Mehri ejective fricatives: an acoustic study

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ABSTRACT

Ejective consonants are not very common cross-linguistically. Even less common is the occurrence of ejective fricatives. This infrequency is generally attributed to the incompatibility of two aerodynamic requirements: a continuing flow of air to create noise frication and an increasing intraoral air pressure to implement ejectivity. This study reports on an acoustic investigation of initial and intervocalic ejective fricatives in Mehri, a Modern South Arabian language spoken in Oman, and seeks to determine how this incompatibility is solved by the 5 subjects recorded. The analysis of different temporal and non-temporal parameters shows a high degree of variability in the way this contrast is implemented. Much of this variability is shaped by the position of the fricatives within the word.

Keywords: Ejective fricatives, Mehri, Modern South Arabian language.

1. INTRODUCTION

Ejectives occur in about 16% of the world languages (92 out of 576) [1]. Ejective fricatives are more infrequently encountered; only 3.7% languages were reported to have at least one such segment. This rarity is generally attributed to aerodynamic constraints that make them acoustically instable: the continuing flow of air necessary to the production of frication is incompatible with the increasing of intraoral air pressure necessary to the production of ejectivity [2, 3]. This raises the question of whether these segments are real ejective fricatives, or whether they should on closer examination prove to be distinguished from their pulmonic counterparts by some other dimension. Faced with this question, Shosted and Rose [3], based on acoustic data from Tigrinya, showed that ejective /s'/ was generally realized not as a fricative but as an affricate [ts']. Affrication, manifested with pre-frication closure lag, was interpreted as a general strategy used to increase intraoral air pressure. Two other strategies to solve the incompatibility of tight glottal constriction and frication have been reported. The first one, used by Yapese speakers, was to have a non-overlapping articulation by producing the ejective fricative not as a single segment but as a sequence of a pulmonic fricative followed by a glottal stop [3]. The second strategy, observed in Tlingit, was to produce ejective fricatives with a much narrower constriction than was used in their pulmonic counterparts [4]. This allowed for glottal closure to overlap the entire frication duration while producing high intra-oral pressure, suggesting that they were indeed ejective fricatives. This 'canonical' ejection of a fricative translated acoustically into shorter duration and a tendency for "scrapiness" or pulsing during frication noise. Similar to what has been observed in Tigrinya, Tlingit ejectives also displayed (near-)silent periods preceding frication noise. The interpretation of this silent gap differed, however. While [4] interpreted it as glottal closure, [3] provided some evidence that the source of this closure is oral.

The phonetic implementation of ejective fricatives has been instrumentally examined in some other languages, including Amharic, Kabardian, Lowland Oaxaca Chontal, and Upper Necaxa Totonac. In a survey of the characteristics of ejective fricatives in these languages, [3] showed that they acoustically displayed shorter and 'scrapy' frication noise, generally preceded and/or followed by a silent interval. From aerodynamic and articulatory perspectives, ejective fricatives were shown to display higher intraoral pressure peaks, larger tongue-palate contact and narrower constriction.

In the present study we report on an acoustic investigation of ejective fricatives in Mehri, a South Arabian Language spoken in Oman. We provide acoustic characteristics of these segments and show how native speakers solve the frication and ejectivity aerodynamic dilemma in light of what has been reported for other related and unrelated languages.

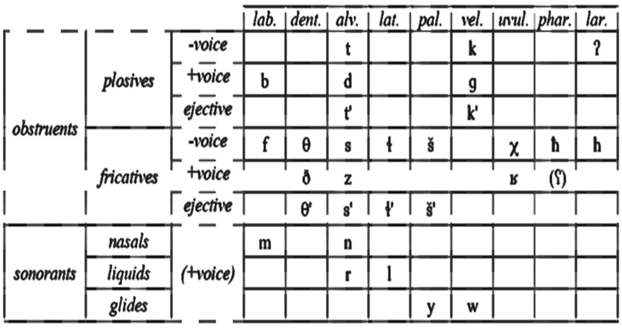
2. EJECTIVES IN MEHRI SYSTEM

We begin with some background information on Mehri and its consonantal system and review some of previous reports on ejective consonants in Modern South Arabian languages.

Mehri is a dialect of the Modern South Arabian language, a subgroup of the Semitic branch of the Afroasiatic family. The dialect investigated in this study is spoken in the province of Dhofar in Oman by an estimated 50,000 native speakers. The consonantal system of the language is given in table 1.

In addition to voiceless and voiced stops and fricatives, the langue has ejective stops as well as a series of 4 ejective fricatives [θ', s', ɬ', š']. Like other Semitic languages, it lacks voiceless labial stop /p/ and labiodental voiced fricative /v/. Each segment in table 1 has a geminate counterpart which can be either lexically given or phonologically derived [5].

Table 1: The consonantal system of Mehri [cf. 6].



			lab.	*dent.*	*alv.*	*lat.*	*pal.*	*vel.*	*uvul.*	*phar.*	*lar.*
obstruents	*plosives*	*-voice*			t			k			ʔ
		+voice	b		d			g			
		ejective			t'			k'			
	fricatives	*-voice*	f	θ	s	ɬ	š		χ	ħ	h
		+voice		ð	z				ʁ	(ʕ)	
		ejective		θ'	s'	ɬ'	š'				
sonorants	*nasals*	*(+voice)*	m		n						
	liquids				r	l					
	glides						y	w			

Ejectives were shown to pattern together with uvulars and pharyngeals as a natural class defined by the feature [+ low]. This class of segments triggers the diphtongization of following long high vowels /i:/ and /u:/ to [aj] and [aw], respectively, and the lowering of long /e:/ into /a:/ [5, 6].

A large amount of variability was reported in the realization of Mehri ejective segments, depending on dialectal origin, place of articulation, manner of articulation, and word position [5, 7-10]. This raised some debate as to whether the description of these segments as ejectives was, in fact, correct. For [5], for example, only /s'/ showed ejective tokens utterance-initially and -finally. Otherwise, it was realized as an emphatic or dorsopharyngealized consonant. For the other fricatives, the reported unmarked realization was emphatic. The interdental fricative was, for example, reported to be invariably pharyngealized in all environments. This has lead some researchers to argue for a gradual sound change which may switch, given the overwhelming influence of Arabic, from a contrast of ejectivity to a contrast of dorsopharyngealization [7, 10].

Most of these reports on Mehri ejectives were limited to dialects spoken in Yemen. They also relied mostly on perception-based segmental transcription to capture the native speakers' productions. [10] provided a preliminary acoustic study of Yemeni Mehri ejectives, based on qualitative analysis of waveforms and spectrograms recorded from one native speaker. The only characteristic examined, however, was the presence/absence of a spike visible on the waveform, which was argued to be typical of ejectives.

For our study we recorded five Omani Mehri native speakers and examined several temporal and non-temporal characteristics that might acoustically differentiate [θ', s', ɬ', š'] from their pulmonic counterparts [θ, s, ɬ, š]. More specifically, we seek to determine whether these cues signal ejectivity or some other dimension such dorsopharyngealization.

3. METHOD

3.1. Speakers

Five male Mehri native speakers aged from 20 to 27 (mean 22.2, SD 2.86) were recorded during a fieldwork in Salalah in southern Omani province of Dhofar. All of the participants reported being able to speak Omani Arabic and Standard Arabic, as is common for native Mehri speakers. None of them had any known history of hearing or speech disorders at the time of recordings.

3.2. Procedure

Table 1 shows the data used in this study. It consisted of 4 pairs of triliteral consonant roots contrasting each ejective fricative with its pulmonic counterpart (a larger data was recorded including filler items and items contrasting ejective stops with their non-ejective counterparts). Each root was conjugated in three verbal paradigms (perf. 3ms, imperf. 3ms, subj. 3ms) and produced within a carrier sentence before them. Only the first two verbal forms were analyzed, yielding data with ejective and pulmonic fricatives in word-initial and word-medial intervocalic positions. The third verbal forms contained word-final ejectives not examined here.

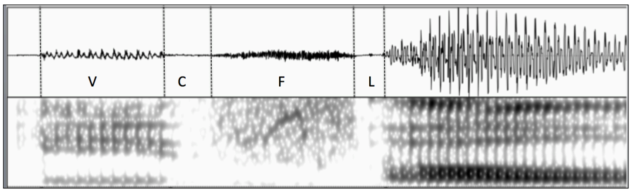
Table 2: List of Mehri items

Root	*Perf. 3ms*	*Imperf, 3ms*	
/**s**bH/	səbu:H	isu:bəH	*“to fix”*
/**s’**br/	s’əbu:r	is’u:bər	*“to support”*
/**θ**br/	θəbu:r	iθu:bər	*“to break”*
/**θ’**br/	θ’əbu:r	iθ’u:bər	*“to blame”*
/**ɬ**br/	ɬəbu:r	iɬu:bər	*“to measure”*
/**ɬ’**bl/	ɬ’əbu:l	iɬ’u:bəl	*“to drink”*
/**ʃ**bl/	ʃəbla	iʃabla	*“to swallow”*
/**ʃ’**rm/	ʃ’əru:m	iʃ’u:rəm	*“to slap”*

Target fricatives in initial position were followed by a schwa vowel. In intervocalic position, they were preceded by /i/ and followed by the long vowel /u:/ (recall that /u:/ following an ejective consonant is realized as a diphtong [aj]). One item had a vowel /a/ as a following vowel due to a lack of actual Mehri verb with the relevant structure. Each verbal root was written down in a slightly modified Arabic alphabet used to transcribe Mehri ejectives. Arabic translation of each item was also provided. For each recording, the speaker was shown the verbal root, asked to produce it with a natural speaking rate, and to maintain the same tempo throughout the session. 397 tokens were included in the statistical analysis (8 fricatives ∗ 2 positions ∗ 5 speakers ∗ 5 repetitions – 3 tokens). Three tokens were excluded from analysis because they were mispronounced (2 repetitions of [θ’əbu:r] and one repetition of [θəbu:r]).

Different durational and non-durational values were taken from the acoustic records for each item. Non-durational values included number of fricatives with pre- and post-frication noise (near-)silent intervals, effects of ejectivity on the intensity and center of gravity (CoG) of frication noise, and effects of ejectivity on pitch and formants at the onset of following and offset of preceding vowels. Temporal measurements included preceding vowel duration, pre-release closure duration, frication noise duration, total fricative duration and post-release silence interval duration. These temporal intervals are illustrated in figure 1.

Figure 1: Illustration of the temporal intervals measured: V = preceding vowel duration, C = pre-frication closure interval, F = frication noise, L = post-frication glottal lag. Token [iθ’u:bər] “to blame”.



4. RESULTS

4.1. Presence/absence of silence

Counts of ejective fricatives with silent lags depending on word position and place of articulation are given in table 3. While no silent lags occurred during the production of pulmonic fricatives, more than 50% of the tokens with ejective fricatives display (near-)silent intervals. Word-initial ejectives (61%) are much more frequently produced with such lags than word-intervocalic ones (21%).

Table 3: Counts of ejective fricatives with pre-frication and post-frication silent intervals, grouped by place of articulation. Symbols as in figure 1.

	Initial	Intervocalic		**Total**
	L	C	L	
Alveolar	13	0	9	**22/50**
Interdental	17	8	5	**30/48**
Lateral	13	7	8	**28/50**
Alveopalatal	17	0	5	**22/50**
Total	**60/98**	**42/100**		**102/198**

Disregarding pre-frication silence, which couldn’t be valued based on acoustic data for word-initial fricatives, no important differences in the proportion of glottal lags (L in table 3) were observed between different places of articulation (~ 22 cases). This shows that, contra to what has been reported, all fricatives, including interdentals, can display (near-)silent intervals characteristics of ejectivity. Important differences among native speakers were observed, however, as shown in table 4.

Table 4: Counts of ejective fricatives with pre-frication and post-frication silence intervals for the 5 subjects, grouped by place of articulation.

	[s']	[θ’]	[ɬ']	[š']	**Total**
S1	0	6	2	0	**8**
S2	8	7	5	5	**25**
S3	10	10	10	10	**40**
S4	4	6	7	5	**23**
S5	0	1	3	2	**6**
Total	**22**	**30**	**28**	**22**	**102**

4.2. Intensity, center of gravity and pitch

Results for these three variables are summarized in table 5. They show that the presence or absence of ejectivity has no significant effect on F0 of the following vowels (for initial fricatives) and on F0 of the preceding vowel (for intervocalic fricatives). Frication noise intensity varies for initial fricatives, with higher intensity for ejectives. No such differences were observed, however, in intervocalic position.

Table 5: Effect of ejectivity on F0, CoG and intensity, grouped by word position.

Position	Airstream	F0	CoG	Intensity
Initial	Ejective	142.88	5036	57.96
	Pulmonic	137.71	4266	54.08
	P-Value	*0.89*	*< 0,0001*	*0.002*
Inter.	Ejective	121.12	4721	59
	Pulmonic	120.84	3874	58.4
	P-Value	*0.93*	*< 0.0001*	*0.21*

Ejective fricatives were well differentiated from their pulmonic counterparts by the CoG measurement: it is significantly higher for ejectives than for their pulmonic counterparts. As expected, important differences were also observed between different places of articulation. CoG was highest for alveolars and lowest for interdentals, with alveopalatals and laterals displaying intermediate values. All pairwise comparisons of fricatives were significant at the $p<.0001$ level, except for the pair alveopalatal *vs.* lateral ($p = 0.25$).

4.2. Effects on vowel formants

As briefly outlined above, several authors have argued that Mehri ejective fricatives are generally realized with an emphatic or dorsopharyngealized configuration, akin to what occurs in Arabic languages. Dorsopharyngealization induces important qualitative effects on adjacent vowels, manifested by a raising of F1 – albeit generally slight - and a large drop of F2 of the adjacent vowels. The produced F1-F2 proximity was shown to be a highly reliable acoustic cue to pharyngealization in different Arabic varieties [11, 12]. One would expect similar acoustic effects of these consonants on neighboring vowels If Mehri ejective fricatives were pharyngealized. We measured F1 and F2 of the schwa vowel following initial fricatives and F1 and F2 of the /i/ preceding intervocalic fricatives (/u:/ was not measured because of the diphtongization that affects this vowel in the ejective context).

In intervocalic position, vowel F1 is higher in the context of ejective fricatives (340.29 Hz, SD=39.09) compared to their pulmonic counterparts (310.55 Hz, SD=28.99). It is important to note, however, that the size of this difference, though significant at the p<.0001 level, is not as important as the one reported in pharyngealized consonants in Arabic [12]. No significant differences between ejective and pulmonic contexts were found as far as vowel F2 is concerned (p=0.22). For word-initial context, significant differences were observed both for vowel F1 and F2. Schwa vowel has a significantly higher F1 and lower F2 following ejective fricatives (F1: 455.94 Hz, SD=50.41; F2: 1200.56 Hz, SD=141.10) compared to their plain counterparts (F1: 392.07, SD=38.60; F2: 1417.49, SD=168.97). In this position, ejective fricatives display expected acoustic outcomes of a dorsopharyngealized articulation.

4.3. Temporal values

Ejectivity has no significant effect on preceding vowel duration (p=0.51). The vowel /i/ has virtually the same duration preceding an ejective fricative (87.82 ms, SD=26.29) or its pulmonic counterpart (90.26 ms, SD=28,68). Two sets of measurements were applied to fricative duration for both initial and intervocalic positions. In set1, we measured only frication duration by subtracting the duration of any silent interval. In set2 we measured the entire fricative duration including silent intervals, if any. For intervocalic position, set1 measurements yield significant differences between ejectives and their plain counterparts (p=0.005). As expected, frication noise for ejectives (87.9 ms, SD=33.03) was shorter than for their plain counterparts (105.8 ms, SD=19.19). No significant differences were observed, however, when total fricative duration was measured (107.48, SD=21.12 for ejectives, and 105.8, SD=19.19 for their plain counterparts).

Absence of significant differences was also observed for initial fricatives (122.39 ms, SD=21.12 for ejectives, and 123.88 ms, SD=19.19 for their plain counterparts) as far as set2 is concerned (p=0.38). Again, as in set1 measurements for intervocalic position, the duration of frication noise is shorter in word-initial ejective fricatives than in plain fricatives at the p<.0001 level (101.94 ms, SD=27.30 for ejectives and 123.88 ms, SD=19.19 for their plain counterparts). Alveolars have the longest duration of this interval and interdentals the shortest. Alveopalatals and laterals lay in between.

The mean duration of the post-frication silent interval in initial position (25.43, SD=12.04) is only slightly longer than in intervocalic position (20.63, SD=8.4). Virtually the same temporal values were obtained for pre-frication noise interval for intervocalic ejectives (24.3, SD=8.8). These durational values are closer to those reported for ejective /s'/ in Amharic [13] and Tigrinya [3] than the longer lags reported for Tlingit ejectives [4].

5. CONCLUSION AND DISCUSSION

The thread of this research was to determine how speakers implement ejectivity in fricatives given its aerodynamic incompatibility with a continuing flow of air. Results show that Mehri ejectives do display characteristics of an ejective articulation (presence of pre- and post-frication silent lags, higher C0G, shorter frication noise duration). But the way these acoustic correlates are implemented varies considerably across speakers, places of articulation and word positions. Indeed, we haven't been able to find an invariant primary acoustic correlate that systematically implements the ejective/pulmonic contrast in fricatives for the 5 speakers studied here. While fricatives do manifest pre-release silent intervals, a salient cue to ejectivity observed in different unrelated languages, this closure lag is only produced by some subjects and occurred in only 15% of the tokens, much less than the 80% reported for Tigrinya for example [3]. Intervocalic ejective fricatives also displayed less post-frication lags compared to word-initial position. CoG is higher for ejectives, suggesting a narrower constriction, but no differences were found between laterals and alveopalatals. Other correlates were most notably present in word-initial position (effects on vowel formants, intensity). Dorsopharyngealization, which could be interpreted as yet another strategy to solve ejection/frication incompatibility, serves as an enhancing gesture introduced in order to increase the perceptual distance between the two phonemic categories. This enhancing gesture is unnecessary in intervocalic position, given that induced vowel diphtongization is salient enough to allow speakers recover the contrast.

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