AN INSTRUMENTAL STUDY OF CHONG REGISTERS[1]

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0. *Introduction*

The Chong language belongs to the Pearic branch of the Mon-Khmer language family (Thomas & Headley 1970; Diffloth 1974; Huffman 1976, 1985; Headley 1977, 1978, 1985). Both amateur and professional linguists who have worked on Chong (eg. Baradat 1941; Martin 1974; Huffman 1985; Gainey (personal communication); Suphanphaiboon 1982) seem to recognize the 'glottal feature' or 'glottalization' which occurs in some Chong words. Some of them (Huffman, Gainey, and Suphanphaiboon) hear phonation types—normal voice vs. breathy voice, etc.—and pitches. On the basis of linguistic descriptions, there is no doubt that Chong is a register (R) language.

In 1983, Gérard Diffloth and I made several linguistic field trips to Chong communities in Makham District, Chanthaburi Province; we also visited Chong villages in Pong Nam Ron district, Chanthaburi Province, in Bo Rai District, Trat Province. During 1983-85, two female Chong informants from Krathing Village, Phluang Sub-district, Makham District, were brought to Bangkok many times for the purpose of checking language data and making high quality recordings and instrumental studies.[2]

In spite of my training as a phonetician and my knowledge of Mon-Khmer languages such as Bru, Nyah Kur (Chao Bon), Mon, Kui (Suai), and Mla Bri, I still think that Chong is very exotic. In my opinion, the cause of the complexity lies in the process of Chong becoming a tone language. In fact, some dialects of Chong, such as the one spoken in Chamkhlo' Village, Takhianthong Sub-district, Makham District, have already become tonal: presyllables are dropped; phonation types are less prominent and in some cases disappear; and pitch differences can be heard clearly, especially in slow speech. Our Chong informants also describe their language as having high, higher, mid and low tones.

The instrumental analysis presented in this paper is based on the speech of four Chong informants from Krathing Village. For the sake of convenience, they will be addressed as MA (first male speaker), MB (second male speaker), FA (first female speaker), and FB (second female

1. This report is part of my research project on 'Registers in Chong, Mon and Kui (Suai): a phonetic study'. I should like to express my gratitude to Chulalongkorn University for providing the research funds and to thank Professor Arthur S. Abramson for his valuable advice. Many thanks go to Jerry W. Gainey, Suraphon Wongthongwatthana and Sitthichai Sisukhon for their assistance in many different ways.

2. Gérard Diffloth and I have made an agreement that he will be responsible for the comparative and historical aspects of Chong whereas the phonetics will be my responsibility.

speaker). The Krathing dialect was chosen because its register phenomena suit my major interest—the acoustical measurements of the register complexes which involve several phonetic parameters. Moreover, the place where it is spoken is easy to reach, and the villagers are also very co-operative.

The phonetic instruments used in the study are as follows:

- Kay Sono-Graph 6061-B;
- Fundamental Frequency Meter, type FFM 650 (F-J);
- Intensity Meter, type IM 360 (F-J);
- Electro-glottograph, type EG 830 (F-J);
- Electro-aerometer, type EA 510/4 (F-J);
- Mingograf 34 T (Siemens AB).

1. *Definitions of 'register'*

The term 'register' has been used in many different ways. As a result, many definitions can be found in the literature depending upon who uses it—music and voice specialists, phoneticians, linguists, or language teachers.

1.1. *Voice register*

Music and voice specialists describe the rate of vocal-fold vibration in terms of registers. Garcia (1855) recognises three voice registers or ranges of pitch: the chest register, the mixed or middle register, and the head register. More often, only the chest and head registers are used. Others have tried to clarify the problems of voice-register terminology: 'The terminology with regard to voice pitch level, i.e. "registers", suffers from the existence of an abundance of terms and an ambiguity of their use.' (Mörner, Fransson & Fant 1963: 18). They therefore define a register by means of its range on the musical scale, suggesting five basic registers, namely: deepest range, deep level, mid level, high level, and highest level. The approximate ranges and boundary limits of these registers are illustrated, and some synonyms are listed, for example:

Deepest range	*Deep level*	*Mid level*	*High level*	*Highest range*
Rayon profond	Chest register	Falsetto I	Falsetto II	Pipe register
	Chest voice	Medium	Falsetto voice	Flute
	Long-reed	Mid voice	Short-reed	Whistle
	Site grave	Site moyen	Site aigu	Rayon élevé

A particular mode of vocal-fold vibration is usually confined within a pitch range. Zemlin says that when an individual reaches the upper limits of his normal pitch range, the mode of vocal-fold vibration may be modified. He states:

> This modification of the mode of vocal-fold vibration may be regarded as an operational definition of voice register. Thus, as a person transcends the limits of a particular vocal register, the voice may undergo an abrupt modification of quality. This vocal quality is often the primary characteristic of voice register. (Zemlin 1968: 193)

Also, according to Zemlin (op.cit.: 206-9), besides normal or acceptable vocal quality, there are three types of unacceptable vocal-quality: breathiness (incomplete blockage during the closed phase results in a continuous flow of air during the entire vibratory cycle), harshness (irregular vocal-fold vibration), and hoarseness (combination of the features harshness and breathiness).

1.2. *Register vs. Contour*

When Pike discusses the types of tone languages, he defines registers as contrastive level phonemes. A language can have two, three, or four registers. The labels for two-, three-, and four-register systems are as follows:

Language A	*Language B*	*Language C*
high —	high —	high —
		mid —
	mid —	norm —
low —	low —	low —

Thus, a register tone language is a tonal language that has a register-tone system, and a contour tone language is the one in which gliding tonemes are basic to the system (Pike 1948: 5-9).

1.3. *Designative register*

Register can also be regarded as part of tone of voice. In some languages, changes of register may be used to express different emotional states and attitudes of the speaker. The same register might not carry the same affective indices in different cultures (Abercrombie 1967: 101). This is a paralinguistic use of register.

1.4. *Register vs. Tone*

Register as used by Henderson (1952) is a phonological concept. It is a cover term not only for laryngeal activity but also for a cluster of activities in the vocal tract. She states:

> The Cambodian 'registers' differ from tones in that pitch is not the primary relevant feature. The pitch ranges of the two registers may sometimes overlap, though what I shall call the *Second Register* tends to be accompanied by lower pitch than the *First Register*.
>
> The characteristics of the first register are a 'normal' or 'head' voice quality, usually accompanied by a relatively high pitch.
>
> The characteristics of the second register are a deep rather breathy or 'sepulchral' voice, pronounced with lowering of the larynx, and frequently accompanied by a certain dilation of the nostrils. Pitch is usually lower than that of the first register in similar contexts.
>
> The register of a syllable is closely bound up with the vowel nucleus of that syllable, the two being mutually interdependent in a way that will be shown hereafter.

> In sentences the word registers are modified according to intonation and by emotional factors. Register may be used, as in many other languages, to express emotion, and when this happens the emotional register may overlie the lexical register, much as in many tone-languages intonation may overlie lexical tone. (Henderson 1952: 151-2).

This new concept of register which was introduced into the field of South-East Asian linguistics by Henderson was adopted by Shorto (1966) and also by linguists of later generations, including myself. Abercrombie established the term. In his book *Elements of general phonetics*, besides mentioning Henderson's work on Cambodian, he also points out (1967: 101-20) that Gujerati, Danish, some dialects of Scots Gaelic, and various West African languages make use of register contrast. He finally concludes: 'It is to be expected that future research will disclose many more examples of the linguistic use of register.' (op. cit., 102). In this sense, a register language may be defined as a language that has a lexically contrastive register complex (a combination of vowel quality, pitch, phonation type, etc.), whereas a tone language has lexically contrastive pitch.[3]

2. *Brief sketch of Chong phonology*

Consonant system

Initial consonants	p t c k ʔ ph th ch kh b d m n ɲ ŋ s h w r l j
Consonant clusters	pr tr kr phr khr pl kl phl khl ml mr kw
Final consonants	p t c k ʔ h m n ɲ ŋ w j

Vowel system

Monophthongs	i e ɛ ɯ ɤ a u o ɔ
	ii ee ɛɛ ɯɯ ɤɤ aa uu oo ɔɔ
Diphthongs	iə ɯə uə

Register system

Static registers	R_1 (clear voice, higher pitch, more open or on-gliding vowel)
	R_3 (breathy voice, lower pitch, raised vowel)
Dynamic registers	R_2 (clear-creaky voice, high-falling pitch, more open vowel)
	R_4 (breath-creaky voice, low-falling pitch, raised vowel)

The co-occurences of registers with initial consonants, final consonants and vowels are given in Charts 1, 2 and 3 below.

3. Diffloth does not like this definition. He thinks that a register language should be defined as 'a language that has contrastive phonation type' (personal communication). Certainly, this definition is more specific. In my view it is also problematic. Both pitch and phonation type can be heard clearly in all register languages that I have come across. Without doing perception testing, I do not think that we can make a definite claim. Native speakers of register languages might hear both or more phonetic features at the same time.

	p	t	c	k	ʔ	ph	th	ch	kh	b	d	m	n	ɲ	ŋ	s	h	w	r	l	j	pr	tr	kr	phr	khr	pl	kl	phl	khl	ml	mr	kw
R_1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−	+
R_2	+	+	+	+	+	+	+	+	+	−	−	+	+	+	+	+	+	+	+	+	+	+	−	+	−	+	+	+	+	+	−	−	−
R_3	+	+	+	+	−	−	−	−	−	−	−	+	+	+	+	−	−	+	+	+	+	+	−	+	−	−	+	+	−	−	+	+	+
R_4	+	+	+	+	−	−	−	−	−	−	−	+	+	+	+	−	−	+	+	+	+	+	−	+	−	−	−	+	−	−	+	+	−

Chart 1: *Co-occurrence of registers with initial consonant.*

	p	t	c	k	ʔ	h	m	n	ɲ	ŋ	w	j
R_1	+	+	+	+	+	+	+	+	+	+	+	+
R_2	+	+	+	+	−	−	+	+	+	+	+	+
R_3	+	+	+	+	+	+	+	+	+	+	+	+
R_4	+	+	+	+	−	−	+	+	+	+	+	+

Chart 2: *Co-occurrence of registers with final consonants.*

	i	e	ɛ	ɯ	ɤ	a	u	o	ɔ	ii	ee	ɛɛ	ɯɯ	ɤɤ	aa	uu	oo	ɔɔ	iə	ɯə	uə
R_1	+	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
R_2	+	−	+	+	−	+	+	−	+	+	+	+	+	+	+	+	+	+	−	−	−
R_3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
R_4	+	+	−	+	+	+	+	+	−	+	+	+	−	+	+	+	+	+	−	−	−

Chart 3: *Co-occurrence of registers with vowels.*

3. *Acoustic measurements*

In this section, an acoustic analysis of Chong vowels in respect of the formant frequency, power spectra, fundamental frequency, duration, and overall intensity will be given. The results of the measurements will indicate the characteristics of the register complex in Chong. Wide band spectrograms were used for measuring formant frequencies and power spectra, and narrow band spectrograms for fundamental frequencies.

3.1. *Formant frequency*

The frequencies of F_1 and F_2 of the following 17 clear vowels, 15 clear-creaky vowels, 18 breathy vowels, and 15 breathy-creaky vowels were measured:

Clear (R_1)	*Clear-creaky (R_2)*	*Breathy (R_3)*	*Breathy-creaky (R_4)*
i	i	i	i
e	–	e	e
ɛ	ɛ	ɛ	–
ɯ	ɯ	ɯ	ɯ
–	–	ɤ	ɤ
a	a	a	a
u	u	u	u
o	–	o	o
ɔ	ɔ	ɔ	–
ii	ii	ii	ii
ee	ee	ee	ee
ɛɛ	ɛɛ	ɛɛ	ɛɛ
ɯɯ	ɯɯ	ɯɯ	–
ɤɤ	ɤɤ	ɤɤ	ɤɤ
aa	aa	aa	aa
uu	uu	uu	uu
oo	oo	oo	oo
ɔɔ	ɔɔ	ɔɔ	ɔɔ

Five test words said in isolation by the two male speakers (MA, MB) were used for each vowel: there were altogether 650 ((65 × 5) × 2) test tokens. The mean values of F_1 and F2 were plotted separately for each speaker on vowel charts (see Figures 1, 2, 3 and 4).

In general, the results of the measurements confirm what can be perceived auditorily: breathy and breathy-creaky vowels are higher than clear and clear-creaky vowels. The two male speakers do not seem to diphthongise their clear vowels. This finding supports Gregerson's (1976) hypothesis that in most Mon-Khmer languages first register (clear) vowels which are produced with retracted tongue-root are always more open than second register (breathy) vowels which are produced with advanced tongue-root. The four vowel formant charts exhibit obvious patterns: clear voice and semi-clear voice vowels of the first and second registers are more open than the breathy voice and semi-breathy voice vowels of the

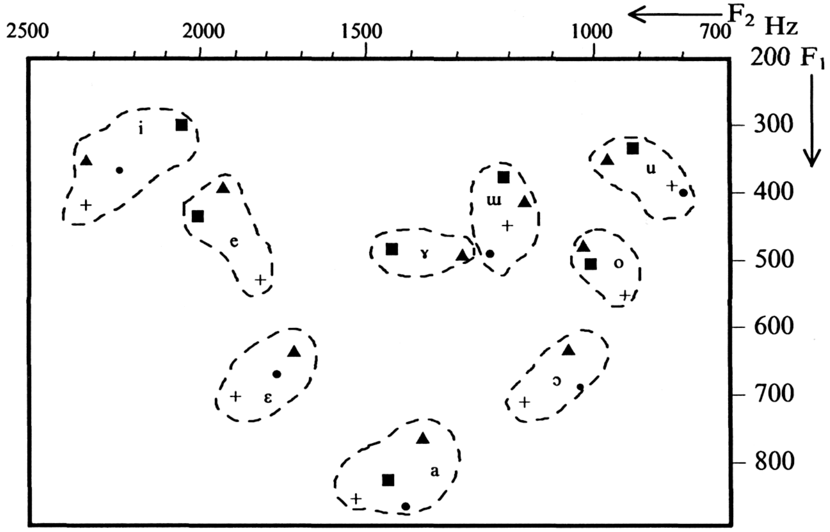

Fig. 1: *Formant frequencies (F_1 and F_2) of 1st, 2nd, 3rd and 4th register short vowels (speaker MA)*

+ clear vowel (R_1) ● clear-creaky vowel (R_2)
▲ breathy vowel (R_3) ■ breathy-creaky vowel (R_4)

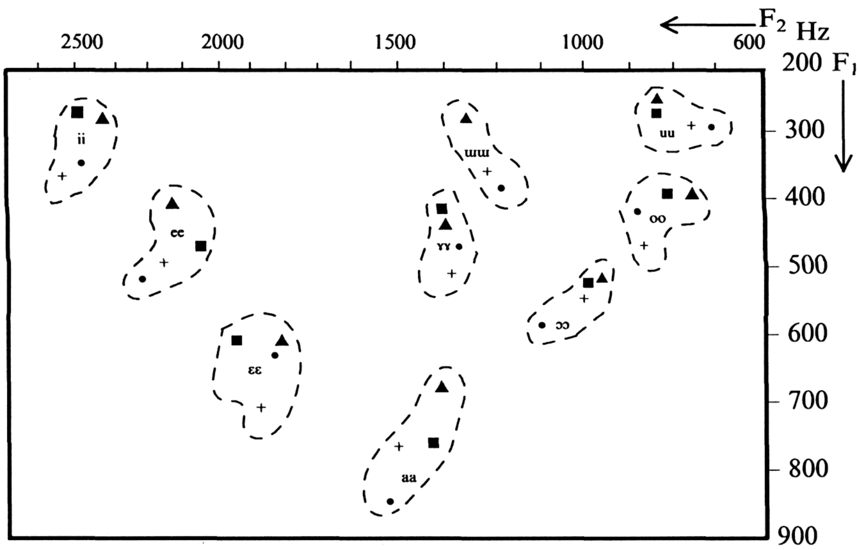

Fig. 2: *Formant frequencies (F_1 and F_2) of 1st, 2nd, 3rd and 4th register long vowels (speaker MA)*

+ clear vowel (R_1) ● clear-creaky vowel (R_2)
▲ breathy vowel (R_3) ■ breathy-creaky vowel (R_4)

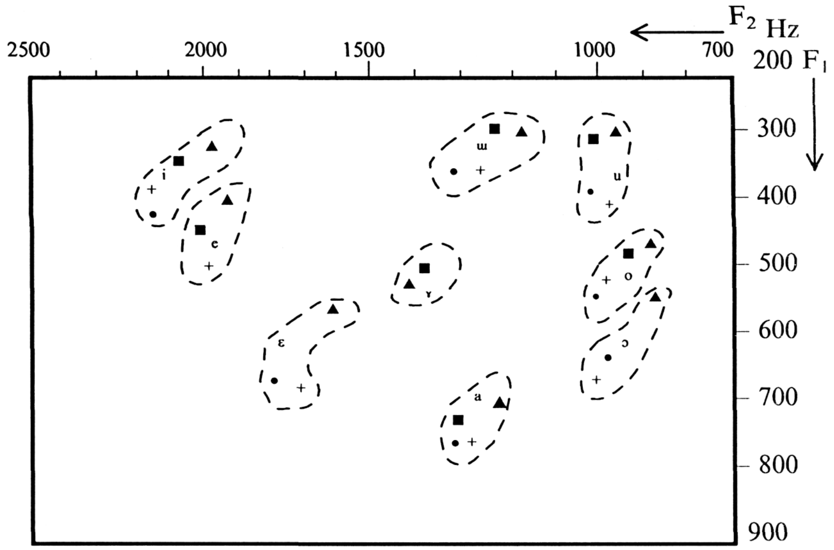

Fig. 3: *Formant frequencies (F_1 and F_2) of 1st, 2nd, 3rd and 4th register short vowels (speaker MB)*

+ clear vowel (R_1) ● clear-creaky vowel (R_2)
▲ breathy vowel (R_3) ■ breathy-creaky vowel (R_4)

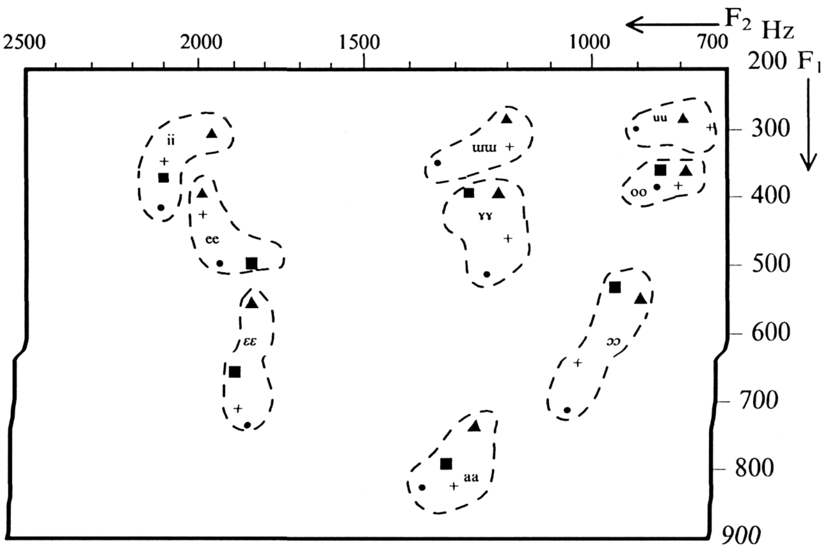

Fig. 4: *Formant frequencies (F_1 and F_2) of 1st, 2nd, 3rd and 4th register short vowels (speaker MB)*

+ clear vowel (R_1) ● clear-creaky vowel (R_2)
▲ breathy vowel (R_3) ■ breathy-creaky vowel (R_4)

third and fourth registers. However, it is still too early to accept Gregerson's claim. Although it works well for Chong, unfortunately it cannot explain the register phenomena in Nyah Kur and Kui (Thongkum 1982, 1985).

3.2. *Power spectra*
Kirk and others point out that the power spectra enable phoneticians to quantify the relative amount of energy in different harmonics. For their study of phonation types in Jalapa Mazatec, they measured the difference in dB between the intensity of the fundamental and the intensity of the first formant. They conclude, 'There is considerable variation from speaker to speaker in the three phonation types; but for each speaker on this measure the value for creaky voice is less than that for modal voice, and the value for modal voice is less than that for breathy voice' (Kirk *et al.* 1984: 109). Following their recommendations I did the same measurements for Chong. For the measurement of power spectra, each of the two male speakers said 325 test words. The results of the measurements may be summed up as in *Table* 1:

Table 1: *Mean values and standard deviation (SD) of the relative amplitude of F_0 and F_1 (in dB).*

	Speaker MA							
	Short vowel				Long vowel			
Register	R_1	R_2	R_3	R_4	R_1	R_2	R_3	R_4
Number of test token	40	30	45	35	45	45	45	40
Mean	–8.09	–8.35	–8.27	–8.61	–9.18	–9.28	–8.86	–8.95
SD	2.01	1.75	1.98	1.76	1.25	1.83	1.57	1.58
	Speaker MB							
	Short vowel				Long vowel			
Register	R_1	R_2	R_3	R_4	R_1	R_2	R_3	R_4
Number of test token	40	30	45	35	45	45	45	40
Mean	–8.38	–7.99	–8.20	–8.82	–9.31	–8.54	–8.97	–8.83
SD	1.98	2.21	1.89	1.92	1.37	1.69	1.44	1.67

It is unfortunate that the results do not meet my expectation; i.e. the measure does not seem to separate out successfully in that the value for modal voice is higher than that for creaky voice and less than that for breathy voice. Why? The reasons that I can think of are as follows:

(i) The measurements were done by hand because I did not have a Kay digital sound spectrograph, and so they could be less accurate.
(ii) As stated by Kirk (*op. cit.* 109), 'This measure can be used for comparing phonation types only in cases in which the vowels being

compared have similar formant frequencies; as the relative intensity of each formant is a function of its frequency.' It is true that in Chong the vowels of each register have specific quality as described in 4.1 above. Moreover, R_2 and R_4 vowels have dynamic or combined phonation types: clear followed by creaky phonation and breathy followed by creaky phonation; this can actually cause problems for the measure.

3.3. *Fundamental frequency* (F_o)

The word list used for F_o measurement consisted of 71 minimal or analogous sets; for example,

Set 20	*puŋ*[1]	'to get pregnant'
	pum[2]	'rash'
	puŋ[3]	'the entrails of animals'
	puŋ[4]	'water melon'

284 meaningful items were said by each of the two female speakers (FA, FB). Narrow band spectrograms were made and measured at ten points starting from the onset to the end of vowel. For plotting the results of F_o measurements, the 284 test words were divided into 20 sets based on register differences and different types of syllable:[4]

Clear	*Clear-creaky*	*Breathy*	*Breathy-creaky*	*Number of Test Token*
CVN	CVN	CVN	CVN	40 (10 × 4)
CVS	CVS	CVS	CVS	16 (4 × 4)
CVVN	CVVN	CVVN	CVVN	100 (25 × 4)
CVVS	CVVS	CVVS	CVVS	88 (22 × 4)
CVH	–	CVH	–	12 (6 × 2)
CVˀ	–	CVˀ	–	8 (4 × 2)

The mean values of F_o (in Hz) are shown in Figures 5 and 6. From the data presented there, the following points can be made:

(i) In CVN, CVS, CVVN and CVVS types of syllable, clear-creaky (R_2) vowels have the highest fundamental frequency. Only the clear part of R_2 and R_4 vowels could be measured because of the irregularities of the creaky part. However, it is possible to claim that R_2 and R_4 vowels have high rise-fall and high fall F_o contours, respectively. The insertion of laryngealisation or creakiness seems to be the cause of falling F_o contour. This may be an explanation of how falling tones are acquired in some tone languages. The narrow band spectrograms of sets 5, 16, 17, 18 and 32 (speaker FB) illustrate the absence of creaky phonation. Thus, clear-creaky (R_2) vowels become clear vowels with higher fall F_o contour, and breathy-creaky (R_4) vowels become breathy-clear vowels with lower fall F_o contour (see Figure 7 below).

4. N: represents nasals and semi-vowels (m n ɲ ŋ w j); S: stops (p t c k); H: glottal fricative (h); and ˀ: glottal stop (ˀ), respectively.

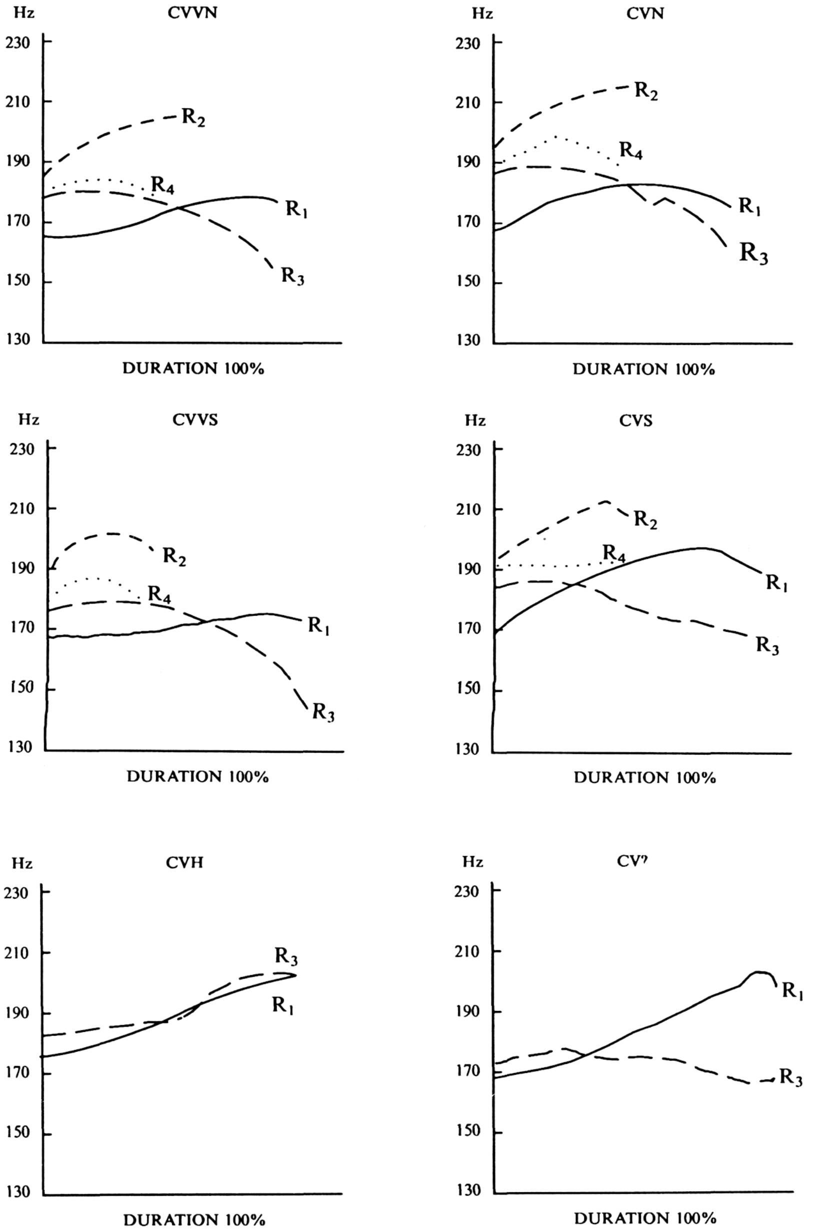

Fig. 5 *Mean F_o values (in Hz) of 1st, 2nd, 3rd and 4th register vowels in 6 syllable types (speaker FA)*

————	clear vowel (R_1)	- - - -	clear-creaky vowel (R_2)
— — —	breathy vowel (R_3)	. . . . .	breathy-creaky vowel (R_4)

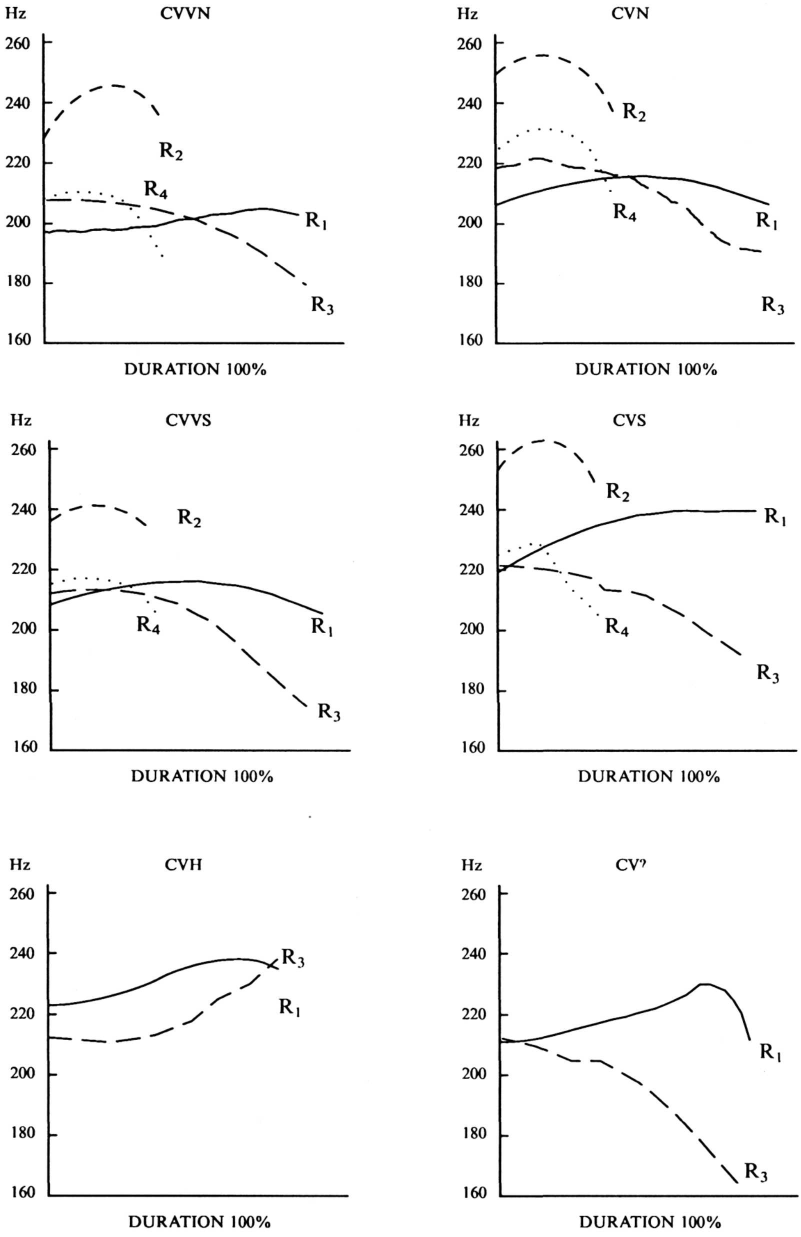

Fig. 6 *Mean F_o values (in Hz) of 1st, 2nd, 3rd and 4th register vowels in 6 syllable types (speaker FB)*

————	clear vowel (R_1)	- - - -	clear-creaky vowel (R_2)
— — —	breathy vowel (R_3)	. . . . .	breathy-creaky vowel (R_4)

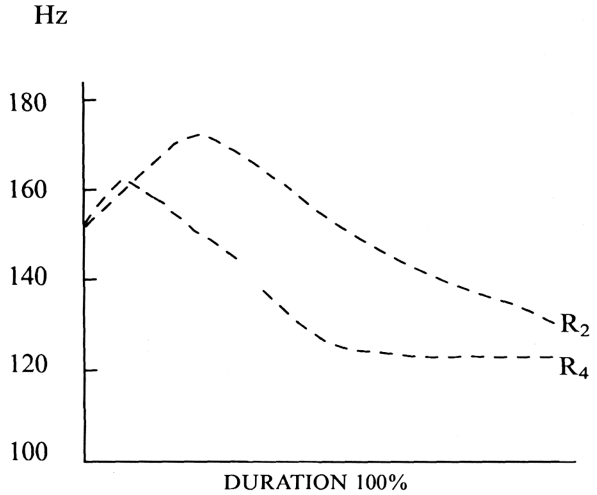

Fig. 7: *Mean F_o values (in Hz) of 2nd and 4th register vowels in CVVS syllable type when creaky phonation disappears and is replaced by falling F_o contour (speaker FB)*

(ii) Although breathy vowels can be perceived auditorily as having the lowest pitch, their F_o does not start low at all. According to the tracings (from 0% up to 30% of the vowel duration) breathy vowels can have even higher F_o than clear vowels. The point where the higher pitch of clear vowels and the lower pitch of breathy vowels can be differentiated is the F_o from 30% up to the end of vowel duration.

(iii) There is a tendency for R_1, R_2, R_3 and R_4 vowels in CVN and CVS types of syllables to have higher F_o than those in CVVN and CVVS syllable types.

(iv) Only clear and breathy vowels can occur in CVH and CVʔ types of syllable. In CVH syllable structure, both types of vowel have rising F_o contour; however, breathy vowels do not always have lower F_o than clear vowels. For speaker FA, the F_o tracings of clear and breathy vowels do not exhibit much difference; i.e. both types of vowel have rising F_o contour. In CVʔ syllable structure, clear vowels have rising F_o contour with an abrupt fall at the end, whereas breathy vowels have falling F_o contour.

3.4. *Duration*

The word-list used for F_o measurement was used again for the measurement of vowel duration and overall intensity. The test words were said by two female speakers of Chong. The audio recordings used as input were made in the recording studio of the Linguistics Research Unit (LRU) at the Faculty of Arts, Chulalongkorn University, and the results of the measurement can be found in Tables 3 and 4.

It is noticeable that breathy-creaky (R_4) vowels seem to be shorter than the other kinds of vowels no matter what the types of syllable. However, there is one exception; i.e. in CVN syllable type, R_4 vowels are somewhat longer.[5]

I have earlier commented that differences in duration caused by differences in phonation types might not be important when the language in question possesses distinctive vowel length (Thongkum 1985: 12). The results of the measurements of Chong vowels give me more confidence. Although breathy or murmured vowels in Gujerati (Fischer-Jørgensen 1977) and Jalapa Mazatec (Kirk *et al.* 1984) have longer duration than clear vowels, we still cannot claim that it is a universal phonetic characteristic.

Regarding clear-creaky (R_2) and breathy-creaky (R_4) vowels, the creaky part of R_4 vowels is longer than that of R_2 vowels, although the overall duration of R_4 vowels is shorter than that of R_2 vowels. This quality can also be perceived auditorily. The proportion (in percentage) of the duration of the first and second parts of vowel pertaining to dynamic registers (R_2 and R_4) is given in Table 2 below.

Table 2: *Mean duration (in percentage) of the clear and creaky parts of the 2nd register vowels and of the breathy and creaky parts of the 4th register vowels.*

Register	SPEAKER FA							
	CVN		CVS		CVVN		CVVS	
R_2	V	V̰	V	V̰	V	V̰	V	V̰
	51.95	48.05	71.43	28.57	53.55	46.45	57.61	42.39
R_4	V̤	V̰	V̤	V̰	V̤	V̰	V̤	V̰
	47.89	52.11	62.50	37.50	51.79	48.21	52.10	47.90

Register	SPEAKER FB							
	CVN		CVS		CVVN		CVVS	
R_2	V	V̰	V	V̰	V	V̰	V	V̰
	52.72	47.28	68.84	31.96	53.08	46.99	57.60	48.40
R_4	V̤	V̰	V̤	V̰	V̤	V̰	V̤	V̰
	51.58	48.42	58.33	41.67	49.23	50.77	45.25	54.75

5. Since the segmentation was done by hand without any computer aids, defects may have been caused by inaccurate segmenting. The beginning part of laryngealised or creaky voice nasals and semi-vowels could have been segmented as part of clear-creaky voice and breathy-creaky voice vowels.

3.5. *Intensity*

Regarding overall intensity, clear vowels and clear-creaky vowels seem to have higher amplitude than breathy and breathy-creaky vowels. The loss of intensity is due to leaking glottis during breathy phonation (Fischer-Jørgensen 1977: 119), and the acoustic energy is lost by the damping effect of the general relaxation of the muscles of the whole vocal system in lax voice (Laver 1980: 135). The intensity curves of clear and breathy vowels look similar (i.e. look more bell-shaped), whereas those of clear-creaky and breathy-creaky vowels look different (i.e. more cone-shaped), which is due to a sudden drop of intensity when clear and breathy vowels become creaky caused by the abrupt closing of the vocal folds. The results of the measurements are given in Tables 3 and 4.

1-5 = overall vowel duration
1-3 = distance from the onset of vowel to the peak of intensity curve
3-5 = distance from the peak of intensity curve to the end of vowel
1-a = amplitude at the onset of vowel
2-b = amplitude at the half distance of the onset of vowel and the peak of intensity curve
3-c = peak of amplitude
4-d = amplitude at the half distance of the peak amplitude and the end of vowel
5-e = amplitude at the end of vowel

3.6. *Manifestation of R_2 and R_4 vowels*

In the recorded material, clear-creaky (R_2) and breathy-creaky (R_4) vowels behave in many different ways.[6] The following are the most obvious manifestations of clear-creaky and breathy-creaky vowels:

(i) Complete change of the oscillatory pattern in the middle or at ¾ of vowel duration;
(ii) Jagged oscillations into the following consonant;
(iii) Brief change of waveforms in the middle of vowel with a decrease in intensity and fundamental frequency;
(iv) Slight change of waveforms which indicates laryngealisation or creakiness throughout the vowel, not found very often.

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6. Danish, it is maintained, is a register language: 'In Danish two such words as *hun* "she" and *hund* "dog" are pronounced alike except for a difference of register, the second having creaky voice.' (Abercrombie 1967: 101).

Peterson (1973) did an instrumental investigation of the Danish '*stød*', which is regarded as a phonologically distinctive element. It is amazing to see that the results of my instrumental study of clear-creaky and breathy-creaky vowels in Chong more or less agree with these of Petersen who also refers to another instrumental investigation of the *stød* which was done by Smith (1944). Smith, who included electromyographic, oscillographic and kymographic registrations, thinks that it is a stress accent, concluding that it often appears to be three-phased:
(1) A ballistic contraction of the expiratory muscles;
(2) Cessation of this activity which causes a lack of balance in the reaction of the vocal folds;
(3) A new activity in the expiratory muscles.

Table 3: *Mean amplitude, mean duration, and standard deviation of 1st, 2nd, 3rd and 4th register vowels in six types of syllable (speaker FA)*

Syllable type	Register	Amplitude (dB) 1-a	2-b	3-c	4-d	5-e	Duration (msec) 1-3	3-5	1-5
(C)VV(N)	R1	23.52	36.32	39.52	36.60	27.60	166	181	347
		(5.34)	(3.63)	(3.59)	(3.73)	(4.67)	(10.45)	(10.02)	(1.87)
	R2	17.20	36.48	40.80	34.68	25.80	122	216	338
		(7.71)	(3.55)	(3.27)	(3.89)	(6.42)	(6.19)	(6.42)	(2.11)
	R3	21.08	33.12	35.96	33.48	24.96	115	220	335
		(6.35)	(4.09)	(3.43)	(3.51)	(3.52)	(6.00)	(5.62)	(2.17)
	R4	19.29	33.17	37.38	28.72	18.63	118	201	319
		(5.62)	(4.76)	(3.98)	(5.91)	(5.54)	(4.45)	(4.87)	(2.81)
(C)VV(S)	R1	21.82	34.64	38.68	34.09	13.14	145	176	321
		(8.68)	(5.04)	(3.55)	(6.04)	(6.45)	(9.23)	(9.48)	(2.96)
	R2	19.55	35.27	39.50	33.05	14.95	095	214	309
		(10.55)	(5.05)	(4.13)	(5.21)	(9.13)	(3.45)	(3.39)	(3.14)
	R3	16.59	30.86	34.14	31.32	10.09	096	238	334
		(8.88)	(5.44)	(5.20)	(5.66)	(7.73)	(5.83)	(5.24)	(2.57)
	R4	14.05	32.18	35.59	28.00	11.59	104	182	286
		(7.67)	(6.81)	(6.41)	(5.75)	(7.46)	(4.47)	(3.50)	(2.90)
(C)V(N)	R1	19.50	32.40	35.50	27.00	23.10	046	171	217
		(7.09)	(2.94)	(2.33)	(3.29)	(3.96)	(2.69)	(4.66)	(2.76)
	R2	14.40	32.40	37.30	28.30	19.30	058	173	231
		(9.67)	(5.04)	(2.49)	(4.61)	(4.38)	(4.31)	(4.65)	(1.76)
	R3	9.30	26.30	29.80	26.10	19.30	063	148	211
		(5.18)	(6.60)	(5.95)	(6.53)	(3.58)	(3.35)	(4.51)	(2.34)
	R4	10.80	26.50	30.80	21.20	10.80	070	143	213
		(8.11)	(5.22)	(6.14)	(6.16)	(4.09)	(3.55)	(3.16)	(2.53)
(C)V(S)	R1	28.50	34.75	38.50	39.00	17.25	453	090	143
		(4.09)	(4.60)	(3.77)	(5.09)	(11.03)	(2.27)	(1.87)	(0.83)
	R2	13.75	31.00	38.50	29.75	11.25	072	103	175
		(8.32)	(2.23)	(3.5)	(2.05)	(6.83)	(2.58)	(2.58)	(0.5)
	R3	15.75	27.00	30.00	25.25	3.00	068	090	158
		(5.85)	(6.08)	(4.84)	(3.70)	(4.12)	(3.63)	(1.58)	(2.58)
	R4	19.25	26.50	32.00	27.00	6.50	040	088	128
		(6.83)	(2.60)	(4.74)	(4.58)	(8.17)	(1.87)	(1.79)	(1.09)
(C)V(H)	R1	20.17	37.17	40.17	34.00	19.67	080	132	212
		(9.5)	(4.59)	(5.75)	(5.36)	(7.34)	(2.58)	(1.34)	(1.57)
	R3	11.33	35.83	37.00	29.83	10.83	102	117	229
		(7.09)	(4.71)	(5.42)	(4.71)	(8.13)	(2.03)	(2.43)	(1.57)
(C)V(ʔ)	R1	29.00	39.75	42.50	40.50	31.25	098	087	185
		(5.20)	(1.48)	(2.69)	(2.18)	(5.36)	(0.83)	(0.83)	(0.50)
	R3	16.75	35.25	38.50	35.50	27.00	082	098	180
		(10.52)	(2.38)	(2.06)	(2.60)	(4.74)	(2.86)	(3.70)	(1.22)

Table 4: *Mean amplitude, mean duration, and standard deviation of 1st, 2nd, 3rd and 4th register vowels in six types of syllable (speaker FB)*

Syllable type	Register	Amplitude (dB)					Duration (msec)		
		1-a	2-b	3-c	4-d	5-e	1-3	3-5	1-5
(C)VV(N)	R1	11.00	24.92	27.36	25.00	17.72	141	150	291
		(6.58)	(3.19)	(3.54)	(3.37)	(3.73)	(6.35)	(6.69)	(2.57)
	R2	9.96	26.72	31.32	22.48	14.92	105	162	267
		(6.31)	(6.28)	(5.24)	(7.76)	(6.05)	(4.28)	(4.19)	(2.78)
	R3	10.28	21.28	24.40	21.44	13.88	096	189	285
		(5.18)	(3.70)	(3.05)	(3.47)	(5.17)	(4.71)	(5.80)	(2.50)
	R4	9.48	22.08	28.52	16.16	12.68	108	153	261
		(5.55)	(3.78)	(3.77)	(5.61)	(4.75)	(2.93)	(3.11)	(2.58)
(C)VV(S)	R1	7.82	23.09	27.41	22.91	11.55	119	181	300
		(6.23)	(5.68)	(3.28)	(4.92)	(7.33)	(6.66)	(6.71)	(2.29)
	R2	6.68	25.00	30.05	21.68	10.82	090	191	281
		(7.09)	(4.49)	(2.85)	(5.06)	(5.98)	(5.06)	(4.87)	(2.28)
	R3	6.27	20.00	22.77	19.36	4.50	080	215	295
		(5.58)	(4.15)	(3.32)	(3.89)	(4.19)	(4.74)	(4.27)	(2.18)
	R4	*7.73*	*21.18*	*26.14*	*16.41*	*7.50*	*807*	*176*	*263*
		(5.48)	(5.25)	(4.63)	(5.27)	(5.95)	(3.08)	(2.52)	(2.56)
(C)V(N)	*R1*	7.30	*21.70*	26.50	*21.70*	*12.90*	*057*	*122*	*179*
		(5.42)	*(3.85)*	*(2.46)*	*(2.61)*	*(4.35)*	*(1.62)*	*(3.22)*	*(2.26)*
	R2	6.50	24.90	30.60	17.60	7.30	053	131	184
		(6.95)	(4.66)	(5.04)	(5.35)	(2.24)	(1.10)	(2.62)	(2.15)
	R3	4.40	19.00	23.00	17.50	10.90	065	116	181
		(4.43)	(5.67)	(5.69)	(6.55)	(3.91)	(2.73)	(4.15)	(2.07)
	R4	5.20	19.70	24.90	8.40	4.40	081	109	190
		(5.13)	(5.16)	(5.26)	(7.36)	(4.45)	(2.74)	(1.45)	(2.93)
(C)V(S)	R1	7.50	21.25	28.50	23.50	10.75	060	078	138
		(7.63)	(2.95)	(2.69)	(4.15)	(3.27)	(3.00)	(1.09)	(2.17)
	R2	9.00	21.75	30.50	27.50	16.50	080	058	138
		(7.28)	(6.57)	(3.84)	(2.87)	(8.20)	(4.12)	(2.77)	(1.79)
	R3	3.75	15.00	23.75	19.00	4.00	055	083	138
		(4.49)	(5.92)	(1.09)	(1.12)	(4.00)	(2.29)	(1.09)	(2.28)
	R4	3.50	19.25	24.50	19.00	3.50	070	050	120
		(4.37)	(6.61)	(4.56)	(7.00)	(3.57)	(2.45)	(1.58)	(1.87)
(C)V(H)	R1	3.67	26.33	31.17	25.33	10.33	060	140	200
		(5.06)	(3.09)	(3.48)	(4.11)	(3.54)	(1.29)	(2.00)	(2.58)
	R3	3.67	25.17	28.83	24.33	7.67	075	108	183
		(3.14)	(7.84)	(5.08)	(6.49)	(5.93)	(2.57)	(0.89)	(2.13)
(C)V(ʔ)	R1	10.00	24.75	31.50	29.50	24.50	080	098	178
		(7.07)	(6.38)	(2.5)	(2.06)	(2.96)	(4.30)	(5.21)	(1.29)
	R3	8.25	24.50	28.50	26.50	17.50	121	042	165
		(2.86)	(2.64)	(2.60)	(3.20)	(6.38)	(2.68)	(1.32)	(3.5)

4. *Notes on laryngeal waveforms and airflow*
For the investigation of laryngeal vibration and airflow, two female speakers of Chong were brought to the Phonetics Laboratory at Chulalongkorn University. No quantitative measurement was attempted. However, it can be seen clearly that the laryngograms of the four sets of Chong vowels look different. At the onset of clear and clear-creaky vowels, there is a relative rise which is produced by the rapid closing of the vocal folds for normal voicing,[7] and on the other hand, there is a relative fall at the onset of breathy and breathy-creaky vowels which is caused by a more open glottis during breathy phonation. There is also a relatively sharp rise after the release of final consonant following clear-creaky and breathy-creaky vowels.

Regarding airflow, the most prominent characteristic of breathy vowels is strong airflow.[8] During the creaky part of R_2 and R_4 vowels, there is a sudden drop of airflow caused by a rapid closing and tightening of the vocal folds.[9]

6. Conclusion
The instrumental investigation of Chong vowels supports what can be perceived auditorily: that is, there are four sets of register complex, namely, R_1, R_2, R_3, and R_4. The phonetic correlates of the four registers may be summed up as follows:

Register 1: higher frequency of F_1 (more open vowel); rather level F_o contour (level pitch); regular audio and laryngeal wave forms; higher amplitude; bell-shaped intensity curve; lower amount of airflow in comparison with R_3; normal voice phonation;

Register 2: higher frequency of F_1 (more open vowel); high rise-fall F_o contour; regular followed by irregular audio and laryngeal waveforms; highest peak of amplitude; cone-shaped intensity curve; sudden decrease of intensity and fundamental frequency; sudden drop of airflow; normal voice followed by creaky voice phonation;

7. In normal voicing there are three distinct parts of the waveform. First, there is a relatively sharp rise which is produced by the rapid closing of the vocal folds which is so characteristic of their normal vibration and is associated with the interval of greatest acoustic excitation of the vocal tract. Second, there is the more gradual fall which is associated with the parting of the vocal folds as the sub-glottal pressure is increased; and third, there is the flatter base of the waveform which corresponds to the interval during which the glottis is open and the vocal folds are out of contact. (Fourcin & Abberton 1972: 165-66)

8. Fischer-Jørgensen measured the airflow of clear and murmured or breathy vowels in Gujerati by means of aerometer. She concludes (1967: 153) that murmured vowels are characterised by a strong airflow which is due to the presence of a small opening in the rear part of the glottis, and/or by an increased activity of the expiratory muscles.

9. When a laryngealised or creaky voice sound is made, the arytenoids are held tightly together while a small length of the ligamental vocal cords is vibrating (Ladefoged 1971: 8).

Register 3: lower frequency of F_1 (more closed vowel); gradual fall Fo contour; regular audio and laryngeal waveforms; lowest amplitude; bell-shaped intensity curve; strong air flow; breathy voice phonation;

Register 4: lower frequency of F_1 (more closed vowel); high fall Fo contour; regular followed by irregular audio and laryngeal waveform; rather low amplitude; cone-shaped intensity curve; sudden decrease of intensity and fundamental frequency; sudden drop of airflow: breathy voice followed by creaky voice phonation.

REFERENCES

Abercrombie, D. 1967. *Elements of general phonetics*. Chicago: Aldine Publ. Co.

Baradat, R. 1941. Les dialectes des tribus sâmrê. Paris: MS, Ec. fr. Extr.-Orient.

Diffloth, G. 1974. Austro-asiatic languages. In *Encyclopedia Brit.*, 480-84.

Fischer-Jørgensen, E. 1977. Phonetic analysis of breathy (murmured) vowels in Gujarati. *ARIPUC* **2** (repr. Annual Report Inst. Phonetics, Univ. Copenhagen) 105-56.

Fourcin, A.J. & Abberton, E 1972. First applications of a new laryngograph. *The Volta Review* **74**(3), 161-76.

Garcia, M. 1855. Observations of the human voice. *London, Edinburgh and Dublin Philosophical Magazine and Journal of Science* **10**, 511-13.

Gregerson, K.J. 1976. Tongue-root and register in Mon-Khmer. In *Austroasiatic Stud.* **1** (Oceanic Ling. Spec. Pub. **13**) (eds.) P. N. Jenner, *et al.* Honolulu: Univ. Hawaii Press, 323-69.

Headley, R.K. 1977. A Pearic vocabulary. *Mon-Khmer Stud.* **6**, 69-149.

..... 1978. An English–Pearic vocabulary. *Mon-Khmer Stud.* **7**, 61-94.

..... 1985. Proto-Pearic and the classification of Pearic. In *Southeast Asian linguistic studies presented to André-G. Haudricourt* (eds.) Suriya Ratanakul, *et al.* Bangkok: Mahidol Univ., 428-78.

Henderson, Eugénie J.A. 1952. The main features of Cambodian pronunciation. *Bull. Sch. Or. Afr. Stud.* **14**(1), 149-74.

Huffman, F.E. 1976. The register problem in fifteen Mon-Khmer languages. *Austroasiatic Stud.* **1** (Oceanic Ling. Spec. Pub. **13**) (eds.) P. N. Jenner, *et al.* Honolulu: Univ. Hawaii Press, 575-89.

..... 1985. The phonology of Chong, a Mon-Khmer language of Thailand. In *Southeast Asian linguistic studies presented to André-G. Haudricourt* (eds.) Suriya Ratanakul, *et al.* Bangkok: Mahidol Univ. 355-88.

Kirk, P.L. 1984. *et al.* Using a spectrograph for measures of phonation types in a natural language. *UCLA Working Papers in Phonetics* **59**, 102-13.

Ladefoged, P. 1971. *Preliminaries to linguistic phonetics*. Chicago: Univ. Chicago Press.

Laver, J. 1980. The Phonetic description of voice quality. Cambridge: Cambridge Univ. Press.

Lee, T. *1983. An acoustic study of the register distinction in Mon. UCLA Working Papers in Phonetics* 57, 79-96.

Martin, Marie A. 1974. Remarques générales sur les dialects pear. *Asie du Sud-Est et Monde Insulindien* 5(1), 25-37.

Mörner, M., Fransson, F. & Fant, G. 1963. Voice register teminology and Standard pitch. *Quarterly Progress and Status Report* 4, 17-23. Stockholm: Speech Transmission Lab., Royal Inst. Technology.

Petersen, Pia R. 1973. An instrumental investigation of the Danish 'stød'. *ARIPUC* 7 (Annual Report Inst. Phonetics Univ. Copenhagen), 195-234.

Pike, K.L. 1948/76. *Tone languages*. Ann Arbor: Univ. Michigan Press.

Shorto, H. L. 1966. Mon vowel systems: a problem in phonological statement. In *In memory of J. R. Firth* (ed.) C. E. Bazell, *et al.* London: Longmans, 398-409.

Suphanphaiboon, Surekha 1982. The phonological system of Chong language, Muban Takhianthong, Tambon Takhianthong, Amphoe Makham, Changwat Chanthaburi. M.A. Thesis, Srinakharinwirot Univ., Bankgok.

Thomas, D., & Headley, R. K. 1970. More on Mon-Khmer subgroupings. *Lingua* 25, 398-418.

Thongkum, Theraphan L. 1982. Register without tongue-root in Nyah Kur (Chao Bon). Paper presented at the 15th International Conference on Sino-Tibetan Languages and Linguistics. August 1982, Beijing.

. . . . . 1985. An acoustic study of the register complex in Kui (Suai). Paper presented at the 18th International Conference on Sino-Tibetan Languages and Linguistics. August 1985, Bangkok.

Zemlin, W.R. 1968. *Speech and hearing science: anatomy and physiology*. New Jersey: Prentice-Hall.