The valves of the throat and their functioning in tone, vocal register, and stress: laryngoscopic case studies

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The standard method of describing phonation for tone, vocal register, stress and other linguistic categories relies on the Continuum Hypothesis that linguistic sounds are produced by means of glottal states determined by the aperture between the arytenoid cartilages; the endpoints of the voiced-voiceless continuum being "open glottis" and "closed glottis". This paper takes a different view by pointing out that many languages make use of a number of valves and that these valves are not articulations on a glottal continuum but represent a synergistic and hierarchical system of laryngeal articulations. These valves constitute a principal source of phonological contrast, with an influence on how oral articulatory events are characterized.

1. Introduction.

Phoneticians have traditionally described *phonation* utilizing the concept *States of the Glottis* (SOG), which means that speakers can set the valve-like organs of the throat to produce regular, cross-linguistic phonological contrasts such as *modal voice*, *breathy voice*, *creaky voice*, as well as pitch trajectories (*tone*) and *stress* prominences. These states of the glottis have been characterized as a CONTINUUM resulting from scalar variation of the *aperture between the arytenoid cartilages*, with "open glottis" and "closed glottis" serving as the endpoints (Ladefoged 1971 and Gordon and Ladefoged 2001):[1]

[open] VOICELESS — BREATHY — MODAL — CREAKY — GLOTTAL(IZED) [closed]

A new view on SOG is found in Esling and Harris (2005), who have shown that in many languages, laryngeal configurations arise by manipulating a more complex system of valves than just the glottis to control airflow through the throat. Moreover, these more complex valves are not organized as a continuum along a single anatomical structural parameter (such as the opening and closing of the arytenoids):

- *(Valve 1)* glottal vocal fold adduction,
- *(Valve 2)* partial covering and damping of the glottal vocal folds by the ventricular folds (hereafter called **ventricular incursion**),

[1] Gordon and Ladefoged (2001:10) do note some exceptions to the mono-dimensional continuum. In talking about the stiffness in Jalapa Mazatec, they note that it " … seems to include not only some compression of the glottis, but also increased tension of the pharyngeal walls. This could be classified as a creaky voice, with a 'helping feature' (Stevens, Keyser & Kawasaki, 1986). In addition, certain vowels in !Xóõ employ a voice quality which is typically referred to as "strident" in the literature (Ladefoged and Maddieson 1996). Traill (1985) has given a good description of this voice quality, including x-ray pictures of his own pronunciation of the sound. (His language consultants attest to the high quality of his pronunciation.) It has a narrowing above the glottis that involves the aryepiglottic fold that affects the vibration of the true vocal folds. Strident vowels are associated with irregular noisy vibrations and higher first and second formant values due to the pharyngeal constrictions associated with the movement of the aryepiglottic fold and backing of the epiglottis (Ladefoged and Maddieson 1996)."

It is also worth noting that States of the Glottis involve vocal qualities such as whisper, falsetto, and other settings not discussed here.

- *(Valve 3)* sphincteric compression forwards and upwards of the arytenoids by means of the thyroarytenoid muscle complex,
- *(Valve 4)* retraction of the tongue and epiglottis moving backward and downward, culminating in extreme cases in full closure onto the pharyngeal wall, by means of the the hyoglossus muscles (hereafter called **epiglotto-pharyngeal constriction**),
- *(Valve 5)* laryngeal raising, with the converse posture of lowering of the larynx,
- *(Valve 6)* narrowing inwards along the path of the palatopharyngeal muscles (hereafter called **pharyngeal narrowing**).

The importance of these six different levels of components in producing laryngeally articulated speech has been underestimated until recently because the pharynx behind the tongue is relatively inaccessible during speech, and the rapidly moving parts of the laryngeal mechanism interact in multiple planes, unlike other topographies of the speech-producing landscape. Although cineradiographic images gave some indication of function, these complex manoeuvres could not be studied extensively in a direct visual way before modern fiber optic laryngoscopy. The mechanism could be observed only imperfectly with the aid of mirrors and reflected sunlight. This changed dramatically in 1968 with the invention by Sawashima and Hirose of a flexible transnasal endoscope with high-quality recording capability and high-powered cold-light sources.

Very soon thereafter, laryngoscopic work by Williams, Farquharson, and Anthony (1975) showed that there exist progressively more extreme sorts of constriction. Williams et al. noted that they could observe not only glottal vocal fold adduction and ventricular incursion, but also "a narrowing of the whole laryngeal vestibule from the sphincteric action of the aryepiglottic folds, epiglottis and even the lateral pharyngeal walls" (p. 310). All of these present a much more complex picture of the States of the Glottis than the mono-valve, mono-dimensional glottal continuum presented above.

2. The vocal tract valves.

Let us begin by examining briefly the anatomy of the vocal tract valves. In Figure 1a we can see the division between the oral vocal tract and the laryngeal vocal tract. The state of the vocal folds determines the glottal state, with pitch being controlled perpendicularly to the adduction/abduction of the vocal folds. The pharyngeal cavity is governed by the interrelated actions of sphincteric aryepiglottic fold constriction, tongue retraction, and larynx raising. Figure 1b presents a video image of a phonating glottis with adducted glottal folds and ventricular and aryepiglottic folds in their open positions. The epiglottis is at the bottom of the image and the arytenoid cartilages are at the top. The orientation of the image is as if the observer were looking straight into the mouth and down into the pharynx.

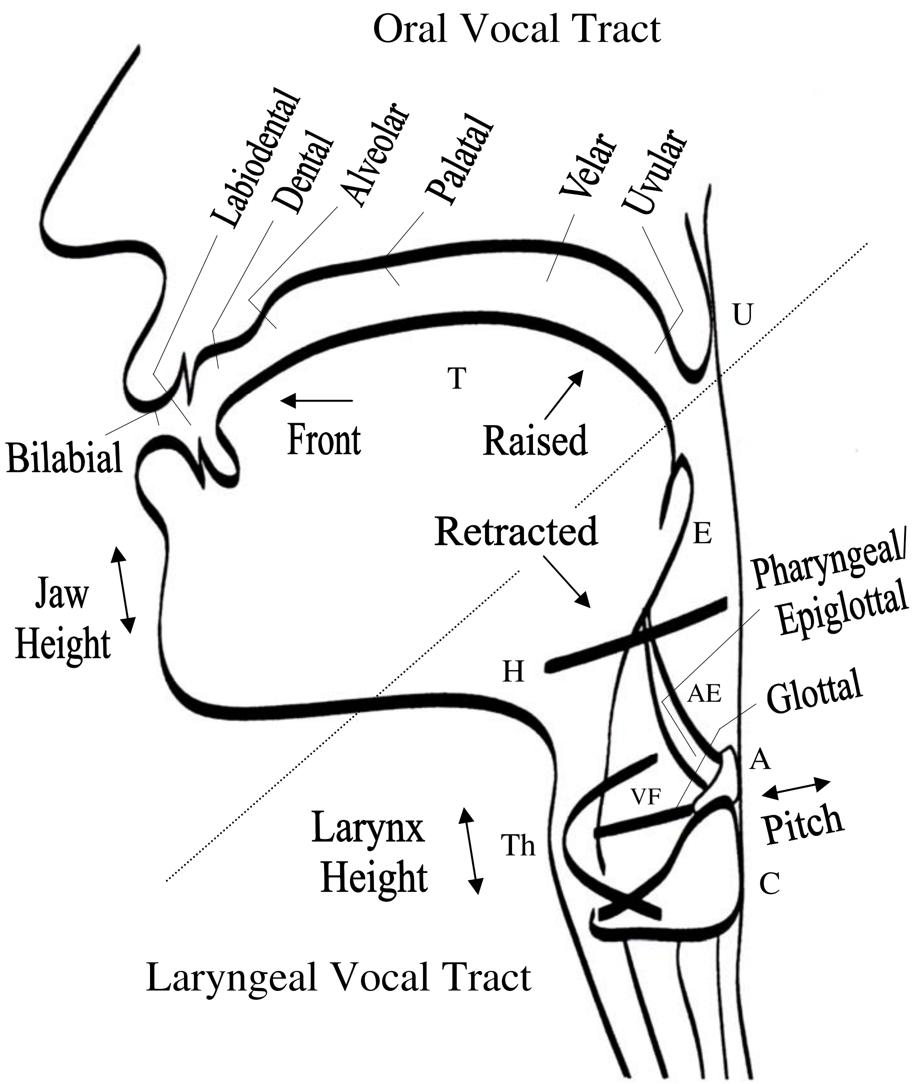


Figure 1a: Vocal tract diagram labelled to represent the oral and the laryngeal articulators. The nasal tract is not shown. T, tongue; U, uvula; E, epiglottis; H, hyoid bone; A, arytenoid cartilage; Th, thyroid cartilage; C, cricoid cartilage; AE, aryepiglottic folds; VF, vocal folds, (from Esling (2005), reproduced by permission, University of Toronto Press).

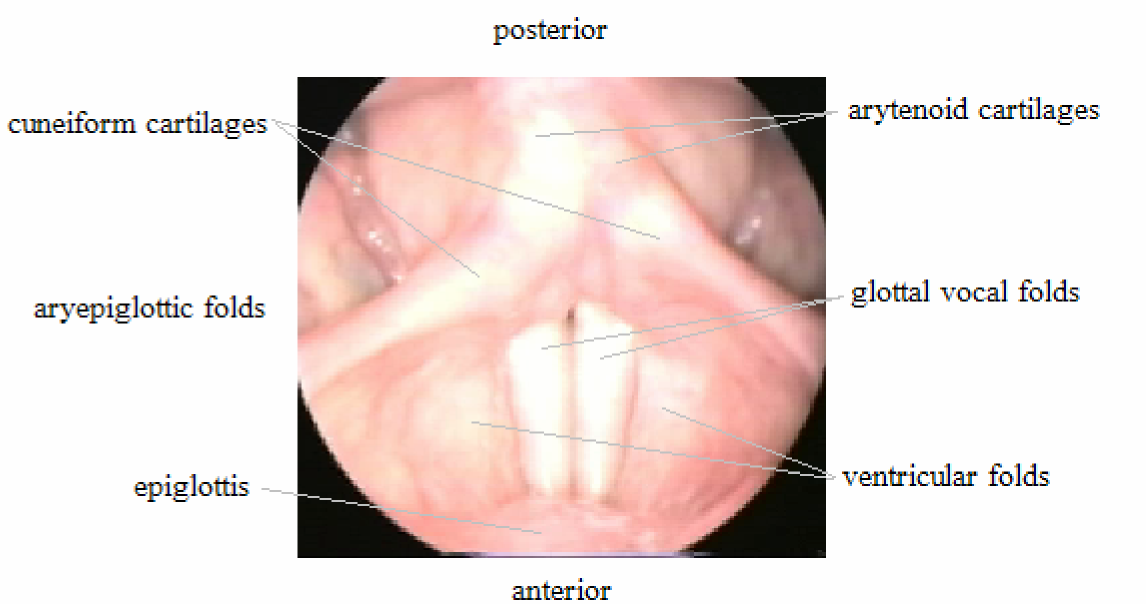


Figure 1b: The lower throat area as seen from the entrance of pharyngeal cavity just behind the uvula and below the tip of the epiglottis with vocal folds adducted and phonating from Esling and Harris (2005). The arytenoid cartilages are tightly adducted, but the cuneiform cartilages of the aryepiglottic folds lie in a straight line from the arytenoids along the aryepiglottic folds up to the epiglottic margins (reproduced by permission, Lawrence Erlbaum Publishers)

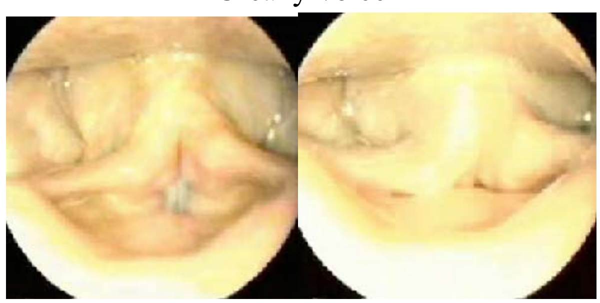
Beginning with **Valve 1** shown in Figure 1b, let us first examine glottal vocal fold adduction. The vocal folds are first brought together by adducting the arytenoid cartilages; just before onset of voicing a convex-convex gap remains in the glottis (prephonation) so that with sufficient air pressure from below phonation can occur, Harris (1999). The most common kind, modal phonation, is exhibited in Figure 1b when the arytenoids are completely adducted, the glottal folds are brought to the midline so that they touch in their oscillation, and the airflow and vibratory pattern are at their most efficient for voiced sound production. An increase in pitch is usually produced by stretching the glottal folds with the cricothyroid muscles, although there are other ways in which pitch can be made to increase. As depicted in Figure 1a, the pitch increasing mechanism is perpendicular to the glottal adduction mechanism. Adduction (for voicing), abduction (for breath), and longitudinal stretching (for increasing pitch) are all glottal activities.

Ventricular incursion, the **Valve 2** constrictive process, occurs when the ventricular folds adduct above the already closed vocal folds.[2] They reinforce the closure of the vocal folds in a moderate glottal stop and damp the vibration of the vocal folds (Esling, Fraser & Harris 2005). In general, the involvement of the ventricular folds indicates tension in both the vocal and ventricular folds. What is called ventricular voice in clinical contexts (i.e. active independent vibratory patterns produced by the ventricular folds themselves) is not a characteristic of the sound produced when the ventricular folds reinforce the action of the phonating vocal folds in

[2] One could distinguish two degrees of this valve, partial incursion and complete covering. Catford (1977:103-4, 163) reports that Paget (1930:34) witnessed Mr. Strath McKay singing two notes at once, one glottal and one ventricular. Catford also says that completely covered ventricular stops occur in several Caucasian languages.

normal speech. Their effect is realized in combination with the vibratory cycles being produced at the glottis. Laryngealization after or before a glottal stop may involve the engagement of Valve 2 or of Valve 3. In the production of creaky voice as seen in Figure 2, Valve 2 is not engaged, but Valve 3 is quite strongly engaged. Valve 1 (at the glottis) remains uncovered as the airstream produces slow undulating vibrations with slack vocal folds. Valve 3, it is important to note, is anything but slack for creaky voice. In the production of harsh voice as seen in Figure 2, Valve 2 is engaged, and Valve 3 is even more strongly engaged than for creaky voice. The vocal folds lose their slack character and produce auditorily harsh (irregular/aperiodic) phonatory quality.

Creaky voice

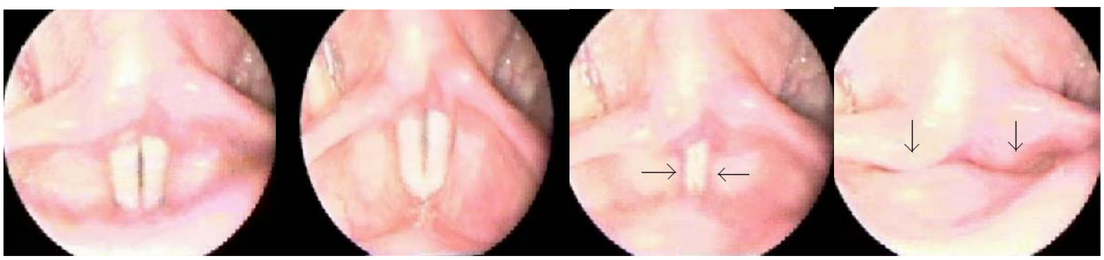


Harsh voice

Figure 2: A comparison of creaky voice, showing relatively slack vocal folds with little or no covering of Valve 2, and harsh voice (at mid pitch, then at low pitch), evidencing use of Valves 2 and 3.

We will now turn to **Valve 3**, which performs what we have termed *aryepiglottic-to-epiglottal* (a-to-e) constriction. The arytenoid cartilages and their associated folds, the aryepiglottic folds, which attach upwards to the margins of the epiglottis, execute a sphincteric closure on top of a glottal plane that may be already adducted (Valve 1) and incursively constricted (Valve 2). The glottis may also remain open during the stricture of Valve 3, for the production of voiceless sounds. The structures involved in the laryngeal constrictor mechanism of Valve 3 are positioned above the glottal/ventricular horizon and operate in their closure at a right angle to Valves 1 and Valve 2, shown in Figure 3, and move in a posterior-to-anterior direction with the cuneiform cartilages within the aryepiglottic folds being pulled towards the surface of the epiglottis. The thyroarytenoid muscles, some fibers of which are buried in the aryepiglottic folds (aryepiglottic muscles), also have fibers in the glottal adductor (lateral cricoarytenoid) muscles and fibers extending up to the margins of the epiglottis (thyroepiglottic muscles) (Zemlin 1998: 129-131). The different parts of the thyroarytenoids are posited to be responsible for the inferior and medial contraction to close Valve 2 and for the superior and lateral contraction to close Valve 3. In harsh voice, the vocal folds and ventricular folds effect stoppage by moving from a lateral position towards the centerline. Valve 3 employs the cuneiform cartilages to close, and this closure very often operates with the assistance of Valves 1 and 2. The separate engagement of Valve 3 can be called the "laryngeal sphincter" mechanism. The combination of Valve 3 + Valve 4 + Valve 5 functioning together can be called the "laryngeal constrictor". In the formation of an epiglottal stop (complete and efficient blocking of the entire airway), Valve 1 + Valve 2 + Valve 3 + Valve 4 + Valve 5 operate in sequence and as a group to close every aspect of the epilaryngeal tube, reducing the volume of the lower pharynx. Valve 5 in this interpretation is assumed to be closed when the larynx is raised (as the unmarked case), although an epiglottal stop can still be held with the larynx lowered (as its marked position).

Valve 1 Valve 2 Valve 3

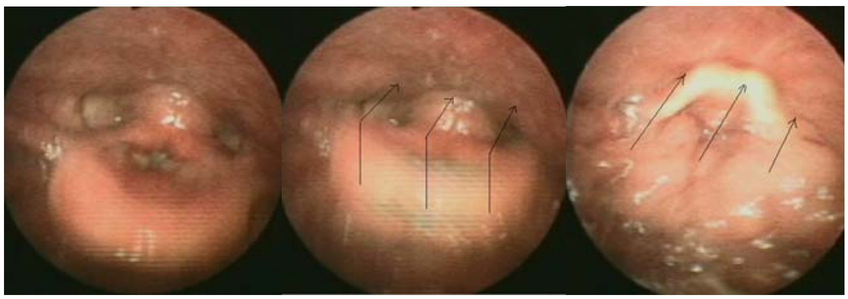


Frame 1 Frame 13 Frame 28 Frame 31

Figure 3: Synergistic action of the laryngeal constrictor Valves 1 2, and 3 for epiglottal stops

Figure 3 illustrates the production of an epiglottal stop from a sequence of five video frames filmed at 30 frames/sec, Frame 1 showing the prephonation position just before voicing begins. By Frame 13 one can see the phonating vocal folds at the glottis and no engagement of Valves 2 and 3 (note the 90° angle between the paired arytenoids and their a-e appendages), Valve 1 with the arytenoids adducted. By Frame 28 the glottal folds have reached stasis and the ventricular folds have advanced appreciably to the center of the airway, whereas the arytenoid cartilages are just beginning to approach the epiglottal surface in a posterior-to-anterior direction, (the angle between them is approaching 180°), showing the execution of Valve 2. Finally, in Frame 31 the arytenoids and their appendages, the a-e folds, rest completely up against the epiglottal surface, Valve 3; the laryngeal constrictor has achieved a triple seal shutting off air from below. Thus, this articulation is properly called an *aryepiglotto-epiglottal stop* or *epiglottal stop* for short, inasmuch as the epiglottis is the passive articulator. We have found direct visual evidence of Valve 1 + Valve 2 + Valve 3 activity (and for other functions than just complete epiglottal stop closure) in: Tibetan, Korean, Nuu-chah-nulth (Nootka), Nlaka'pamux (Thompson), Thai, Sui, Amis (an Austronesian language of Taiwan), Pame (an Otomangean language of Mexico), Kabiye, Somali, Arabic, Tigrinya, Cantonese, Yi, Dinka, and Bai. We believe this mechanism is found widely in many languages, paralinguistically if not linguistically.

Valve 4 has two aspects. The first is the concomitant lingual retracting feature of laryngeal constriction, and the second is extreme closure of the pharyngeal point of lingual stricture. As a point of closure, it is an airflow constrictor that has, to our knowledge, not been documented before. It involves a more extreme form of the laryngeal constrictor just described. In a laryngeal gesture such as an epiglottal stop, closing off the lower pharynx as in Figure 3, the tongue must retract to meet the advancing and rising aryepiglottic articulator (see Figure 1a). Tongue retraction is therefore by definition not only backing but also descending (Esling 2005). In its more extreme realization, Valve 4 can be said to begin from the epiglottal stop position with the a-to-e settings in place. From a position near the arytenoid cartilages, the tongue and epiglottis continue their posterior movement towards the back wall of the pharynx. The action of this valve is illustrated in Amis *riri'* [ririʡˤ] 'grasshopper', Figure 4. Frame 1 is taken in the middle of the second syllable where the a-to-e constriction is nearing completion. Quite rapidly, as Frame 2 shows, the epiglottis compacts further in a posterior direction, and, indeed, in Frame 4, presses down against the pharyngeal wall to form a stop. This process is called *linguo-epiglotto-pharyngeal constriction*), since the passive articulator is the pharynx wall and the active articulators are the epiglottis and sides of the tongue. This gesture resembles the epiglottal activity observed by Laufer and Baer (1988), while being more extreme.



Frame 1 Frame 2 Frame 4

Figure 4: Amis riri' [ririʡˤ] 'grasshopper' showing the lingual pharyngeal constrictor

In past literature this voiceless epiglotto-pharyngeal stop has been called a *linguo-pharyngeal articulation* or a *radico-pharyngeal articulation*, neither of which accounts for the activity of the laryngeal valves that must be operating beneath in order for this degree of lingual stricture to occur (Catford 1977). Our observations show Valve 4 to be an enhancement of the laryngeal constrictor when special emphasis is needed, for example, in a stressed Amis syllable.

The pharyngeal space is further modified by a fifth valve that is related, like Valve 4, to the action accomplished by Valve 3. **Valve 5** is the larynx-raising mechanism, which has an opposite setting from its neutral posture - active larynx lowering. As an unmarked concomitant of laryngeal constriction, as in the case of lingual retraction for Valve 4, Valve 5 can be thought of as the larynx raising that assists aryepiglottic sphinctering and tongue retraction during laryngeal constriction, further compacting the pharyngeal space from below. Thus, the basic shape of the laryngeal constriction mechanism as a buckling manoeuvre includes participation by Valves 3, 4, and 5. In some cases, however, the larynx can be lowered while the a-to-e mechanism is tightly contracted, producing a longer pharynx and correspondingly lower acoustic formant values. We have observed varieties of Arabic (e.g. Palestinian) to have pharyngeal sounds that are also larynx-lowered (so that the aryepiglottic mechanism cannot be seen below the epiglottis), whereas other Semitic varieties such as Tigrinya produce pharyngeals with extremely raised larynx.

Finally, **Valve 6** is a pharynx-narrowing mechanism that depends on the height of the larynx itself. This is the opposite of what has often been termed pharyngeal "expansion", described above in terms of lowering the larynx; but it may explain what has been described as "vocal tract wall tension" (Dart 1987). The narrowing of the sides of the pharynx that accompanies constriction as in Figure 5 should not be confused with the narrowing of the "faucal pillars" that may be seen behind the oral cavity during the production of "faucalized voice" (Laver 1980). The former occurs when the aryepiglottic sphincter is already tight and the larynx is raised; the latter is a realization of "expanded pharynx", which is usually accomplished by lowering the larynx and therefore expanding the pharyngeal cavity vertically. Valve 6 is therefore engaged during extreme phases of constriction, together with or separately from Valve 4, retracting of the tongue, and Valve 5, raising the larynx. It may be a concomitant effect of raising the tongue, as for uvularization. Whether it is caused by constriction or whether it results secondarily from other simultaneous articulations, its effect is to reduce the size of the resonating pharyngeal space. Valve 6 is normally associated with strong constriction and usually functions as an added enhancement to other constricting valves.

Frame 1 Frame 7 Frame13

Figure 5: Pharyngeal narrowing in Somali *qî̠q* [ˈq͡ʡî̠q͡ʡ] ‘to emit smoke’

In Somali the voiceless dorso-uvular-epiglottal stop, written as **q** [q͡ʡ], is a uvular stop accompanied by an epiglottal stop. It has constricted quality, due largely to the action of Valve 3, and moderate Valve 4 retraction as well as moderate to extreme Valve 6 narrowing. Frame 1 begins in the vowel before the word-final stop where the sides of the pharyngeal wall are cleanly separated from the lateral edges of the epiglottis. In Frame 7, the tongue and epiglottis retract as the laryngeal aryepiglottic folds move forwards and up underneath the epiglottis. As this happens, the pharyngeal walls are simultaneously drawn toward the centerline and forwards. Maximum stricture is reached in Frame 13.

These six valves might be likened somewhat to the valves of a brass instrument, changing the timbre and resonance of the sound emitted. Some have a strong effect on the character of vibration. Clearly, Valve 1 (glottal adduction) is a major source of voicing. Valve 2 and especially Valve 3 have a dramatic effect on phonatory quality, and when there is trilling of the aryepiglottic folds, the laryngeal constrictor can be a secondary sound source. Valves 4, 5, and 6 are most significant in shaping the resonating cavity of the pharynx. For the production of word level prosodies, these valves are essential—especially for quality changes in vocal register—to which we now turn.

3. Voice register.

In order to see the functioning of the six valves described above, we now examine three types of vocal register. We first present for each a model, a cardinal state of the glottis (Esling and Harris 2005), which is a canonical profile of laryngeal function as a way to establish points of reference against which languages or regional varieties of a language can be compared. The articulatory profiles are modeled on categories developed through the work of Catford (1964, 1977), Laver (1980), Edmondson, Esling, Harris, Li, and Lama (1999) on Bai and Yi, Carlson, Esling and Harris (2004) on Nlaka'pamux, and Esling and Harris (2005). In the following we sketch the functioning of six valves described above in some major postures of the laryngeal apparatus, which can be used as distinctive features, as prosodic markers, or as sustained voice qualities-Harsh Voice, Creaky Voice, Breathy Voice, and Hollow Voice.

3.1. Breathy Voice

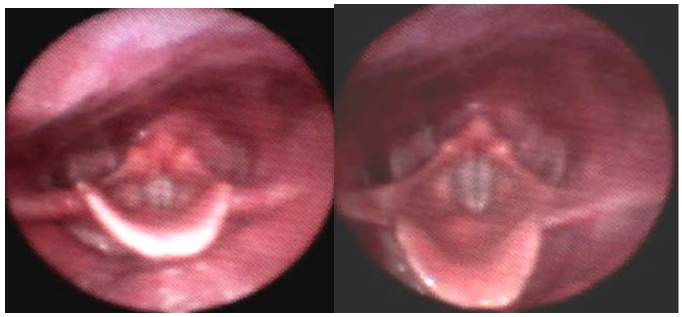
Breathy voice is described by Catford 1964, 1977 as “breath + voice”, “sigh-like” so that the glottal folds “simply ‘flap in the breeze’ of the high-velocity air-flow” (Catford 1977:99). Others have used metaphors such as a “flute-like tone” with excess air flowing past the vibrating glottal fold with turbulence. It resembles the out-of-breath speech of a person who has just experienced strenuous exercise or great excitement, presumably because of high volume velocity airflow across the glottis. Breathy Voice is usually associated with voiced consonants and low pitches. So, for example, Breathy Voice is found in the low tone set among older speakers of Wu-type Chinese (Shanghai, Ningbo, and Zhejiang Province) as well as Tày of Cao Bằng Province, Vietnam, Mon-Khmer languages and many other languages from Asia, Mexico, and Africa. In Figure 6a we first see Esling’s Cardinal state for Breathy Voice.

Figure 6a: Cardinal Breathy Voice

Figure 6b: Bai [p^{h}i̤^{31}] ‘worthless person’

Figure 6a shows Valve 1 in partially closed mode, with the arytenoid cartilages slightly but not completely adducted and the vocal folds therefore slightly separated during voicing. Glottal tension is rather loose so that the edges of the folds can be oscillated without touching along the length of the glottis in a high volume airstream. In Figure 6b, for Bai, a Tibeto-Burman language of Yunnan Province, China, the pitch on words with breathy quality is mid-to-low falling with slightly open glottis and high volume airflow. Two of the cells in the 15-cell Bai tonal register paradigm have this phonatory quality (Edmondson, Esling, Harris, Li, and Lama 1999).

Dinka, a Nilotic language of Sudan also has a modal voice-breathy voice contrast. Job Malou (1988) gives the following set of example pairs: *rīŋ* ‘run’ vs. *rì̤ŋ* ‘meat’, *wīl* ‘guinea fowl’ vs. *wì̤l* ‘words’, *t̪ɔ̄k* ‘mouth’ vs. *t̪ɔ̤̀k* ‘goats’, *t̪ɔ̄ŋ* ‘spear’ vs. *t̪ɔ̤̀ŋ* ‘to bid goodbye’ (marked with nothing for Modal Voice and two dots under the vowel for Breathy Voice; overbar represents level tone and grave a falling tone). In Figure 7 we present two comparative video images showing this Modal Voice vs. Breathy Voice contrast in one of our speakers.



rīŋ 'run' *r̤īŋ* 'meat'

Figure 7: Dinka Modal Voice vs. Breathy Voice

The two images are taken from comparable locations in the syllable and show for *rīŋ* 'run' that the vocal folds are adducted, and the laryngeal sphincter is slightly more constricted than might be expected for a modal setting. In *r̤īŋ* 'meat' there is less evidence of constriction as the vocal folds are more visible, the aryepiglottic folds are stretched and less pinched, and the tongue is less retracted, suggesting that the vocal folds may be emitting more air and more turbulent flow, as would be expected for breathy phonation, but it is not possible to detect this visually with laryngoscopy. The auditory quality of this token is clearly breathier than the modal member of the minimal pair. There can also be variation among speakers, since contrastiveness is relative, but pitch is usually lower for breathy voice. Across speakers, there is variation from very breathy to only lax tension for this register.

3.2. Harsh Voice

First there is Harsh Quality at high pitch, which is often called Ventricular or Pressed Voice.[3] Harsh Voice at high pitch, cf, Figure 8, when viewed laryngoscopically shows a "hawkeye" shaped aperture through the epilaryngal tube onto the glottal plane. This aperture remains open while the ventricular folds cover a substantial portion of the vocal folds, as in the static glottal state for Glottal Stop (Esling and Harris 2005), compressing them and damping oscillation. The aryepiglottic sphincter does not appear appreciably engaged, but this may be because the constriction mechanism, which would normally reduce the opening over the glottis from back to front, is being directly opposed by the mechanism for increasing pitch (stretching the glottis from front to back). This so-called "ventricular voice" is often produced when people lift heavy weights, so that pulmonary air can help support the torso without being too quickly expelled. Harsh Voice at mid and low pitch shows complete engagement of the aryepiglottic sphincter. The "hawkeye" shaped aperture disappears and the aryepiglottic folds and arytenoid cartilages are positioned forwards onto the epiglottal surface. When pulmonary air comes from below, the folds flutter flaccidly against the epiglottal surface with a frequency of about 50 Hz. If voiceless, this gesture resembles "throat clearing". Boone and McFarlane (1993) observed that the "epiglottis and the arytenoids approach each other during phonation". Esling and Harris (2005:373) describe in detail from direct observations how in Harsh Voice first there is glottal adduction, followed temporally by ventricular incursion, and finally by aryepiglottic constriction.

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[3] As Esling and Harris (2003, 2005) point out, however, ventricular (pressed) voice is not a particularly apt name, as the ventricular folds, in fact, do not oscillate in the airstream, as they are said to do in the pathological form of speech called *plica ventricularis*, called *double voice* in Catford (1977:103-4). For tone languages of Asia we use the Scale-of-Five System of Y. R. Chao.

Bai is a language with three phonatory contrasts: (1) modal voice (indicated by no mark); (2) breathy voice (indicated by two dots under a vowel V̤); and (3) harsh voice (indicated by V̰ and by V̰̰ when there is aryepiglottic trilling). The Bai language has eight prosodic contrasts on oral syllables (and seven on nasal syllables) that are composites of tone and the three phonatory registers as follows: (a) 55, *tɕi*^{55} 'much, more', (b) 6̰6̰, *tɕḭ*^{66} 'to send, mail', (c) 33, *tɕi*^{33} 'to pull', (d) 4̰4̰, *tɕḭ*^{44} 'leech', (e) 3̤1̤, *tɕi̤*^{31} 'nephew', (f) 42̰, *tɕḭ*^{42} 'hurry, to', (g) 2̰̰1̰̰, *tɕḭ̰*^{21} 'flag' and (h) 3̰5, *tɕḭ*^{35} 'worried'. The Harsh voice in high level pitch and mid level pitch syllables has a trajectory slightly higher in pitch and shorter in duration as the glottal fold vibration come more quickly to stasis. The 6̰6̰ tone shape could be alternatively described as what some have called pressed voice, because of the pitch level. Prosodic category 2̰̰1̰̰ has strong a-e trilling, but some is also found on the 42̰ and 3̰5 prosodic categories as well. As one can observe, there are several different tone levels, and each causes distinctive subtypes. Bai constitutes an excellent example of a language that employs one phonatory register category "harsh" over several different pitch ranges. Compare the Cardinal State of Harsh Voice in Figure 8a with the harsh, high register in Figure 8b from Li Shaoni, a Jianchuan Bai speaker.

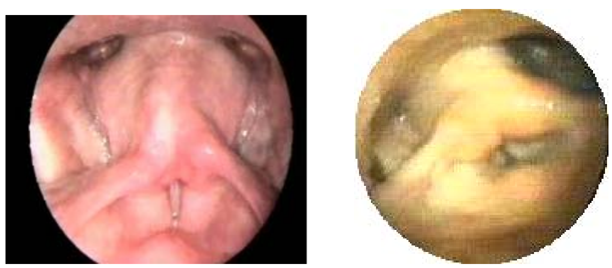
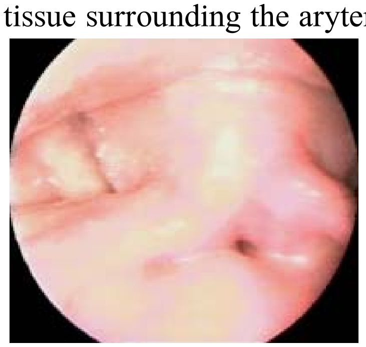


Figure 8: a) Canonical Harsh/Pressed Voice (High pitch); b) Bai Harsh/Pressed Voice [tɕḭ^{66}] 'to mail'

If the accompanying pitch to Harsh Voice quality lowers to mid range, then Valve 3 is more in evidence as the aryepiglottic folds press up onto the epiglottal surface. There is often some periodic flapping of the epithelial tissue surrounding the arytenoid cartilages.



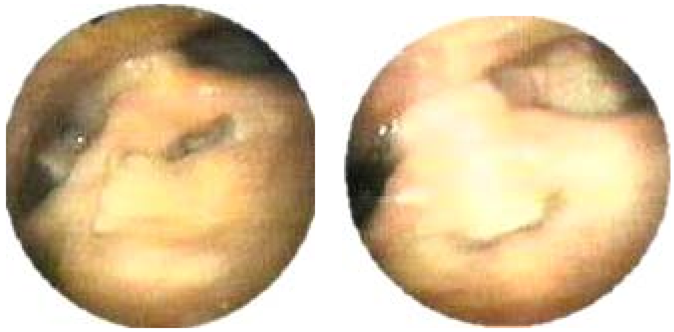


Figure 9: a) Canonical Harsh Voice (Mid pitch), b) Bai Harsh Voice (Mid pitch) [ʨi̠̰^{44}] ‘leech’, c) Bai Harsh Voice (Mid-rising) [ʨi̠̰^{35}] ‘nervous, worried’

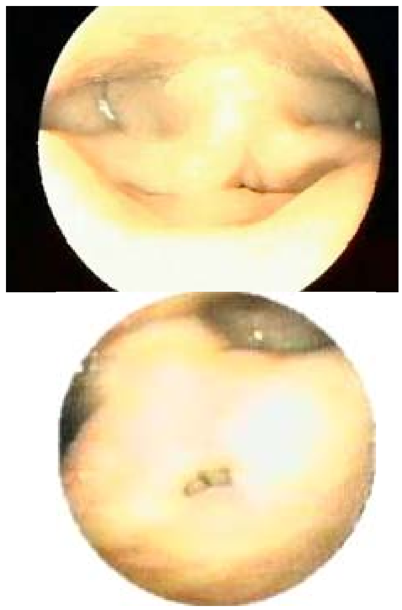


Figure 9: d) Canonical Harsh Voice (Low pitch) and e) Bai Harsh Voice Quality [ʨi̠̰̰^{21}] ‘flag’

When the pitch is low, as in Figure 9d and e, then there is an even greater likelihood that the aryepiglottic folds will be involved in trilling onto the epiglottal surface.

Dinka Bor like Bai possesses harsh voice, but unlike Bai the Dinka of Bor has very strong pharyngeal narrowing accompanying the harsh quality. In Figure 10, the sides of the pharynx push in against the lateral edges of the epiglottis as the tongue retracts. It is possible instead of being an independent action of the palatopharyngeal muscles along the sides of the pharynx that this stricture is a concomitant effect of the actions of all the other valves. Valve 1 is engaged for voicing; Valve 2 may contribute to the quality of that voicing; Valve 3 is actively constricted beneath the epiglottis (perhaps the key element in most qualities labeled "harsh" or "tense"); Valve 4 contributes the expected level of tongue retraction to accompany Valve 3, but not full closure; Valve 5 contributes larynx raising (also expected to accompany Valve 3, as opposed to larynx lowering); and Valve 6 adds the final narrowing of the entire pharyngeal mechanism, which once may have been assumed to be the only articulatory correlate of pharyngealization. Syllables with this phonation often lose aspiration or show some jitter (irregularity of pitch). These would be phonetically predictable outcomes. Although many of the relationships between valves are entailed and hierarchical once a certain degree of stricture is reached, any changes to the status of one or another valve could lead to variation and to changes in the way a given sound is produced.

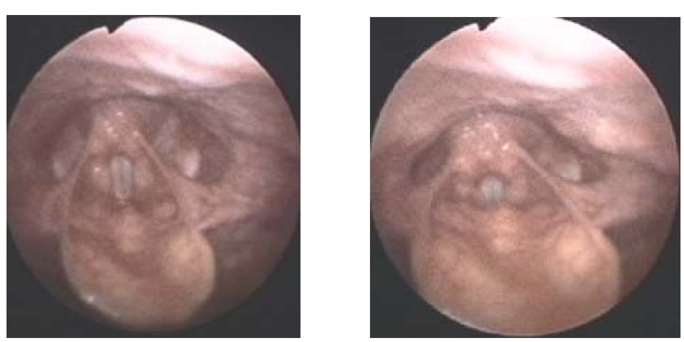
kō̲o̲r 'to want' kò̲o̲r 'cyclone, dustdevil'

Figure 10: Two examples of Harsh Voice in Dinka

3.3. Constricted valve postures in Somali.

Somali exhibits another set of permutations of valve posture in a series that could be described as "constricted", which contrasts with another "non-constricted" series. Somali is a Cushitic language spoken in Somalia, Ethiopia, Djibouti, and Kenya with a population of about 8-10 million. Standard Somali is based on northern forms of the language, which is the variety reported on here.

The key feature, to be discussed here, we believe to be the system of its voice registers that result from its differences of *non-constricted and constricted laryngeal register*. The previous work on Somali has called the phenomenon by many different terms. For example, Berchem (1992:29) describes two sets of vowels, dividing them into a "...neutrale und eine zentralisierte Form". Orwin (1994) says the system of Somali vowels is divisible into a "front series" and a "back series". Saeed (1999:11-6) speaks about plus or minus Advanced Tongue Root [ATR] to describe these two sets of vowels. He emphasizes that the two series: (1) are not allophonic variants of one another, (2) are involved in independent harmony sets so that all vowels in a polysyllabic root belong the same [ATR] series. An example is the minimal pair: *dîid* [ˈd̥îiʔ͡t] 'to refuse' (Set 1) vs. *dîid* [ˈd̥î̲i̲ʔ͡t] 'to faint' (Set 2).[4]



[4] In the transcriptions for Somali Harsh voice with an underline under the vowel, for example V̲, stress with a macron [ˈ] before the syllable that is stressed, and tones in Somali and in Bor Dinka will be marked over vowels as follows: HIGH is marked with [´]; LOW is marked with [`], and MID is marked with [¯].

Figure 11: a) Somali *dîid* [ˈd̥îʔ͡t] ‘to faint’ Lax Voice (Set 1) vowel middle vs. b) Somali *dîid* [ˈd̥î̠ʔ͡t] ‘to refuse’ Harsh Voice (Set 2) vowel middle

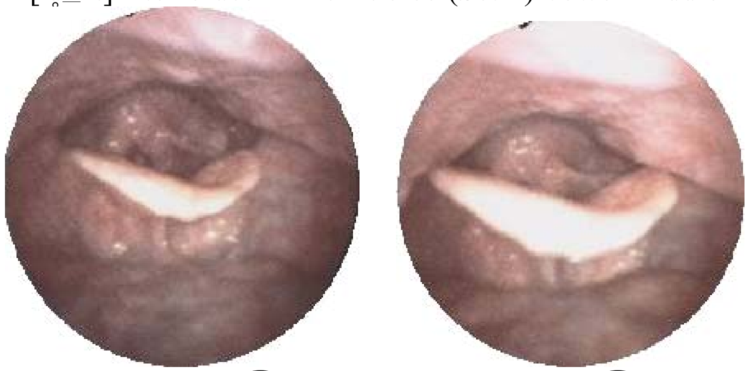


Figure 11: c) vowel end *dîid* [ˈd̥îʔ͡t] ‘to faint’ vs. d) *dîid* [ˈd̥î̠ʔ͡t] ‘to refuse’ vowel end

In Figure 11, views a and b contrast the non-constricted series *dîid* [ˈd̥îʔ͡t] ‘to faint’ vs. with the constricted series *dîid* [ˈd̥î̠ʔ͡t] ‘to refuse’. Each frame depicts the middle of the vowel. Views c and d show the glottal stop at the end of each word, illustrating that the harsh, constricted posture of Set 2 is nearer articulatorily (in valve setting) to the posture for glottal stop (which represents closure of Valve 2). In Set 1, Valve 1 is closed (at the glottis, for voicing), but no other valves are active. In Set 2, Valves 1, 2, and 3 are actively constricted; Valve 4 appears to be slightly active although it is not as constricted here as in other languages in the database; Valve 5 is raised, and Valve 6 is more active here than in other languages. Since each valve posture has an effect on acoustic resonance, and since speakers use auditory criteria to learn and to distinguish sounds, the overall effect of the choice of valve combinations on the resonating properties of the pharynx and of the oral vocal tract is more significant than the individual articulatory postures themselves. The properties are:

Non-constricted Larynx (Set 1)	Constricted Larynx (Set 2)
1. Openness of the arytenoid-epiglottal aperture in the anterior-posterior dimension.	1. Sphincteric compacting of the arytenoid-epiglottal aperture in the posterior-anterior dimension.
2. Vowel quality that is more fronted and/or raised.	2. Vowel quality that is more retracted.
3. Phonatory quality that is not constricted. (modal, breathy)	3. Phonatory quality that is constricted. (harsh, raised larynx, creaky)

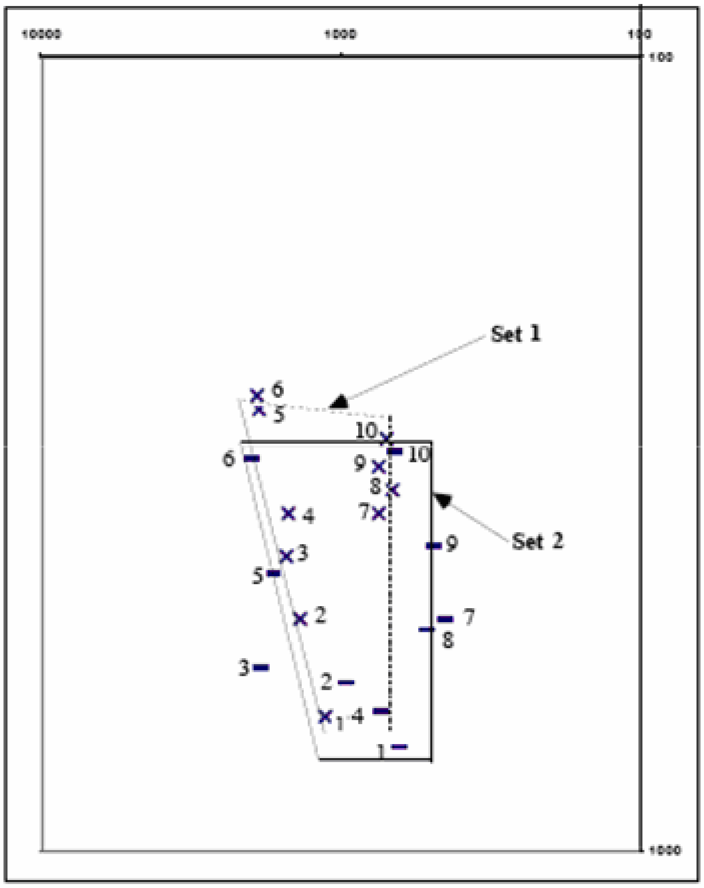


Figure 12: Somali Phonatory Register influence on Vowel Quality

The effect on vowel quality in Somali, both for short and for long vowels, is to generate a retracted counterpart for each lax (non-constricted) vowel, which is consistent with the relationship between lingual retraction and laryngeal constriction illustrated in Figure 1a. Figure 12 represents acoustic measurements of the first two formants of ten vowel pairs sampled at five locations within the vowel. Using the laryngeal articulator model (Esling 2005), this effect can be explained as a hierarchically predictable result of the action of Valve 3 (the aryepiglottic stricture mechanism) on Valve 4 (lingual retraction) rather than as a primary function of establishing a separate lingual target for each vowel. Both economy of vowel target accuracy and the economy of harmony across syllables can be explained with the model of the laryngeal articulator leading the lingual articulator.

3.4. Faucalized Voice.

Where Somali non-constricted register can have either modal or breathy phonatory quality, Dinka Bor exploits these phonatory possibilities as phonological contrasts. While phonation that is termed "modal" can be regarded as "neutral" (or "open") in terms of most valve settings, breathy phonation usually occurs in the opposite circumstances from laryngeal constriction. That is, breathy phonation is predicted to occur when Valve 1 is not completely closed (but open between the arytenoids), Valves 2, 3 and 4 are not active, and Valve 5 is not only neutral but beyond neutral (to lowered larynx position). Valve 6 is not in its narrowed, constricted state during breathiness, but since Valve 6 (in a circular rather than a linear world) is at the end of the range of constriction that is possible in the pharynx, the muscular connections are such that extreme lowering of the larynx (or extreme raising of the tongue, to uvular position) can also provoke stretching and therefore visible narrowing of the faucal pillars (ostensibly the palatoglossal and palatopharyngeal muscles and folds) running vertically at the rear of the oral vocal tract (see Laver 1980: 56, 72). Narrowing of this sort, with the larynx lowered and pharynx "extended", does not produce the same sound as the sort of pharyngeal narrowing that we have seen in conjunction with extreme stricture of the other valves in producing laryngeal constriction. The difference, again, is between what the sides of the pharynx are doing in a large pharyngeal space vs. what they are doing when the pharyngeal space has all but disappeared as is the case during laryngeal constriction.

In the Bor Dinka language of Sudan, there is a Harsh series, as seen in Figure 10, where most valves of the larynx/pharynx are closed or approximated. Most kinds of Dinka and the closely related Nuer demonstrate only two registers (Modal and Breathy). If Modal is relatively neutral, Breathy has lowered larynx (the opposite setting of Valve 5 from constriction) as in Figure 7. This makes a breathy setting an ideal contrast to a harsh (constricted) setting, as was seen in the Bai tonal registers. In some varieties of Bor Dinka, there are four register contrasts (Modal, Breathy, Harsh, and Faucalized Voice): (a) Modal Voice *ɓàai* ‘village, town, home’, (b) Breathy Voice *k*^{h}*ṳ̀ṳr* ‘lion’ (vs. *k*^{h}*ō̲o̲r* ‘want’ and *k*^{h}*ò̲o̲r* ‘cyclone, dust devil’), (c) Harsh Voice *mà̱i̯̱* ‘fire’ (vs. Faucalized Voice *mē̤i* ‘fires’), and (d) Faucalized Voice *ɓē̤i* ‘villages, towns, houses’. These have been discussed by Keith Denning (1989), who—following Tucker and Bryan—suggested the names “Hollow Voice”, which we term *Faucalized Voice* (marked, following Denning, with quotes under the vowel), and Harsh Voice (marked with an underline under the vowel). Bor Dinka has three tones (high, mid, and low), but there are not a great many lexical contrasts formed by tone alone.

Faucalized Voice is a voice quality type relatively new in the linguistic literature, but it has been discussed extensively in the speech science and singing literature under the name “Yawny Voice”. The auditory impression of Faucalized Vvoice is familiar to all from movieland gangsters and Runyonesque characters who punctuated their speech on the silver screen with ‘dems’ and ‘dose’ in the manner epitomized by the late actor Sheldon Leonard and by some regional varieties of English in New York and Boston, such as Ed Norton of the TV sitcom "The Honeymooners". Yawning while speaking has also been prescribed as therapy for children with hyperactive aryepiglottic folds (a-e folds) as it opens up the pharynx and lowers the larynx (Boone and McFarlane 1993); it is thus in many regards the antithesis of Harsh Voice.

Faucalized Voice is a voice quality that is produced with a very low larynx setting, with the absence of tongue retraction, with higher pitch and with airflow reduced over the high volume velocity of Breathy Voice, and with expansion of the pharyngeal cavity through lowering of the larynx. It has a posture that is mostly diametrically opposed to that of Harsh Voice, which has sphincteric contraction of the aryepiglottic mechanism, strong tongue retraction, raised larynx, and often vertical narrowing so that the pharynx is compressed inwards as well as upwards. Faucalized Voice can be viewed as a modification of the breathy type, but with "dramatic laryngeal lowering" (Denning 1989: 132). Acoustically, Faucalized Voice has lowered values of F1, consistent with larynx lowering, and the entire pharyngo-oral airspace resonates with stronger lower harmonics, whereas the oral airspace will emphasize the higher harmonics, giving sustained harmonic energy values with roll-off properties quite unlike Breathy Voice with its rapid decrease of higher frequency energy at values greater than 10dB per octave. In their analysis of larynx height voice settings, Esling et al. (1994) point out that Faucalized Voice and Lowered Larynx Voice, the auditory features described by Laver (1980), share the same articulatory posture of larynx lowering but that their pitch differs—Faucalized Voice being perceived when pitch rises. This is the inverse relationship to Raised Larynx Voice and Pharyngealized Voice, which share the same raised-larynx (constricted) articulatory posture but differ in pitch—Raised Larynx Voice being perceived when pitch rises. Faucalized Voice has the attributes of Hollow Voice, which contrasts well with Breathy Voice in Bor Dinka, since breathiness tends to occur in a lower pitch range and would be markedly difficult to produce at the higher pitch typical of Faucalized Voice (Hollow Voice). Faucalized Voice is so named because of the stretching of the vertical fauces at the sides of the pharynx. As described above, even though this effect was once thought to be the main articulatory correlate of constriction (and can also be observed as Valve 6 in extreme constriction), it is more likely a concomitant feature of vertical (downwards and/or upwards) stretching of the pharyngeal space. It could also be termed Lowered Larynx Voice at high pitch. In Bor Dinka, it is not a sustained voice quality but is employed as a linguistically contrastive feature.

Frame 1

Frame 9

Frame 13

Frame 37

Figure 13: Hollow voice in Dinka Bor *mē̤i* ‘fires’

To illustrate Faucalized Voice, Figure 13 shows a series of video images taken from the production of *mē̤i* ‘fires’. Frame 1 shows the breath position before the gesture, and Frame 37 shows the laryngeal mechanism returning to neutral. Frame 9 shows the descent in the laryngeal plane as the larynx lowers and the pharynx becomes larger during the first part of the vowel. Valve 1 is active here, but Valve 5 is in its inverse (lowered/expanded) mode. Frame 13 shows the end of the vowel as pitch rises still further and there is some incursion of the ventricular folds (Valve 2). This could represent a glottalization feature being applied at the coda in this series. Still, this small degree of final constriction remains distinct from the combined valve action that characterizes Harsh Voice in Bor Dinka. In this way, laryngeal setting interacts with phonatory quality and with pitch to define contrasts in register. Pitch on Modal Voice could be described as mid falling; Breathy Voice as low; Harsh Voice as low falling; and Faucalized Voice as mid rising. A matrix of the valve distributions differentiating these registers (Table 1) could be sufficient to maintain the contrasts, but specification of the pitch attributes of the four types of syllables adds redundancy to the matrix and ensures optimal contrastiveness across registers. There will of course still be interaction between each register category and the particular segments that make up a word, but these can also be defined using an even more detailed matrix.

The following examples of the four-way register contrast in Bor Dinka are taken from a laryngoscopic study of three speakers of the language.

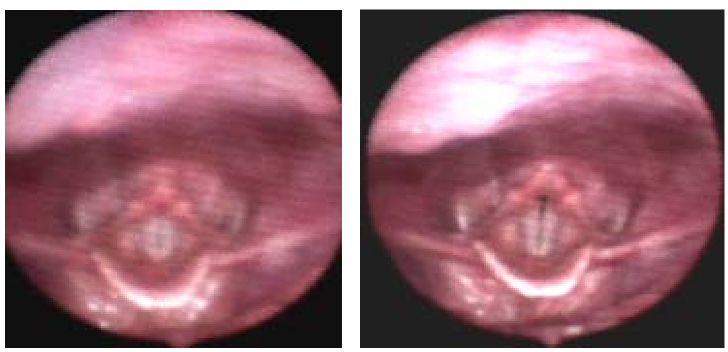


Figure 14: a) Modal Voice tɕìt̪ 'diarrhea'   b) Breathy Voice tɕì̤t̪ 'to go ahead

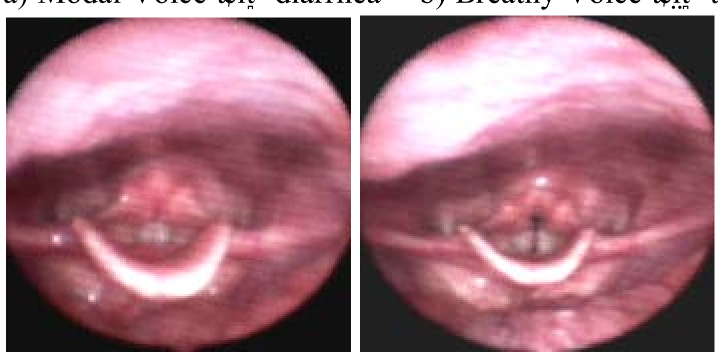


Figure 14: c) Harsh Voice tɕì̠t̪ 'scoporions'   d) Faucalized Voice tɕì͈t̪ 'to swallow'

Figure 14 shows images of a minimal set of contrasts. Valve 3 appears engaged to a greater degree in 14 c) Harsh Voice and 14 d) Faucalized Voice. There is also less closure in the application of Valve 1 for 14 b) and 14 d).

4. Harmony in Kabiye of northern Togo.

Kabiye is a Gur language of the Gurunsi branch spoken by about 1.2 million people in Togo, Benin, and Ghana. It has many of the features that are usually associated with West African languages: (1) high and low tones, (2) the coda of rhymes is tone bearing, e.g. *kɔ́m̀* 'to come' has a H-L (falling) tone shape, (3) downstep phenomena, (4) a harmony rule that only vowels of Set 1 /u o i e a/ or Set 2 /ʊ ɔ ɪ ɛ a/ may appear together in any phonological word, and (5) a noun class system of seven or eight categories with manifestations on mostly elements within the NP.

The harmony paradigm has often been described as [+ATR] (advanced tongue root) and [-ATR] (retracted tongue root). ATR was first proposed by Stewart (1967) as an alternative to the tense/lax distinction often said to exist in the Germanic languages, whereby tense meant: (1) higher muscular tension, (2) more extreme movements of the articulators, (3) longer duration and (4) greater subglottal air pressure. Stewart argued that the movement of the tongue root position, creating an expanded pharyngeal cavity provided a better account of the harmony facts of Akan than the Germanic tense/lax account used for English vowels. The two series also differ in tongue (or larynx) height (Ladefoged and Maddison, 1996:302-307). Various imaging techniques have been used in an attempt to find evidence for the tongue root hypothesis (Tiede 1996).

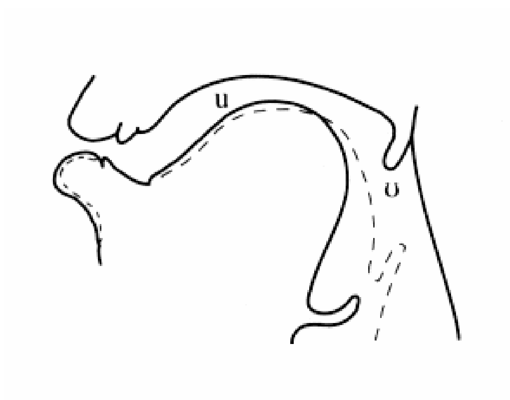


Figure 15: Cineradiographic analysis of an Igbo speaker by Ladefoged 1964 of the +ATR vowel solid line and –ATR vowel dashed line.

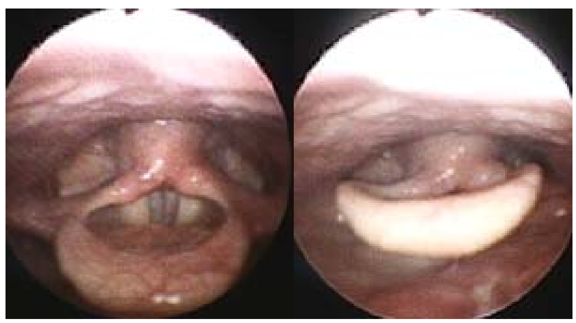
There has been some difficulty in verifying the change in the tongue root predicted by ATR theory. Theraphan L-Thongkum says, "X-ray photographs of a Nyah Kur speaker were made in order to observe the movements and positions of his tongue when pronouncing seven pairs of Nyah Kur vowels. The radiographical technique used in the experiment was fluoroscopy by image intensifier, together with a video recording system. The tracings of the X-ray photographs show that for each pair of vowels, clear voice versus breathy voice, there are no obvious differences in tongue-root positions." (L-Thongkum 1982). Fulop et al. (1995: 3419) note, "A variety of articulatory gestures seem to be needed to convert a vowel from one set into the other". They recorded eight speakers and extracted from their data three kinds of acoustic information: formant frequencies, amplitudes, and bandwidths. Subsequently, these data were input to a synthesizer in order to attempt to produce the other set. A similar result is reported in a tagged cine MRI and ultrasound study for German vowels by Pouplier, Buchwald, and Stone (2004:36) that "Tense and lax vowels create different coarticulatory effects in an utterance.

Also compression and expansion patterns differentiate the vowels throughout the utterance. For the /i - ɪ/ pair, the tense vowel exhibits a root advancement and concomitant GGP [Genioglossus posterior] compression pattern that the lax vowel lacks. For the /o - ɔ/ pair, the tense vowel remains unchanged in the root, while the lax vowel begins movement immediately. The tense vowel exhibits a retraction movement in tip and body that differentiates it from the immediate fronting movement of the lax vowel."

What has been pointed out less often in the enormous literature on ATR is the difference in laryngeal valve settings for the two sets. Figure 14 illustrates the kind of evidence produced by cineradiographic analysis. Filling in the parts that are missing from the lower region of the vocal tract in Figure 14 with the laryngeal articulatory structures diagrammed in Figure 1a, the picture of how the tongue operates in conjunction with the laryngeal constrictor mechanism becomes clear. Our prediction is that if the tongue is retracting and the larynx is rising, then Valve 3 of the laryngeal constrictor mechanism must be engaged. This paradigmatic relationship is similar to the distinction in Somali, but in Somali the constrictor interacts with phonation to produce a substantially different quality of voicing. In Kabiye, the quality of voicing is not particularly different between the two sets.

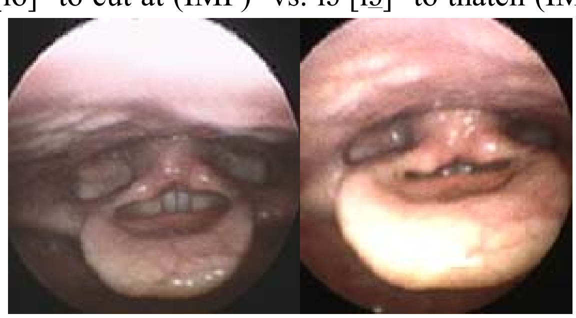
Compare now the nine Kabiye vowels with non-constricted and constricted laryngeal register below:

Set 1 Set 2

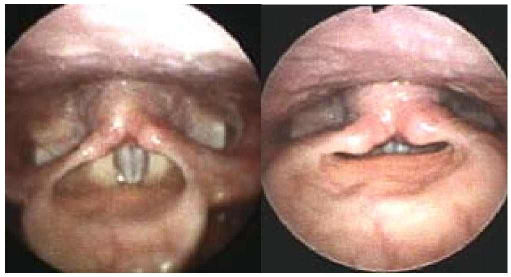


tú [tú] 'elephant vs. tʊ́ [t<u>ʊ́</u>] 'bee'

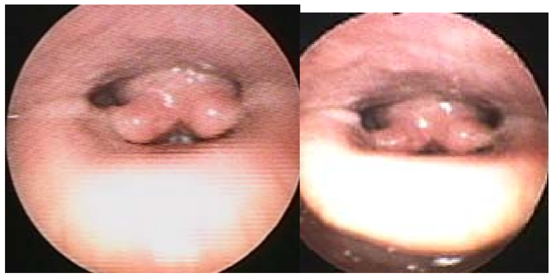
lò [lò] 'to cut at (IMP)' vs. lɔ̀ [l<u>ɔ̀</u>] 'to thatch (IMP)'



le [lè] ‘to dry (IMP)’ vs. cɛ [tɕɛ̱̀] ‘to cut (IMP)’



li [lì] ‘to swallow (IMP)’ vs. sɪ [sɪ̱̀] ‘to die (IMP)’



hólá [xólá̱] ‘nerves’ vs. mílá [mí̱lá̱] ‘sorghum’

Figure 16: Kabiye laryngeal postures for vowels in non-constricted (Set 1) and constricted (Set 2) context.

The posture of the laryngeal valves and their effect on the size of the pharynx can be seen in Figure 16. Mid-vowel images a and b show the difference between Kabiye [u] and [ʊ] on high tone; c and d between [o] and [ɔ] on low tone; e and f between [e] and [ɛ] on low tone; g and h between [i] and [ɪ] on low tone. In each case, Set 2 adds Valves 3, 4, and 5 (raised larynx), which are not active in Set 1. Images i and j show the difference between [a̱] in the context of non-constricted harmony and [a̱] in the context of constricted harmony on high tone. As the images in Figure 14 demonstrate, the constricted vowels (Set 2) all show constriction of the arytenoid cartilages and aryepiglottic folds sphinctering against the epiglottal surface. The vowel /a̱/ is noteworthy in the sense that it demonstrates constriction in both Set 1 and Set 2 registers, but Valve 3 and Valve 4 constriction appear to be greater in the constricted context. Moreover, a vowel with retracted quality such as [a̱] is inherently constricted and does not allow a nonconstricted form (unless the oral settings are significantly changed, as happens, for example in Somali). The major effect of the laryngeal constrictor in producing lower (i.e. more retracted) vowels in the constricted set is the shortening of the laryngeal vocal tract and concomitant descent of the tongue in the same way that pharyngealization produces a lower F2 and a higher F1. Very probably, other factors also contribute to vowel changes. There is independent evidence in Kabiye that [a̱] belongs to the constricted set. The leftmost vowel always determines if a word is to have Set 1 or Set 2 vowels. If a word begins with a Set 1 vowel, then [a] is licensed to occur later in the word. But, if the word begins with [a̱], then all following vowels must belong to Set 2. That is to say, Kabiye possesses no lexical items with the structure C_1aC_2\{i e u o\} only C_1aC_2\{ɪ ɛ ʊ ɔ a̱\}.

Table 1
Laryngeal features of the non-constricted and constricted series in several languages

	Pitch	Voice	V1	V2	V3	V4	V5	V6
(L = lowered larynx, R = raised larynx)								
Bai								
ModV	high, mid	+	+	-	-	-	-	-
BreaV	mid falling	+	-	-	-	-	L	-
HarV	mid falling	+	+	+	+	-	R	-
	high, mid, mid rising							
Dinka								
ModV	mid falling	+	+	-	-	-	-	-
BreaV	low	+	-	-	-	-	L	-
HarV	low falling	+	+	+	+	+	R	+
FaucV	mid	+	+/-	+/-	+/-	-	L	-
Somali								
BreaV	mid, falling, rising	+	+	-	-	-	L	-
HarV	mid, falling, rising	+	+	+	+	+	R	+
Amis								
ʔ H + Stress	falling	-	+	+	+	+	R	+
ʔ H - Stress	falling	-	+	+	+	-	R	+
ʔ - Stress	falling	-	+	+	-	+	R	+
Kabiye								
- Const	high low	+	+	-	-	-	L	-
+ Const	high low	+	+	+	+	+	R	+

A summary of the status of each laryngeal valve for each phonological series in the languages discussed here is presented in the matrix in Table 1. The laryngeal parameters are listed beginning with the glottal attributes Pitch and Voice and Valve 1, followed by Valves 2-6.

5. Conclusions.

This paper has shown that there are six major valve mechanisms that control airflow in the lower vocal tract. They are responsible for voicing, the quality of voicing, differences in phonation type for vocal register (Breathy Voice, Harsh Voice, Creaky Voice, and Faucalized Voice), pharyngeals, laryngealization and pharyngealization, and are involved in the formation of the glottal stop, of the epiglottal stop, and of tone contrasts, and are used in some cases to add strength to stressed syllables. The valves and their actions are: (1) adduction of the glottal vocal folds, (2) ventricular incursion, (3) engagement of the aryepiglottic sphinctering mechanism of the laryngeal constrictor, (4) retracting of the tongue and epiglottis in laryngeal constriction, and lingual closure against the posterior pharyngeal wall, (5) raising of the larynx in laryngeal constriction, or, conversely, lowering of the larynx, usually associated with non-constricted contexts, and (6) narrowing of the lateral walls of the pharynx, usually associated with laryngeal constriction. The structures involved in each of these valves belong to identifiable anatomical actions, function in groups that are highly entrained for sequential operation, and are temporally synchronized and carefully automated to operate together in hierarchical fashion. In the distinction between breath and voicing only (1) is involved; in a moderate glottal stop (1) and (2) are involved; in Harsh Voice and in an aryepiglotto-epiglottal stop (1), (2), and (3) are involved; and in all except Amis (4) acts in conjunction with the engagement of (3). Valves (5) and (6) are variably associated with laryngeal constriction, although (5) is usually in raised mode for an epiglottal stop, in which (1), (2), (3), and (4) are already closed or closing. The picture that emerges from these case studies is that the lower throat is organized on the basis of function and not on the basis of anatomical form. That is, articulatory gestures are physically and phylogenetically distinct, but the demands of speech are capable of reconfiguring the functioning of systems if sufficient benefit will accrue. Moreover, these six valves interact with the pitch-control mechanism to create auditory phonetic constructs that operate in major phonological prosodies such as tone, phonatory register, and stress as well as in vowel quality modification and possibly syllable duration.

These valves function mostly as articulators in the airstream and shapers of vocal tract resonance. In the case of Valve 1 and to some extent Valve 3, they also act as major sources of acoustic energy, although all rapid movement can generate acoustic energy. These data also connect to a new view about the acquisition of the ability to produce speech sounds. Esling et al. (2004) have suggested that pre-babbling speech is not random vocalization without purpose, but the active development of articulatory phonetic control over place, manner, timing and force parameters as precursor behavior to speech sound production in babbling. The infant research has shown that the laryngeal articulator shaping the pharynx is the first and guiding element in the earliest ontogenetic phonetic vocalizations and that only later does the oral cavity develop its fine articulating ability. In a sense, it could be argued that the pharyngeal region, controlled by the laryngeal articulator, is the origin of phonetic awareness and that the complex of laryngeal mechanisms defined by the valves of the throat may be the phonetic primordial swamp out of which the world of phonological order via the process of linguistic acquisition ensued. In the context of the framework proposed here, it certainly deserves more serious scrutiny as a sound-shaping mechanism that does more than just produce voice.

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