CQ of laryngeal gestures and settings in Wa

Justin Watkins
School of Oriental and African Studies, University of London

ABSTRACT

Laryngographically (EGG) derived closed quotient (CQ) was used to investigate phonation types in Wa. The laryngeal activity responsible for phonation types is divided into two categories: firstly, the adjustment of laryngeal tension settings for the typically slightly tense vs. slightly lax phonation types of the suprasegmental register contrast; secondly, glottal abduction-adduction gestures causing extreme changes in CQ in the articulation of segmental /ʔ/, /h/, and the aspiration of stops or sonorants. Neutralisation of the register contrast after initials involving a laryngeal gesture suggests that the occurence of a distinctive phonatory setting following such a gesture may be physiologically or articulatorily constrained.

1. INTRODUCTION

This paper comprises a summary of the results of a laryngographic (EGG) study of Wa, highlights from a wider investigation of the phonetics of this language (Watkins 1998).

1.1 Laryngographically derived Closed Quotient (CQ).

CQ has been used in the fields of speech pathology [1] and other vocal research [6, 7], but less often in a linguistic context [but see 10,13]. CQ is defined as the portion of the laryngograph waveform period *T* for which the glottis is closed, expressed as a percentage. This portion of each period is known accordingly as the *closed phase*, the remaining part of each cycle being the *open phase*. The method by which CQ was calculated in this study is illustrated in Figure 1; other methods are described by Howard [6] and Marasek [13]. Several studies [e.g. 13, 14] consider instead the open quotient (OQ), which is essentially the same measure, expressed instead as the proportion of the waveform period taken up by the open phase.

It is generally true of vocal fold vibration that the closure is rapid, while the opening phase takes up more of the cycle [15]. A sharply defined peak in the differentiated laryngograph waveform, representing the point at which vocal fold area contact is increasing most rapidly, is used to define the instant of closure. CQ increases in response to activity which causes the vocal folds to stay closed for more of the vibration cycle, which includes all three laryngeal parameters used by Laver [9] in the articulatory description of phonation types: adductive tension, medial compression and longitudinal tension. An inverse relationship between CQ and vocal fold abduction may be inferred from the study of vocal fold abduction by Rothenberg and Mahsie [16]. Conversely, lower CQ is an indication of lower levels of these parameters. Ní Chasaide and Gobl [14] attribute a high CQ to creaky and tense phonation and low CQ to breathy voice, and imply that a slight decrease in CQ is consistent with lax phonation. CQ may therefore be considered a generally reliable index of phonation type.

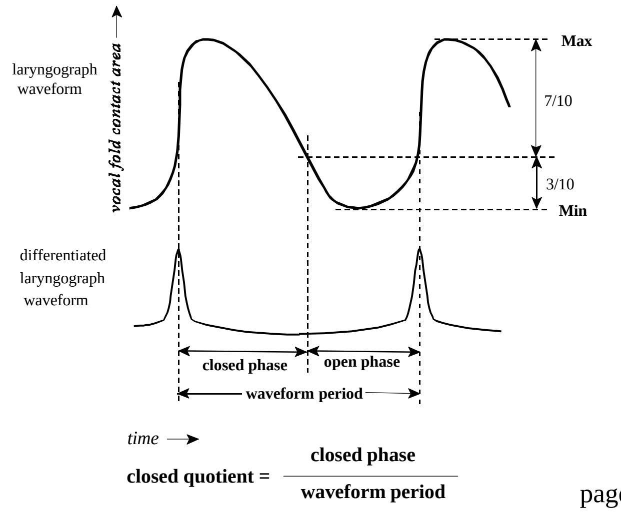

Figure 1. Calculating Closed Quotient (CQ) from the laryngograph trace

1.2 The Wa language.

Wa (Paraok; /pəˈɹa̰o̰k̚/) belongs to the Palaungic branch of Northern Mon-Khmer [2]. Wa speakers number roughly one million, and are located in an area which Gérard Diffloth [2] has described as the Waic corridor, between the Salween and Mekong rivers in the Shan States of Burma and China's Yunnan province. The only area of linguistic phonetics in which Wa has previously featured with any prominence has been the study of the linguistic use of phonation types. Research on this topic [8, 11, 12] owes much to Peter Ladefoged and the UCLA phonetics laboratory.

1.3 Register in Mon-Khmer.

Mon-Khmer register is a binary phonological contrast which is associated with a variety of phonetic phenomena. The principal phonetic correlates are pitch-based tone, as attested in Kammu [17] and Blang [20], phonation type, as in Wa [12,18,19,20], Mon [11,3] and Chong [4], or vowel quality, as in Khmer [5] or Xīměng Wa [20], or some amalgam of these and other features. Though many names for the two registers of Mon-Khmer languages may be encountered, this paper follows the example of Gérard Diffloth [2] and Theraphan Luang-Thongkum [11] in using the labels 'clear' and 'breathy' to describe the registers of Wa.

2. CQ ACTIVITY IN WA SOUNDS

2.1 CQ and the register contrast

This paper is concerned with only the phonation type component of the register contrast in Wa, i.e. only one of several phonetic correlates of the register contrast. Other (principally acoustic) measures are recounted by Watkins [19]. CQ was measured at the mid-point of each vowel in 198 clear-breathy pairs of CV syllables in Wa (9 vowels x 11 speakers x 2 repetitions). The results are given in Table 1 (4 other measurements are included for information). Clear register phonation has consistently greater CQ than breathy register. The magnitude of the CQ difference between the registers is relatively consistent (s.d.=5.58%) in comparison to the other variables, which involve a greater degree of variation between speakers.

n=396 (198 data pairs)	grand mean	s.d.	clear register mean	breathy register mean	mean difference	s.d of difference.	paired t-test
CQ (%)	47.37	6.38	51.22	43.51	7.70	5.58	< 0.0001
F0 (Hz)	162.87	33.42	166.80	158.94	7.86	15.63	< 0.0001
duration (ms)	342.37	57.27	343.54	341.21	2.33	54.14	0.2734
H2-H1 (dB)	5.06	5.07	6.41	3.69	2.69	5.05	< 0.0001
F1-F0 (dB)	10.87	7.27	12.76	8.90	4.09	6.51	< 0.0001

Table 1. Summary of effects of the register contrast on 5 phonetic variables.

2.2 CQ and laryngeal consonants

Wa /ʔ/ is realised as a short period of true creaky phonation, characterised by aperiodicity and or high CQ. Wa /h/ is realised as a period of breathy phonation, which may be accompanied and/or followed by friction noise generated at the glottis and in the vocal tract by high airflow through the abducted glottis. The phonetic implementation of /ʔ/ and /h/ in /kiʔ ʔah nan/ "we say (it) like that" is illustrated in Figure 2. /ʔ/ can be described as a shift towards creaky phonation, identifiable as increased CQ, while /h/ is a shift towards breathy phonation, a dip in CQ.

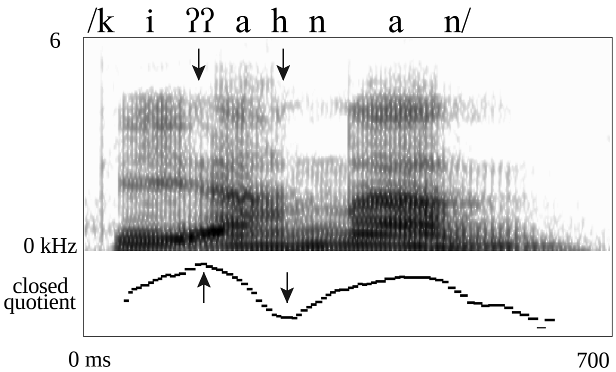

Figure 2. Spectrogram (120 Hz bandwidth) and CQ of /kiʔ ʔah nan/ "they say that way". Arrows indicate the /ʔ/ CQ peak and the /h/ CQ trough.

2.3 CQ and aspiration

Stop and sonorant consonants in Wa may be aspirated. Gesture-evident CQ contours of aspirated consonants support the invocation of a glottal abduction-adduction gesture to account for the articulation of aspirated continuants in Wa, observable in the third syllable /l^{h}ai/ in Figure 3. The end of this gesture is identifiable as an abrupt change in gradient in the CQ trace, typically 100ms after the release of the consonant articulators. In Figure 3 the CQ traces of the syllables /lai/ and /la̤i/ with unaspirated initials show further that the phonation type determined by the register of the vowel is anticipated during the approximant: CQ during /l/ is higher in /lai/ than in /la̤i/. Anticipatory coarticulation of registral phonation type is consistently evident not only in sonorant initials, but also in the prenasalisation phonation of prenasalised voiced unaspirated stops /^{m}b ^{n}d ^{ɲ}j ^{ŋ}g/.

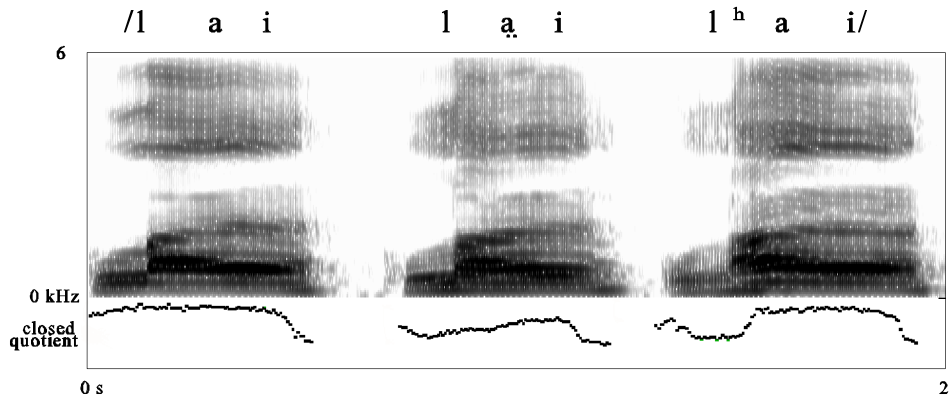

Figure 3. Spectrogram and CQ trace of the Wa words /lai/ "why", /la̤i/ "writing" and /l^{h}ai/ "crooked".

2.4. CQ and conflicting phonation types

Phonation type plays a phonologically contrastive role in the articulation of the register contrast, of aspiration and of laryngeal consonants /ʔ/ and /h/. A single syllable may require the larynx to produce a range of phonation types in quick succession, such as is the case for the 9 syllables illustrated in Table 2. For instance, breathy register (low CQ) vowel /ɛ̤/ adjoins/ʔ/, which is realised as slightly tense phonation (high CQ),in the syllable /tɛ̤ʔ/ "wager", while in the syllable /tɛh/ "to lessen", the clear register (high CQ) vowel /ɛ/ is followed by breathy phonation (low CQ) for /h/. The coarticulation of the conflicting phonation types in such syllables may be measured using laryngographically derived CQ.

final	initial consonant		
	unaspirated initial		aspirated initial
	clear register	breathy register	
(none)	tɛ "sweet"	tɛ̤ "peach"	t^{h}a "to wait"
h	tɛh "to lessen" [SOUND 0655_01.wav]	tɛ̤h "to turn over" [SOUND 0655_02.wav]	t^{h}ah "to cut wood"
ʔ	tɛʔ "land" [SOUND 0655_03.wav]	tɛ̤ʔ "to wager" [SOUND 0655_04.wav]	t^{h}ɯʔ "to shove"

Table 2.Phonological contrasts involving laryngeal articulations in 9 Wa syllables.

To chart the course of phonation type through these syllables, CQ was sampled at five points in the syllable: the 1st and 4th periods of vocal fold vibration, the mid-point of the vowel, and then the 4th from last and last periods of vocal fold vibration. The 18-item word-list included the 9 syllables in Table 2 and a further 9 with prevoiced initials, so that 396 syllables were measured in all (18 x 11 speakers x 2 repetitions). Sampling in this way was a crude means of monitoring CQ, to investigate the changing phonation types required to preserve the register contrast and to articulate aspiration and laryngeal consonants /h/ and /ʔ/.

The corpus of recordings on which this study is based did not contain sufficient data to enable a description of the CQ contours of vowels following initial laryngeal consonants. Initial /h/ and /ʔ/ involve laryngeal gestures similar to their final counterparts. Furthermore, both initial and final /h/ have much in common with the glottal abduction-adduction gesture which underlies aspiration in Wa. These parallels are reiterated by the fact that the register contrast is neutralised after initial /h/ and /ʔ/, just as it is after aspirated consonants.

The mean CQ measurements at each of the 5 sample points are presented in Table 3 and illustrated in Figures 4 ,5 and 6.

final	register	1st period	4th period	mid vowel	4th from last	last period
(none)	clear	45.15	50.05	52.98	41.40	34.90
	breathy	39.10	42.60	42.03	40.30	38.00
	aspirated	31.75	41.20	48.13	45.35	39.50
/h/	clear	45.10	50.75	52.59	34.75	25.95
	breathy	32.40	36.85	37.96	28.60	23.30
	aspirated	32.75	43.95	46.93	37.90	27.35
/ʔ/	clear	45.35	52.55	55.64	53.65	48.35
	breathy	32.75	39.20	41.00	52.80	45.90
	aspirated	29.73	38.78	49.60	56.48	54.80

Table 3. Mean CQ (in %) sampled through nine types of syllable

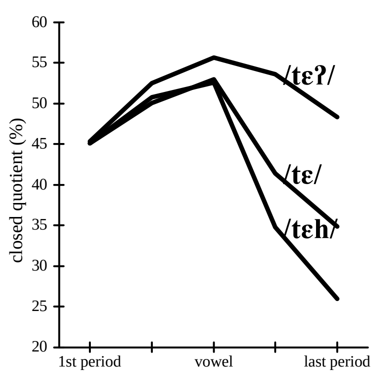

Figure 4. CQ in syllables with unaspirated initials and clear register vowels.

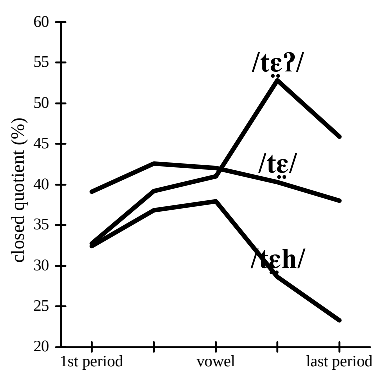

Figure 5. CQ in syllables with unaspirated initials and breathy register vowels.

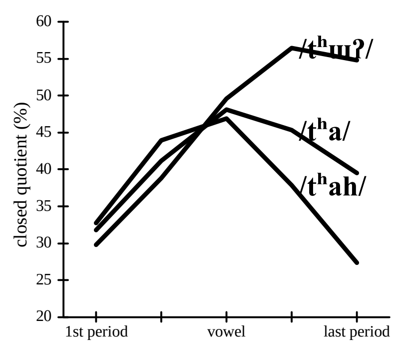

Figure 6. CQ in syllables with aspirated initials.

It must be borned in mind that the temporal structure of the ballistic laryngeal abduction-adduction gestures of aspirated initials is markedly different from the sustained phonation types of clear or breathy register (evident from Figure 3). It is helpful to compare the crude CQ traces in Figs 4,5,and 6 to the smoother CQ traces in Figure 3 above.

3. DISCUSSION

The assessment of the phonation types of the Wa register contrast by Ladefoged and Maddieson [22] describes clear and breathy register as "slightly breathy and slightly stiff" phonation. Their index of the difference is airflow, by means of which they find that there is higher mean airflow in breathy register vowels, and conclude that the glottis must be less constricted in breathy register. Ladefoged points out that in Wa the difference between the phonation types is not as extreme as in other languages whose contrastive use of phonation type has been investigated experimentally, such as Jalapa Mazatec and !Xóõ [21]. This is consistent with the CQ characteristics of the Wa registers described in section 2.1 above.

Clear register phonation may be described as modal tending towards slightly tense phonation, while breathy register is modal tending towards slightly breathy and/or lax. The difference between the two is often slight. On the other hand, laryngeal consonants /ʔ/ and /h/ and aspiration involve a transition between either of the near-modal register phonation types and more extreme phonation types: creaky voice or creak in the case of /ʔ/ and extremely breathy phonation in the case of /h/ or aspiration. These extremes are evident in Figures 4,5 and 6.

Phonation type in Wa is better explained in terms of a continuum such as that posited by Ladefoged and Maddison [22], with creaky phonation at one end, breathy phonation at the other, and modal phonation in the middle. Lax and tense voice are incorporated slightly to either side of modal voice. This hypothetical continuum may be invoked to describe the relative breathiness or creakiness of the phonation types in any two instances of phonation without any need to quantify them precisely. In this view, the phonation types of vowels in clear and breathy register are rather close to one another on the continuum, with clear register on the tense/creaky side of modal, and breathy register tending towards the lax/breathy side, but with some overlap between the two. The phonation types reached in the articulation of laryngeal consonants or of aspiration involve travel towards the extremes of the continuum. This conceptualisation is illustrated in Figure 7.

A distinction can be drawn between two types of laryngeal activity in Wa. The production of registral phonation types involves minor adjustments of laryngeal setting which appear to be inherently static, as evidenced by the coarticulatory effects of register observed across sonorant and even stop consonants. On the other hand, laryngeal gestures, such as the glottal abduction-adduction gesture which is present in stop consonant aspiration and laryngeal consonants, are dynamic.

Finally, it is suggested that it is not by coincidence that the register contrast is neutralised in syllables with initial aspirates, /h/ and /ʔ/, but maintained when final /h/ and /ʔ/ are present. It is possible that the resumption of a distinctive, specific phonatory setting following a laryngeal gesture may be physiologically or articulatorily constrained, while a laryngeal gesture is unaffected by the larygeal setting which prevails at its initiation.

REFERENCES

[1] Abberton, Evelyn, David Howard and Adrian Fourcin. 1989. Laryngographic assessment of normal voice: a tutorial. *Clinical linguistics and phonetics* 3.3:281-296.

[2] Diffloth, Gérard. 1980. The Wa Languages. *Linguistics of the Tibeto-Burman Area* 5.2.

[3] Diffloth, Gérard. 1985. Registers of Mon vs. the spectrographist's tones. *UCLA Working Papers in Phonetics* 66:55-58.

[4] Edmondson, Jerold A. 1996. Voice qualities and inverse filtering in Chong. *Mon Khmer Studies* 26:107-116.

[5] Henderson, Eugénie J.A. 1952. The main features of Cambodian pronunciation. *Bulletin of the School of Oriental and African Studies* 14:149-174.

[6] Howard, David M. 1995. Variation of electrolaryngographically derived closed quotient for trained and untrained adult female singers. *Journal of Voice* 9.2:163-172.

[7] Howard, David M., Geoffrey A. Lindsey and Bridget Allen. 1990. Toward the quantification of vocal efficiency. *Journal of Voice* 4.3:205-212.

[8] Ladefoged, Peter. 1983. The linguistic use of different phonation types. In D. Bless and J. Abbs (eds) *Vocal Fold Physiology: Contemporary Research and Clinical Issues*, 351-360. San Diego: College Hill Press.

[9] Laver, John. 1980. *The phonetic description of voice quality*. Cambridge: Cambridge University Press.

[10] Lindsey, Geoff, Katrina Hayward and Andrew Haruna. 1992. Hausa glottalic consonants: a laryngographic study. *Bulletin of the School of Oriental and African Studies* 60.3:511-527.

[11] Luang-Thongkum, Theraphan. 1988. Phonation Types in Mon-Khmer Languages. In Fujimura Osamu (ed.) *Vocal Fold Physiology: Voice Production, Mechanisms and Functions* New York: Raven Press.

[12] Maddieson, Ian and Peter Ladefoged. 1985. Tense and Lax in Four Minority Languages of China. *UCLA Working Papers in Phonetics* 1985 Feb 60:59-83 or *Journal of Phonetics* 13:433-454.

[13] Marasek, Krzysztof. 1997. Electroglottographic description of voice quality. *Phonetik AIMS* (Arbeitspapiere des Intituts für maschinelle Sprachverarbeitung), Universität Stuttgart 3.2 Universität Stuttgart.

[14] Ní Chasaide, Ailbhe, and Christer Gobl. 1997. Voice Source Variation. In William J. Hardcastle and John Laver (eds) *The Handbook of Phonetic Sciences*, 427-461. Oxford: Blackwell.

[15] Orlikoff, Robert F. and Joel C. Kahane. 1995. Structure and function of the larynx. In Norman J. Lass (ed.) *Principles of Experimental Phonetics*:112-181. St Louis: Mosby-Year Book.

[16] Rothenberg, M. and J.J. Mahsie. 1988. Monitoring vocal fold abduction through vocal fold contact area. *Journal of Speech and Hearing Research* 31:338-351.

[17] Svantesson, Jan-Olof. 1983a. Kammu Phonology and Morphology. *Travaux de l'Institut de Linguistique de Lund* 18. Lund: Gleerup.

[18] Svantesson, Jan-Olof. 1983b. The phonetic correlates of register in Va. In Cohen and van den Broeck (eds.) *Abstracts of the 10th International Congress of Phonetic Sciences*. Dordrect: Foris.

[19] Watkins, Justin. 1998. *The Phonetics of Wa*. PhD dissertation. SOAS, University of London.

[20] Zhōu Zhízhì and Yán Qíxiāng. 1984. *Wǎyǔ jiǎnzhì*. Běijīng: Mínzú chūbǎnshè.

[21] Ladefoged, Peter, Ian Maddieson and Michel Jackson. 1988. Investigating Phonation Types in Different Languages. In Fujimura Osamu (ed.) *Vocal Fold Physiology: Voice Production, Mechanisms and Functions*, 297-318. New York: Raven Press.

[22] Ladefoged, Peter and Ian Maddieson. 1996. *The Sounds of the World's Languages*. Oxford: Blackwell.