An Expanded Taxonomy of States of the Glottis

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ABSTRACT

Direct visual evidence from laryngoscopic observations suggests that the traditional classification of states of the glottis needs to be revised. We show that the sound-generating role of the epilaryngeal tube – comprising the ventricular folds, aryepiglottic folds and laryngeal sphincter mechanism – adds a vertical dimension to the 'source' signal and contributes to phonation type, necessitating an expanded set of categories. We find that the traditional model of glottal closing and opening inadequately explains many of the contrastive features resulting from the full variety of sound-producing capabilities in the larynx and pharynx. We propose to expand the basic states of the glottis to include: breath, modal voice, whisper, unphonated (glottal stop, epiglottal stop), prephonation, falsetto, whispery voice, breathy voice, creaky voice, harsh voice, and ventricular voice. Adding new components to the taxonomy will allow us to relate changes in larynx height to glottal activity more accurately. All categories are documented with images of cardinal values and of native-speaker language examples.

1. INTRODUCTION

Three issues require us to revise the classification of states of the glottis. One is the notion of what a 'completely closed glottis' is. In laryngoscopic studies of speakers of nine different languages to evaluate the articulatory relationship of pharyngeal to laryngeal behaviour, we have observed that epiglottal sounds are a function of the aryepiglottic sphincter, coordinated with extreme lingual retraction, as subcomponents of the pharyngeal articulator [1,2]. Our studies suggest that partial ventricular fold adduction and slight epilaryngeal tube constriction are key components in producing glottal stop. Full engagement of the laryngeal sphincter results in epiglottal stop [3].

Another issue is that the 'voiceless' state is too broad. Our observations of voiceless unaspirated oral stops in several languages confirm a state where the arytenoids are adducted as for voice but the vocal folds remain parted medially with a convex-convex opening, which we term 'prephonation' [4,5].

A third issue is that some 'simple' phonation types in existing taxonomies are physiologically entailed by the action of the laryngeal sphincter. For example, 'breath' implies an open sphincter, while 'creak' implies a constricted sphincter [6]. Whisper is also a function of laryngeal sphinctering [7], as is harsh voice. To account for the range of contrasting registers we have encountered, we propose a new relationship between harsh voice and pitch, replacing the term 'ventricular voice' with a pitch designation that relates it to falsetto.

2. RESEARCH PARADIGM

We have examined the laryngeal physiology involved in the production of glottal, glottalized, phonatory register, and pharyngeal phenomena, including the action of the aryepiglottic sphincter mechanism, in several languages: Nuuchahnulth (Wakashan), Nlaka'pamux (Salish), Bai, Cantonese (Sinitic), Yi, Tibetan (Tibeto-Burman), Arabic, Tigrinya (Semitic), Thai (Tai), Sui (Kam-Sui), Pame (Oto-Manguean), Korean (Altaic). The fibreoptic laryngoscopic research methodology used to obtain the photographs illustrated here – including the Kay 9100 RLS and VCR, the Olympus ENF-P3 flexible nasendoscope, the Kay rigid oral laryngoscope, 28mm wide-angle lens, and Panasonic KS152 camera – has been amply described elsewhere [1,3,6]. Data from the above languages will illustrate the categories in our taxonomy of states of the glottis.

3. BREATH, MODAL VOICE, FALSETTO

According to Catford [8], 'breath' and 'nil phonation' are both phonation types of 'voicelessness', and both have a wide open glottis; but breath has turbulent airflow sufficient to be recognized as 'audible breathing'. Nil phonation is defined auditorily as 'silent breathing'. We take a moderately open glottis (less open than during forced inhalation) to be the standard shape for breath as in [h] and voiceless fricatives, with some variation possible depending on the degree of oral stricture.

Figs. 1–2 illustrate the breath state of the glottis and the broadly open epilarynx for [h], as in Nuuchahnulth /himwits'a/ 'story', and during the aspiration phase of a voiceless aspirated stop in Nlaka'pamux, as in [mḭjˀə̥tʰ] 'spreading disease'. We observe no difference in glottal aperture in these different contexts of [h]. The same glottal shape characterizes Thai aspiration and the /h/ of Tigrinya in Figs. 3–4. In primary opposition to breath is the state of voicing or modal voice, which is illustrated in Figs. 5–6 for [iː] from Nuuchahnulth and Tigrinya [iː]. The closest linguistic realization we have found to falsetto is the high-pitched tone in the lax series of Bai [6]. Fig. 7 shows modal voice for the vowel at tone 33, while Fig. 8 shows

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the stretching in the antero-posterior glottal plane for the vowel at high tone 55. Some larynx raising as a function of tilt is apparent, but vocal fold movement is not detailed.

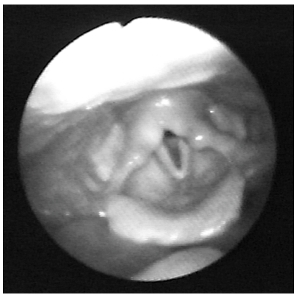

Figure 1: Nuuchahnulth [h]

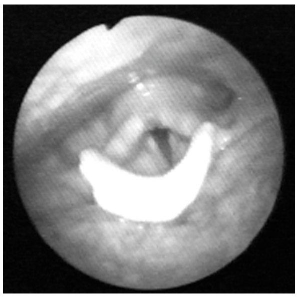

Figure 2: Nlaka’pamux [h]

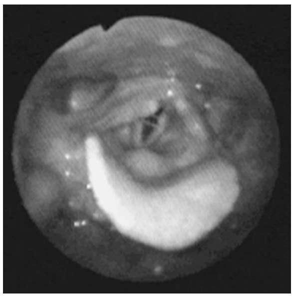

Figure 3: Thai [h]

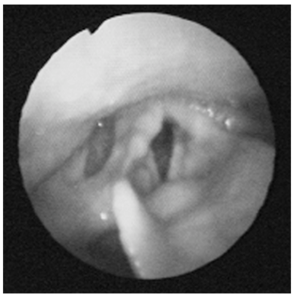

Figure 4: Tigrinya [h]

Figure 5: Nuuchahnulth [i]

Figure 6: Tigrinya [i]

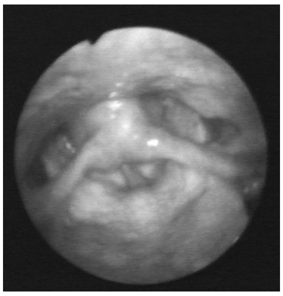

Figure 7: Bai /tɕĩ33/ ‘near’

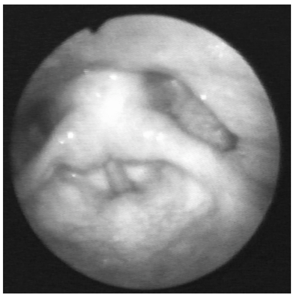

Figure 8: Bai /tɕĩ55/ ‘gold’

4. GLOTTAL VS. EPIGLOTTAL STOP

Voiceless glottal stop [ʔ] is a brief sequence where the ventricular folds momentarily arrest the vibration of the vocal folds in response to slight sphincteric tension, with a resulting slightly more constricted epilaryngeal tube, as in Nuuchahnulth /ʔiːħ/ ‘big’ (Fig. 9). Our research finds many examples of moderate [ʔ], as in Figs. 10–12, which achieves complete glottal closure, partial ventricular fold adduction, and only partly engages the laryngeal sphincter.

Comparing Figs. 6 and 12 illustrates the small degree of posterior-to-anterior adjustment of the cuneiform tubercles of the aryepiglottic folds required to squeeze the ventricular folds in and over the glottis to stop vocal fold vibration for [ʔ]. The brighter reflection in the image of glottal stop in Fig. 10 is a function of larynx raising that accompanies moderate sphinctering.

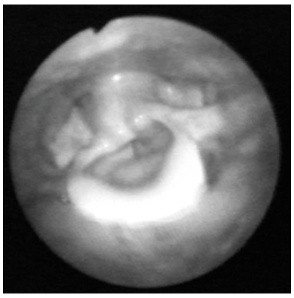

Figure 9: Nuuchahnulth [ʔ]

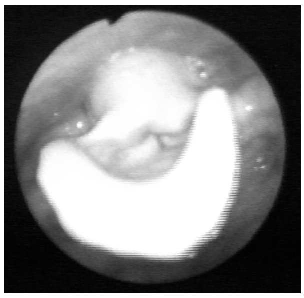

Fig. 10: Nlaka’pamux [ʔ]

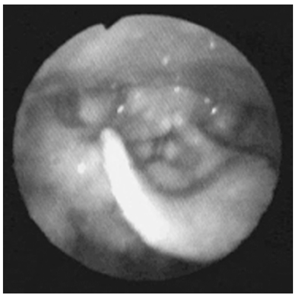

Fig. 11: Thai [ʔ]

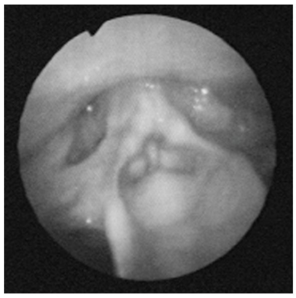

Fig. 12: Tigrinya [ʔ]

Traditionally, only glottal stop was considered complete closure of the airway. We propose the addition of a new category in classifying unphonated states of the glottis. Our research finds several examples of full laryngeal sphincter engagement for maximally efficient valvular sealing off of the airway, which implies complete glottal and ventricular adduction as well. We have identified this category as epiglottal stop [1,2,3]. Phonemic realizations of epiglottal stop [ʡ], in contrast to [ʔ] in Figs. 9–10, are shown in Figs. 13–14 for Nuuchahnulth and Nlaka’pamux.

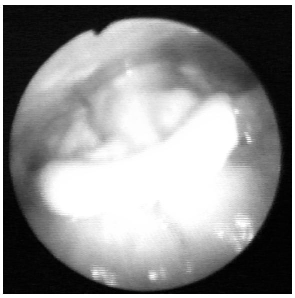

Fig. 13: Nuuchahnulth [ʡ] /ʕiħuː/ [ʡˤɪħˤuː] ‘to cry after’

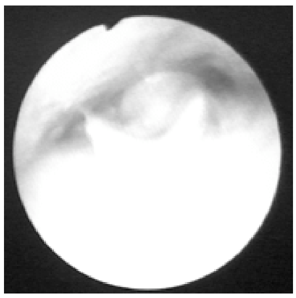

Fig. 14: Nlaka’pamux [ʡ] /npaʕʷ’/ [nːpaˤʡ̥ʷ] ‘ice’

Because of concomitant larynx raising and tongue retraction into the pharynx for [ʡ] (and consequent bright reflection off the tongue), it is difficult to see all of the structures in the throat when sphincteric closure is at its maximum, so the Nlaka’pamux image shows the structures just after they have opened slightly after maximum occlusion for [ʡ].

5. PREPHONATION

Laryngeal observations of the state of the glottis during the articulatory stricture phase of initial unaspirated oral stops and affricates indicate a state of the glottis different from both nil phonation and unphonated, referred to as ‘prephonation’ [4]. Prephonation, as distinct from other voiceless states of the glottis such as breath, is made with the arytenoid cartilages adducted as for modal voice, but the vocal folds form a narrowed convex-convex opening medially in the glottis during which there is presumably insufficient subglottal air pressure to initiate airflow through the partially open glottis throughout the closure phase of oral articulatory stricture. The view of the larynx in Figs. 15–16 shows the prephonation state of the glottis during syllable-initial unaspirated [t] oral closure.

Fig. 15: Prephonation
Thai /tiʔt/ ‘touch’

Fig. 16: Prephonation
Cantonese /tiʔt ^{3}/ ‘order’

We propose the term prephonation be used to refer to the state of the glottis accompanying voiceless unaspirated oral stops and affricates, following Sweet’s description [9]. Our research has also shown that in English and Thai the prephonation state can precede an initial vowel in modal voice that does not have a glottal stop before it.

6. WHISPER AND WHISPERY VOICE VS. BREATHY VOICE

A further relationship in the analysis of states of the glottis that parallels the difference between the openness and relative openness for breath [h] and glottal stop [ʔ] and the epilaryngeally closed, sphinctered states of pharyngeals and epiglottals is the difference between breathy and whispery phonatory states. As in breath, the production of breathy voice requires an open epilaryngeal space. The defining trait of whisper is the action of the sphinctering mechanism and its effect on the shape of the space through which sound is generated [7]. In a cardinal example of breathy voice (Fig. 17), breathy flow escapes between the arytenoid cartilages, while voicing occurs anteriorly through the vocal folds, which are separated as far as they can be and still achieve voicing. Cardinal whisper (Fig. 18) is open glottally (with no vocal fold vibration) but closed aryepiglottically (with the aryepiglottic folds raised and advanced fully to the epiglottis). The key is not glottal shape but the shape of the epilaryngeal channel formed by the fronted and raised cuneiform cartilages at the ‘elbow’ of the aryepiglottic folds, bent in nearly a right angle.

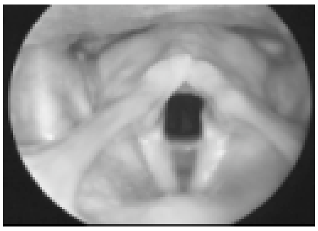

Fig. 17: Breathy voice

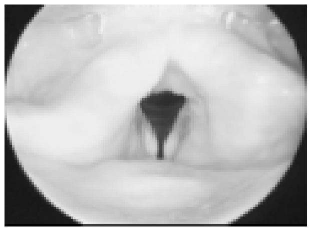

Fig. 18: Whisper

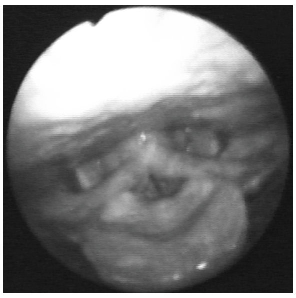

Fig. 19: Bai /tɕĩ^{31}/ ‘alkaline’

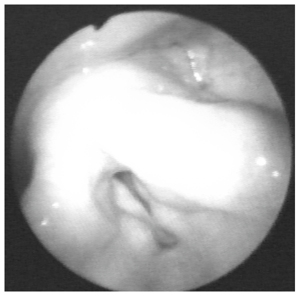

Fig. 20: Bai /tɕĩ^{33}/ ‘near’ (spoken in whisper)

The ‘breathy’ token of the Bai lax paradigm is mid-falling tone 31. Its auditory quality falls between breathy voice and whispery voice (for which we have no independent linguistic example), and therefore epilaryngeal openness is more subtle than in cardinal breathy voice. In an experiment where Bai tones were filmed in whispered speech, the fronting and raising action of the sphincter is apparent The lexical item in Fig. 20 is the same as in Fig. 7, but without voicing. To preserve the effect of mid-falling tone with adequate loudness using only friction noise, the epilaryngeal channel is narrowed by sphincteric action over the glottis. The effect at the glottis proper is not much different than in a voiceless pharyngeal fricative, but the degree of aryepiglottic sphincteric constriction in the production of Bai whispered tones has less tongue retraction than in the phonemic tokens of [ħ] we have observed, as in the case of Tigrinya /ħ/. Otherwise, the features of [ħ], [-voice] and [+sphincter], can be said to match the characteristics of whisper. The main difference here perhaps is that the Bai vowel is [-consonantal].

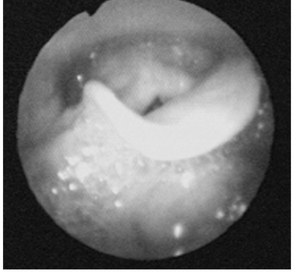

Fig. 21: Tigrinya [ħ]

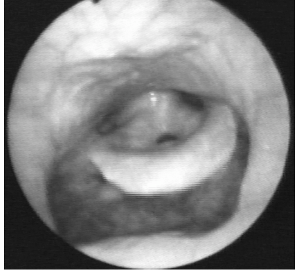

Fig. 22: Bai /tɕḭ̃^{21}/ ‘bracelet’

7. CREAKY AND HARSH VOICE

Fig. 21 shows how the extreme degree of sphinctering in a pharyngeal consonant compares with sphinctering for a harsh voiced vowel at the lowest pitch of the Bai tense series (Fig. 22). We identify aryepiglottic trilling in the Bai

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21 tone and characterize it as harsh voice at low pitch. Creaky voice is usually thought of as a token of low pitch, but we have no linguistic example of creaky register at this time. Although the sphinctered posture of the articulators looks very similar for creakiness and for harshness at low pitch (due to the requirement for shortness and mass at the glottis), we think of the creaky effect as a function of glottal voicing control and harshness as a function of posterior-to-anterior laryngeal sphincter constriction.

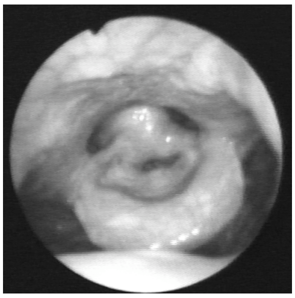

Fig. 23: Bai /tɕĩ̠□42/ 'arrow'

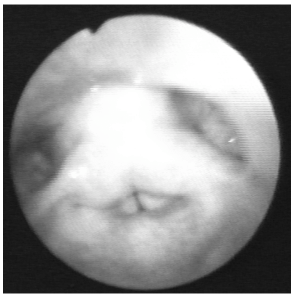

Fig. 24: Bai /tɕĩ̠□66/ 'sword'

The extremely narrowed sphincter at low tone, inducing periodic vibration of the aryepiglottic folds, corresponds to similar uses of the same mechanism for sphincteric phonation in !Xóõ [10] and 'growling' tone in Zhenhai [11]. The harsh state at mid pitch is illustrated by tone 42 of Bai (Fig. 23). Configurationally, it has slightly less constriction of the sphincter, and the aperiodic effect is a function of the supraglottic channel but not of any added trilling. The harsh state at high pitch, which had been referred to as 'ventricular voice' [12], is most closely illustrated by the highest tone 66 in the Bai tense series (Fig. 24). This state combines antero-posterior stretching of the vocal folds at the glottis with posterior-to-anterior constriction of the aryepiglottic sphincter epilaryngeally, inducing ventricular fold compression. The effect is as if forcing voicing through a glottal stop at high pitch.

8. CONCLUSIONS

We have revised our view of sounds produced in the larynx to include not only glottal but also supraglottic articulations. By expanding the classification of states of the glottis beyond the glottal plane to include sounds produced by the action of vertical laryngeal sphinctering, we are integrating the full range of phonation types into a multidimensional model of laryngeal behaviour

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REFERENCES

[1] J.H. Esling, "The IPA categories 'pharyngeal' and 'epiglottal': Laryngoscopic observations of pharyngeal articulations and larynx height," *Language and Speech*, vol. 42, pp. 349–372, 1999.

[2] J.H. Esling, "Voice quality settings of the pharynx," *Proceedings of the 14th International Congress of Phonetic Sciences,* vol. 3, pp. 2449-2452, Berkeley: University of California, 1999.

[3] J.H. Esling, K. Fraser and J.G. Harris, "Glottal stop, glottalized resonants, and pharyngeals in Nuuchahnulth (Nootka): A laryngoscopic study," *Journal of Phonetics*, in press.

[4] J.G. Harris, "States of the glottis for voiceless plosives," *Proceedings of the 14th International Congress of Phonetic Sciences*, vol. 3, pp. 2041-2044. Berkeley: University of California, 1999.

[5] J.G. Harris, "States of the glottis of Thai voiceless stops and affricates," in *Essays in Tai Linguistics*, K. Tingsabadh and A.S. Abramson, Eds., pp. 3–11. Bangkok: Chulalongkorn University Press, 2001.

[6] J.H. Esling and J.A. Edmondson, "The laryngeal sphincter as an articulator: Tenseness, tongue root and phonation in Yi and Bai," in *Phonetics and its Applications: Festschrift for Jens-Peter Köster on the Occasion of his 60th Birthday*, A. Braun and H.R. Masthoff, Eds., pp. 38–51. Stuttgart: Franz Steiner Verlag, 2002.

[7] M. Gao, *Tones in Whispered Chinese: Articulatory Features and Perceptual Cues.* MA thesis, Univer-sity of Victoria, 2002.

[8] J.C. Catford, "The articulatory possibilities of man," in *Manual of Phonetics*, B. Malmberg, Ed., pp. 309–333. Amsterdam: North-Holland, 1968.

[9] H. Sweet, *A Handbook of Phonetics,* Oxford: Clarendon Press, 1877.

[10] A. Traill, "The laryngeal sphincter as a phonatory mechanism in !Xóõ," in *Variation, Culture and Evolution in African Populations: Papers in Honour of Dr. Hertha de Villiers*, R. Singer and J.K. Lundy, Eds., pp. 123–131. Johannesburg: Witwatersrand University Press, 1986.

[11] P.J. Rose, "Phonetics and phonology of Yang tone phonation types in Zhenhai," *Cahiers de Linguistique Asie Orientale*, vol. 18, pp. 229–245, 1989.

[12] J. Laver, *The Phonetic Description of Voice Quality*, Cambridge: Cambridge University Press, 1980.