The IPA Categories "Pharyngeal" and "Epiglottal": Laryngoscopic Observations of Pharyngeal Articulations and Larynx Height

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Language and Speech 1999; 42; 349
DOI: 10.1177/00238309990420040101

The IPA Categories "Pharyngeal" and "Epiglottal": Laryngoscopic Observations of Pharyngeal Articulations and Larynx Height*

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KEY WORDS

aryepiglottic

epiglottal

laryngeal

laryngoscopic

larynx height

pharyngeal

ABSTRACT

The phonetic problem is to describe accurately the articulatory mechanism, or mechanisms, responsible for the production of a series of sounds that are presently labelled on the chart of the International Phonetic Association as either pharyngeal or epiglottal. The sounds on which these categories are based are found in the Semitic languages, in the languages of the Caucasus, and in the languages of the Pacific Northwest coast of North America. In order to reconcile a variety of descriptive terms with a logical phonetic taxonomy, auditorily distinguishable parameters are deduced from a naturally occurring variety of sounds, isolated articulatorily, and observed with a fibreoptic laryngoscope to define a cardinal set of articulatory possibilities. Auditory comparisons with database illustrations of the sounds of various languages inform the production of cardinal values in the laryngoscopic study. Voiceless pharyngeals (fricatives) are identified by aryepiglottic fold constriction and a medial aperture. Voiced pharyngeals (approximants) are identified by aryepiglottic fold constriction and a covered glottis. Trilling can occur laterally along the aryepiglottic folds in either voiceless (fricative) or voiced (approximant) mode. A pharyngeal plosive is identified by full occlusion of the aryepiglottic sphincter. "Epiglottal" sounds, which have been described auditorily as "deeper" or "more extreme" than pharyngeals, are associated with either the trilled varieties of the simple fricative or approximant, or the default raised larynx posture of the aryepiglottic sphincter, with radical retraction of the tongue. They are therefore more severely constricted, but not physiologically "deeper" than simple [ħ] or [ʕ]. Pharyngeal articulations may also be produced with larynx lowering. Voiceless pharyngeal [ħ] may be accompanied by lowering of the larynx to distinguish it from a larynx-raised [ʜ] variant. Larynx height variations are also found in "tense/lax" register distinctions.

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* *Note:* A version of this paper was presented at the International Conference on Voice Physiology and Biomechanics May 28–31, 1997 in Evanston, Illinois.

Acknowledgments: This research was carried out with a grant from the Social Sciences and Humanities Research Council of Canada (#410-93-0539). I am grateful to Lynn Heap, Jocelyn Clayards, Michael Mawdsley, and Alan Lupin for their participation in the research, to Jimmy G. Harris for his advice and theoretical discussions, and to the staff of Speech Technology Research Ltd. for their technical support and collaboration. Thoughtful comments and criticisms by J. C. Catford and by John Kingston during the editing process are particularly appreciated.

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INTRODUCTION

The objectives of this paper are to re-examine the sounds produced at the pharyngeal place of articulation, to review the linguistic phonetic realizations of sounds which have been labelled "pharyngeal" and those which have been labelled "epiglottal," and to investigate the production of a series of pharyngeal sounds under conditions of larynx raising and larynx lowering. A phonetic contrast is implied by the presence of two series of places of consonantal articulation in the chart of the International Phonetic Alphabet (IPA, 1999): pharyngeal and epiglottal. Although the Semitic phonemes /ħ/ and /ʕ/ are traditionally described as pharyngeals, they are also sometimes described as epiglottals (Laufer & Condax, 1981). This paper focuses on the effect that larynx height brings to the production of contrasting pharyngeal manners of articulation. It is founded on an exploration of the nature of the continuum of glottal/aryepiglottic closure, and uses cardinal auditory categories as a basis for the visual examination of sounds labelled as pharyngeal or as epiglottal.

THE PHARYNGEAL PLACE OF ARTICULATION

In his 1968 review of articulatory possibilities, Catford advanced the term "epiglottopharyngeal" to characterize "extreme retraction of the tongue, so that the epiglottis approximates to the back wall of the pharynx" (p. 326), but doubted whether a stop articulation could be performed at this location "since it seems to be impossible to make a perfect hermetic closure between epiglottis and pharynx wall—stop-like sounds produced in this way appear to involve glottal closure as well as epiglottopharyngeal close approximation. However, epiglottopharyngeal *fricative*, *approximant*, and possibly *trill* can be produced" (p. 326). Catford's tentative inclusion of epiglottopharyngeal stop and trill categories, in parallel with fricative and approximant, in his table of articulatory possibilities (p. 327) has prompted research to identify where a stop and trills in this region can originate. The nature of what is meant by "epiglottopharyngeal" is examined in detail in Esling (1996) with respect to (a) the aryepiglottic sphincter mechanism and (b) contrasting manners of articulation. The observations reported in that paper suggest that "epiglottal" articulations can be treated as a category of manners of articulation at the pharyngeal place of articulation; and that manners of pharyngeal articulation closely parallel the uvular manners of articulation. This explanation, however, is not entirely adequate. If sounds that have been called epiglottal are auditorily distinct from sounds that have been labelled pharyngeal, then some other parameter must be coming into play which has not yet been fully integrated into the explanation of that distinction.

The physiology of pharyngealization

Laufer and Baer (1988, pp. 184–185) report early findings about the involvement of the epiglottis and the arytenoids (Brücke, 1860), and the participation of the suprahyoid muscles in lowering (retracting) the epiglottis, raising of the larynx, and the constriction of the pharynx (presumed to be by the constrictor muscles) as components in the production of pharyngeals (Panconcelli-Calzia, 1924). They also report findings by Tur-Sinai (1937) about the analogy to swallowing in the production of pharyngeals.

As Catford argued, the epiglottis does not generally compress fully against the back wall of the pharynx. At least there is no physiological need for it to do so. The structures between the epiglottis and the glottis, however, play a major role in deglutition, as described in the clinical phonetic literature. Although it is doubtful that the epiglottis moves independently of the tongue root, it is important to point out that Laufer and Condax (1981, p. 51) accept that there is no complete closure between the epiglottis and the pharyngeal wall in the production of /ħ/ and of /ʕ/ in Arabic and Hebrew, but identify either creakiness (glottalization) and/or a voiceless stop articulation between the epiglottis and the arytenoids. In, 1988, Laufer and Baer demonstrated that differences in degree of constriction imply two distinct manners of articulation — a voiceless fricative [ħ] and a voiced approximant [ʕ]. Based on laryngoscopic images at the time, they preferred to label both of these sounds "epiglottal" since the tip of the epiglottis visibly retracts to approximate the back wall of the pharynx. Their results suggest that lateral compression of the pharynx plays little role in pharyngealization, and is at least not independent of tongue/epiglottis retraction. Kodzasov's fibreoptic study of pharyngeals in Daghestanian languages, such as Avar or Agul, linked pharynx-tube narrowing with lingual retraction, observing "inward movement of the posterior and lateral pharyngeal walls accompanied by the backward movement of the tongue root together with the epiglottis which led to a narrowing of the pharyngeal passage" (Kodzasov, 1987, p. 143).

These observations imply that pharyngeal quality is more likely to be initiated through epiglottal and laryngeal (front-back lingual) compression than by lateral pharynx compression. Williams, Farquharson, and Anthony (1975, p. 310) observed a progression of constrictions consisting of "narrowing of the whole laryngeal vestibule from sphincteric action of the aryepiglottic folds, epiglottis and even the lateral pharyngeal walls," and Roach (1979, p. 2) has also noted that the stricture accompanying certain glottalized consonants "is in fact made with closure not only of the true vocal folds but also of the false vocal folds and the aryepiglottic folds." Gauffin (1977, p. 308) refers to this mechanism as protective closure of the larynx, achieved by constricting "larynx tube opening" at the level of the laryngeal sphincter, and characterizes a simple glottal stop as "reduced protective closure." The implication of this research is that the laryngeal sphincter is the primary anatomical mechanism responsible for *full* protective closure, and that the phonetic realization of the working of this articulator can be associated with Catford's epiglottopharyngeal stop or "strong" glottal stop (referred to below), interpreted here as a pharyngeal stop.

Painter (1986, p. 330) describes the laryngeal sphincter mechanism in detail as part of the swallowing process, where "approximating the cuneiform cartilages and aryepiglottic folds" has the effect that "the epiglottis is drawn backwards over an already closed airway." This interpretation differs from the traditional notion of a flap-like epiglottis which actively curls back to shield the airway. Painter describes the components of these physiological "effort and swallowing gestures" as a sequence of vocal fold adduction, ventricular fold adduction, cuneiform cartilage and aryepiglottic fold approximation, and epiglottis retraction (in conjunction with general tongue retraction). This revised interpretation is consistent with Negus' (1949, p. 182) description of the epiglottis as "fairly big but degenerate … because of immobility and lack of function" where "during swallowing, contraction of the sphincteric muscle fibres contained between the layers of the aryepiglottic folds closes the aperture of the larynx and prevents inundation." The remaining articulatory phonetic issue is to identify the dependence relationships between the different components of this physiological gesture and how they are associated with pharyngeal sound quality. A principal component remaining to be examined is the (upward) movement of the larynx as the sphincter engages.

A significant contribution to the understanding of the role of aryepiglottic postures in the production of distinctive voice qualities in singing is the finding of Yanagisawa, Estill, Kmucha, and Leder (1989) that certain singing styles involve a tightened aryepiglottic sphincter. Their laryngoscopic photographs demonstrate that a range of auditory targets can be correlated with contrasting degrees of aryepiglottic fold closure, as well as with varying heights of the larynx for some of the target qualities. The auditory descriptions of the vocal styles which they investigated have auditory parallels with pharyngeal speech quality. It is similarly apparent that the sphincter mechanism represented in their photographs is the major physiological mechanism in the pharynx differentiating the singing qualities which they studied. From their auditory descriptions and photographs of the sphincter, it can be interpreted that speech sounds that involve a "narrowing" of the pharynx probably utilize these same pharyngeal stricture gestures. Their photographs are indicative of a posture where the laryngeal valve is so narrowly constricted that it is about to be shut off, as in the so-called strong glottal stop. Their labels of singing styles suggest constriction from tongue retraction or larynx raising, as in pharyngealization.

Honda, Hirai, Estill, and Tohkura (1995, p. 36) identify a "tightening of the larynx tube, or the aryepiglottic space [for Opera, as] an effective gesture for producing a ringing voice quality used for producing loud and bright sounds." In conjunction with "a forward shift of the hyoid bone while maintaining a low larynx position for Opera quality," they identify "a bending and a stricture of the aryepiglottic space." A comment by Pierrehumbert in Honda et al. (1995, p. 37) suggests that the glottalized voice quality of pharyngeal consonants in Semitic and Salish languages may be related to this same aryepiglottic constriction. In the following sections, the pharyngeal manners of articulation investigated by Esling (1996) are reviewed.

Stop

Hockett (1958, p. 66) identified a "pharyngeal catch" (as distinct from a continuant) in some dialects of Arabic, and Catford (1983, p. 347) has noted a "pharyngealized glottal stop" or "strong glottal stop" in languages of the Caucasus, and a "pharyngeal stop" in Chechen. Butcher and Ahmad (1987) observed that the voiced pharyngeal in Iraqi Arabic sometimes functions as a stop. Early work by Stephen Jones (1934) at University College London influenced Catford to draw a relationship between pharyngeal constriction and the ventricular phonatory setting, which occurs when "the ventricular bands are brought together…, plus some generalized constriction of the upper larynx and pharynx," so that "ventricular or strong glottal stop may be represented by [ʕ͜ʔ]" in contrast to [ʔ] (Catford, 1977a, p. 163). Gaprindashvili (1966) describes this articulation as a "pharyngealized glottal stop" (Catford, 1977a, p. 163). The strong glottal stop occurs in the Nakh languages and in some Daghestanian languages (Kodzasov, 1987), and is sometimes termed a "pharyngeal stop" in the Georgian literature (Catford, 1977, p. 289). This sound has been isolated as an "epiglottal plosive" in the inventory of the IPA, and given the symbol [ʡ] (IPA, 1999). The location of stricture has been identified at the aryepiglottic folds — at the laryngeal sphincter mechanism, the third level of closure above the glottis and the ventricular folds — which seals the airway in an anterior movement against a descending tongue root (Esling, 1996). It appears from this research that the larynx usually rises to lift the arytenoids forward to effect the most efficient, strongest seal.

Fricative and approximant

In, 1979, Laufer and Condax used laryngoscopy to observe the activity of the epiglottis in the production of Semitic pharyngeals, presenting evidence that the voiceless and voiced fricatives in Arabic and Hebrew involve constriction localized in the epiglottal region. They also confirm that under different circumstances the voiced Arabic /ʕ/ is produced as a glide (i.e., as an approximant), or as a voiced fricative, or as a voiceless stop (Al-Ani, 1970, 1978; Laufer & Condax, 1981, p. 55). Catford (1977a, p. 163) reports that in the production of [ħ] and [ʕ], viewed orally, "the part of the pharynx immediately behind the mouth is laterally compressed, so that the faucal pillars move towards each other. At the same time the larynx may be somewhat raised..... It is largely a sphincteric semiclosure of the oro-pharynx, and it can be learned by tickling the back of the throat, provoking retching." Viewed laryngoscopically, both [ħ] and [ʕ] demonstrate aryepiglottic fold constriction, between the compressing arytenoids and a point close to the base of the epiglottis (Esling, 1996). For the voiceless fricative, a medial triangular opening remains between the arytenoids, above the level of the glottis, as they press forward against the epiglottic tubercle. This funneling of the laryngeal vestibule can be hypothesized to be the source of friction giving rise to voicelessness. The pharyngeal approximant demonstrates a similar constricted posture of the aryepiglottic folds, but lacks the medial opening of its voiceless counterpart. Although the vibrating vocal folds are not visible during [ʕ], airflow may be free to pass through a lateral gap between either aryepiglottic fold and the epiglottis.

Trills

Ever since Jones' (1934, pp. 8–9) observation "that the ventricular bands and the surrounding tissue were in rapid vibration" and that there was "a lift in the glottis and a narrowing of the supra glottal pharynx" in the pharyngeals of Somali, there has been recurring speculation on the presence of a supralaryngeal source of vibration. Jones' reference to ventricular vibration, resembling "double voice," was one source that led Catford to speculate about ventricular voice or trilling as a pharyngeal property. Another source was Paget (1930; Catford, 1977a, pp. 103–104). Catford's 1983 (p. 347) description of pharyngeals in Caucasian languages locates the trilling in the region of the epiglottis rather than at the ventricular bands. Esling (1996) presents evidence that the trilling occurring when pharyngeal fricatives are articulated forcefully is a vibration of the aryepiglottic folds above the ventricular folds at the level of the aryepiglottic sphincter. The contribution of the ventricular folds themselves to the vibratory mass, and of the true vocal folds for that matter, has yet to be determined. Since the trilling can be produced in both voiceless and voiced mode, it is assumed that the vocal folds either vibrate or not, and that the ventricular folds may behave similarly. Traill (1985, 1986) presents persuasive evidence of the laryngeal sphincter as a "phonatory" mechanism, occurring in !Xóõ (Bushman) as a contrast between "plain voiced," "murmured" and "sphincteric" vowels. His x-ray photographs clearly illustrate a simultaneous narrowing of the pharynx behind the epiglottis, raising of the larynx, and approximation of the arytenoid cartilages to the base of the epiglottis. The reported vibration of the arytenoids and/or of the epiglottis, difficult to isolate in Traill's sagittal x-ray views, can be explained by the evidence in Esling (1996) of the existence of a voiced and voiceless trill at the level of the aryepiglottic sphincter, where airflow escaping laterally between the upper portion of the aryepiglottic folds and the surface of the epiglottis causes vibration to occur.

LINGUISTIC PHONETIC REALIZATIONS OF PHARYNGEALS

The auditory descriptions of a number of languages motivate the investigation of pharyngeal quality. To some extent, manner of pharyngeal articulation can account for the qualities observed, but in many cases, an additional parameter must be posited. Semitic /ħ,ʕ/ involve pharyngeal stricture where /ħ/ is a fricative and /ʕ/ is considered an approximant (Laufer, 1996). "Glottalized" sounds in Salish and Wakashan languages (e.g., the difference between /m/ and /m'/) can be interpreted as adding a glottal stop or strong glottal stop before or after the continuant or, possibly, as adding secondary pharyngeal approximation. In Spokane, the pharyngeal approximants themselves are glottalized — /ʕ', ʕʷ'/ — which is interpreted in Esling (1996) as the addition of a stop component in the same way that Catford's [ʕ͜ʔ] is taken to represent a pharyngeal stop in Caucasian languages. Agul, illustrated in the UCLA HyperCard database, *Sounds of the World's Languages* (Ladefoged & Maddieson, 1996, pp. 38, 167–170), is a good example of this sound, represented as [ʡ] (Kodzasov, 1987). Manner of articulation accounts for the paralinguistic enhancement of phonological /ħ,ʕ/ in Ahousaht (Nootka) to [ʜ, ʢ], where [ʜ] and [ʢ] are trills (Esling, 1996). Trilling may also be responsible for Butcher and Ahmad's reports of "laryngealization" during Iraqi Arabic /ħ, ʕ/ (1987, p. 166). Phonologically distinctive fricatives in Caucasian languages such as Agul, symbolized as /ʜ, ʢ/, can also be explained as a homorganic shift in manner of articulation from pharyngeal fricative to trill in the same way that uvular fricatives are often described as being enhanced by the addition of uvular trilling. Catford's (1990, p. 26) impression that [ʜ] and [ʢ] are more "genuinely fricative" than [ħ] and [ʕ] is consistent with the interpretation that they are fricatives with the addition of trilling (Esling, 1996, p. 82). What Catford labelled "ventricular fricative trill" with "ventricular turbulence" can be more comprehensively understood in the context of aryepiglottic trilling at the laryngeal sphincter. Within that context, the second parameter that appears auditorily to distinguish [ʜ, ʢ] from [ħ, ʕ] is their raised larynx quality.

It is possible for vowels as well as consonants to carry aryepiglottic trilling in addition to glottal voicing. This was pointed out above for the "strident" vowels in Khoisan (Traill, 1986). Traill's auditory data and laryngoscopic and x-ray evidence for these !Xóõ vowels is identified as voiceless aryepiglottic trilling in Esling (1996, p. 82), but it can also be observed that the larynx elevates for the "strident" (trilled) series compared to modal or breathy vowels. The reason why the larynx should elevate in order to achieve optimal trilling is that the aryepiglottic folds can approximate the passive epiglottal articulator more closely when the larynx is raised than when it is lowered.

Languages with vocalic tongue root distinctions therefore also deserve further clarification. Jacobson (1978, p. 80) reports that Lindau, Jacobson, and Ladefoged's (1972) studies of African languages with ATR register or "vowel harmony" distinctions "did not provide clear measurable outlines for the larynx," although Lindau's (1975) results make it likely that advancement of the tongue root correlates with a concomitant depression of the larynx causing an expansion of the pharyngeal space. In Esling (1996) it was suggested that the retracted tongue root vowels of Igbo and in Akan (Ladefoged & Maddieson, 1996, pp. 300–302) are produced by tongue backing together with larynx raising due to the constriction that occurs at the aryepiglottic sphincter. In this interpretation, based on Laver's (1980) auditory categories for voice quality labelling and on physiological assumptions about the working of the sphincter mechanism, lowered larynx voice is associated with [+ATR] vowels, which are not pharyngealized, while raised larynx voice is associated with [–ATR] vowels, which have pharyngealized characteristics.

Mon-Khmer and Tibeto-Burman languages also exhibit register contrasts, often independently of tone, which have been linked to the pharyngealized setting of the aryepiglottic sphincter by virtue of their raised larynx auditory quality. The "stiff vocal cord," "tense vocal tract wall" series of Bruu, and the "laryngealized," "creaky voice" series of Mpi (Ladefoged & Maddieson, 1996, pp. 315–317; originally investigated by Jimmy G. Harris and available in the *SOWL* database) both exhibit the auditory characteristics of pharyngeal approximation or, in Laver's terminology, raised larynx voice (Esling, 1996). Beyond auditory identification, laryngoscopic studies confirm that raising of the larynx and engagement of the aryepiglottic sphincter are responsible for the "tense" series in Yi (Nosu) for continuant consonants as well as vowels (Esling, Clayards, Edmondson, Qiu, & Harris, 1998). The "tense/lax" vowel system of Yi suggests a direct parallel with the vocalic oppositions in ATR languages, where the opener vowel of each pair can be expected to exhibit larynx raising.

One final linguistic parallel that can be drawn between manner of pharyngeal articulation and the position of the larynx is the quasi-phonatory voice quality common to many rhythm and blues singers. Louis Armstrong, Koko Taylor, and Bobby Blue Bland illustrate this style particularly well (Dennis Preston, personal communication; van Buuren, 1983). Based on auditory comparisons, it is posited that this style is achieved through long-term trilling of the aryepiglottic folds superimposed on all voiced segments (Esling, 1996, p. 82). The relationship to larynx height is this: if the laryngeal sphincter is engaged to effect trilling, that is, in close approximation, and the larynx is elevated as the tongue retracts in order to accommodate close aryepiglottic approximation, then it might be expected that the speech surrounding such pharyngealized events, whether or not trilling occurs, could be characterized by raised larynx voice quality. One approach to such a question would be a sociolinguistic analysis of communities where raised larynx quality is present. Another would be a phonetic examination of the effect of larynx raising, or lowering, on a set of segments. The consonantal segments which can be viewed at the same time as the larynx itself are the pharyngeals [ħ, ʕ, ʡ, ʜ, ʢ] and the glottals [h, ʔ].

THE EFFECT OF LARYNX HEIGHT

Kodzasov (1987) distinguishes three places of articulation in the pharynx area: uvular, pharyngeal, and epiglottal; and notes that tongue and epiglottis retraction as well as larynx raising are the most likely articulatory correlates of the auditory category of epiglottal sounds. Kodzasov reports that Trubetzkoy (1969, p. 131) had already assumed that the [ħ, ʕ] sounds involve larynx raising—a view reiterated by El-Halees (1985).

Raised larynx quality is a second component associated with pharyngeal articulatory postures which has been identified auditorily, and which requires further physiological explanation. Catford (1977a) has dealt extensively with these secondary auditory distinctions, positing articulatory explanations such as "ventricular" and "anterior" glottal. References to similar auditory qualities appear in various phonetic and phonological analyses of Semitic, Salish, and Wakashan, and Caucasian consonants, and of Mon-Khmer languages, to account for movements of the larynx that accompany the production of tone.

Traill (1986, p. 125) identifies the "laryngeal sphincter" as a phonatory mechanism, employed in !Xóõ (Bushman) to contrast "plain voiced," "murmured," and "sphincteric" vowels, [a, a̤, a̰]. His x-ray photographs of the sphincteric vowels of Khoisan, reproduced in Ladefoged and Maddieson (1996, p. 311), very clearly illustrate a simultaneous narrowing of the pharynx behind the epiglottis, raising of the larynx, and approximation of the arytenoid cartilages to the base of the epiglottis. Fibreoptic laryngoscopic photographs of Traill's (p. 124) imitative model of the sounds support his description, showing very clearly a voicing mode and a breathy voicing mode at the glottis in contrast with the laryngeal sphincter in pharyngealized mode. He also reports vibration in the arytenoidal and epiglottal regions, which corresponds to the description of aryepiglottic trilling presented above. Traill's detailed account of these vowel sounds (1985, pp. 78–79), in which he comments on the constricted aryepiglottic folds in conjunction with an apparently abducted glottis and open supraglottal lumen, is interpreted as describing the configuration of a voiceless aryepiglottic (pharyngeal) trill (Esling, 1996, p. 69). Rose (1989) has identified such trilling auditorily as an accompaniment to certain tones in Zhenhai, to which "harsh voice" of Bai is reported by Edmondson and Li (1994) to bear a resemblance.

Pharyngealization has been associated primarily with tongue retraction, as in the case of vowels. "Pharyngealized vowels involve a compression of the pharynx simultaneously with the primary vowel articulation. This is usually effected by a backward thrust of the root of the tongue, tending to narrow the pharynx in a front-to-back dimension" (Catford, 1977a, p. 182). This occurs in several Caucasian languages, and Catford reports that "pharyngealization adds a slightly 'squeezed' quality to the auditory impression of vowels in these languages and tends to impart a somewhat 'fronted' (advanced) quality to back vowels, both in terms of auditory impression and formant-shifts in spectrograms." The most likely explanation for this auditory impression is provided by Laver's description of the acoustic effect of vocal-tract shortening caused by larynx raising (1994, p. 330). Catford observes "some raising of the larynx" along with "a retraction of the root of the tongue" in the production of Arabic pharyngeals (1977a, p. 193); and since it is likely from a physiological point of view that the aryepiglottic sphincter plays the central role in this process (Esling, 1996), the contribution of larynx raising must be examined as a potential concomitant gesture.

Such observations are consistent with Nolan's (1983) assumption that there is a relationship between raised larynx voice and pharyngealized voice. It has been shown that these two qualities are not auditorily distinguishable from each other at some pitches and that, given the same intended target, pharyngealized voice is the quality identified in a voice with low pitch and that raised larynx voice is the quality identified in a voice with higher pitch (Esling, Heap, Snell, & Dickson, 1994; Esling, 1995). As auditory voice quality labels, they are complementary, and pitch-dependent. It has been suggested (Esling, 1996, p. 83) that Catford's "ventricular" and "anterior" glottal categories refer to the same auditory quality as Laver's raised larynx voice. This interpretation takes into account the potential for trilling in this posture, and the perceptual possibility that this same setting will be heard as pharyngealized voice when pitch is low.

Initial laryngoscopic observations confirm that tightening of the aryepiglottic space referred to by Honda et al. (1995), that is, of the laryngeal vestibule referred to by Painter (1986), occurs when either sound quality — pharyngealized voice or raised larynx voice — is produced (Esling, 1996). Investigating the relationship between larynx height and pharyngealization in long-term postures of the vocal tract, Nolan (1983, pp. 182–187) cites acoustic, radiographic, and physiological evidence to associate pharyngealization with elevation of the larynx. Nolan's (p. 183) x-ray tracings show clearly that the posture for raised larynx voice both alters the angle and constriction of the larynx tube and involves the tongue and epiglottis filling more of the lower pharyngeal space. Laryngoscopic observations using a rigid oral scope reveal that this same mechanism is being used in retracting the tongue to the pharyngeal wall as in producing the auditory effect of a shortened vocal tract associated with raised larynx voice (Esling, 1996). With a fibreoptic laryngoscope, the source of constriction at the aryepiglottic sphincter mechanism can be clearly seen. The tongue and epiglottis can also be seen to retract, as the larynx rises for aryepiglottic closure, tucking itself up under the epiglottis as it does in pharyngeal stop mode during swallowing. The issue to investigate then, is whether this elevated position of the larynx is its natural, unmarked position when the tongue retracts and the aryepiglottic folds constrict for a pharyngeal articulation.

LARYNGOSCOPIC METHODOLOGY

To investigate the articulatory correlates of pharyngeal quality, it would be desirable to observe speakers of languages where pharyngeal segments contrast phonologically, as has been customary in many of the studies cited here. However, a case can be made for establishing a framework of comparison based on articulatory possibilities such as those posited by Catford in 1968. Furthermore, phonological realizations of pharyngeal targets may not be immediately distinguishable from long-term pharyngeal or larynx height voice quality settings in the voice of any given speaker of a specific language. Therefore, the approach adopted initially in this study is to examine cardinal consonantal articulations in order to document a baseline of pharyngeal articulatory possibilities, and to isolate segmental properties from characteristics of background setting. This is consistent with the laryngoscopic approach adopted by Traill, although the productions in the present research are not imitative of any particular phonemic target.

We used a Kay 9100 Rhino-Laryngeal-Stroboscope system with an Olympus fibreoptic laryngoscope to observe articulations behind the back of the tongue and beneath the level of the top of the epiglottis. Contrasting degrees of pharyngeal stricture and contrasting larynx height parameters were examined. Articulations were performed with a carrier phrase and, to expose maximum pharyngeal area, in the environment of the close front vowel [i_i]. The computer-controlled system includes a dual halogen (fixed) and xenon (strobe) light source, a Panasonic KS152 camera, a Mitsubishi S-VHS video cassette recorder BV-2000 (running at 30 frames/sec) and printer. This system comes equipped with a rigid, oral endoscope; but the view obtained with the rigid scope does not extend beyond the apex of the epiglottis during activities involving pharyngeal constriction. In fact, it is difficult to see beyond the apex of the epiglottis even using a flexible fibreoptic laryngoscope during anything but a close front vowel. This was the case in the extensive laryngoscopic observations of Semitic pharyngeal articulations carried out by Laufer and Condax (1981) and Laufer and Baer (1988) with native-speaker subjects. In order to find an optimal view of the laryngeal and pharyngeal mechanisms behind the apex of the epiglottis during pharyngeal articulations, an Olympus ENF-P3 flexible fibreoptic laryngoscope was attached to the Kay system for nasal insertion, with a 28 mm lens for wide-angle view. The subject in all nasendoscopic observations was the author, producing maximally contrastive cardinally defined speech data. The auditory values of the relevant consonants are illustrated by Wells and House (1995) and in Dickson (1995). The pharyngeal/laryngeal view in the photographic images presented here is taken from above the larynx, at about the level of the apex of the epiglottis or lower, and slightly from the right of center (left in the picture). The image is not perfectly vertical but rotated about 20° (notch at the top), in order to eliminate Moiré effects — striated interference patterns produced by the interaction of fibrescopic and camera optics (Yanagisawa & Yanagisawa, 1993, p. 262).

A series of seven cardinal glottal and pharyngeal sounds [h, ʔ, ʡ, ħ, ʕ, ʜ, ʢ] described in Esling (1996) were produced in raised larynx voice, neutral larynx (modal voice), and lowered larynx voice modes, according to the auditory criteria defined by Laver (1980) and available on tape. Photographs generated by the Kay system are presented in Figures 1–7 to illustrate each condition observed. A single frame represents 1/30 s at the point of maximum stricture of the articulators in a given sequence. Analysis is based on viewings of the videotape in real time and frame by frame, and on sequences of frames of each articulation exported as computer graphics. Visual interpretations are offered using standard landmark reference.

RESULTS OF OBSERVATIONS

In the neutral mode, the glottal setting for [h] involves a wide open laryngeal vestibule with its characteristic quadrilateral shape, and the setting for [ʔ] involves a slight constriction of the laryngeal sphincter resulting in pursing of the laryngeal vestibule. In raised larynx mode, the shape of the laryngeal aperture is altered by the engagement of the laryngeal sphincter so that [h] and [ʔ] resemble their pharyngeal counterparts [ħ] and [ʡ]. The context of larynx lowering has the effect of stretching the aryepiglottic folds (between the descending arytenoid cartilages and variably retracted tongue root and epiglottis), so that the open shape of the glottal aperture is preserved while the size of the pharyngeal cavity is enlarged vertically. This effect is greatest in Figures 4 and 5.

Figure 1 illustrates the rhino-laryngoscopic view of the pharynx and larynx during voiceless aspiration mode [h]. It shows the supraglottal lumen containing the glottis bounded by the epiglottis, aryepiglottic folds and arytenoids with the posterior pharyngeal wall behind and the pyriform recesses beneath. In each figure, the neutral, modal condition is in the middle of the figure, with the raised larynx condition on the left, and the lowered larynx condition on the right. In each case, the frame shown is taken from the middle of the intervocalic consonant, when the articulators are in maximum constriction. (Each frame

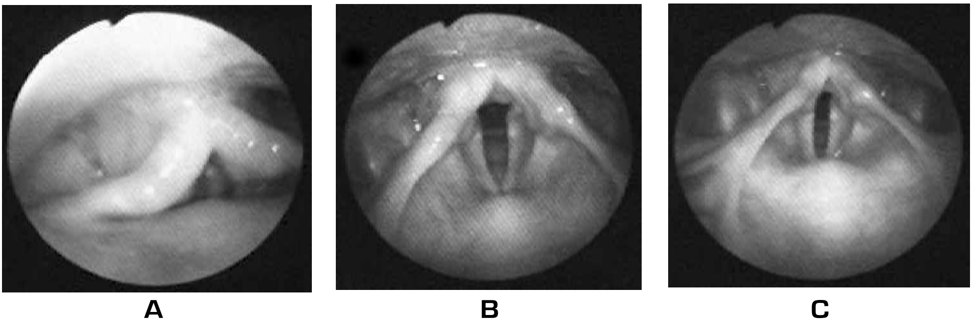


Figure 1

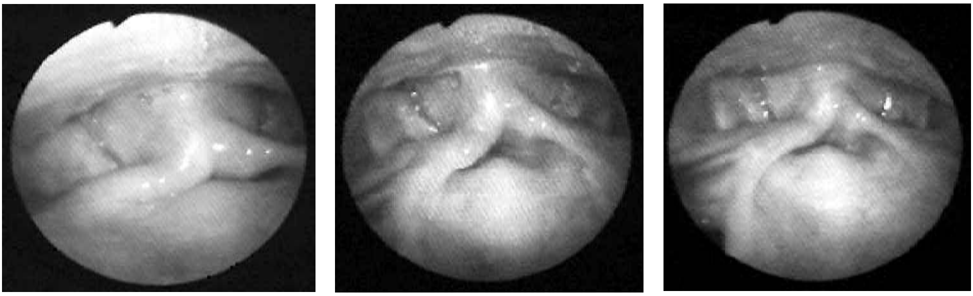
Rhino-laryngoscopicview of the pharynx: intervocalic glottal fricative [h] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.

represents 1/30th sec at maximum occlusion in an [ihi] sequence.) In these images, top is posterior and bottom is anterior; the approximately V-shaped structure (flattened considerably in the raised larynx displays) is the aryepiglottic folds, connected posteriorly on either side of the vertex of the inverted V to the apices of the arytenoid cartilages; the vocal folds and the glottis can be seen inside the V in the middle and right panels in Figure 1; and the anterior white structure which the aryepiglottic folds approximate in many of the displays is the body of the epiglottis.

The glottis is delimited above by the epiglottis, aryepiglottic folds, and arytenoids, with the posterior pharyngeal wall behind and the pyriform recesses beneath. In Figure 1(B), the momentary abduction of the vocal folds within this open epilaryngeal space is clearly visible. This is also true in view 1(C), although the vertical stretching of the aryepiglottic folds pulling against the more tightly adducted arytenoids narrows the epilaryngeal space somewhat. In view 1(A), the laryngeal vestibule narrows as a function of the aryepiglottic sphincter. This sphincteric action is epilaryngeal, and has the effect of lengthening the aperture into a tube or funnel above the glottis. This is the same effect observed in the series of pharyngeal fricatives in Figure 5. The posture for glottal airflow in raised larynx mode in Figure 1(A) closely resembles the postures for pharyngeal frication in Figures 5(B) and 5(A). The target of a pharyngeal fricative in 5(B) results in the same postural modifications, with some differences in degree, as for a raised larynx pharyngeal fricative in 5(A) and for a raised larynx glottal fricative in 1(A). The raised larynx setting thus appears to be an inherent trait of the pharyngealized posture.

The glottal stop illustrated in Figure 2 is slightly more extreme or stronger than a minimal glottal stop. (Each frame represents 1/30th sec at maximum occlusion in an [iʔi] sequence.)

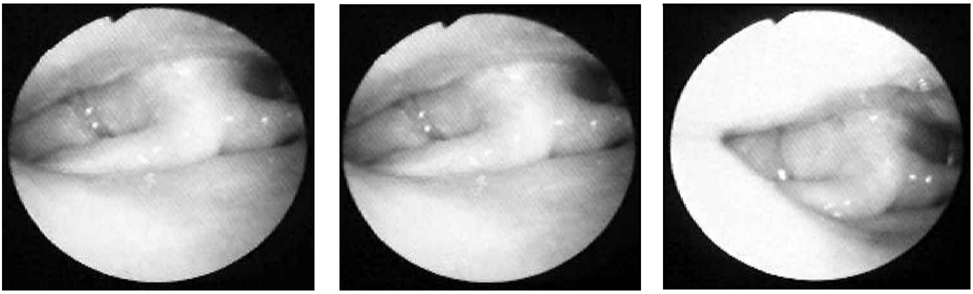
In both the modal and lowered larynx conditions, the vocal folds are obscured by a partial initiation of the aryepiglottic sphincter mechanism, but in the raised larynx condition the sphincter is activated to such a degree that [ʔ] stricture begins to resemble [ʡ] stricture. That is, glottal stricture with raised larynx voice superimposed, in Figure 2(A), is minimally distinguishable from the full pharyngeal (aryepiglottic) stop in Figure 3. Here again, the



A B C

Figure 2

Intervocalic glottal stop [ʔ] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.



A B C

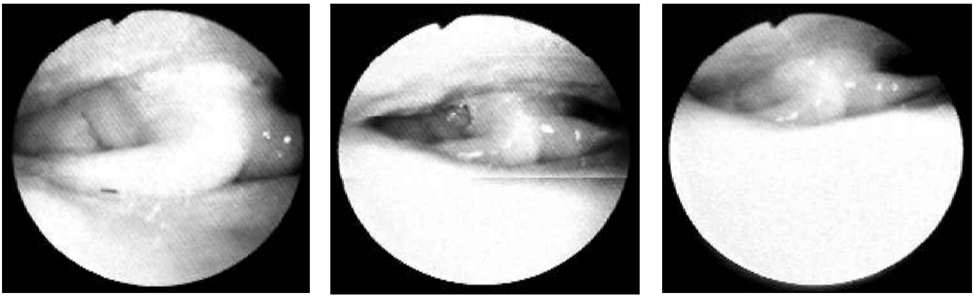
Figure 3

Intervocalic pharyngeal (epiglottal) stop [ʡ] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.

effect of adding a raised larynx feature to a glottal articulation is the same as the effect of producing a pharyngeal articulation in any larynx height condition.

Full pharyngeal occlusion of the airway characterizes the pharyngeal stop in Figure 3. (Each frame represents 1/30th sec at maximum occlusion in an [iʡi] sequence.) Stop closure is clearly audible during [ʡ], although the glottis itself is not visible. Since it is not certain that the aryepiglottic folds are completely sealed along their length against the surface of the epiglottis, simultaneous glottal closure is hypothesized during the stop portion of [ʡ]. The pharyngeal stops take slightly longer to perform than a glottal stop, presumably as the articulators have further to move; and the cartilages and folds can be seen to rise as the tongue retracts. Comparing Figure 3 with Figure 2(A), a raised larynx setting can be argued to be a component of pharyngeal occlusion, and a pharyngeal stop can be argued to involve a more complete closure of the laryngeal sphincter than a glottal stop even in raised larynx mode.

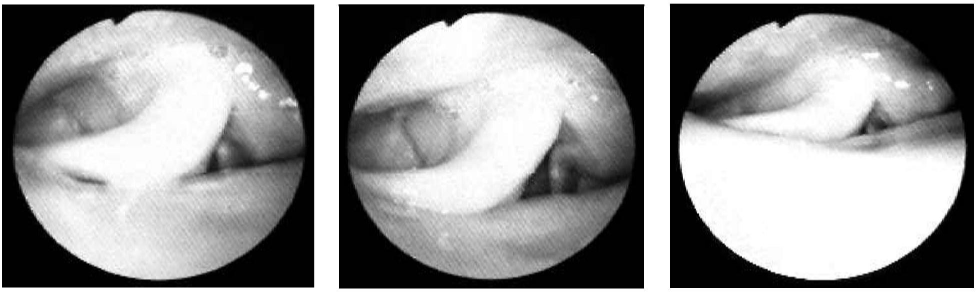
The pharyngeal approximant in Figure 4 resembles pharyngeal stop closure. (Each frame represents 1/30th sec at maximum occlusion in an [iʕi] sequence.) Sustained voicing is clearly audible during [ʕ], although the glottis itself is not visible and although the



A B C

Figure 4

Intervocalic pharyngeal approximant [ʕ] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.



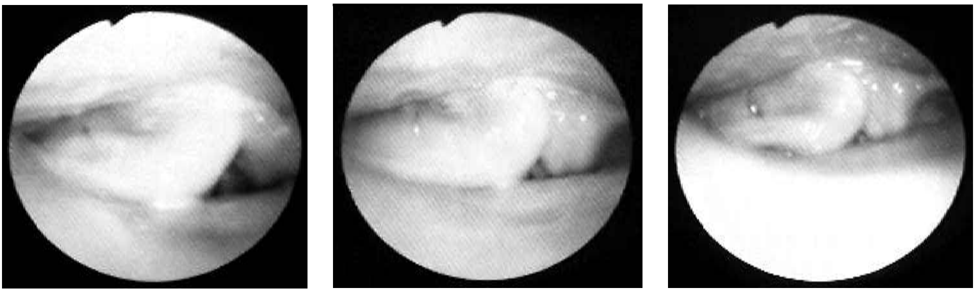
A B C

Figure 5

Intervocalic pharyngeal fricative [ħ] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.

sphincter might appear to be even more constricted for [ʕ] than for [ʡ]. Clearly, the aryepiglottic folds are not completely sealed along their length against the base of the epiglottis during the pharyngeal approximant, and therefore perhaps not during the pharyngeal plosive either. The sphinctered posture of the aryepiglottic folds is clearly the principal mechanism associated with the dominant auditory feature of pharyngealization. The arytenoids are even more raised and the tongue more retracted during the articulation of the approximant than for the stop.

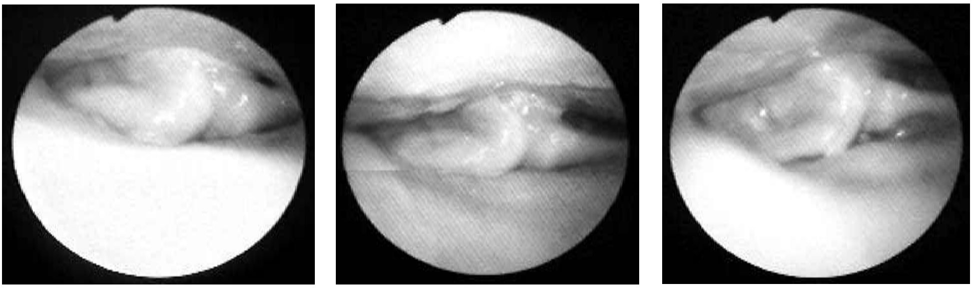
The voiceless pharyngeal fricative [ħ] in Figure 5 retains aryepiglottic fold constriction but with a triangular aperture remaining between the arytenoids as they press up against the epiglottic tubercle. (Each frame represents 1/30th sec at maximum occlusion in an [iħi] sequence.) It is hypothesized that this space generates the pharyngeal friction accompanying voicelessness. Raising of the sphinctered folds to meet the retracting tongue root is extreme in raised larynx mode, but occurs even in lowered larynx mode where the aperture is almost hidden beneath the tongue root. In fact, of all the pharyngeal articulations, the voiceless fricative appears to require the greatest raising of the larynx and concomitant backing of the tongue root.



A B C

Figure 6

Intervocalic voiceless pharyngeal trill (epiglottal fricative) [ʜ] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.



A B C

Figure 7

Intervocalic voiced pharyngeal trill (epiglottal fricative) [ʢ] in three larynx-height conditions: (A) raised larynx, (B) modal voice, (C) lowered larynx.

The voiceless and voiced pharyngeal trills in Figures 6 and 7 reiterate the postures for the pharyngeal fricative and approximant, respectively. The voiceless aperture is present in all three larynx height modes for the voiceless trill, and in both trills the lateral, ligamental portions of the aryepiglottic folds are seen to vibrate. In the voiceless trill, there is both medial, intercartilaginous glottal airflow and lateral aryepiglottic trilling. The lateral blur in these 1/30 s shots has been measured from spectrographic striations as a 50-cycle source. (Each frame represents 1/30th sec at maximum occlusion in an [iʜi] sequence.) These productions match the description of "sphincteric" phonation in so-called "strident" Bushman vowels, and of Catford's "ventricular fricative trill." All three conditions maintain similar interarytenoid opening as the voiceless fricative in Figure 5, with the addition of lateral vibration of the aryepiglottic folds. Epiglottal quality is predisposed by condition (A) when only friction is present. In the voiced trill, the cartilaginous ends of the folds are pulled forward against the epiglottic tubercle together with the tightly adducted arytenoid cartilages. (Each frame represents 1/30th sec at maximum occlusion in an [iʢi] sequence.) These configurations resemble the approximant, with the addition of lateral vibration of the aryepiglottic folds. By using the [ʢ] symbol, trilling is taken to represent an enhanced degree of friction, localized at the aryepiglottic sphincter.

The pharyngeal trills in raised larynx mode appear to be in a default or unmarked mode for efficient pharyngeal stricture. These are shown in Figures 6(A) and 7(A). Compression of the laryngeal vestibular space appears to be more complete than in the neutral mode, and the aryepiglottic folds are bunched and slack in close approximation to the epiglottic tubercle. Trills produced in lowered larynx mode in Figures 6(C) and 7(C), however, show the vertical stretching of the aryepiglottic folds that occurs, and the gap that opens between the folds and the epiglottic tubercle, even at maximum stricture. Phonetic production of the trills is challenging with the larynx in lowered position, and the vertical stretching of the aryepiglottic folds appears to pull them away from the base of the epiglottis. The opening of the epilaryngeal space appears to parallel the increase in size of the pharyngeal space between the tongue root and the glottis that results when the larynx is lowered. Vertical movement, up and down with larynx raising and lowering, is evident in the videotape. What is not easy to determine in these photographs, however, is the dimension of vertical distance. Although measurements of articulator positions can be anticipated, the present comparisons of combinations of auditorily specified articulations rely on observations of relative changes in pharyngeal configurations.

DISCUSSION

It appears from the comparison of pharyngeal consonants in raised larynx and modal conditions that the unmarked position of the laryngeal sphincter when activated is raised, although all of the manners of pharyngeal articulation can be articulated with the larynx in lowered position as well. This interpretation is supported by the observation that superimposing a long-term raised larynx posture on glottal articulations has the effect of pharyngealizing them. Such a relationship is consistent with predictions by Catford and others that the larynx rises during pharyngeal sounds.

The fact that the larynx as a whole can be lowered during pharyngeal (aryepiglottic sphincter) stricture suggests that an auditory parameter other than place of articulation, or even manner of pharyngeal articulation, can be added to the sound quality distinctions that arise in the pharynx. The interdependencies of these articulatory setting parameters could explain the conflicting acoustic effects observed by Nolan (1983), where pharyngealization sometimes appeared to be affected by variable larynx heights. Since pharyngeal consonants appear to be in a default or unmarked setting for efficient pharyngeal stricture when the larynx is raised, a lowered setting of the larynx concurrent with pharyngealization would constitute a marked deviation from the natural anatomical tendency, and this would presumably be a more difficult muscular relationship to maintain. When the vertical height dimension is added to the horizontal or back-to-front dimension of pharyngealization and in combination with four possible adjustments in manner of pharyngeal articulation (frication, approximation, trilling, and plosion), a number of complex auditory effects can be accounted for in the linguistic examples cited above.

It has been shown that the body of the tongue is flattened and lowered in the mouth during the production of Arabic pharyngealized consonants, and that the epiglottis draws back towards the posterior pharyngeal wall as the thyroid cartilage is tilted (El-Halees, 1983). El-Halees has suggested, furthermore, that the epiglottis is a passive articulator and not the main active articulator in pharyngeal consonants. The present research supports the rationale for such a view by identifying the aryepiglottic sphincter mechanism as the primary point of constriction for all of the consonants in the pharyngeal series, and the tip of the epiglottis (or tongue root) as a second, less severe point of stricture which never-the-less contributes critically to the cavity shaping that distinguishes some pharyngeal qualities. In the case of pharyngeal articulations, if the aryepiglottic folds are considered the active articulator, then the epiglottis and tongue, once fully retracted, can be considered the passive articulator. From this perspective, instead of viewing the epiglottis as being pulled down to close the airway, the larynx and aryepiglottic folds are viewed as being pulled up (by not only the thyroarytenoid and aryepiglottic muscles but also by the suprahyoid muscles) towards the epiglottis. The other alternative is to view pharyngeals as having double (or more) articulators, but this is a matter for further debate.

Sapir and Swadesh (1939, pp. 12–13) describe the pharyngealized tongue backing of the two "laryngealized glottals" of Ahousaht (Nootka), but do not consider larynx height effects or where the stop might be occurring other than at the glottis: "⁏ represents a glottal stop pronounced with the pharyngeal passage narrowed by the retraction of the back of the tongue toward the back pharyngeal wall. ḥ is h pronounced with the pharyngeal passage thus constricted."

It was suggested above that the presence of aryepiglottic trilling at the laryngeal sphincter is one way to account for the difference between the "pharyngeal" and "epiglottal" series of Agul: that /ħ/ does not involve aryepiglottic trilling but that /ʜ/ does. In languages where "epiglottal" fricatives have been identified, such as Agul and Avar, it is either aryepiglottic constriction, or fricative enhancement due to trilling, or the raised larynx setting that could account for their production. The auditory quality of the Avar fricatives in the *SOWL* database suggests the latter explanation. An auditory evaluation of the voiceless Agul fricatives in the *SOWL* database suggests that both trilling and a raised larynx setting (an extremely constricted laryngeal sphincter) characterize the epiglottal fricative, while the pharyngeal fricative has a lowered larynx setting and no trilling (which is predictably less likely in lowered larynx mode).

Acoustic comparisons convey a visual impression of the possible relationship between the cardinal sounds established here and the way that similar sounds are distinguished phonemically in Agul. Figure 8 illustrates the author's production of intervocalic [iʜi] under raised larynx and lowered larynx conditions. The midpoint of each fricative corresponds to the photographs in Figures 1(A) and 1(C). The author's production of intervocalic [iħi] is similarly displayed in Figure 9, corresponding to Figures 5(A) and 5(C). Figure 10 shows the Agul epiglottal fricative [ʜ] in the word [mɛʜɛr] 'wheys', followed by the pharyngeal fricative [ħ] in the word [muħar] 'barns', (collected by Kodzasov, described in Ladefoged & Maddieson, 1996, p. 168). The vocalic contexts are not strictly comparable, as laryngoscopic data collection requires an [i] context, and minimal pairs for sounds in this part of the vocal tract are not plentiful in Agul. The most definitive thing that can be said about these juxtaposed spectrograms is that the raised larynx condition and the epiglottal articulation in Agul share greater noise from frication and, in the case of Agul, periodic pulsing as well. The lowered larynx condition, like the pharyngeal context in Agul, reduces the level of noise in the fricative. This can be explained by the likelihood of aryepiglottic trilling occurring in the

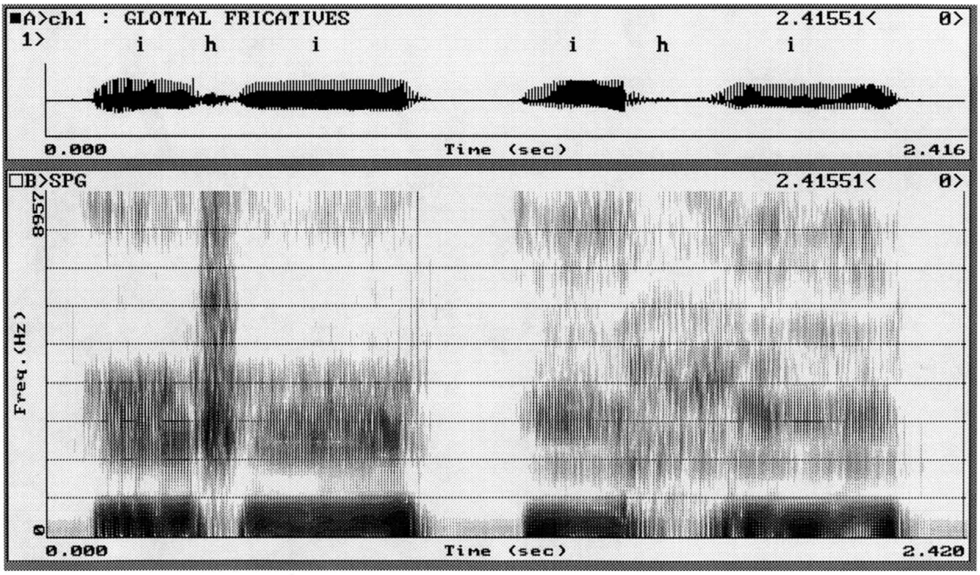


Figure 8

Waveforms and spectrograms of the author's production of [ihi] with raised larynx voice and lowered larynx voice, corresponding to Figures 1(A) and 1(C), respectively. Frequency divisions are approximately 1000 Hz.

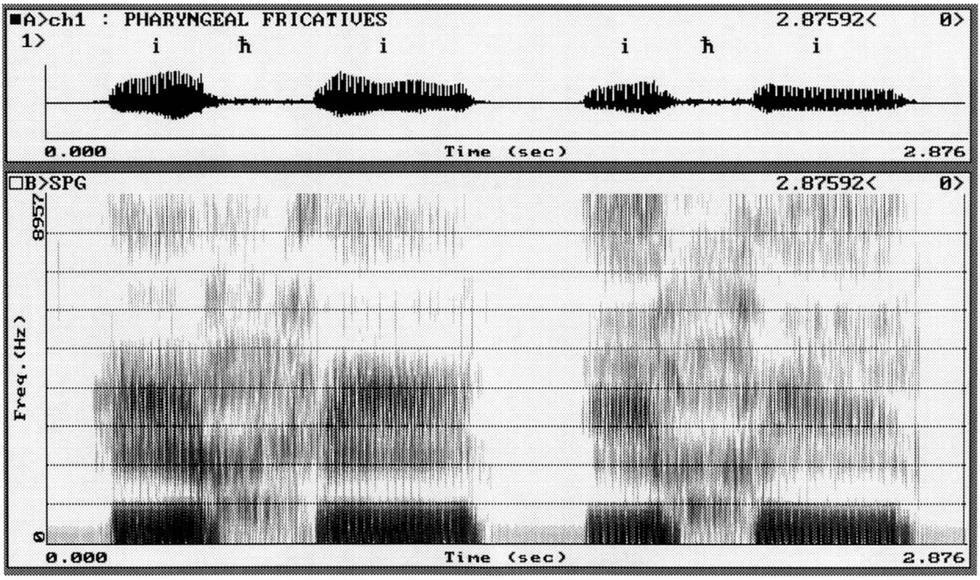


Figure 9

Waveforms and spectrograms of the author's production of [iħi] on raised larynx voice and lowered larynx voice, corresponding to Figures 5(A) and 5(C), respectively. Frequency divisions are approximately 1000 Hz.

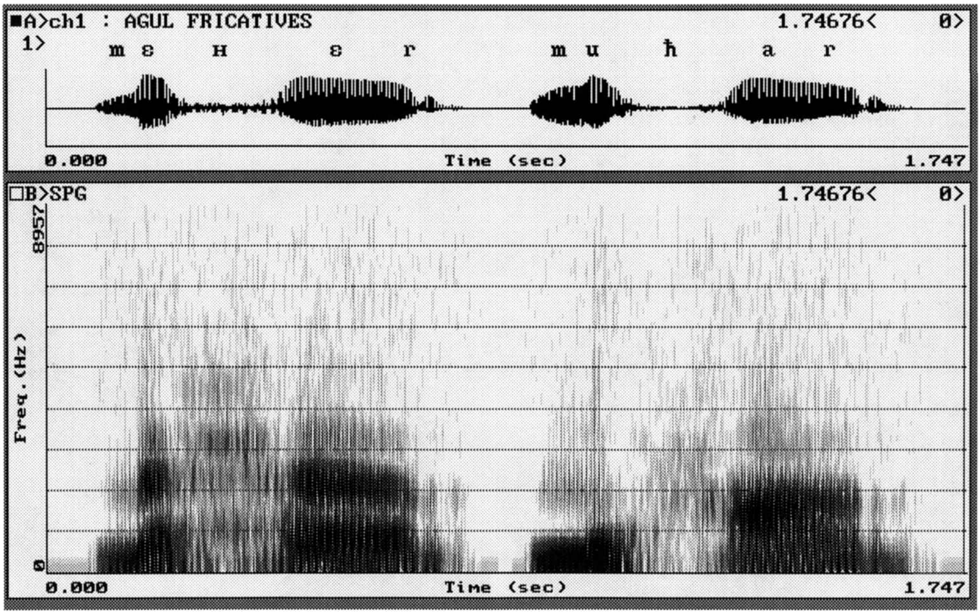


Figure 10

Waveforms and spectrograms of the Agul words [mɛʜɛr] 'wheys', and [muħar] 'barns' spoken by a female speaker of the Burkikhan dialect; from the *SOWL* database. Frequency divisions are approximately 1000 Hz.

raised larynx / epiglottal context, while it is less likely that trilling or even very great fricative noise will occur when the larynx is lowered — the pharyngeal context in Agul.

These spectrographic parallels are not intended to be conclusive, but they give an indication of the magnitude of the acoustic differences which typify the set of sounds in question. The productions in Figures 8 and 9 are not intended to be compared as "the same sounds" as those in Figure 10. Firstly, the vowels are not the same phonetically, and in Figure 10 they are changing from syllable to syllable. Secondly, the consonants in Figures 8 and 9, respectively, are not intended to change in place of articulation, while the labelling of the Agul examples assumes that they do. Thirdly, both vowels and consonants in Figures 8 and 9 are invested with a raised larynx and lowered larynx quality, respectively, so both are shifting in formant characteristics, either up or down. The vowels in Figure 10 are presumably influenced mainly by the quality of the target consonant. The argument is that the lowered larynx setting induces what have commonly been described acoustically as pharyngeal characteristics, while the noisier raised larynx setting provokes descriptions resembling those of epiglottal consonants.

Full pharyngeal occlusion in Agul is described as an epiglottal stop /ʡ/ (in contrast with /ʔ/) because of both the action of the sphincter and the raised larynx quality that accompanies it. Gaprindashvili's (1966) "pharyngealized glottal stop" is an adequate minimal description of [ʡ], noting both the glottal component and the pharyngeal component. The defining role of aryepiglottic constriction and larynx raising is suspected, as in the Ahousaht sound.

As described by Laufer and Baer (1988), in pharyngeal articulations with varying degrees of friction and closure, the epiglottis is seen to retract towards the posterior pharyngeal wall. This creates a narrowed or constricted space at the back of the oral tract, where the distance between the apex of the epiglottis and the posterior pharyngeal wall narrows to almost nothing, especially during an open vowel. The role of the aryepiglottic sphincter mechanism as defined in Esling (1996) is to close off the airway beneath the level of the root of the tongue, so that closure is not necessary at the apex of the epiglottis above. A somewhat paradoxical effect of larynx lowering, observed in these videotapes, is that as the cartilages of the larynx descend, the aryepiglottic folds exert increasing pull on the sides of the epiglottis and tongue root to which they are attached. This action draws the tongue root and apex of the epiglottis back even further towards the posterior pharyngeal wall than when the larynx is raised. For this reason, the views of the laryngeal sphincter in Figures 3–7(C) are more obscured than when the larynx is in a neutral position or raised. As the larynx lowers for the consonantal articulation, the articulators disappear beneath the root of the tongue, and the apex of the epiglottis pushes back against the tip of the fibreoptic bundle. The views in Figures 3–7 are therefore obtained from within the pharyngeal cavity, in a resonating chamber defined by the apex of the epiglottis as its "roof." Acoustic predictions based on this observation might address the effect of a more occluded upper epiglottal passage in conjunction with a slightly less occluded lower laryngeal sphincter, or examine the formant resonances produced within an extended pharyngeal chamber of this shape.

The voiceless pharyngeal fricative, therefore, which retains aryepiglottic fold constriction but with a narrow triangular space remaining open between the arytenoids as they press against the epiglottic tubercle, will have predictably different acoustic characteristics depending on whether the larynx is raised or lowered. If the larynx is raised, then the resonating chamber of the pharynx is reduced, as in Figures 5–7(A). If the larynx is lowered, then the airstream flowing through the funneled epilaryngeal tube is afforded not only a vertically extended chamber, but also a partially covered space by virtue of the fully retracted epiglottal tip over it.

These laryngoscopic observations associate Honda et al.'s tightening of the aryepiglottic space and Painter's narrowing of the laryngeal vestibule with the voice qualities labelled by Laver as "pharyngealized voice" and as "raised larynx voice." These qualities have been shown to differ auditorily only with respect to pitch. This implies that languages using a larynx height setting contrastively at any pitch level can retain pitch contrasts (e.g., tone) and exploit larynx height separately (e.g., register) but that the raised larynx feature is likely to be categorized the same as the pharyngealization feature, as these configurations are the same physiologically. Even though phonetic differences in auditory quality can be detected as pitch changes, there is more evidence to associate pharyngealization with raised larynx quality than with lowered larynx quality. This implies further that a raised larynx setting, used contrastively in a language, can be expected to coincide with a pharyngealized (sphinctered) posture more commonly than a lowered larynx setting could be expected to combine with pharyngealization. Laryngeally, the lowered larynx setting would be more likely to coincide with an open glottis and an unsphinctered epilarynx, because these postures represent the opposite physiological setting to the protective closure action of the aryepiglottic sphincter.

The identification of three contrastive parameters in the pharynx — aryepiglottic sphinctering (with larynx raising), manner of pharyngeal articulation, and larynx lowering — lend support to the prediction that the register differences in Southeast Asian languages cited earlier demonstrate a contrast between larynx raising and larynx lowering. The auditory association of raised larynx voice with the "stiff vocal cord," "tense vocal tract wall" series in Bruu implies that the laryngeal sphincter is activated in this register. The raised larynx or pharyngealized quality of this series would be a function of the laryngeal sphincter. The contrasting series, termed "slack vocal cords" and "nontense vocal tract walls" in the *SOWL* database, would then reflect the opposite setting — lowered larynx without activation of the laryngeal sphincter. The lowered larynx terminology fits logically with the notion that the vocal tract walls are not tense, since pharyngealization is not present, and with the notion that the vocal folds are slack, since the epilarynx is not constricted and the glottis is likely to be open when the larynx is lowered. Correspondingly, the raised larynx terminology fits logically with the notion that the vocal tract walls are tense, since pharyngealization is present, and with the notion that the vocal folds are stiff, since the epilarynx is in sphinctered mode and the glottis is likely to be pressed closed when the larynx is raised. Raised larynx voice is also associated with the "laryngealized," "creaky voice" series in Mpi, implying that the laryngeal sphincter is activated in this register both for high tones and for low tones, where the quality on low tones might be judged to be pharyngealized. Whatever the pitch on the syllable, the raised larynx or pharyngealized quality of this series would be a function of the laryngeal sphincter. The contrasting "plain" series reflects the opposite setting — lowered larynx. The raised larynx terminology fits with the notion of laryngealization, because it is likely that phonation affected by the sphincter will be creaky or ventricular — "tight" or "pressed" in some terminologies (see Painter, 1986, and van Buuren, 1983). In Mpi, therefore, pitch (tone) is controlled independently of the overall positioning of the larynx, in either raised or lowered mode. An articulatory hypothesis for subsequent experimental testing would be that tokens in the "raised" series involve a greater degree of epilaryngeal stricture, as in Figures 1–2(A), while tokens in the "lowered" series involve little epilaryngeal stricture if any at all, as in Figures 1–2(C).

Other linguistic distinctions that can be accounted for by the raised larynx parameter include the second low tone of Hanoi Vietnamese (Esling, 1999). In addition to final glottal stop, it has a constricted auditory quality similar to the "tense" (raised larynx) register in Bruu and contrasts with the opener "whispery" phonatory character of the parallel low tone. A pharyngeal component can therefore be added to the glottal contrast to distinguish this pair of tones. Finally, it is necessary to consider a relationship between laryngeal sphinctering and the larynx raising observed during [–ATR] vowels in West African languages. Investigations of Akan which indicate a smaller pharyngeal space for [–ATR] vowels also show an elevated larynx and a more constricted epilaryngeal area than their [+ATR] counterparts (Tiede, 1996, p. 410). As Tiede points out, this is not the same mechanism that would be identified with "tense" vowels in English. The [+ATR] series could logically be described as lowered larynx, and nonsphinctered, with a predictably more open (less constricted) glottal posture for phonation. This auditory opposition is evident in the Akan examples in the *SOWL* database. This interpretation is consistent with Denning's (1989) comprehensive review of ATR contrasts which shows that an advanced tongue root is often accompanied by lax or breathy voice and occasionally lower F0 while a retracted tongue root is accompanied by tense or creaky voice and occasionally higher F0.

CONCLUSIONS

The purpose of laryngoscopic filming was to contrast tongue and larynx position for the auditorily specified long-term voice quality settings raised larynx voice and lowered larynx voice. A raised larynx quality invokes the same tongue and epiglottal posture as a pharyngealized quality, and a number of degrees along a pharyngealization continuum are possible which cannot be accounted for by observing the position of the tongue root or epiglottis alone. Glottal articulations [h] and [ʔ] assume characteristics of pharyngealization when produced in the context of raised larynx voice. Glottals produced in the context of lowered larynx voice do not demonstrate the characteristics of pharyngealization. In essence, the long-term effects of the raised and lowered larynx settings on a given segmental articulation can be shown to change that articulation into a heterorganic one, by superimposing the traits of the (new) place of articulation on the (old) segmental units.

Pharyngeal articulations are accomplished by retracting the tongue root (with the attached epiglottis) towards the back wall of the pharynx, raising the larynx and approximating the cuneiform cartilages of Wrisberg within the aryepiglottic folds to the base of the epiglottis, bringing the folds parallel with the coronal line of the epiglottis. This mode of stricture accounts for Catford's epiglottopharyngeal category of sounds, and conforms to the prediction of concomitant larynx raising. Contrasting manners of articulation at the aryepiglottic sphincter include stop closure, which may require concurrent glottal closure, an approximant, a voiceless fricative, and a voicedless and voiced trill. All of these manners of articulation involve the same laryngeal sphincter mechanism to effect stricture. No independent epiglottal place of articulation is identified apart from the general laryngeal sphincter mechanism. Nevertheless, "epiglottal" may be a more appropriate term because the epiglottis functions as the passive articulator. Larynx raising is associated with the pharyngealization process, but pharyngeal articulations can also be performed with the larynx lowered. Pharyngeal [ʡ, ʕ, ħ, ʜ, ʢ] (defined as stop, approximant, fricative, and trills) appear more closely constricted when a raised larynx voice setting is superimposed than in the neutral setting. When lowered larynx voice is superimposed on [ʡ, ʕ, ħ, ʜ, ʢ], the aryepiglottic folds are stretched downwards, retracting the tongue root and apex of the epiglottis above the sphincter even closer to the posterior wall of the pharynx than when these sounds are articulated with the larynx in raised mode. In lowered larynx mode, therefore, the term "pharyngeal" may be more appropriate as the posterior pharyngeal wall is the passive articulator.

These findings imply that there are more manners of pharyngeal articulation than expected, which are more similar to the categories of uvular manners of articulation than previously assumed. Pharyngeal sounds are distinguished from glottal sounds by the action of the laryngeal sphincter. There is also vestibule constriction in [ʔ], but not to the same extent. Distinctions between pharyngeal and epiglottal sounds can be represented either as a function of manner of articulation or as a function of the larynx height parameter. When the vertical setting of the larynx is raised as in "raised larynx voice," pharyngeal constriction is assumed to be present, but the converse does not necessarily apply — when pharyngeal constriction is present, the larynx as a whole may be either raised or lowered. Using this paradigm, two dimensions or planes of movement, antero-posterior stricture and raising-lowering of the larynx, are adequate to account for the auditory categories that have been used to label pharyngeal or epiglottal sounds.

Pharyngeal/epiglottal articulations can be performed with various settings of larynx height. Raising of the larynx and corresponding retraction of the tongue root appear to be most extreme for the voiceless fricative and voiceless trill, which may be necessary in order to shape a channel with enough epilaryngeal depth to produce efficient funneling of the airstream for friction. During aryepiglottic sphinctering, the larynx is normally raised as a "default" setting of the laryngeal sphincter. This setting corresponds most commonly to sounds identified auditorily as epiglottal. Sounds identified as pharyngeal appear to require larynx lowering in order for the tongue to be retracted while leaving a space between the apex of the epiglottis and the glottis. A further hypothesis that could follow on from this research is to examine when the jaw might be expected to open as a concomitant of larynx raising. That is, although the posterior suprahyoid muscles are sufficient to raise the larynx while retracting the tongue and closing the sphincter, we would like to observe whether the anterior suprahyoid muscles pull the mandible open under conditions of extreme sphinctering. Choking episodes illustrate the possible reflex connection involving the jaw. In the less extreme phonetic production of glottals and pharyngeals, the larynx can also be lowered, but this causes the ligaments and muscles of the aryepiglottic folds which are anchored on the arytenoid cartilages to pull against the back of the tongue, tending to open the epilaryngeal passage at the bottom. As these vertical movements are also related to pitch changes, further research to investigate and quantify the relationship of pharyngealization (tongue retraction and aryepiglottic-fold constriction) to vertical larynx-height adjustments will also need to control pitch independently (cf. Sundberg & Askenfelt, 1983). Given the potential use of contrastive larynx height as a function of register, another area to investigate is the relationship of the raised larynx, sphinctered posture to creaky and ventricular phonation types, and the relationship of the lowered larynx posture, especially in unsphinctered, nonpharyngealized mode, to more open phonation types such as breathy voice.

Received: April 13, 1998; revised manuscript received: May 11, 1999
accepted: July 15, 1999

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