The Acoustics of Guttural Fricatives in Three Languages

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1 Introduction

Gutturals, consonants produced in the posterior portion of the vocal tract, are considered to include uvulars (e.g., /q, ɢ, χ, ʁ/), pharyngeals (/ħ, ʕ/), and, by some accounts, laryngeals (/ʔ, h/) [1]. Unlike consonants of other places of articulation, gutturals have been relatively phonetically understudied, with previous acoustic investigations being limited to a handful of languages and often few speakers. The existing acoustic work has been done mainly on guttural fricatives, /χ, ʁ, ħ, ʕ, h/, in Modern Standard Arabic ([2-4]). These works have established that duration of fricative noise distinguishes voiced from voiceless fricatives, as well as /h/ from the other fricatives. Noise spectra, on the other hand, were found to play an important role in differentiating place, as, for example, centre of gravity of noise correlates with the relative posteriority of the constriction. Spectral properties were also noted to differentiate voicing.

The goal of this study is to provide an acoustic analysis of voiceless and voiced guttural fricatives in three languages: Emirati Arabic (EA, Semitic), Iraqi Central Kurdish (IK, Iranian, Indo-European), and Lebanese Western Armenian (LA, Armenian, Indo-European). The first two languages contrast voiceless and voiced uvulars /χ, ʁ/ (which are in some sources described as velars /x, ɣ/), voiceless and voiced pharyngeals /ħ, ʕ/, and the voiceless laryngeal /h/ ([5] on EA; [6] on IK). LA contrasts voiceless and voiced uvulars /χ, ʁ/, and the voiceless laryngeal /h/ [7-8]. All these languages/varieties are relatively understudied phonetically, or hardly studied at all.

2 Method

The study involved 59 participants: 18 speakers of EA, 20 speakers of IK, and 21 speakers of LA, residing predominantly in Abu Dhabi and Dubai (UAE), Sulaymaniyah and Kirkuk (Iraqi Kurdistan), and Beirut (Lebanon), respectively. The participants were roughly balanced by gender (32 females, 27 males) and were of similar age - mainly in their 20s. In addition to their L1, they also spoke English and, for LA, Arabic. They were recruited through personal networks and local contacts in respective countries, and paid an equivalent of 15 CAD for their participation. Audio recordings were performed using an online experiment platform Gorilla.sc [9] and recording devices of participants' choice.

The materials included real words with the target consonants /χ, ʁ, (ħ, ʕ,) h/, embedded in a carrier phrase. Care was taken to keep the stimuli and phrases as similar as possible across the languages. Each utterance (1 word per fricative in intervocalic position) was repeated 3 times, giving 9 to 15 tokens per speaker, depending on the language.

The data were annotated in Praat [10], with boundaries set manually to indicate onsets and offsets of fricatives and adjacent vowels. Measurements were extracted using a script and included fricative duration and spectral moments taken at the midpoint of the fricative. Among the spectral measurements, we will here be concerned with only one -centre of gravity (COG), higher or lower frequency of which corresponds to the relative posteriority of the fricative constriction (i.e., expected to be lower for, e.g., /ħ/ than /χ/).

3 Results

To examine differences among fricatives, Linear Mixed Effects Models were performed for duration and COG separately for each language, as well as by Place in voiceless fricatives and Voicing in uvular and pharyngeal fricatives. The results, summarized in Table 1, revealed robust differences across 3-way (EA and IK) and 2-way (LA) place contrasts, as shown in the table. They also revealed consistent voicing differences. With the exception of the duration difference for uvulars and pharyngeals between EA and IK, all observed differences were the same across three languages.

Table 1: A summary of statistical results for Place (uvular, pharyngeal, laryngeal) and Voicing (voiceless, voiced) by language; '>' indicates higher values.

Parameter	Place (voiceless)			Voicing (non-/h/)
	EA	IK	LA	All
Duration	phar > uvu > lar	uvu > phar > lar	uvu > lar	vls > vd
COG	uvu > phar > lar		uvu > lar	vls > vd

To illustrate these results, Figure 1 presents fricative duration and centre of gravity ((a) and (b) respectively) by consonant and language. For duration, we can see a clear difference in voicing for uvular (red) and pharyngeal (green) sounds: the voiced consonants are much shorter. We can also see that /h/ is shorter than its voiceless counterparts. Turning to COG, recall that lower values of this variable indicate a greater posteriority of the consonant, reflecting the highest concentration of spectral energy along frequencies. Considering voiceless fricatives first, we can see in the plot that their COG values decrease from uvulars (red) to pharyngeals (green), and then to laryngeals (blue). This is consistent for all three languages (but note that LA lacks pharyngeals). The same is observed for voiced sounds of two places. In terms of voicing, voiced sounds show lower COG, given the low-frequency voicing energy, and likely frequent approximant-like realizations (due to lenition).

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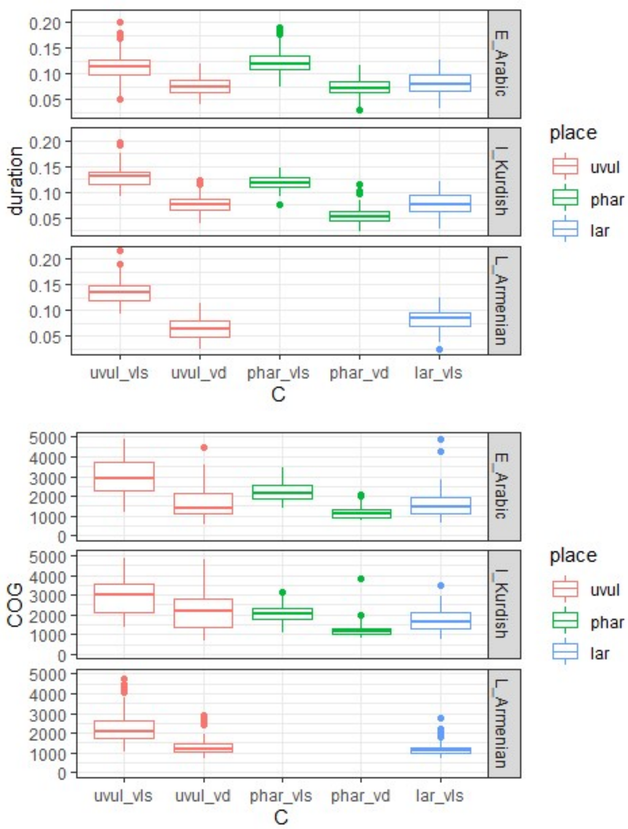

Figure 1: Boxplots for duration (sec; top plot) and COG (Hz; bottom plot) by consonant (voiceless and voiced uvulars and pharyngeals, voiceless laryngeal) and language.

4 Discussion

The results obtained in this study are similar to previous findings for Standard Arabic. Taking voiceless fricatives, for example, we can see in Figure 2 that COG values reported in several previous studies of Arabic fricatives (N1983 [2], AK2005 [4], AAM2005 [3]) were lower for pharyngeals and laryngeals, which is also the case obtained for EA, IK, and (in part) LA in this study. The lower COG for /h/ in our results is also consistent with the findings of [3]. There is also considerable agreement in mean values for the fricatives across the studies, despite the very different recording conditions.

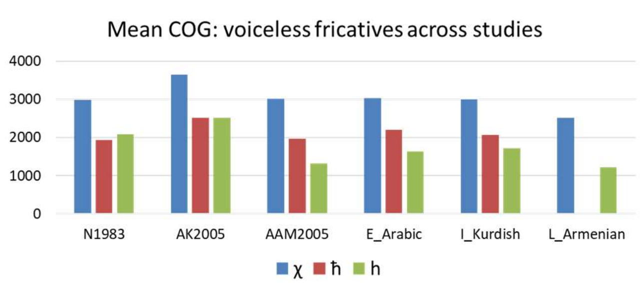

Figure 2: A comparison of mean COG (Hz) values across previous studies of Arabic voiceless fricatives (see text) and current results.

As a next step, we are planning to investigate additional variables, such as standard deviation, skewness, kurtosis, and intensity of fricative noise, as well as vowel transitions to/from fricatives (as these could further clarify place of articulation differences). The analysis will also be extended to word-initial and word-final positions, for which we have also obtained the data.

5 Conclusion

To conclude, this study contributes to the phonetic documentation of guttural sounds by covering new languages/varieties and using relatively large speaker samples. This study also serves to confirm the validity of the online audio recording method, which has been increasingly used in phonetics during the pandemic of COVID-19.

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References

[1] J. J. McCarthy. Semitic gutturals and distinctive feature theory, In B. Comrie & M. Eid (eds.), Perspectives on Arabic linguistics III, 63-91. Amsterdam: Benjamins, 1991

[2] K. Norlin. Acoustic analysis of fricatives in Cairo Arabic. Working papers/Lund University, Department of Linguistics and Phonetics, 25, 1983.

[3] A. S. Abu-Al-Makarem. The acoustics of fricative consonants in Gulf Spoken Arabic. PhD dissertation. Bowling Green State University, 2005.

[4] M. A. Al-Khairy. Acoustic characteristics of Arabic fricatives. PhD dissertation. University of Florida, 2005.

[5] T. T. C. Leung, D. Ntelitheos, and M. Al-Kaabi. Emirati Arabic: A comprehensive grammar. Routledge, 2020.

[6] W. M. Thackston. Sorani Kurdish: A reference grammar with selected readings. Harvard University, 2006.

[7] D. Sakayan. Western Armenian for the English-speaking world: A contrastive approach. Yerevan State University Press, 2012.

[8] Vaux, B. The phonology of Armenian. Oxford University Press, 1998.

[9] A. L. Anwyl-Irvine, J. Massonnié, A. Flitton, N. Kirkham, J. K. Evershed. Gorilla in our midst: An online behavioral experiment builder. Behavior research methods; 52(1):388-407, 2020.

[10] P. Boersma, and D. Weenink. Praat: doing phonetics by computer [Computer program]. Version 6.1.50, retrieved 20 June 2021 from http://www.praat.org/, 2021.