contrasts were conducted using emmeans package in R [30]. The mixed function in the afex package [31] was used to conduct likelihood ratio tests for the fixed effects, with the argument method set to 'LRT'. Linear discriminant analysis was carried out with SPSS (Version 20) to classify ejective stops of the languages based on their places of articulation. The acoustic measures were entered stepwise and F0 was not included in the analysis as it was not statistically significant [21].

3. Results

3.1. VOT

The significant main effect of sound (ejective stops) is found for VOT [χ2 (2) = 28, p<0.001]. Post-hoc comparisons of mean VOT reveal that /p'/ is significantly different and /k'/ while /t'/ from (p<0.001). No significant main effect of language is observed for VOT [χ2 (1) =1.58, p= 0.21]. The interaction of language and sound is not also significant for VOT [χ2 (2) =2.33, p= 0.31].

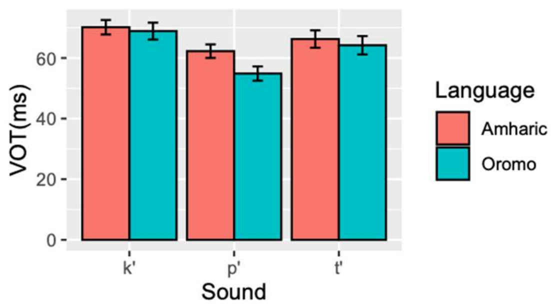

Figure 2: Mean values of VOT (ms) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

3.2. Relative burst intensity and intensity rise time

The results show that ejective stops significantly differ in their relative burst intensity (R_int), [χ2(2) = 70.75, p<0.01] and intensity rise time (Rise_time) [χ2(2) = 19.06, p<0.001]. Post-hoc comparisons of relative burst intensity indicate that /p'/ is significantly different from /k'/ and /t'/, (p<0.001) while intensity rise time significantly separates /t'/ from /k'/, (p<0.001).

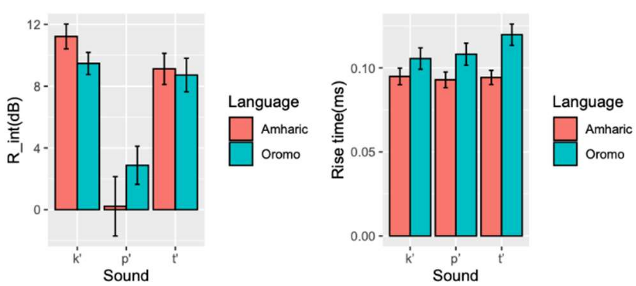

Figure 3: Mean values of relative burst intensity (dB) and intensity rise time (ms) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

However, such significant main effect of language is not found for relative burst intensity [χ2 (1) =0.02, p=0.89], and for intensity rise time [χ2 (1) =3.39, p=0.07]. In addition, no significant interaction of language and sound is found for both relative intensity, [χ2 (2) = 4.98, p=0.08]; and intensity rise time, [χ2 (2) =1.89, p= 0.39].

3.3. F0 and h1-h2

Ejective stops do not exhibit a significant variation in F0, [χ2 (2) = 13.3, p<0.001] and h1-h2, [χ2(1) = 1.4, p=0.5]. Main effect of language is only found for h1-h2 [χ2(1) = 11.79, p<0.001] but not for F0, [χ2 (1) = 0.01, p<0.91]. The ejective /k'/ is significantly different from /t'/ at p<0.001 in mean h1-h2. Significant interactions of language and sound are found for F0, [χ2(2) = 5.74, p=0.06] and for h1-h2, [χ2 (2) =1.82, p= 0.4].

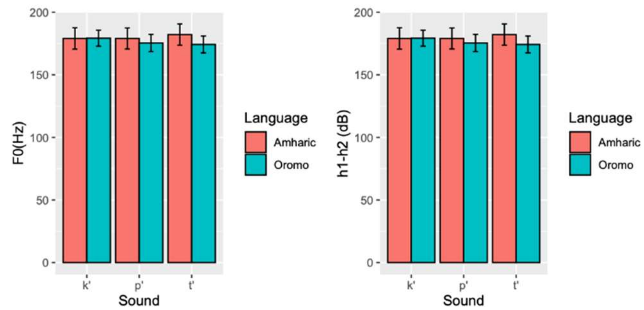

Figure 4: Mean values of F0 (Hz) and h1-h2 (dB) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

F0 and h1-h2 are used to identify the type of phonation involved in the production of the following vowel. A creaky phonation has weaker h1 and lower pitch than modal phonation [3, 32]. Thus, ejective stops in both languages seem to be followed by a vowel with modal phonation. Both languages have higher pitch at the onset than at the midpoint of the following vowels and this is more obvious in the case of Amharic (Figure 4). Higher F0 at vowel onset is arguably considered to be the feature of stiff or strong ejective stops [4], and mean h1-h2 separates ejective stops from other stops [33].

3.4. Spectral mean and standard deviation

The results show the main effect of sound for spectral mean of ejective stops, [χ2 (2) = 124.426, p<0.001]. Post-hoc tests also reveal that all possible pairwise comparisons are significantly different from each other, [p<0.001]. A significant main effect is not found for language, [χ2(2) =1.27, p=0.26]

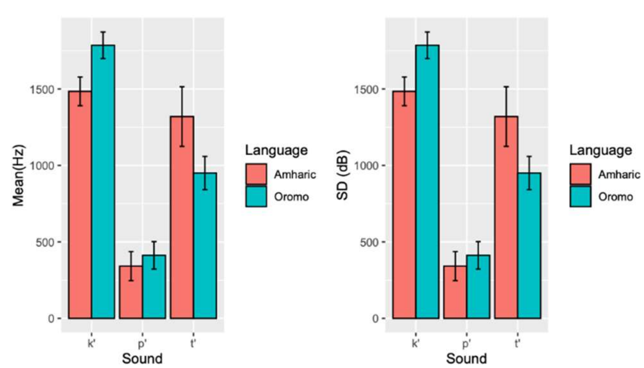

Figure 5: Mean values of spectral mean (Mean) and standard deviation (SD) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

Like spectral mean, standard deviation increases from anterior to posterior parts of the vocal tract (Figure 5). Accordingly, /p'/ is the least compact ejective stop while /k'/ is the most compact ejective stops. Standard deviation significantly varies with sound, [χ2 (2) =163.53, p<0.001] and /p'/ significantly differ from all other ejective stops [p<0.001].

However, the acoustic feature does not vary with language, [χ2 (1) = 0.05, p= 0.82]. The interaction of language and sound is not also significant, SD, [χ2 (2) = 0.97, p=0.62] while there is a significant interaction of language and sound for Mean, [χ2 (2) =12.24, p< 0.002].

3.5. Skewness and kurtosis

The sound /p'/ has the highest mean skewness while /k'/ has the lowest value for the acoustic measure and there is a significant main effect of sound on mean skewness, [χ2 (2) =165.41, p<0.001]. Post-hoc comparisons also indicate that /p'/ significantly differs from all other ejective stops [p<0.001]. Amharic has higher mean skewness for /p'/ and /t'/ but language type does not have a significant main effect on skewness of ejective stops, [χ2 (1) =1.79, p=0.18].

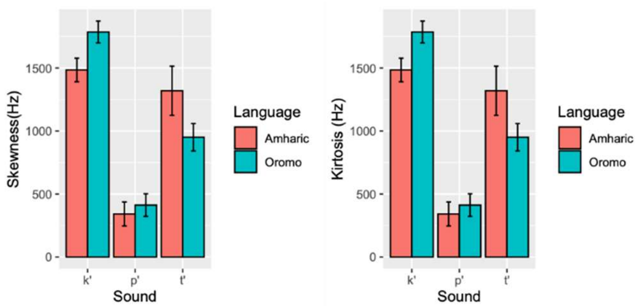

Figure 6: Mean values of skewness and kurtosis (Hz) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

Kurtosis determines if spectral energy is found concentrated over small frequencies forming a sharp peak, or distributed over large frequencies forming a flat peak. The sound /p'/ has the highest mean kurtosis whereas /k'/ has the lowest mean kurtosis, suggesting a high concentration of energy over a small range of frequencies for /p'/ (FIG. 6). Ejective stops significantly vary with respect to their mean kurtosis, [χ2(2) =242.61, p<0.001]. Post-hoc comparisons show that /p'/ significantly differs from all other ejective stops [p<0.001]. The languages do not significantly differ from each other with respect to mean kurtosis of their ejective stops, [χ2 (1) =0.46, p=0.5]. The interaction of language and sound is significant for both skewness [χ2 (2) = 16, p=0.001] and kurtosis, [χ2(2) =8.3, p= 0.02].

3.6. Discriminant analysis

Linear discriminant analysis was carried out to determine to the extent to which different sets of acoustic parameters would classify ejective stops of the two languages. When VOT, intensity rise time and relative intensity were entered into the classifier, /p'/ had the highest classification with 72% and 63 % of its tokens correctly classified respective in Amharic and Oromo. The ejective /t'/ was poorly classified in both languages and the classification accuracy of this sound was rather poorer in Amharic because it was greatly confused with /k'/ and /p'/. However, the sound was better classified in Oromo with the set of acoustic parameters. The overall classification accuracy was higher for Oromo ejective stops but /p'/ was better separated in Amharic than in Oromo.

Table 2: Percentages of correct classification for ejective stops of Amharic and Oromo.

	Amharic				**Oromo**			
Parameter	p'	t'	k'	Total	p'	t'	k'	Total
VOT, Rise_time, R_int, h1-h2	72	22	57	51	63	43	61	56
Mean, SD, skewness, kurtosis	83	54	65	67	80	69	78	75
All	83	54	65	67	80	67	82	76

The ejective stops were better differentiated with mean values of the spectral moments, with 67% and 75% of the ejective tokens correctly classified in Amharic and Oromo respectively (Table 2). In both languages, the ejective /p'/ had the highest classification accuracy followed by /k'/ while /t'/ had the lowest classification accuracy but tokens of this sound were by far better classified in both languages when the spectral moments were employed. The addition of VOT, intensity rise time and relative intensity to the spectral moments did not improve the classification accuracy of each sound and the overall results of both languages. However, the Oromo /k'/ could benefit from the addition of the acoustic parameters while the Amharic sounds did not benefit at all.

4. Discussion

This study aims at comparing the acoustic features of Amharic and Oromo ejective stops. One of the findings of the study is that there are significant variations within ejective stops in all acoustic features considered except F0 of the following vowel. VOT of ejective stops increases from anterior to posterior of the oral cavity in the current study. A similar finding was reported in previous studies for French and English stops, and Georgian ejective stops [5, 9]. The sounds in the current study do not have the same place of articulation; /p'/ is bilabial, /t'/ is alveolar and /k'/ is velar [1, 2]. The acoustic features which show significant variations with an ejective category can serve as reliable acoustic correlates of place of articulation of the sounds. However, the features are not robust to disambiguate all ejective stops as such. The subsequent pairwise comparisons indicate that only spectral mean separates all possible pairs of the three ejective stops. Other measures cannot separate /t'/ from /k'/ though they significantly separate /p'/ from other ejective stops.

The other finding of the study is that the acoustic features do not show significant variations with language type. One possible reason for their similarity might be that the speakers of Oromo had studied Amharic as a subject starting from grade five. In addition, the speakers had a chance to use Amharic with non-Oromo speakers at the university since Amharic is a language of a wider communication. A lack of a significant difference between the languages may be because of the impact of the phonetic knowledge of Amharic on part of the Oromo speakers [34]. The other reason could be that Amharic has been in close contact with Oromo and other Cushitic languages for many years though it is remotely related genetically to these languages. The impact of this language contact has been already attested in the morphosyntax where Amharic has a nominalisation pattern which is similar to that of the Cushitic languages [35]. A language contact might have caused ejective stops of the languages to have similar acoustic properties. Clearly, a further study is needed to identify the possible reasons for phonetic similarities of ejective stops of the languages.

The study also shows that spectral moments of noise bursts classify ejective stops of Amharic (65%) and Oromo (75%) by far better than VOT, intensity rise time, relative intensity and h1-h2 do. Spectral moments may be considered as primary acoustic cues for places of articulation of ejective stops of both languages and they are particularly more robust in separating /p'/ from the other sounds. Again, they are more robust in separating Oromo ejective stops, which suggests that the strength of acoustic cues of the sounds differ between languages. When they were employed together with VOT, intensity rise time and relative intensity, the classification accuracy of ejective stops of both languages did not improve because the two sets may have an overlapping or complementary role in disambiguating the sounds based on their places of articulation. Clearly, additional studies may be needed to investigate the relative roles of the two sets of acoustic parameters in classifying ejective stops of these languages and those of other languages. Overall, the discriminant analysis indicates that Oromo ejective stops with different places of articulation (bilabial, alveolar and velar) were better classified but in both languages, the alveolar sound, /t'/ was poorly classified, being confused with the other sounds. This sound was better separated when the spectral moments were used, which suggests that spectral shapes of their bursts present reliable acoustic cues for their places of articulation.

One of the objectives of the current study was to investigate how the ejective stops of the two languages would behave typologically. The traditional classification (either weak or strong) is particularly problematic as ejective stops hardly satisfy all the criteria set in some previous studies [4]. In one of such studies, VOT and creaky phonation are viewed as reliable parameters for classifying ejective stops [36]. In another study, 60 ms of VOT is used as a threshold to classify ejective stops into strong and weak; if the duration is greater than 60 ms, the sound is classified as strong, otherwise as weak [37]. Both studies provided no explanations why 60 ms is set as a threshold and why VOT is a reliable measure. This binary division of ejective stops into strong or weak has been challenged. Evidence from the comparison of some languages shows that the variation of acoustic features with language makes this binary division impossible or difficult to work for many or even for two languages [16, 24]. In other words, the other acoustic features do not pattern together with VOT to classify the sounds into weak or strong ejectives.

The current study used VOT together with other acoustic measures to determine how the languages typologically behave [4, 17, 18]. Like languages in the previous studies, Amharic and Oromo have both weak and strong ejective stops in their sound systems [11, 16]. Collectively, Oromo ejective stops have faster intensity rise time (0.11 ms) and greater relative intensity (8.2 dB). Based on these measures, the Oromo sounds can be collectively classified as strong ejective stops. As a group, Amharic ejective stops have longer VOT (70 ms), and higher F0 (180.62 Hz) for the onset of the following vowel. As a result, Amharic ejective stops generally tend to be realised more as strong. Both languages have high positive h-h2, which suggests that their ejective stops are strong causing modal phonation in the following vowel. This is consistent with the generalisations made above. Nonetheless, the individual sounds show a different pattern; for instance, the sound /k'/ likely belongs to the class of strong ejective stops because in both languages, it has longer VOT, fast rise time, intense burst, high F0 and modal phonation in the following vowel. The position /t'/ could occupy on the continuum of weak and strong ejective stops is variable based on the acoustic feature considered. Taken together, the current study provides good evidence in favour of the proposal that considers the typological classification of ejective stops as a continuum of weak and strong sounds.

In the past studies, the overall spectral shape of bursts as indicated by standard deviation and kurtosis were used to classify plain stops into diffuse and compact based on place of articulation [13, 14]. Particularly, kurtosis is used for the classification since it is strongly correlated with standard deviation, [r (430) = -0.84, p<0.001]. The presence of strong correlation between the two measures is taken as evidence for representing the same articulatory feature [13]. In the current study, the two spectral moments were employed to classify burst spectra of ejective stops /p', t', k'/ into compact and diffuse. Standard deviation is inversely related to compactness but directly to diffuseness. These sounds, /p'/ and /k'/, have the lowest (417.16) and the highest mean standard deviations (1564.61) respectively, representing the two ends of a diffuse-compact continuum. Burst spectra of ejective stops will become more and more compact (but less and less diffuse) when their place of articulation moves to the posterior of the vocal cavity. Thus, /k'/ is the most compact ejective stop while /p'/ is the most diffuse ejective stop for Amharic and Oromo. The burst of /t'/ has more compact than diffuse spectrum as its standard deviation (1303.65) is closer to that of /k'/.

As explained above, the sounds significantly differ on all spectral moments, but language effect is not significant in any one of the spectral measures. Oromo ejective stops have collectively higher mean standard deviation (1316.56) and lower mean kurtosis (1.43) for their burst spectra than do Amharic ejective stops, suggesting that bursts of Oromo ejective stops tend to be realised more as compact than diffuse spectrum. Amharic has higher mean kurtosis (1.66) and lower mean standard deviation (1287.89) for burst spectra of its ejective stops than does Oromo, which implies that burst spectra of Amharic ejective stops tend to be realised more as diffuse than compact. Like the binary division of weak and strong, the diffuse-compact dichotomy (as in [14] is problematic as there is no cut-off-point to assign sounds to one of the categories based on mean standard deviation or mean kurtosis of their burst spectra or both. This problem could be somewhat solved if the categories are construed as a continuum of diffuse and compact.

5. Conclusion

This study is most probably one of the few studies that investigated acoustic variations within ejective stops and across languages. The study found significant acoustic differences within ejective stops with respect to all acoustic properties considered with the exception F0. A significant variation between the two languages was not found in all acoustic features. Spectral moments could correctly classify more tokens of ejective stops of both languages than do VOT, intensity rise time and relative intensity as a group. Typologically, ejective stops of the two languages could not be classified as strong or weak and diffuse or compact but they could be placed on the continua of the categories on the basis of their acoustic features. Overall, the ejective stops show significant differences among themselves but not between languages. In the current study, acoustic measures were extracted from the onsets of monosyllables to compare acoustic properties of ejective stops of two languages. Future studies will provide us with more reliable and valid data if they compare acoustic features of ejective stops, which are extracted from initial and medial positions of real words.

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