THE PHONETICS OF REGISTER IN TAKHIAN THONG CHONG

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1. Introduction

The phonological term "register" in Southeast Asian languages refers to a collection of phonetic and phonological cues that are used by speakers to distinguish meaning between words (Henderson 1952, 1985). These cues may include phonation type, pitch, vowel quality, and other characteristics like intensity and vowel duration. A "register" language is distinct from a "tone" language because register contrasts have an array of cues which usually include a phonation type contrast. Tone languages are characterized mainly by their use of pitch to distinguish words prosodically. Most register languages contrast only two phonation types, e.g. Middle-Khmer (Jacob 1968) and Wa (Watkins 2002). Register languages contrasting three phonation types are quite rare, but do exist, e.g. Jalapa Mazatec (Kirk, Ladefoged and Ladefoged 1993) and Bai (Edmondson and Esling 2006). However, languages with a 4-way phonation-type contrast are extremely rare. There are only two languages in the world that have this number of contrasts: Chong (Thongkum 1991) and !Xóõ (Traill 1985). There is no language known with a 5-way phonation type contrast. As the number of registers in Chong is exceptional from a typological standpoint, it is of interest to the study of phonetics, phonology, and phonological typology to understand how speakers produce it. The study of rare phonological phenomena like this broaden our perspective and often cause us to revise our theoretical assumptions regarding the number of features required to represent such contrasts.

This article is organized as follows: In part 2, I provide a basic description of the phonology of Chong. In part 3, I review previous work on the register contrast in the language. In part 4, I examine the phonetics of register, including an analysis of phonation type using electroglottography, an analysis of pitch, and duration. In part 5, I provide a summary of my results, their implications, and a conclusion.

2. Chong Phonology

Chong is a Pearic language in the Mon-Khmer family with three major dialect areas: Northern Khao Khitchakut, Eastern (Pong Nam Ron), and Southern Khao Khitchakut (Choosri 2002). The described dialects of Chong are spoken mostly in the Khao Khitchakut district of Chanthaburi province, Thailand, which borders Cambodia. There is an uncertain number of Chong speakers who also live in the adjacent areas in Cambodia, but whose language has not been investigated to date. There are approximately 4,000 speakers of different Chong dialects in Thailand (ibid). Takhian Thong Chong belongs to the Northern Khao Khitchakut dialect region. Data in this paper are from the author's fieldwork. Word-lists and acoustic/laryngographic data was gathered during summer 2005 through the generous help of Mahidol University, which has an extensive project on revitalizing the language (Premsrirat and Malone 2003).

Takhian Thong Chong phonology is noteworthy for having a four-way contrast among place of articulation in stops, a complex vowel inventory, and a four-way contrast in register. The consonant inventory contains a series of aspirated/unaspirated stops with a four-way place distinction. Unlike many languages with palatal places of articulation, voiceless palatal stops in Thakhian Thong Chong are produced with very little affrication. The "aspirated" series, however, is produced with regular frication following the burst release. The consonant inventory is given in Table (1) and the vowel inventory in Table (2).

Takhian Thong Chong is a register language, meaning that the prosodic distinction distinguishing words in the language includes contrastive phonation type (voice quality), contrastive tone, and durational cues. Contrasts involving a specific phonation type, pitch contour, and duration are grouped together as a "bundle" to form what is known as a register (Thurgood 2000). Takhian Thong Chong has a four-way register contrast which includes a modal register, a modal-tense register, a breathy register, and a breathy-tense register. The hyphen here indicates that there is a movement from one voice quality to another over the vowel's duration. Thus, the "breathy-tense" register consists of breathy voice following the release of the onset consonant, with a change in voice quality towards more tense or "pressed" phonation" (Laver 1979, Titze 1994, Story and Titze 2002).

The labels chosen for the registers resemble closely those given by Thongkum (1988), who first claimed the existence of four registers in the language and completed a phonetic investigation on it. However, I have chosen to use the word "tense" instead of "creaky" (as Thongkum does) as it more accurately describes the phonation-type found in Takhian Thong Chong. Creaky phonation contains little active longitudinal tension of the vocal folds and often results in what is called "vocal fry" (Catford 1977, Laver 1980). This creak has low amplitude and contains substantial amounts of jitter, which corresponds to the degree of difference in the duration of successive glottal cycles (Gordon and Ladefoged 2001). By contrast, the "tense" register in Chong often has higher amplitude (Thongkum 1988), little jitter, and is auditorily similar to what phoneticians have described as "pressed" or "tense" phonation, also called "ventricular voice" (Edmonson and Esling 2006). Either of these phonation types may occur before a glottal stop in languages, but only tense phonation regularly involves higher pitch and strong periodicity, which is the case in Takhian Thong Chong. Edmondson (1997) makes a similar observation of the "creaky" registers in Khlong Phlu Chong, saying that they are in fact, tense. Examples of each voice quality are given in table (3).

Chong words are mostly monosyllabic or sesquisyllabic. Sesquisyllables are words consisting of a very short syllable (also called a pre-syllable) followed by a longer one (Matisoff, 1973). An example is given in (3) with the word 'bean.' Mon-Khmer languages and other languages throughout Southeast Asia commonly have such word-structure. In some cases the pre-syllable has been lost, as in Mon (Diffloth 1984), or lengthened into a separate and longer syllable, as in Vietnamese (Vuori

TABLE 1. Takhian Thong Chong Consonant Inventory

	Bilabial	Alveolar	Palatal	Velar	Glottal
Stops	p p^{h}	t t^{h}	c, cɕ	k k^{h}	ʔ
Fricatives		s			h
Trills		r			
Nasals	m	n	ɲ	ŋ	
Laterals		l			
Approximants	w		j		

TABLE 2. Takhian Thong Chong Vowel Inventory

	Front	Central	Back Unrounded	Back Rounded
Close	i, ii			u, uu
Close-Mid	e, ee	ə, əə	ɤ, ɤɤ	o, oo
Mid-Open	ɛ, ɛe			ɔ, ɔɔ
Open		a, aa		
Diphthongs	iə, iu	ai, ao	ɤə	uə

TABLE 3. Takhian Thong Chong Registers

Word	*Register*	*Gloss*	*Syllable Structure*
lɔɔŋ	modal	‘stride’	CVVN
ceet	modal	‘to sharpen wood’	CVVT
tɔŋ	modal	‘house’	CVN
p^{h}at	modal	‘tail’	CVT
lɔ̰ɔ̰n	modal-tense	‘navel’	CVVN
cḛḛt	modal-tense	‘deer’	CVVT
pa̰j	modal-tense	‘palm’	CVN
cɕo̰k	modal-tense	‘pig’	CVT
ra̤a̤j	breathy	‘ten’	CVVN
pa̤a̤t	breathy	‘peel’	CVVT
pə̤t	breathy	‘to fan’	CVT
pa̤a̰j	breathy-tense	‘two’	CVVN
cɕɔ̤ɔ̰ŋ	breathy-tense	‘Chong’	CVVN
kəta̤a̰k	breathy-tense	‘bean’	CVVT
tṳṵŋ	breathy-tense	‘squash’	CVN
p^{h}ɤ̤ɤ̰t	breathy-tense	‘rattan’	CVT

2000). Takhian Thong Chong appears to be undergoing some loss of pre-syllables, as words like ’bean’ above are not produced with the pre-syllable “kə” by all speakers, and optionally by those who do produce it.

All consonant phonemes given in (1) may occur as the onset of a syllable with any of the vowels. Most of these same consonants can occur as codas, with the exception of the aspirated stop series, /s/, and /r/. The glottal fricative /h/ may also occur as a coda consonant, but only on modal and breathy registers. Most consonants occur together freely in Chong with respect to register. For instance, all registers may occur on closed syllables containing both long and short vowels, sonorant or stop codas. I have attempted to show this in the above table, but I was unable to elicit CVN (short vowel + sonorant coda) forms for the breathy register during fieldwork. All other registers shown in (3) allow these vowel and coda types. However, Thongkum (1988) mentions that only the modal and breathy register may occur on open syllables. For instance, in Takhian Thong Chong the word tṳṳ 'to escape' is breathy while the word hɔɔ 'dinner, food' is modal. Therefore, the modal-tense or breathy-tense registers do not occur on open syllables.

There is a problem with this analysis, however. It has to do with how one chooses to analyze "ʔ". If we consider it a coda, then one is led to believe that words of the shape CVʔ and CV̤ʔ are sequences of a modal vowel and breathy vowel (respectively) followed by a glottal stop coda. However, these could just as easily be analyzed as cases of either the modal-tense or breathy-tense register without a coda, where glottal tension may increase so much as to create full glottal closure at the end of the vowel. There is nothing in Thongkum's description of the Chong data to rule out this possibility, suggesting that all registers may occur on all syllable types in Chong. Huffman's description of Chong (1985), in fact, suggests that there is neutralization here between the different registers, where a breathy vowel followed by a glottal stop is no different than a breathy-tense vowel without a coda while a modal vowel followed by a glottal stop is no different than a modal-tense vowel without a coda. There is inconclusive evidence to agree with either analysis though.

Aspirated stops have a restricted distribution with respect to register in Takhian Thong Chong. They occur only as the onsets of modal vowels, in words like $\mathrm{t^h}$oh 'breast' and $\mathrm{p^h}$at 'tail'. This is distinct from the nearby dialect of Khlong Phlu Chong which maintains the aspiration distinction on all registers, but similar to the Wang Kraphrae dialect which has lost many of the aspirated stops in these environments (Ungsitipoorporn 2001). The restriction of aspirated consonants to the modal register may not be surprising on phonetic grounds. Maintaining an aspiration contrast involves an adjustment of glottal aperture following the release of the stop closure. The register contrast on the vowel also involves an adjustment of glottal aperture, on a cline from more adducted vocal folds during tense phonation to more abducted vocal folds during breathy phonation. There may be some physiological or auditory mechanism that makes it difficult for speakers to produce or distinguish between glottal aperture configurations related to the onset and those that are specified for the vowel. As a result, one glottal aperture configuration is produced for the entire CV sequence or possibly for the entire syllable.

The palatal stop series is an exception to this rule however, as the aspirated stop occurs as the onset of a syllable with any of the registers. The "aspiration" on this stop is different from the other stops though, consisting of frication noise produced at the palatal place of articulation. This noise is not produced at the glottis, which is the case for the other voiceless aspirated stops. So, it is not technically an aspirated stop, but rather a palatal affricate. The upstream constriction used to produce a palatal fricative is separate from the glottal aperture configuration, so producing this sound does not cause a potential conflict among glottal aperture configurations the way that producing other aspirated stops does. In the Chong literature, however, this phoneme is written as "ch", emphasizing the uniformity that all stops have both aspirated and unaspirated variants phonologically.

There is some effect of register on vowel quality in Chong. This is most noticeable on the non-closed vowels. In general, vowels occurring on the breathy or breathy-tense register are higher than those occurring on the modal or modal-tense register. In fact, open-mid vowels never occur on each of these registers; there is no /ɛ/, /ɛe/, /ɔ/, or /ɔɔ/ on these registers. The vowel /a/ is realized with a slightly higher variant when it occurs on the breathy or breathy-tense register. This is most noticeable on words with a long vowel in the breathy-tense register because the vowel quality as well as the voice quality changes throughout the course of the vowel. So, a word like /pa̤a̰j/ “two" is realized as [pʌ̤a̰j] where the initial duration of the long vowel is more closed. The correlation between breathiness and vowel-raising has been mentioned in the previous literature on Chong (Ungsitipoorporn 2001) and is a well-established phenomena within Mon-Khmer languages as a source of sound change (Ferlus 1979).

3. Background on Chong Register

Chong register has been of particular interest to the study of the production and control of laryngeal gestures as well as comparative Southeast-Asian phonology and phonetics. It is interesting to linguists studying laryngeal gestures because of its unique property of having many lexically-contrastive laryngeal configurations. Each of these glottal configurations is associated with a tone in the language. Research on phonation type has found that there is an interaction between the degree of glottal aperture and pitch (Thongkum 1988, Gordon and Ladefoged 2001). The connection between phonation type and pitch may be phonetically-motivated, where, for instance, speakers are unable to produce higher pitch with breathy phonation and lower pitch with tense phonation. If there is a strong interaction between these two phenomena, then it has the potential for informing synchronic phonological theories where phonetic grounding plays a role in determining co-occurrence patterns between laryngeals and tone, e.g. Silverman (1997a). Furthermore, it also has explanatory potential in determining the origin of tone and tone sandhi in languages. If certain laryngeal states are natural pitch depressors or raisers, then we have a phonetically-grounded explanation for why certain tones develop in the context of different laryngeal configurations.

Chong register is of interest to Mon-Khmerists and other linguists working on Southeast Asia because it extensively exploits a genetic (or areal) characteristic, register. It is of general interest to phonology because it contains what may be called “phonation-type contours” or “dynamic registers” as Thongkum (1991) states. The notion of a tonal contour is well-known to most phonologists, where a single prosodic unit may have two or more suprasegmental specifications given an autosegmental representation (Goldsmith 1976). However, the presence of phonation-type contours implies that multiple laryngeal specifications may be present on a single prosodic unit. Phonation may behave prosodically like tone in its representation in the phonology of a language.

3.1. **The Phonetics of Register.** Therapan Thongkum (1988, 1991) completed the first instrumental phonetic analysis of Chong. Aside from measuring the acoustics of register in the language, she states that some of the complexity of the register system in the language derives from it becoming tonal (1991, p.141). Not only does Chong contain four contrastive phonation types, but each of these phonation types is associated with a particular tonal contour, set of vowel quality modifications, and durational properties. The association of multiple phonological and phonetic phenomena used to mark a single phonological entity defines the notion of "register" in Mon-Khmer languages. However, there is not a simple mapping between phonation type and tonal contour. Thongkum (ibid) mentions that there is a tendency of all registers to be realized with higher pitch when they occur on short vowels. Additionally, both the modal and breathy register are realized with a rising pitch when they occur with a coda /h/. In other contexts, these registers appear with a falling pitch. In general, she finds that the clear-tense register has the highest F0 value, appearing with a rise-fall F0 contour in most cases (Thongkum 1988), while the breathy register has the lowest F0 values.

With respect to vowel quality, Thongkum found that both the breathy and breathy-tense register condition a lowering of F1 on the vowels on which they occur, while vowels in the modal and modal-tense register have higher F1 values. F1 lowering correlates with a higher vowel quality. Thus, breathiness on vowels has the result of raising vowel quality in Chong. Thongkum also finds that duration is not a strong cue to the register contrast in Chong, with the exception of the breathy-tense register which is often shorter than the other registers. However, she finds no difference in vowel duration between the other registers.

The four phonation types were analysed by Thongkum (ibid) using power spectra on the acoustic signal. However, she did not find a consistent difference between the registers using this method. Power spectra usually involves a comparison between the amplitudes of the first harmonic (H1) and the second harmonic (H2) a comparison between H1 and the harmonic corresponding to the position of the first formant (A1). The theory behind this method is that more adductive tension between the vocal folds (as found in tense or creaky phonation) causes more rapid closure on each consecutive glottal cycle, which causes the vocal tract to be excited with more energy (amplitude) in the higher harmonics (H2 and A1). By contrast, less adductive tension (as found in breathy phonation) causes slow glottal closure for each consecutive cycle, which means that the higher harmonics are not excited and will have lower amplitude (Ladefoged, Maddieson, and Jackson 1988, Ní Chasaide and Gobl 1997). Thus, one measures the amplitude of higher harmonics to see, albeit indirectly, how tense the vocal folds are during their vibration. Unfortunately, Thongkum only took one measure of power spectra on the vowel. Since Chong has register contours, as noted above, a measure of the power spectra at a single location on the vowel is not suitable to notice an acoustic difference between the phonation types on each register. Rather, what must be examined is the phonation type at separate points across the duration of the vowel.

This *dynamic* method for investigating phonation type is explicitly used in Edmondson's (1997) and Blankenship's (2002) analyses of Chong. Edmondson briefly investigated glottal airflow throughout the duration of selected tokens of the different registers. He found that the breathy and breathy-tense registers have high amplitude glottal airflow at the onset of the vowel while the modal-tense and breathy-tense registers have a marked low amplitude glottal airflow pulses during the second half of their duration, with some concomitant irregularity in the pulse amplitude. This suggests that the registers with breathiness have more airflow mainly during the beginning of the vowel while the registers with tenseness have increased tension and lower airflow over the latter portion of the vowel. This finding agrees with what Thongkum suggests about the modal-tense register: glottal tension is timed toward the end of the vowel. Blankenship examined power spectra at 25 ms. intervals throughout the vowels, focusing on the modal and breathy registers. She found that power spectra can be reliably used to distinguish between these two registers. Contra Edmondson, she also finds that the breathy register has gradually increasing breathiness (and therefore increasing glottal airflow). However, it is not clear that they examined the same dialect of Chong. However, their use of a dynamic measure on the duration of the vowels allowed them to accurately distinguish between Chong registers using acoustic measurments. It is with this dynamic method that I have chosen to analyze Chong register, as it has the ability to capture gradual changes in phonation type and pitch which are relevant to the characterization of register in Chong.

4. The Phonetics of Register

4.1. **Methods.** In order to investigate the register contrast in Takhian Thong Chong, both acoustic and laryngographic (EGG) data from 7 subjects (4 female, 3 male) was acquired where each person repeated words 5 times each in isolation. In total, 39 words were elicited from each subject, chosen from a word-list that I created after spending a few days in the field. The word-list was designed to be balanced so that each register would appear in multiple syllable types, with and without coda laryngeal consonants (/ʔ/, /h/), on short and long vowels. Upon later investigation, some of the words that I elicited turned out to contain long vowels rather than short ones. As a result, there is a balanced list for all registers with long vowels followed by either a coda sonorant (N) or a coda stop (T). It is this list that I examine here. As this is a preliminary study, only 4 out of the 7 speakers were analyzed. Two of these subjects were females (Speakers 2 and 4) and two were males (Speakers 1 and 3). All were between 40 - 75 years old. Due to the loss of connection between the subject's neck and the electrodes, tokens with final stops was not considered for subject 1. Due to time limitations, laryngographic data from subject 4 was not analyzed.

While phonation type in Chong has been indirectly investigated using power spectra, a more direct method of investigating voice quality is with electroglottography (EGG). EGG involves the use of elecrical current to determine the degree of abduction or adduction between the vocal folds. Two electrodes, placed on opposite sides of the person's neck, pass a weak electrical current between each other. The closed period of the glottal pulse allows conductance of the electrical signal while the open period impedes it. If the vocal folds are more closed, then more electrical current can pass between the electrodes, and vice versa. Using this method allows a direct investigation of the movement of the vocal folds, where the main excitation in the signal corresponds to vocal fold closure and the weaker excitation with vocal fold opening (Fourcin 2002). The main excitation corresponds to the maxima in the EGG wave while the weaker excitation corresponds to a slight change in slope before the minima in the EGG wave. However, it is visually difficult to tell the location of this slight change in slope, especially when the vocal folds have longer opening phases during breathy phonation. However, taking the derivative of the EGG signal, computing the difference in slope over successive samples, allows us to clearly see the location of the opening gesture of the vocal folds. This measure, called DEGG, has been used as a reliable measure in the analysis of phonation type in other Mon-Khmer languages, such as Vietnamese (Michaud 2004). It is used here as a method of analysis. Three places along the duration of the DEGG wave were analyzed, at a position 25 ms. after the onset of the vowel, the midpoint of the vowel, and at a position 25 ms. before the end of the vowel. This allows us to view changes in phonation type across the duration, as a dynamic measure. All calculations were made by hand without the use of a script and analyzed using Praat (Boersma and Weenink 2006).

In addition to the EGG measurements, regular acoustic recordings were made, sampled at 22.1 kHz. Measurements of pitch and duration were made on this acoustic signal. Pitch and duration measurements were made with the aid of two scripts. The pitch script measured F0 at 12 evenly divided points across the duration of the vowel. This method allows us to examine pitch dynamically and to make comparisons between the registers because the duration of the vowels is normalized. The duration script simply extracts the vowel duration from the acoustic signal. Both duration and pitch were analyzed and compared using the R Statistical Package (R- Development Core Team).

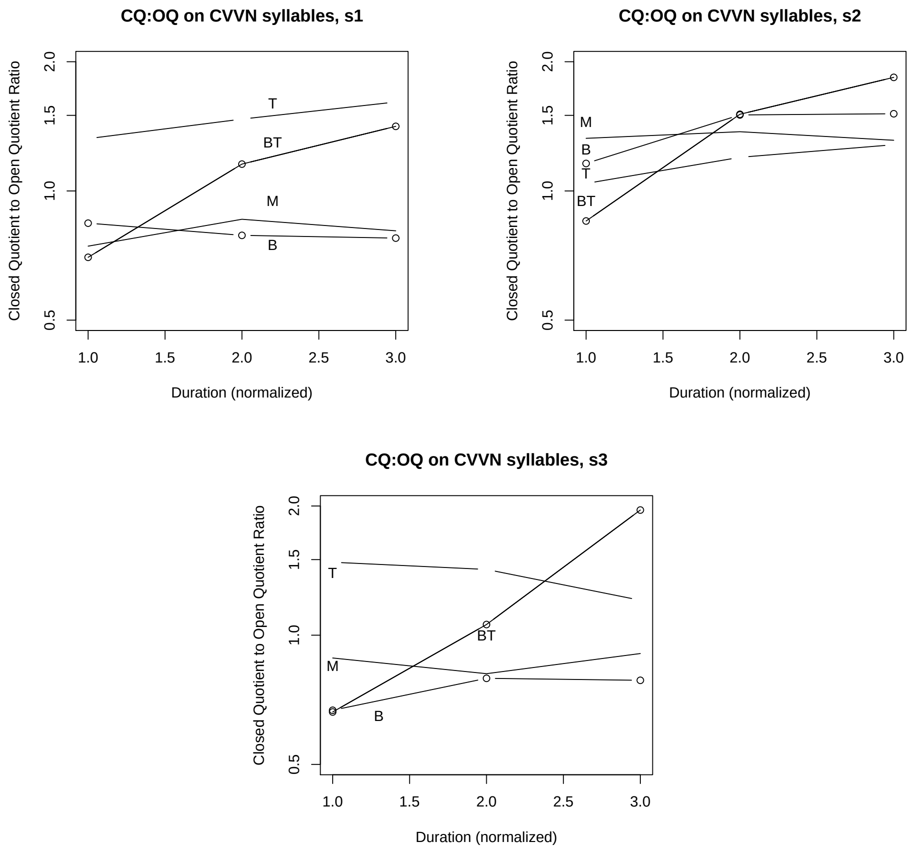
4.2. **Phonation Type.** For the examination of phonation type, eight words for chosen: four with a long vowel followed by a sonorant coda and four with a long vowel followed by a stop coda. Each of the four words used contain one of the four registers found in the language. Data from three speakers was analyzed. The words used in this analysis are given in table (4).

Table 4. Phonation Type Analysis Set

Word	*Register*	*Gloss*	*Syllable Structure*
lɔɔŋ	modal	'stride'	CVVN
ceet	modal	'to sharpen wood'	CVVT
lɔ̰ɔ̰n	modal-tense	'navel'	CVVN
cḛḛt	modal-tense	'deer'	CVVT
ra̤a̤j	breathy	'ten'	CVVN
pa̤a̤t	breathy	'peel'	CVVT
pa̤̰a̤̰j	breathy-tense	'two'	CVVN
kəta̤̰a̤̰k	breathy-tense	'bean'	CVVT

The percentage of the the glottal period where the vocal folds are opened is called the open quotient (OQ) while the percentage of the glottal period where the vocal folds are closed is called the closed quotient (CQ). During tense phonation we expect to have a longer CQ than OQ, due to an increased adductive and longitudinal tension within/between the vocal folds. During breathy phonation, we expect to have a longer OQ than CQ, due to a low adductive tension between the vocal folds. I compared the OQ to CQ ratio on each of these registers. This ratio represents how much constriction there is between the folds. The results for three speakers data (s1-s3) on /CVVN/ syllables is given in Set (1).

Except for the modal register, all registers are realized with some change in CQ:OQ ratio along the duration of the vowel, indicating that all are realized with some degree of movement between a more open state of the glottis and a more closed one. For speaker 2 and 3, the breathy register has a greater CQ:OQ ratio throughout its duration, having low glottal tension (lowest ratio) at the onset of the vowel. For speakers 1 and 2, the modal-tense register gradually increases in

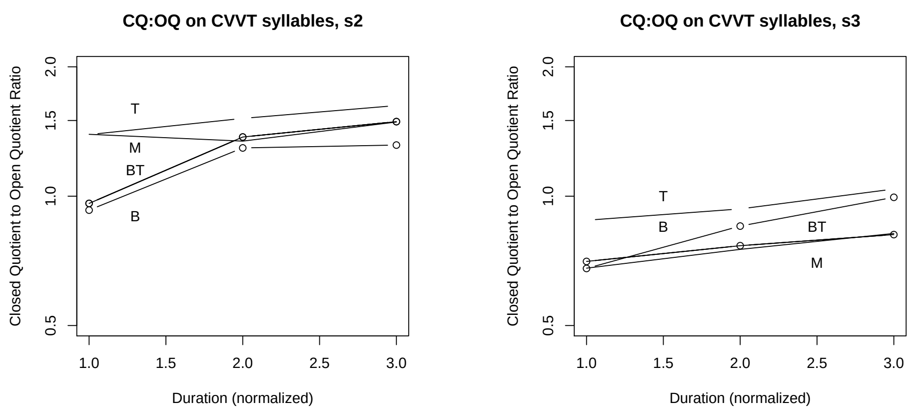


Set 1. Closed Quotient to Open Quotient Ratio
(M=Modal, B=Breathy, T=Modal-Tense, BT=Breathy-Tense)

CQ:OQ ratio, indicating increasing glottal tension toward the end of the vowel. For all speakers, the breathy-tense register is realized with a high magnitude change in CQ:OQ ratio across the vowel duration, where there is low glottal tension at the vowel onset and high glottal tension at the end of the vowel.

Second, we notice that *some* registers are realized with consistently higher or lower CQ:OQ ratios than others. For Speakers 1 and 3, the modal-tense register is realized with the highest CQ:OQ value among the registers, signalling the greatest amount of glottal tension for this register. Similarly, the breathy-tense register for all speakers is realized with high CQ:OQ ratio values at the end of the vowel (where it is predicted to be tensest, given descriptions of it in the literature). Thus, the described glottal tension that is present in both the modal-tense and breathy-tense register is directly observable by extracting the CQ:OQ ratio found on these vowels. The "tense" registers do have increased glottal tension.

However, if we take the modal register as a baseline for each speaker, we do *not* always find that the tense register has a higher CQ:OQ ratio and the breathy register has a lower one. For Speaker 2, the breathy register has a lower CQ:OQ



Set 2. Closed Quotient to Open Quotient Ratio
(M=Modal, B=Breathy, T=Modal-Tense, BT=Breathy-Tense)

ratio than the modal register only in the beginning of the vowel, but actually has a higher CQ:OQ ratio than the modal register and the modal-tense register throughout the latter half of its duration. For the same speaker, the modal-tense register has a lower CQ:OQ ratio than the modal register throughout its duration, but this ratio increases throughout the vowel's duration. It does not directly follow that a phonological register labelled as "tense" could actually involve less glottal constriction as a register labelled "breathy". However, if we are to look instead at the direction of change in the CQ:OQ ratio for this register, we notice that it increases. It is perhaps then, the case that the direction of change in the ratio of CQ to OQ is a significant cue to signalling the presence of glottal tension on the modal-tense register. This seems to follow directly from Thongkum's (1988) first description of this register a *clear-creaky*, stressing the dynamic nature of the register.

Examples with a final stop were considered separately. While final sonorants do not appear laryngealized in Chong, it is not uncommon that final stops surface with concomitant laryngeal gestures in languages of the world (Silverman 1997a). Thus, it is of interest to see how the different registers surface in these contexts. Data from Speakers 2 and 3 is presented in Set (2)

We notice in Set (2) that the registers have similar realizations to Set (1). Similar to the sonorant final cases, we find that the modal-tense register is realized with the highest CQ:OQ ratio of any register, gradually increasing across the vowel's duration. The modal register is not realized with much change in the CQ:OQ ratio throughout its duration. The breathy register rises in CQ:OQ ratio for both speakers, but begins with a very low ratio (breathy) for Speaker 2 while it simply becomes more tense for speaker 3. This would seem to suggest that it is the direction of movement in the CQ:OQ ratio, the gradual increase in glottal tension throughout its duration, that acts as a cue for its realization. This is interesting as it suggests that breathy vowels in Chong are not simply characterized as having a low CQ:OQ ratio, but rather as what Thongkum describes as "dynamic registers."

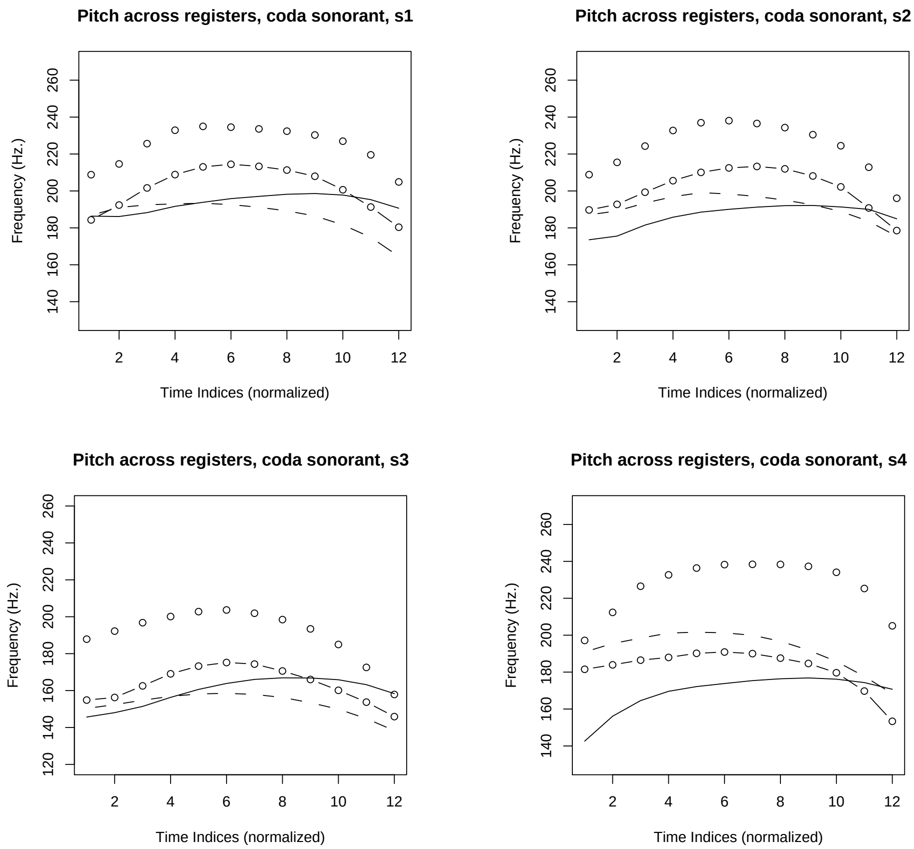
However, the breathy-tense register has a distinct realization in a coda stop environment compared to the coda sonorant environment. This register shows a clear and rapid rise in CQ:OQ ratio when it occurs before a sonorant, but a much more diminished rise when it occurs before a stop. In fact, it does not appear to be distinct from the modal register for Speaker 3, where both are realized with a small rise in CQ:OQ ratio.

4.3. **Phonation Summary and Discussion.** Across both data sets, there is a substantial amount of variation in how the speakers realize the different registers. We may extract a few generalizations however. First, all four registers have a distinct realization for each of the speakers. The breathy register may or may not have a consistently lower CQ:OQ ratio, but usually is realized with some degree of rise in CQ:OQ ratio. It begins in a position of lower glottal tension and increases somewhat. The modal register usually involves a medium degree of glottal tension, having a CQ:OQ ratio somewhere between the modal-tense and breathy register. The modal-tense register is usually realized with the greatest degree of glottal tension, having a high or rising CQ:OQ ratio for all speakers. The breathy-tense register is realized with a low degree of glottal tension at the beginning, but has a large magnitude rise in CQ:OQ ratio on /CVVN/ tokens, but a rise of much lower magnitude when it occurs on /CVVT/ tokens.

Second, both the degree of glottal tension and the relative change in glottal tension appear to be cues to signalling the register contrast in Takhian Thong Chong. For Speaker 2, who produces the modal-tense register with a relatively low CQ:OQ ratio on /CVVN/ tokens, this register still shows a characteristic rise in this ratio, indicating an increase in glottal tension. For Speaker 3, who produces the breathy register with a relatively high CQ:OQ ratio on /CVVT/ tokens, this register still shows a characteristic rise in this ratio, while his tense register is much tenser than the breathy case.

While these data are suggestive, we must not eliminate the possibility that there may be some neutralization in how tense or breathy each of these registers is. Thongkum (1988) suggests that the language is becoming tonal. Indeed, pitch is an additional characteristic cueing the register distinction in the language. However, the investigation of a larger data set may reveal a more solid generalization regarding the degree of glottal tension that is used to distinguish between these registers. Since a limited data set was considered here, no statistical evaluation of these generalizations can be made. However, for both pitch and duration, there are more compelling findings.

4.4. **Pitch.** While much attention is given to the four contrastive phonation types in Chong register, it should be noted that pitch is a very strong cue used to distinguish between registers. Thongkum (1991) mentions how pitch is realized on a number of different registers in Thung Kabin Chong and Ungsitipoorporn (2001) does the same for Khlong Phlu Chong. Their observations are similar. They note that the modal-tense register has a high rising-falling pitch contour. Both dialects have lower pitch for the breathy register, but it is a low-falling pitch contour, where 30 percent of the vowel's duration in the beginning may have a higher pitch than the modal register (Thongkum 1988). The modal register is somewhere between the modal-tense and breathy register in terms of pitch for each of these registers. The



Set 3. Pitch Curves on Different Registers
(Solid Line=Modal, Dashes=Breathy,
Points=Modal-Tense, Dashes and Points=Breathy-Tense)

one difference is that Thung Kabin Chong has a rise-fall contour for the breathy-tense register while the Khlong Phlu dialect has a high falling pitch for this register.

I examined pitch on Takhian Thong Chong vowels, where 3-5 /CVVN/ words were grouped together. This yielded approximately 15-25 tokens analyzed per register per speaker. I found similar results to those mentioned by Thongkum and Ungsitipoorporn, but only for sonorant coda words. In syllables closed by a stop, there is a different pitch pattern on words with the breathy register, the breathy-tense register, and for some speakers, on words with the modal register. The pitch on words with sonorant codas is given for four speakers in Set (3).

For all speakers, the modal-tense register is realized with a high rising-falling pitch contour in sonorant coda contexts. The breathy-tense register also is realized with a rising-falling pitch contour but it is lower in pitch than the tense contour. For Speakers 1-3, it is higher in pitch than the modal or breathy registers, but for Speaker 4, it is slightly lower than the breathy contour in pitch. This seems to be a characteristic of the pitch on this speaker's breathy register though, which is very high. For all speakers, the breathy register is realized with a lower, falling pitch contour, but pitch always seems to begin higher for this register than the modal register, similar to what Thongkum (1988) mentions about the Thung Kabin dialect. For all speakers, the modal register is realized with a slight pitch rise over the first half of the vowel's duration, which is somewhat level for the remainder.

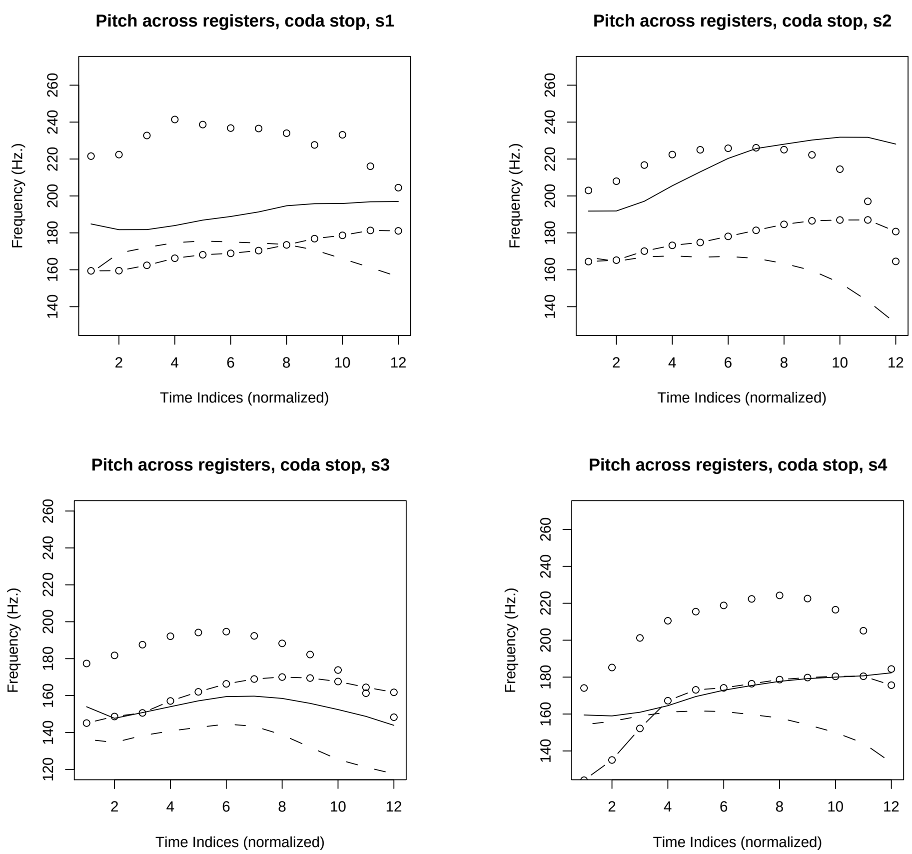
In many ways this description matches what Thongkum (1988) describes for the Thung Kabin dialect. In Takhian Thong Chong, both the modal-tense and breathy-tense register have higher pitch while the breathy register has a lower falling pitch. In order to determine the significance of pitch in distiinguishing the registers, pitch values between registers were compared at time index 2, 6, and 11 for each of the speakers. A table with the results of ANOVA is given in Table (5). These results indicate that pitch is a significant cue in distinguishing the registers from each other across their entire duration for all speakers.

TABLE 5. Pitch Difference Statistics

Speaker	*Time Index*	*ANOVA*	*p-value*
Speaker 1	2	F(3, 90)=28.96	$p < 0.001$ ***
Speaker 2	2	F(3, 87)=43.04	$p < 0.001$ ***
Speaker 3	2	F(3, 90)=62.41	$p < 0.001$ ***
Speaker 4	2	F(3, 88)=39.51	$p < 0.001$ ***
Speaker 1	6	F(3, 90)=28.48	$p < 0.001$ ***
Speaker 2	6	F(3, 87)=52.92	$p < 0.001$ ***
Speaker 3	6	F(3, 90)=54.32	$p < 0.001$ ***
Speaker 4	6	F(3, 88)=62.17	$p < 0.001$ ***
Speaker 1	11	F(3, 88)=47.52	$p < 0.001$ ***
Speaker 2	11	F(3, 87)=76.98	$p < 0.001$ ***
Speaker 3	11	F(3, 88)=69.06	$p < 0.001$ ***
Speaker 4	11	F(3, 88)=111.21	$p < 0.001$ ***

The pitch curves given in (3) are distinct from those found on vowels with a coda stop in Takhian Thong Chong. In particular, the breathy register begins with a lower pitch and falls more in pitch when followed by a coda stop than when followed by a coda sonorant. Furthermore, the breathy-tense register begins much lower in pitch which rises throughout its duration. The modal register also appears to rise more in pitch than it does before a coda sonorant. Data with the pitch curves from /CVVT/ words in Takhian Thong Chong is shown in Set (4).

The effect of coda stops on the pitch of these registers most visibly affects the breathy and breathy-tense register, causing their pitch to be lowered. An interesting aspect of this pitch lowering is that it occurs across the entire vowel. It does not simply occur during the short duration preceding the coda stop. It is well-known that voiceless stops have a tendency to cause pitch lowering in many languages (Hombert, Ohala, and Ewan 1979). However, this effect is non-local, so it can not be explained as a byproduct of phonetic pitch lowering due to the presence of voicelessness. Instead, there may be a phonological difference between the pitch produced on these syllable types. This would suggest that each of these registers has a distinct phonological pitch contour when they occur; i.e. there are two breathy "tones" and two breathy-tense "tones".



Set 4. Pitch Curves on Different Registers
(Solid Line=Modal, Dashes=Breathy,
Points=Modal-Tense, Dashes and Points=Breathy-Tense)

The difference between the pitch found in the words with stop codas and the pitch on words with sonorant codas is statistically significant as well. ANOVA tests examining the predictability of pitch based on the coda consonant confirmed this for each speaker. The results are given in Table (6).

The statistics in Table (6) suggest that the breathy and breathy-tense registers are realized with significantly different pitch when there is a coda stop as compared with a coda sonorant. In particular, the breathy register is realized with lower pitch across its entire duration when it occurs before a coda stop. The breathy-tense register is realized with lower pitch from the beginning to the midpoint of the vowel, but is similar in pitch value near the end of the vowel (at time index 11). For Speakers 2, 3, and 4 the modal register has a slightly higher pitch before the coda stop as it does before the coda sonorant. However, this difference is only marginally significant for speakers 3 and 4, but significant for speaker 2. This agrees well with the data, as Speaker 2's production of the modal register has a very high pitch when it occurs on /CVVT/ tokens, as seen in Set (4).

Table 6. Pitch Differences as a Function of Coda Consonant Type

Speaker	Register	*Time Index*	*ANOVA*	*p-value*
S1	Breathy	2	$F(2, 26)=26.92$	$p < 0.001$ ***
	Breathy	6	$F(2, 26)=24.68$	$p < 0.001$ ***
	Breathy	11	$F(2, 26)=43.60$	$p < 0.001$ ***
S2	Breathy	2	$F(2, 25)=17.14$	$p < 0.001$ ***
	Breathy	6	$F(2, 25)=13.66$	$p < 0.001$ ***
	Breathy	11	$F(2, 25)=57.00$	$p < 0.001$ ***
S3	Breathy	2	$F(2, 27)=18.12$	$p < 0.001$ ***
	Breathy	6	$F(2, 27)=2.07$	$p = 0.146$ ns
	Breathy	11	$F(2, 27)=19.94$	$p < 0.001$ ***
S4	Breathy	2	$F(2, 26)=14.39$	$p < 0.001$ ***
	Breathy	6	$F(2, 26)=10.42$	$p < 0.001$ ***
	Breathy	11	$F(2, 26)=80.97$	$p < 0.001$ ***
S1	Breathy-tense	2	$F(1, 18)=14.91$	$p < 0.005$ **
	Breathy-tense	6	$F(1, 18)=30.13$	$p < 0.001$ ***
	Breathy-tense	11	$F(1, 18)=1.14$	$p = 0.300$ ns
S2	Breathy-tense	2	$F(1, 18)=12.78$	$p < 0.005$ **
	Breathy-tense	6	$F(1, 18)=55.70$	$p < 0.001$ ***
	Breathy-tense	11	$F(1, 18)=0.61$	$p = 0.446$ ns
S3	Breathy-tense	2	$F(1, 18)=2.89$	$p = 0.106$ ns
	Breathy-tense	6	$F(1, 18)=6.07$	$p < 0.05$ *
	Breathy-tense	11	$F(1, 18)=24.24$	$p < 0.001$ ***
S4	Breathy-tense	2	$F(1, 17)=143.70$	$p < 0.001$ ***
	Breathy-tense	6	$F(1, 17)=12.47$	$p < 0.005$ **
	Breathy-tense	11	$F(1, 17)=2.08$	$p = 0.168$ ns

4.5. **Pitch Summary and Discussion.** The results from the analysis of pitch are much clearer than those found with the phonation measure. Modal-tense register has a high rising-falling pitch for all speakers. Breathy register has a low falling pitch for all speakers, but the fall is lower when it occurs before a coda stop. Breathy-tense register occurs with a mid-level rising-falling pitch before a coda sonorant, but with a low to mid rising pitch before a coda stop. Modal register occurs with a relatively level pitch throughout its duration on coda-sonorant rimes, but this pitch rises slightly at the end of coda-stop rimes.

These findings imply a general trend in the association between voice quality and pitch. Increased glottal tension, found on the modal-tense register, occurs concomitant with higher pitch across the vowel. Decreased glottal tension, found on the breathy register, occurs concomitant with lower pitch across the vowel. However, the timing relationship between pitch and phonation does not seem to match across register-type. For instance, for Speakers 2 and 3, there is an increase in CQ:OQ ratio near the end of both breathy and breathy-tense register on /CVVT/ tokens, as shown in Set (2). However, pitch rises on the breathy-tense register and falls on the breathy register, as shown in Set (4). So, there does not seem to be a direct correlation between an increase in glottal tension and an increase in pitch. The same holds for Speakers 1, 2, and 3, on /CVVN/ tokens, where an increase in CQ:OQ across the vowels (Set (3)), does not imply an increase in pitch.

Pitch falls from the midpoint of the vowel to the endpoint on breathy, breathy-tense, and modal-tense tokens in Set (3). On this same duration, glottal tension increases. While there is a connection between relative voice quality and pitch, incremental changes in voice quality and pitch do not seem to be correlated. In order to more definitively address this question, one would need to analyze CQ:OQ ratio on a statistically-viable sample and determine the degree of correlation. This preliminary study suggests no connection, however.

Instead, these findings suggest that each register has a particular tonal melody with which it is associated. This melody is phonological and may phonetically correlate with voice quality in global pitch level, but is not simply a phonetic byproduct of the voice quality of the register on which it occurs. Rather, register is a phonological distinction that includes both voice quality and a tone.

Finally, these findings match those given by Thongkum (1988) for Thung Kabin Chong. In her data, she found that the modal-tense and breathy-tense registers were realized with a high rising-falling pitch contour, as they are in Set (3) for Takhian Thong Chong. Furthermore, she found that the breathy register normally involves a low falling pitch which may begin higher than the modal register. The same observation is found here for Takhian Thong Chong. While Thongkum does not mention it directly, one sees more pitch lowering on the breathy register on /CVVT/ tokens than is found on all breathy tokens in her data. This matches well with the description that we have made about breathy register on /CVVT/ tokens here. However, the breathy-tense register is very different on /CVVT/ words in Takhian Thong Chong. In both Thongkum's (1988) and Ungsitipoorporn's (2001) data, the breathy-tense register is realized as a high falling tone on these words. In Takhian Thong Chong, it is realized with a rise.

4.6. **Duration.** Fischer-Jørgensen (1967) and Kirk et al. (1984) mention that in Gujarati and Jalapa Mazatec (respectively), breathy vowels have longer duration than modal vowels. Silverman (1997b) generalizes on these findings, saying that breathy vowels in languages are longer so that speakers have additional time to perceive the voice quality on the vowel. This finding is also generalized in Gordon and Ladefoged's work (2001, p.393), who state that *"...the overall duration of non-modal vowels is substantially longer than that of modal vowels"*. There is some interest in the literature on the durational properties of vowels with contrastive phonation type. As such, it is of interest to consider how much duration plays a role in the register system of Chong. Thongkum (1988) mentions that duration is a relatively unimportant cue because the language has contrastive vowel length. Both Gujarati and Jalapa Mazatec are free to use duration as a cue to phonation type because they lack a phonological length contrast. However, she does make some observations on vowel duration, mentioning that vowels with the breathy-tense register are shorter than the other registers.

We can clearly determine how vowel duration is affected by register in the language since we controlled for vowel length, having restricted our analysis to long vowels in closed syllables. However, vowel duration can be influenced by other factors distinct from register, such as coda type and vowel quality, often called extrinsic and intrinsic vowel duration (Keating 1985). Since other factors that may cause a change in vowel duration, we must determine how much register plays a role compared to them. We analyzed duration as a function of register and coda type

SET 5. Durational Differences by Register and Coda Type

to see how much each play a role in vowel duration in the language.[1] In addition to the /CVVC/ tokens, two /CVV/ breathy tokens were used as a comparison to see how much of a durational difference there is between open and closed syllables. The same four speakers' data as in Set (3) were analyzed to determine how vowel duration correlates with register. The results are shown in Set (5).

The results in Set (5) indicate that the breathy register consistently occurs with the longest vowel duration of any of the registers, followed by the modal register, then the modal-tense register. Similar to Thongkum's (1988) observation, the breathy-tense register has the shortest duration of any of the registers. Vowel duration differences varied consistently as a function of the register on which they occurred, significantly for each of the speakers. Despite this, the difference in vowel duration between registers was not too substantial between speakers. The breathy-tense register, while shortest among the other registers in Takhian Thong Chong, is only 31-28% shorter than the breathy register for Speakers 1, 3, and 4 and only 5% shorter for Speaker 2. The tense register is between 29-17% shorter than the breathy register for all speakers. The modal register is between 16-13% shorter than the breathy register for Speakers 1, 3, and 4, but the same duration as the breathy register for Speaker 2.

Considering coda type, the results in Set (5) show that vowels on open syllables are longer than vowels that occur on the closed syllables. This finding was significant for all speakers. However, there is not much difference in vowel duration as a function of the coda type on a closed syllables. For Speakers 1 and 3, the vowel is shorter when it occurs before a coda stop, while for speaker 4, the vowel before the coda stop is longer. For Speaker 2 there was no significant difference as a function of coda type. Thus, there were mixed findings with respect to the effect of coda type on vowel duration. Statistical data from both the analysis of duration related to register and stop type is given in Table (7).

The statistics in Table (7) show that vowel duration varied significantly as a function of both register and coda type in Chong. However, a post-hoc Welch 2-sample t-test showed that much of the significance of the Coda Type parameter arose from considering open syllables as a possible coda type (i.e. Ø coda). Thus,

[1]Vowel quality was not able to be considered as the registers were not balanced with respect to different vowels. Therefore, a vowel like /oo/ would appear to be shorter duration because it only appears in a breathy-tense token that was analyzed.

TABLE 7. Duration Difference Statistics

Speaker	*Predictor*	*ANOVA*	*p-value*
S1	Register	F(3, 81)=102.96	p < 0.001 ***
S2	Register	F(3, 77)=14.30	p < 0.001 ***
S3	Register	F(3, 82)=88.94	p < 0.001 ***
S4	Register	F(3, 79)=21.64	p < 0.001 ***
S1	Coda Type	F(4, 81)=55.95	p < 0.001 ***
S2	Coda Type	F(4, 77)=5.19	p < 0.001 ***
S3	Coda Type	F(4, 82)=75.49	p < 0.001 ***
S4	Coda Type	F(4, 79)=6.72	p < 0.001 ***

there is a significant contrast between open syllables and closed syllables in terms of vowel duration (see Table (8), but only some significant difference in duration based on whether the syllable had a stop coda or a sonorant coda for Speakers 1 and 3. The level of significance of register as a duration predictor for all speakers is greater than the level found with Coda Type. This indicates that register plays a greater role (aside from contrastive vowel length) in determining duration than Coda Type.

TABLE 8. Coda Type Post-hoc Test Statistics

Speaker	*Predictor*	*t(df)*	*p-value*
S1	Coda stop vs. Coda sonorant	t(82.9)=-3.3	p < 0.005 **
S1	Coda stop vs. Open syllable	t(12.1)=-18.1	p < 0.001 ***
S1	Coda sonorant vs. Open syllable	t(15.2)=-14.8	p < 0.001 ***
S2	Coda stop vs. Coda sonorant	t(41.6)=0.7	p = 0.497 ns
S2	Coda stop vs. Open syllable	t(20.1)=-4.5	p < 0.001 ***
S2	Coda sonorant vs. Open syllable	t(14.2)=-5.5	p < 0.001 ***
S3	Coda stop vs. Coda sonorant	t(86.7)=-3.4	p < 0.005 **
S3	Coda stop vs. Open syllable	t(9.5)=-10.5	p < 0.001 ***
S3	Coda sonorant vs. Open syllable	t(10.5)=-9.2	p < 0.001 ***
S4	Coda stop vs. Coda sonorant	t(48.2)=-2.3	p < 0.05 *
S4	Coda stop vs. Open syllable	t(16.3)=-7.4	p < 0.001 ***
S4	Coda sonorant vs. Open syllable	t(12.5)=-9.6	p < 0.001 ***

4.7. **Duration Summary and Discussion.** While the phonological vowel length contrast must be a strong predictor of observed phonetic vowel duration, register also has a significant role in explaining the variance in vowel duration in Takhian Thong Chong. While Thongkum (1988) did not mention vowel duration as a strong cue for register in Thung Kabin Chong, it functions as a cue to register in Takhian Thong Chong. In particular, breathy vowels have the longest duration, followed by modal, and then modal-tense and breathy-tense. This finding is in agreement with findings by Fischer-Jørgensen (1967) and Kirk et al. (1984), who find that breathy vowels in Gujarati and Jalapa Mazatec also have long duration. However, it is not the case that all vowels with non-modal phonation are necessarily longer than those with modal phonation. Vowel duration is affected differently by vowels with increased glottal tension and vowels with decreased glottal tension, the former having shorter duration.

There is perhaps a historical reason for the development of longer phonetic duration on breathy vowels and shorter phonetic duration on tense or (hypothetically) creaky vowels. Breathy vowels often derive from historically aspirated initial stops. In these cases, the loss of the duration of aspiration following the stop may cause the vowel to undergo compensatory lengthening. As a result, a longer vowel occurs with breathy phonation. On the other hand, glottal tension often derives from a historical glottal stop at the end of the vowel. Final glottal stops may cause vowel shortening if the vowel is shorter before voiceless stops as a general phonetic trend. We know that this is true synchronically for some speakers in Takhian Thong Chong, as shown in Set (5), but it is also true for a variety of other languages, as suggested by Chen (1970). Rather than suggesting that vowel duration of non-modally phonated vowels is synchronically-related to some active parameter of enhancement, it may be directly motivated by its historical origin.

5. Discussion

5.1. **Summary.** We have explored three major acoustic domains which comprise the four-way phonological contrast in register in Takhian Thong Chong. An analysis of the acoustic parameters for voice quality (closed quotient to open quotient ratio), pitch, and duration suggest that the register system in this language utilizes all three of these prosodic cues. Each register can therefore be defined as follows:

(1) *Modal Register* is characterized with modal phonation which remains modal throughout the duration of the vowel, a mid-level pitch which remains level before sonorant codas, but rises before stop codas, and average duration compared with other vowels of the same length.
(2) *Modal-Tense Register* is characterized with modal to tense phonation at the vowel onset, which increases in magnitude throughout the vowel's duration, a high rising-falling pitch contour, and slightly shorter duration than either breathy or modal vowels.
(3) *Breathy Register* is characterized with breathy phonation at the beginning of the vowel, that gradually becomes slightly more tense throughout the vowel duration, often resembling the modal register. Before a coda sonorant, it begins at a level pitch slightly higher than the modal register and falls throughout its duration. Before a coda stop, it begins at a pitch level lower than the modal register and falls throughout its duration to a very low pitch. It is characterized as having a longer duration than all registers.
(4) *Breathy-Tense Register* is characterized with breathy phonation at the beginning of the vowel which quickly changes to tense phonation across the vowel duration. Before a coda sonorant, it is realized with a mid rising-falling pitch contour. Before a coda stop, it begins with a very low pitch which rises to mid throughout the vowel's duration. It is characterized as having the shortest duration among all registers.

5.2. **Commentary.** A general trend that one sees in Chong register is the dynamic nature of all nonmodal registers. Each of the registers with non-modal phonation increase in glottal tension throughout their duration, but may begin breathy or tense phonation. This suggests that it is the dynamic nature of these registers that characterizes them. In fact, we may even label the breathy register as "breathy-modal" since it increases in glottal tension across its duration. Phonologists have described tone languages where a vowel with a contour tone, like a fall, is represented as a sequence of High and Low Tones, associated sequentially via autosegmental phonology. However, the same type of representation fits the Takhian Thong Chong data shown here, where dynamic registers may be represented sequentially with laryngeal features. For instance, each of the registers may be represented on Chong vowels as in Table (9).

Table 9

Modal Vowel	[-constricted glottis]
	[-spread glottis]
Modal-Tense Vowel	[-constricted glottis][+constricted glottis]
Breathy-Modal Vowel	[+spread glottis][-spread glottis]
Breathy-Tense Vowel	[-constricted glottis][+constricted glottis]
	[+spread glottis][-spread glottis]

The only potential issue with this representation in Table (9) is that the modal-tense register may actually have some glottal constriction at the beginning of the vowel. However, this representation captures the change in phonation type observed over the vowel duration in Takhian Thong Chong. Similar to tone, phonation type is capable of having contours, where more than one laryngeal feature may be specified per vowel[2].

The dynamic nature of Chong register implicitly supports the method of analysis chosen here. A dynamic measure of phonation type and pitch, where temporal information is included, allows us to capture precisely those phonetic characteristics that are pertinent to the phonological contrast in register. Dynamic prosodic contrasts can not be captured with static phonetic measures.

If Chong were a phonation-type language where voice quality is the major acoustic correlate of the prosodic contrast in the language, then we would expect that pitch would correlate with voice quality. Voice quality influences pitch in many languages (Silverman 1997a), so we would expect changes in voice quality to correlate with changes in pitch. However, the presence of *distinct* pitch contours that do not correlate with voice quality suggests that the language has lexical tones; pitch changes are not simply phonetic byproducts of phonation type. While these pitch contours may be associated with voice qualities, they are phonetically independent from them. We can therefore reject the hypothesis that pitch is only a *phonetic* result of changes in phonation type across vowels. This finding matches closely Thongkum's description of Chong (1991) suggesting that the language is in the process of becoming tonal.

The strong effect of final stops on the pitch across vowels suggests that Chong has either two distinct allotones that are conditioned on long vowels before coda stops or 6 distinct tones that occur on four contrastive phonation types. Allotones before voiceless stop codas are not uncommon within Southeast Asia. They occur in Thai-Phake (Rose 1990) and Hong Kong Cantonese (Rose 2004). However, Rose (2004) comments that a strong phonetic similarity between a tone before a sonorant coda and one before a stop is usually a prerequisite to calling the latter allotonic. If we observe the two distinct tones shown in Set (4), we see that the pitch on

[2]While in many tone languages tone is associated to larger prosodic units, like rimes or syllables, register is a feature of vowels in Mon-Khmer languages (Henderson 1985)

the breathy-tense register is very distinct from the pitch on the same register in Set (3). The former is higher in pitch and has a rising-falling contour. The latter has a low-mid rising pitch. There is little phonetic similarity between these two pitch contours, even though they occur on the same register. A similar observation is found with the pitch contour on the breathy register. Before a coda sonorant, it always begins at a pitch level higher than the modal register and falls. In this context, it could be called a mid-low falling tone. Before a coda stop, it begins very low and continues to fall. In this context, it is a low falling tone. These are similar because they both fall, but the pitch level difference between them is significantly different across the entire vowel duration. In terms of pitch, these two conditioned patterns represent additional phonological tones because they are phonetically distinct from all the other tones. If so, then we are forced to say that four phonation types cross-classify with six lexical tones. However, the problem of classifying these pitch contours in the phonology of Chong is difficult unless an independent perceptual experiment were carried out to determine how speakers classify them.

The prosodic distinction between vowels in Takhian Thong Chong consists of a complex system where phonation type and pitch are independent phonological parameters put together in distinct "phonological bundles" (Thurgood 2000) called *registers*. The fact that Chong has a 4-way contrast in register makes it exceptional from a typological viewpoint, especially since each register's phonation type is distinct. The presence of distinct tones appearing before final stops indicates that Takhian Thong Chong has an added layer of phonological complexity, where there are potentially six possible tones occurring with these registers. The results of the acoustic phonetic analysis of the register distinction in this language add support to the view that the specific timing relationship of laryngeal configurations across the syllable is relevant in marking phonological distinctions in languages of the world. This argues in favor for phonological models which include the ability to represent temporal dynamics not only between prosodic units, but within them.

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