ARYEPIGLOTTIC TRILLED VARIANTS OF /ʕ, ħ/ IN IRAQI ARABIC

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ABSTRACT

Aryepiglottic (AE) trilling in the pharyngeals of Iraqi Arabic is observed, qualified and quantified using acoustic, EGG, kymographic, high-speed laryngoscopic and aperture estimate techniques. Articulatory stricture occurs at the superior AE-fold borders of the epilaryngeal tube. Periodic AE vibration acts as a secondary phonation source. Quantitative evaluation of trilling frequency and duration shows a greater degree of laryngeal constriction for voiced trills. We suggest that the mucosal wave causes a phase shift amongst the driving forces acting on the AE folds, resulting in more irregular vibration than for the vocal folds.

Keywords: aryepiglottic trilling, Iraqi Arabic, high-speed laryngoscopy, articulatory phonetics

1. INTRODUCTION

Although Arabic /ʕ, ħ/ have always been labeled voiced and voiceless pharyngeal fricatives, their aryepiglottic or trilling components have not previously been attested. Since the early Arab grammarians, there has been disagreement over their precise place and manner of articulation. Sibawayh placed them in the middle part of the throat [4], implying between the glottis and uvula. They are also placed generally in the pharynx for different varieties of Arabic, e.g. Tripoli Libyan [20], Sudanese [1], Qatari [5], Iraqi [21], and Lebanese and Palestinian Arabic [9, 26]. While ‘epiglottal’ is the IPA auditory label for ‘more extreme’ pharyngeals [19], recent research has shown the pharyngeal/epiglottal category of sounds to be produced by epilaryngeal constriction with tongue retraction [8, 12]. Heselwood [17] notes the importance of epilaryngeal tube shape beneath the stricture point and of larynx-height variations. Esling [11] notes that both pharyngeals and epiglottals occur at the aryepiglottic sphincter point of stricture, and sounds which have been described auditorily as epiglottal, ‘deeper’ or ‘more extreme’ than pharyngeals, are associated either with AE trilled varieties of the simple fricative or approximant or with the default raised-larynx posture of the laryngeal sphincter, with radical retraction of the tongue.

Different manners have been reported for different Arabic dialects or phonological contexts. Early studies classify /ʕ/ as fricative [6, 13, 15, 22], whereas it is classified as stop by Al-Ani [2, 3] for Iraqi Arabic (thought to be an occlusion at the ventricular bands), for Sudanese [1] and for Qatari [5]. An approximant variant has also been reported for /ʕ/ [21], a glide [16] and most recently a *tight* approximant [17]. A trilled variant based on Sibawayh’s term *taraddudiyyah* ‘frequentative’ has been posited [14], interpreted by Heselwood as evidence that *‘ayn* was a trill in the 8th century [17]. Arabic /ħ/ may not have as much phonetic variation as /ʕ/, but recently it has been noted to occur as an aryepiglottic trill [8]. Both /ʕ, ħ/ can demonstrate extreme laryngeal constriction of the AE folds at the top border of the epilaryngeal tube. Auditorily, the folds are heard to trill, especially in the case of a medial geminate /-ħħ-/, e.g. /saħħar/ ‘made magic’. The voiced counterpart /ʕ/ may also be realized with slight AE trilling [8].

2. METHODOLOGY

We performed high-speed laryngoscopy of native Iraqi Arabic productions of voiced and voiceless aryepiglottic (AE) trills. We present a qualitative analysis of the trills and illustrate them using video frame montages and composite plots containing electroglottographic, acoustic, kymographic, and aperture estimate signals. Quantitative evaluation is made of trilling frequency and duration.

2.1. Speech data

Our participant is an adult male native speaker of Iraqi Arabic, born and raised in Basra. Before performing high-speed filming and capture, we made preliminary normal-speed laryngoscopic observations of the speech items suspected to be produced with AE trilling to confirm that trilling did indeed occur.

The data consist of four Iraqi Arabic words containing trilled variants of the /ħ/ and /ʕ/ consonants in intervocalic context (/aCi/). These words can be grouped into two pairs by morphological relation, and each pair is minimally differentiated by consonant length:
/raħiːl/ 'travel' ~ /raħħiːl/ 'travel a lot' and
/saʕiːd/ 'happy' ~ /saʕʕiːd/ 'make people happy'.

2.2. High-speed laryngoscopy

The system used to capture the trilling sequences was an SL Kamera 500 connecting a rigid oral endoscope to a Weinberger SpeedCam Lite interface (Erlangen, Germany), set to a frame rate of 500 Hz with a resolution of 262x256 pixels.

Throughout the recording session, the audio signal of the trills was obtained using a head-mounted AKG C410 microphone, positioned 4 cm from the lips, with a 45 ° angle from sagittal, sampled at 44 100 Hz, 16-bit resolution. Larynx periodicity was obtained with a Glottal Enterprises EG2-PCX EGG, placing the surface electrodes externally over each thyroid lamina. The audio and video signals were digitized using ANAVOX (custom software; Vannier-Photelec, Antony, France). A time-to-live signal was used to ensure synchronization of the audio with the video signal. Uncompressed audio and video files (exported from ANAVOX) were processed and analyzed using MATLAB (version R2009a).

2.3. Data analysis

Our data analysis is primarily a qualitative evaluation of all signals obtained from the session (EGG, audio, and video). Only the participant's right AE fold is examined.

The reader will observe that the EGG signals are unstable during the trills and contain numerous discontinuities. This was likely due to change in larynx height during the pharyngeals. Despite this, the EGG signals are included in the results. This is partially to present a complete picture of our data, but it is also because these signals do contain regions of clarity, usually during modal voicing, which provide a rough index of laryngeal state.

Another feature of the analysis is the inclusion of the aperture signal, which is an estimate of the patency of the epilaryngeal tube as a function of time. This signal is calculated by summing the difference between 255 (full white in 8-bit grayscale) and the grayscale value of each pixel in the kymographic strip; the result then normalized as a percentage. The aperture signal serves two purposes for our analysis. It provides a clean image of AE fold activity (in complement to the kymography) and can be used to obtain an estimate of AE frequency by means of a fundamental frequency algorithm based on peak detection.

3. RESULTS

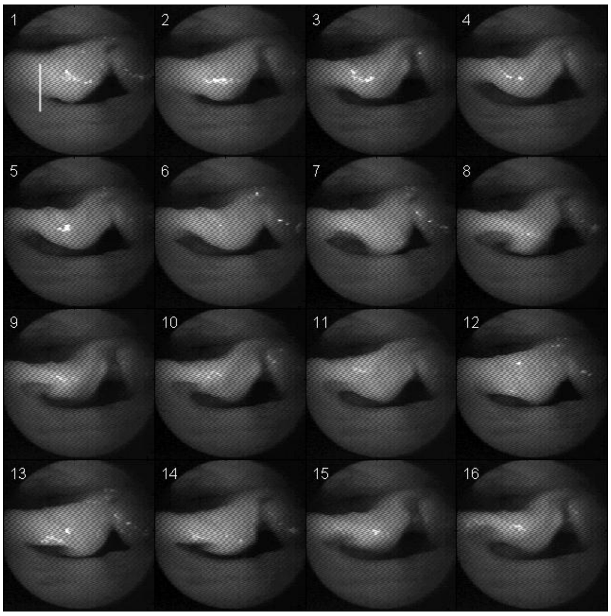
Duration and frequency measurements for all four trill tokens are presented in Table 1. Due to limited space, we only present full results for the geminate trills (Figs 1-4). While AE trilling was evident for all trills recorded, the geminates exhibited the greatest degree of AE fold displacement since there was more time for the AE folds to overcome their resting inertia.

Table 1: AE trill duration and average frequency.

word	duration (ms)	avg. freq. (Hz)
/raħiːl/	59	87
/raħħiːl/	211*	78
/saʕiːd/	69	130
/saʕʕiːd/	93	107

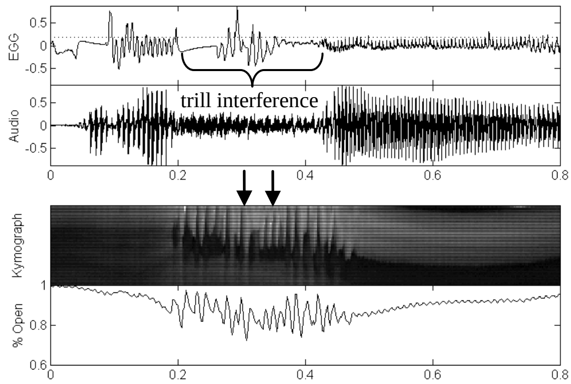
*The geminate voiceless trill is atypically long because these were recorded separately and at a slower speech rate.

Figure 1: Montage of contiguous frames of the voiceless AE trill in /raħħiːl/. White line: kymographic strip. Time of start and ending frames of sequence shown in Figure 2 (arrows). (video file 1, audio file 1).



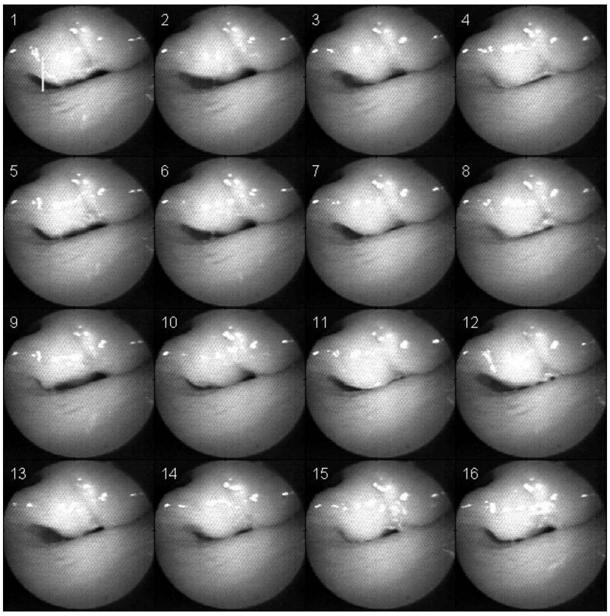
One important difference between the voiced and voiceless trills was the degree of laryngeal constriction, which was notably greater for the voiced trills (partially aided by vocal fold adduction). This is evident by comparing the appearance of the epilaryngeal tube in Figs 1 & 3. The difference is partly reflected in trilling frequency, although the singleton voiceless trill is more rapid than the geminate, which may be due to the greater mucosal wave that occurs for the latter.

Figure 2: Composite plot of /raħħiːl/. Arrows mark start and end points for montage in Figure 1.



Also worthy of note is the EGG signal, which sharply cuts out while AE trilling is occurring. Regions of interference are marked on the plots to show this. Changing laryngeal configuration during trill production is the most probable cause for this effect. Once the larynx returns to a more neutral position, the signal resumes (as in the latter parts of the /i/ vowel).

Figure 3: Montage of contiguous frames of the voiced AE trill in /saʕʕiːd/. White line: kymographic strip. Time of start and ending frames of sequence shown in Figure 4 (arrows). (cf. video file 2, audio file 2).



4. DISCUSSION

Aryepiglottic trilling is not strictly local to the pharyngeal segment. Its periodic pseudo-phonatory quality is superimposed over the adjacent vowel periphery as a modulation of the voice source but is most intense during the pharyngeal itself. Both voiced and voiceless pharyngeals cause this effect, which we transcribe by using a superscript voice aryepiglotto-epiglottal trill [ˁ] to indicate this transitional phase into the pharyngeal proper. Table 2 shows the narrow transcriptions. The voiceless AE trills exhibit much more AE fold displacement than for the voiced trills, which are produced with narrower epilaryngeal constriction.

Figure 4: Composite plot of /saʕʕiːd/. Arrows mark start and end points for montage in Figure 1.

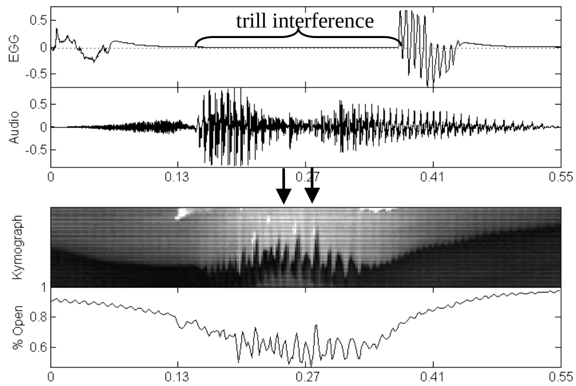


Table 2: Narrow phonetic transcription of Iraqi Arabic aryepiglotto-epiglottal trills.

word	Transcription	meaning
/raħiːl/	[raˁʜˁiːl]	'traveling'
/raħħiːl/	[ᵊraˁʜʜˁiːl]	'to travel a lot'
/saʕiːd/	[saˁʢˁiːd]	'happy'
/saʕʕiːd/	[saˁʢʢˁiːd]	'make people happy'

The apices of the arytenoids also participate in the oscillation during the voiceless trill (see Figure 1). Also manifest (especially for the voiceless trills) is a mucosal wave that radiates outwards across the surface of the AE fold, impacting the oscillatory dynamics by changing the phasing relationship between the input energy into the AE folds and its elastic recoil. Also, following observations about tongue tip trilling [23], it is reasonable to posit that the epilaryngeal lumen acts capacitatively by causing input DC air flow to become periodic. Thus, these two factors prevent static equilibrium between air energy input into the AE folds and their elastic restoring forces. In parallel with vocal fold dynamics [28], the mucosal wave undoubtedly causes a phase shift amongst the driving forces acting on the folds, but the result is *more irregular* than for the vocal folds. This is attributed to the geometry (which adds degrees of freedom) and structural nature of the AE folds (being less stiff than the vocal folds). The irregularity that characterizes AE kinematics [25] is essential to the acoustic product of trilling, which is described as harshness.

5. CONCLUSION

Aryepiglottic trilling occurs as an allophonic variant of Iraqi Arabic pharyngeal consonants /ʕ/ and /ħ/. The trills coarticulate with neighbouring vowels yielding a harsh phonatory quality. Trill biomechanics are dynamically complex and lead to irregular pulse periods. Voiced trills show entrainment with the vocal folds and, depending upon internal mechanical factors, the AE folds can approach the fundamental frequency of the vocal folds. Formally, these sounds are voiced and voiceless aryepiglotto-epiglottal fricative trills for which we use the symbols [ʢ] and [ʜ], respectively.

Previous studies of unrelated languages such as !Xõó [18, 29], Ju|hoansi [24], Zhenhai dialect of Wu Chinese [27], Jianchuan Bai [8], and various Caucasian languages [7, 19], all provide accounts that strongly suggest aryepiglottic trilling occurs in these languages, despite the sparseness of visual evidence. We propose to undertake new research using laryngoscopy to confirm whether this is the case. Increased awareness of the incidence of AE trilling (and epilaryngeal source generation in general) either as a segment or a distinctive register will be important in refining and expanding on the current phonetic model of laryngeal features.

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7. REFERENCES

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