LARYNGOSCOPIC ANALYSIS OF PHARYNGEAL ARTICULATIONS AND LARYNX-HEIGHT VOICE QUALITY SETTINGS

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ABSTRACT

Using fibreoptic laryngoscopy to observe pharyngeal articulations, the aryepiglottic sphincter mechanism is shown to be responsible for the production of speech sounds in the phonetic category "pharyngeal." Major differences in auditory/acoustic quality are also produced when the larynx as a whole is raised or lowered during the production of pharyngeals.

The voiceless pharyngeal fricative and voiced pharyngeal approximant are the result of increased sphincteric constriction of the laryngeal "tube" in a continuum that begins with normal glottal stop and ventricular fold closure. A pharyngeal stop is produced when the aryepiglottic sphincter mechanism achieves complete closure, and trilling accompanying friction is evident at the pharyngeal place of articulation in both voiceless and voiced modes. It is suggested that all five sounds share a common, pharyngeal place of articulation, but differ in manner of articulation. Raised larynx is the default setting for these articulations, but they may be produced with lowered larynx.

1. PHARYNGEAL SOUNDS

Pharyngeals occur as discrete phonemes or as a secondary characteristic where a series of sounds is modified by the presence of a pharyngeal posture. Linguistic phonetic realizations of pharyngeal gestures include Semitic pharyngeals, pharyngeals in Caucasian languages, glottalization in North American languages (Salish and Wakashan), laryngealization in West African languages, implosives and ejectives, a feature of tone in Vietnamese and of segmental articulation in Danish, the [-ATR] vowel harmony series in West African languages, "strident" vowels in Khoisan phonology, and the pharyngealized voice quality in a number of singing styles that have been analyzed phonetically.

Laufer and Condax [1] and Laufer and Baer [2] have demonstrated that native-speakers of Arabic and of Oriental Hebrew produce a voiceless fricative and a voiced approximant from a stricture behind the epiglottis. Butcher and Ahmad [3] confirm that the voiceless Arabic pharyngeal is a fricative and that the voiced Arabic pharyngeal is an approximant, but that the latter is most often realized as a stop. Catford [4,5,6] uses the term "epiglottopharyngeal" to refer to these sounds and to fricative, approximant, stop and "possibly" trill sounds in the Caucasian languages investigated by Kodzasov [7,8]. Kodzasov also observes that the larynx is typically raised in the production of pharyngeals. This possibility is supported by El-Halees [9] and by Stephen Jones who found in early radiographic studies of Somali pharyngeals not only that the larynx was elevating but that there also appeared to be some sort of vibration around the epiglottis during some articulations [10].

There is additional evidence that larynx raising may be inherent in pharyngeal articulations. Esling, Heap, Snell and Dickson [11] demonstrate that there is no auditory perceptual distinction between pharyngealized voice and raised larynx voice at certain pitches, and that pharyngealized voice is likely to be perceived when pitch is low while raised larynx voice is likely to be perceived when pitch is high. Esling [12] presents evidence that the pharyngeal articulator is responsible for the production of both pharyngealized voice and what Laver terms raised larynx voice [13]. Negus [14], Gauffin [15], Roach [16] and Painter [17] present detailed insights into supraglottal strictures, and Yanagisawa, Estill, Kmucha, and Leder [18] and Honda, Hirai, Estill and Tohkura [19] provide evidence that the epilaryngeal tube is elevated during many singing styles. What is unanswered here is to demonstrate the phonetic relationship between these singing styles and pharyngealized voice, and between larynx raising and the various possible manners of pharyngeal articulation.

2. PROCEDURE

Phonetically controlled articulations produced systematically by the author and modelled on Catford's [4,5,20] and Laver's [13] auditory categories were observed in order to document a baseline of pharyngeal articulatory possibilities, following the laryngoscopic modelling approach adopted by Traill [21,22].

A Kay 9100 RLS light source and recording system and Olympus ENF-P3 fibreoptic laryngoscope attached to a 28mm lens were used to observe the pharynx, videotaping to S-VHS at 30 frames/sec. Contrasting degrees of pharyngeal stricture and contrasting larynx height parameters were examined. Consonantal articulations were performed in a carrier phrase in an [i_i] environment.

Manipulations included varying manner of articulation at the same pharyngeal place, varying larynx height between a raised, neutral and lowered setting, and varying pitch in eight steps between 87Hz and 440Hz. Only the study of contrastive manners of articulation is reported here, with mention of the implications of larynx raising.

Using auditory categories well-established in the alphabet of the International Phonetic Association [23] and informed primarily by Catford's interpretation of these categories as reviewed above in section 1, a range of stops was produced beginning with a weak glottal stop and progressing to the most extreme stop possible, as defined in the phonetic literature. The familiar fricative and approximant as defined in the literature were also produced, and an attempt was made to increase tension and airflow to generate enhanced fricatives with vibration in the area of the epiglottis.

3. OBSERVATIONS

The contrast between a glottal stop and pharyngeal or epiglottal stop is shown in Figure 1. The latter involves more extreme activation of the aryepiglottic sphincter, in which the aryepiglottic folds (linking the adducted arytenoids with margins of the epiglottis) press up under the body of the epiglottis as the tongue retracts.

The views in Figure 1 are taken with the tip of the laryngoscope positioned in the velo-pharynx at about the height of the uvula, looking down directly onto the epiglottis (attached to the back of the tongue), and the cartilaginous valvular mechanisms of the glottis and pyriform recesses beneath. The glottis is central, between the arytenoid cartilages, and the opening to the oesophagus would be exactly behind (above) the arytenoids at the base of the posterior pharyngeal wall.

The views in Figures 2 and 3 are taken much deeper, beneath the level of the apex of the epiglottis to a point where the aryepiglottic folds can be seen to attach laterally to the margins of the epiglottis. This valvular structure has also been called the "laryngeal sphincter," separating the airway from the oesophageal pathway during swallowing or in holding the breath [14]. Catford's descriptions of the relationship of the physiological mechanisms to phonetic speech sound production are particularly incisive [5].

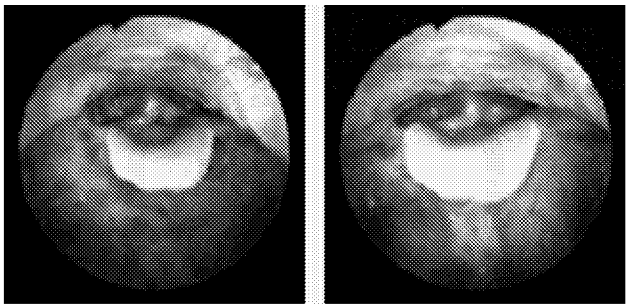

Figure 1: A laryngoscopic view of the pharynx shows that even a strong glottal stop (left) occludes the airway without noticeably changing the size of the pharynx. A pharyngeal stop (right) shows more tightly occluded arytenoid cartilages and aryepiglottic folds, which are elevated in the pharynx as the tongue and epiglottis retract. This gesture reduces the size of the pharynx as well as overall vocal tract length.

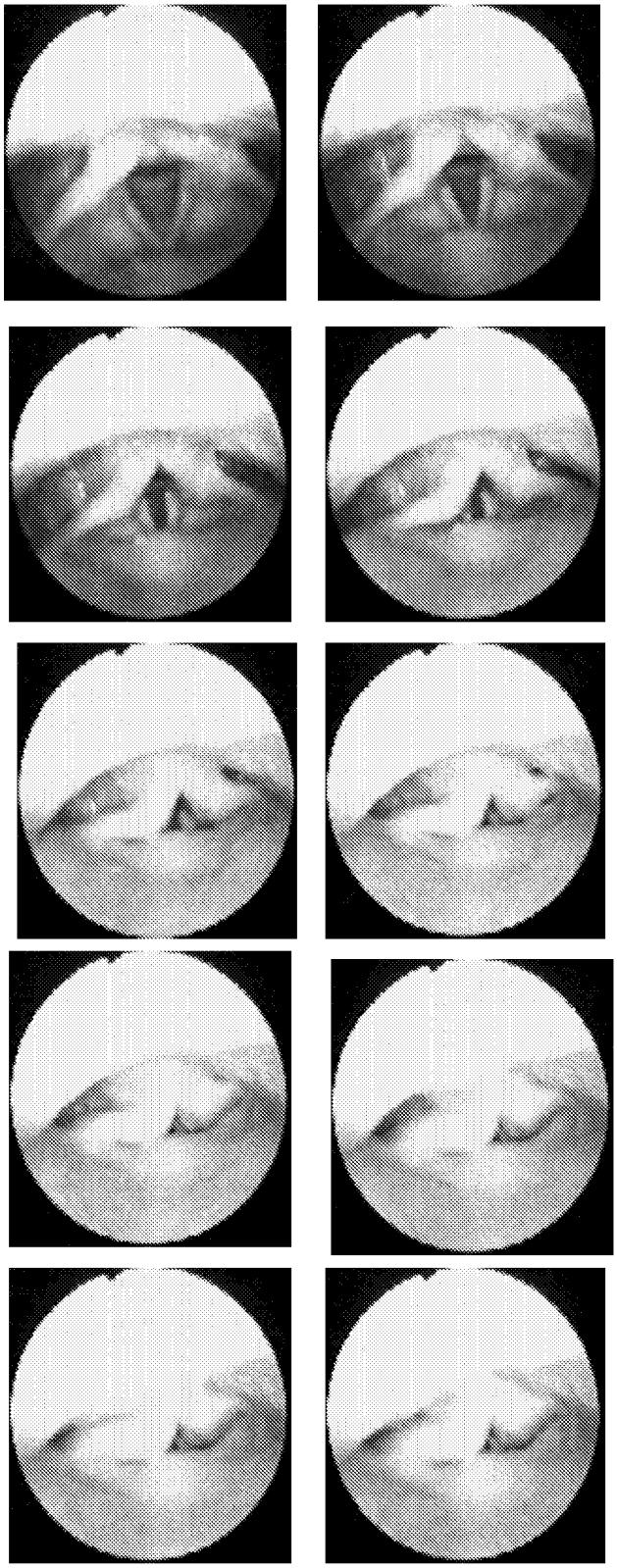

Figure 2: Beginning with an open glottis, viewing from left to right, the production of a pharyngeal fricative with enhanced friction involving trilling results in a characteristic mid-glottal channel (frames 5 and 6), with sphincteric

aryepiglottic fold compression. Larynx raising is most evident in voiceless pharyngeals. This view is take from behind and beneath the apex of the epiglottis. When trilling is initiated (frames 7–10), the lateral margins of the aryepiglottic folds undulate, suggesting a parallel air channel to the sides of the mid-glottal aperture between the arytenoids.

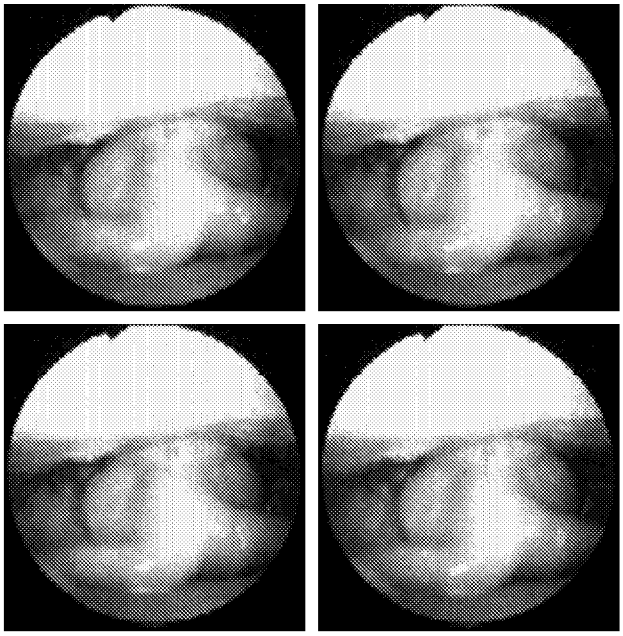

Figure 3: Trilling of the aryepiglottic folds can also occur together with glottal voicing. This view, substantially far behind the epiglottal cartilage itself, shows the arytenoid cartilages and aryepiglottic folds tightly sphincteredforward at the top of the tracheal tube. The production is clearly voiced auditorily, although the location of the air channel is not evident. Aryepiglottic fold vibration occurs laterally, between the tightly advanced cuneiform cartilages and the margins of the epiglottis. 4/30 sec are represented.

4. FINDINGS

The voiceless pharyngeal fricative [ħ] and voiced pharyngeal approximant [ʕ] are the result of increased sphincteric constriction of the laryngeal "tube" in a continuum that begins with normal glottal stop [ʔ] and ventricular fold closure. A pharyngeal stop [ʡ] is produced when the aryepiglottic sphincter mechanism achieves complete closure. Trilling accompanying friction is evident at the pharyngeal place of articulation in both voiceless [ʜ] and voiced [ʢ] mode. It is suggested that these five sounds [ħ, ʕ, ʜ, ʢ, ʡ] share a common, pharyngeal place of articulation, but differ in manner of articulation. In this interpretation, there is no distinction in place of articulation between what have been termed phonetically "pharyngeals" and what have been termed "epiglottals." Raised larynx is the default setting for all of these articulations, but they may be produced with lowered larynx. Phonetic distinctions which have been observed in the literature between "pharyngeals" and "epiglottals" are more likely due to the setting of the larynx-height parameter.

The present auditory and laryngoscopic observations demonstrate a number of conclusions:

- that Catford's epiglottopharyngeal category involves the aryepiglottic sphincter mechanism behind the epiglottis,
- that stop closure is possible at the aryepiglottic location, homorganic with other pharyngeals,
- that extreme retraction of the tongue to the back wall of the pharynx accounts for only the orally visible component of pharyngeal articulation,
- that trilling can also occur aryepiglottically,
- that these articulations are produced at the same location as the pharyngeal fricative and approximant, that is, that pharyngeal articulations are a function of the action of the laryngeal (aryepiglottic) sphincter, with its inherent elevation of the larynx and retraction of the tongue root.

5. IMPLICATIONS

Evidence of raising of the larynx especially in the pharyngeal fricative implies that linguistic distinctions such as those found in Akan with retracted tongue-root sounds (see Tiede [24]) also make use of the aryepiglottic sphincter mechanism at the same time as narrowing the supraglottal space by retracting the tongue and raising the larynx. This implies in turn (and is supported logically by narrow phonetic listening) that the "laryngealized" series of many Tibeto-Burman languages can also be interpreted as a raised-larynx articulatory series,

These observations may be taken as a phonetic template for comparing back-of-the-throat articulatory phenomena in the languages cited here. The model of phonetic pharyngeal function which this report proposes has the potential to inform models of glottal function by indicating how to add a pharyngeal (supraglottal) component and to inform speech analysis and synthesis algorithms by predicting the effect that varying pharyngeal impedance may have on the glottal source.

In further research, the effects of changing pitch and of systematically raising and lowering the larynx during pharyngeal consonants and during pharyngealized vowel production will be examined.

6. WEB SITE VIEWING

The laryngoscopic images illustrated in this paper can be viewed as moving animations, with reference audio files, at the University of Victoria Phonetics Laboratory web site:

http://web.uvic.ca/ling/research/pharynx.html

7. ACKNOWLEDGEMENTS

This research was carried out with a grant from the Social Sciences and Humanities Research Council of Canada (# 410-93-0539), and with the assistance of Craig Dickson and the staff of Speech Technology Research Ltd. in Victoria.

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