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# Interaction between breathy tones and aspirated consonants in S'gaw Karen

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## Abstract

This instrumental study first describes the five lexical tones in S'gaw Karen and their interaction with breathy, creaky and modal phonation types. It is found that there is a phonotactic restriction on onset consonant and phonation. The combination of an aspirated onset with a breathy high tone is exceptionally rare and an aspirated onset does not co-occur with a breathy low tone. Acoustically, the aspiration release causes breathiness at vowel onset, while tonal breathiness is distinguished from the consonant breathiness in terms of timing and magnitude. In addition, an aspirated stop has a shorter VOT with a breathy tone than with a modal tone. It appears that onset VOT is correlated with tones in S'gaw Karen. These findings demonstrate that the gap of $C^h$V̤ might result from avoidance of the ambiguity between the phonological vowel breathiness and the phonetic breathiness overlapped from the aspirated onset.

**Index Terms**: S'gaw Karen, breathy phonation, consonanttone interaction

## 1 Introduction

S'gaw Karen is a Tibeto-Burman language spoken in Burma and Thailand by approximately 1.5 million people (Ethnologue, 2015). Because the Karen people are a marginalized ethnic minority in Burma, their language has been understudied. Gilmore (1898) provided an impressionistic description of the sound system of S'gaw Karen based on the orthography. Recent works (Ratanakul, 2001; Brunelle & Finkeldey, 2011; Fischer, 2013; Rattanaporn, 2014) collected production and perception data and found that nonmodal phonation (breathy or creaky voice) accompanies certain lexical tones. However, there were differing conclusions on the tonal properties.

The goals of this study are to describe the acoustic properties of S'gaw Karen tones and to further understand the breathy phonation from the perspective of consonant-tone interaction. The vowels following an aspirated stop have been determined to be breathier than those vowels following an unaspirated stop (Garellek, 2011; Cho, Jun & Ladefoged, 2002). An experiment on Shimenkan Miao (Kong, 1993) demonstrated that voiced aspiration is a breathy voice which appears not only in voiced aspirated consonant but also in the entire rhymes. Those studies indicated that consonant breathiness is phonetically realized as a breathy aspirated release into the following vowel. Esposito and Khan's (2012) research on Gujarati and White Hmong, both of which have phonemic voiced aspirated onset and breathy vowel, demonstrates that consonant breathiness can affect vocalic breathiness but breathy vowels are acoustically different from post-aspirated vowels in the two languages. Following the previous findings that consonant aspiration affects vowel breathiness, the current study focuses on the interaction between onset aspiration and breathy tones in S'gaw Karen and aims at to shed light on the discussion of consonant breathiness and vocalic breathiness.

## 2 Methods

A 25-year-old native male speaker participated in the elicitation and recording sessions at the department of linguistics at University at Buffalo. His first language and primary daily life language is S'gaw Karen, and his second language is Burmese. He currently lives in the United States and he is fluent in English. First, a combination of translation, pronunciation judgments, spontaneous response and minimal pair judgments was used during the early elicitation courses in order to obtain the phonemic inventory. After the phonemes were established based on minimal pairs, a list of CV words written in Karen orthography involving all the possible combinations of consonants, vowels and tones was given to the subject. He was asked to judge whether there exists such a word. If it was a real word, he was asked to read the word three times in isolation. His utterance was recorded with a Marantz Professional PMD660 audio recorder. The acoustic analysis was performed using Praat (Boersma & Weenink, 2005).

## 3 Sound system of S'gaw Karen

### 3.1. Vowels and Consonants

From the elicitation process and acoustic examination, the phonemic inventory consisting of 25 consonants and 9 vowels was observed: /b, p, $p^h$, d, t, $t^h$, k, $k^h$, ʔ, θ, s, ʃ, x, ɣ, ɦ, h, d͡ʒ, t͡ʃ, ɹ, l, m, n, ɲ, w, j/ and /i, ɛ, e, ɨ, ə, a, u, o, ɔ/. There are two differences in the consonant inventory between this report and Gilmore's (1898) descriptions. First, three consonants /g, ŋ, $s^h$/ reported by Gilmore are not observed in this study. Second, Gilmore found that /d͡ʒ/ was a nonnative sound which used to represent the English letter *j*. However, /d͡ʒ/ and /t͡ʃ/ are uncovered in many daily life words in this study, such as /t͡ʃɔM/ ('older brother') and / d͡ʒɔM/ ('chicken') ('M' symbolizes a mid modal tone). The vowel categories agree with Gilmore's observation and other previous research (Ratanakul, 2001; Brunelle & Finkeldey, 2011). Vowel transcriptions provided in this paper are based on both minimal pair contrasts and acoustic measurements of the first and second formants of the recorded vowels in the CV sets. In terms of syllable structure, a syllable has an optional onset or onset cluster and has no coda: (C)(C). A glottal stop only co-occurs with two glottalized tones. In many cases, final creakiness of the vowel is observed without a clear glottal stop when the two tones are produced. Therefore, the glottal stop can be considered as a tone feature, instead of a coda consonant. Detailed descriptions of the phonological system of S'gaw Karen will be reported in a future paper.

### 3.2. Tones

Tones are represented orthographically in the Burmese-derived script with six distinct tone markers. However, the number of


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tones is controversial (cf. Brunelle & Finkeldey, 2011; Rattanaporn, 2014). The consultant for this project indicated five lexical tones. According to the speaker, the sixth written tone is pronounced and perceived exactly the same as one of the five tones, which is labeled as Glottalized Low Tone in this paper. It is possible that there was a historical merger of the two tones. Or, the consultant's dialect does not have the sixth tone in spite of the orthography.

Based on the five observed minimal sets, acoustic measurements of tones are given in Table 1. Plotted pitch contours of the five tones based on the average F0 (5 points at every 20% of the tonal duration) and duration values from 3 repetitions of /nɔ, ma, me, wa, lɛ/ are shown in Figure 1.

Voice quality is measured by the aplitude difference between the first and second harmonics (H1-H2), which has been identified as the most salient acoustic property of breathy phonation in many langauges as divers as Jalapa Mazatec (Garellek & Keating, 2010), Green Mong (Andruski & Ratliff, 2000), Takhian Thong Chong (DiCanio, 2009). Andruski and Ratliff (2000) explained the usefulness of this measure; values of H1-H2 around +5dB indicate breathy phonation, values around -5dB indicate creakiness, and values close to zero indicate modal voicing.

**Table 1.** *Average acoustic measurements of F0, tone duration, and spectral tilt from the recordings of the three repetitions of each word, and phonation type of the five lexical tones in S'gaw Karen.*

| Tone | F0 (Hz) | | | Duration | H2-H1 (midpoint) | Phonation type |
|---|---|---|---|---|---|---|
| | Average | Onset | Offset | | | |
| Glottalized High | 122 | 132 | 112 | 112ms | 6.8dB | Creaky |
| Glottalized Low | 93 | 107 | 78 | 120ms | 5.1dB | Creaky |
| Modal Mid | 111 | 112 | 110 | 356ms | -3.4dB | Modal |
| Breathy High | 111 | 120 | 102 | 230ms | -10.1dB | Breathy |
| Breathy Low | 94 | 99 | 84 | 244ms | -9.8dB | Breathy |

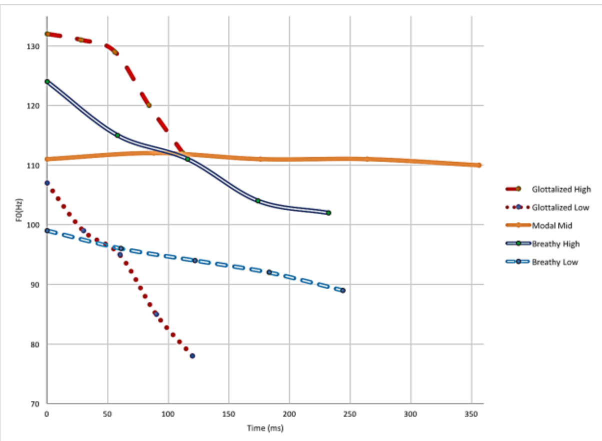


**Figure 1.** *Plotted pitch contours of the five tones in S'gaw Karen.*

Table 1 and Figure 1 show that the five tones differ in phonation, pitch height and duration. Modal Mid Tone is the only modal tone (H2-H1= -3.4dB), and it has the longest duration (356ms), relatively mid pitch and relatively level pitch contour. Glottalized High Tone and Glottalized Low Tone are short (112 ms, 120ms) and creaky (H2-H1= 6.8dB, 5.1dB), but the Glottalized High Tone is 29Hz higher than the Glottalized Low Tone. There is steep falling slope for the two glottalized tones with a short duration. The short duration might be a result of a glottal stop or final creakiness of the bowel. Breathy High Tone and Breathy Low Tone are both breathy (H1-H2= -10.1dB, -9.8dB) but they can be distinguished by pitch height (19Hz). Breathy High Tone has the average pitch hight as Modal Mid Tone does (111Hz) but Breathy High Tone (-10.1dB) is substantially breathier than the Modal Mid Tone (-3.4dB). Breathy Low Tone and Glottalized Low Tone have similar average pitch heights (94Hz, 93Hz) and pitch contour. However, the two tones contrast in phonation and breathy tones have shallower slopes than glottalized tones do. Although the five tones also contrast in duration, they can be clearly distinguished based on phonation and pitch height, illustrated in Table 2 below.

**Table 2.** *Tonal categories expressed in terms of features.*

| | | |
|---|---|---|
| +Glottalized | +High | Glottalized High Tone (GH) |
| | +Low | Glottalized Low (GL) |
| +Breathy | +High | Breathy High (BrH) |
| | +Low | Breathy Low (BrL) |
| Unmarked | Unmarked | Mid Tone (M) |

## 4 Interaction between breathy tones and aspirated consonants

In order to investigate the interaction between the aspirated onset and breathy tones, phonological distribution as well as acoustic measurements were analyzed.

For phonological distribution, CV combinations were constructed from onset /p, $p^h$, k, $k^h$, t, $t^h$/, all nine vowels and all five tones. The speaker then judged whether such a combination exists in S'gaw, e.g., /piM, piBrH, piBrL, piGH, piGL/. Table 3 indicates the numbers of real words for each consonant-tone group. For each consonant-tone group, there are nine possible words, e.g., /p/ with nine vowels /i, ɛ, e, ɨ, ə, a, u, o, ɔ/.

**Table 3.** *Numbers of real words for consonant-tone groups and the phonological distribution of $C^h$V̤.*

| Onset | Glottalized High | Glottalized Low | Modal Mid | Breathy High | Breathy Low |
|---|---|---|---|---|---|
| p | 6 | 6 | 7 | 5 | 6 |
| t | 5 | 6 | 8 | 9 | 7 |
| k | 5 | 6 | 8 | 9 | 7 |
| $p^h$ | 6 | 6 | 9 | 1 | 0 |
| $t^h$ | 6 | 5 | 9 | 3 | 0 |
| $k^h$ | 5 | 5 | 9 | 0 | 0 |

Only four real words consisting of an aspirated consonant and a breathy tone are observed: /$t^h$ɛBrH/ ('till'), /$t^h$uBrH/ ('dull sound'), /$t^h$ɨBrH/ ('make a sound'), and /$p^h$ɔBrH/ ('measure weight'). The combination of aspirated onset and Breathy Low Tone does not exist. Therefore, the existence of $C^h$V̤ is apparently limited, compared with the greater number of real words consisting of an unaspirated onset or a nonbreathy tone. Regardless of vowel quality, there is a gap of $C^hV^{BrL}$ and an avoidance of $C^hV^{BrH}$ in the system of S'gaw Karen. This observation suggests that consonant-tone interaction plays a role in phonotactics in S'gaw Karen.

The $C^h$V̤ word /$t^h$ɛBrH/ together with words /tɛM/ ('say'), /tɛBrH/ ('bag'), /toGH/ ('grain'), /$t^h$ɛM/ ('bamboo weaving'), and /$t^h$ɔGH/ ('climb') form an aspiration-tone set, which includes two conditions of aspiration and three conditions of tone phonations. Each word in the aspiration-tone set was recorded in isolation with three repetitions.

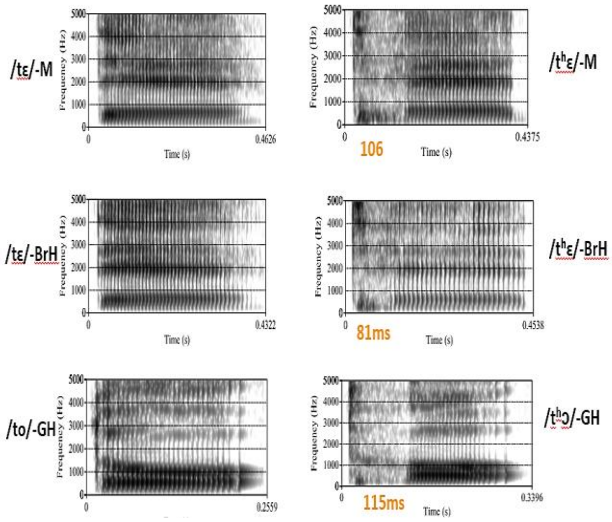


**Figure 2.** *Spectrograms of the consonant-tone set illustrating VOT and third formant noise in different consonant onset and tone conditions.*

Figure 2 provides the spectrogram comparison between aspirated and unaspirated conditions, and comparison between modal phonation and non-modal phonation. When /t$^{h}$/ differs in tonal situations, its VOT varies based on phonation. The VOT is longer with Glottal High Tone (115ms) than with Modal Mid Tone (106ms) than with Breathy High Tone (81ms). In addition, through visual examination, there is a dissimilarity in third formant between unaspirated and aspirated onset, and between Modal Tone and Breathy Tone. In /tɛM/, the third formant bands are dark and clear, indicating that there is no aspiration noise throughout the entire vowel. The third formant is relatively faint in /tɛBrH/ in comparison with /tɛM/. Moreover, third formant in /t$^{h}$ɛBrH/ are fainter than in /tɛBrH/. Comparing /t$^{h}$ɛ/ with /tɛ/, more aspiration noise around third formant at vowel onset in /t$^{h}$ɛ/ can be seen. As aspiration noise is one of the crucial cues of breathiness (Klatt & Klatt, 1990), the third formant differences suggest that aspirated onset leads to breathiness in the vowel onset and possibly enhances the vowel breathiness when there is a Breathy High Tone.

Onset VOT and vowel breathiness are measured in order to test the observations in the spectrograms. Spectral tilt (H2-H1) measurements were conducted on the vowels in the consonant-tone set, as shown in Table 4. VOT values were obtained from the recording of words with /p, p$^{h}$, t, t$^{h}$/ onset and all the five tones, given in Table 5.

**Table 4.** *Average spectral tilt values at the onset, midpoint and offset of the vowels in three repetitions of /tɛM, tɛBrH, t$^{h}$ɛM, t$^{h}$ɛBrH, toGH, t$^{h}$ɔGH/.*

| H2-H1 (dB) | tɛM | tɛBrH | t$^{h}$ɛM | t$^{h}$ɛBrH | toGH | t$^{h}$ɔGH |
|---|---|---|---|---|---|---|
| Onset | -3.1 | -6.5 | -7.0 | -8.5 | 2.6 | -1.3 |
| Midpoint | -3.4 | -9.9 | -6.2 | -10.4 | 2.7 | 2.8 |
| Offset | -4.2 | -9.5 | -5.3 | -8.2 | 3.2 | 2.9 |

**Table 5.** *Average VOT values in three repetitions of /p$^{h}$ɔM, p$^{h}$ɔBrH, p$^{h}$ɔGH, p$^{h}$ɔGL, t$^{h}$ɛM, t$^{h}$ɛBrH, t$^{h}$ɔGH, t$^{h}$ɔGL, pɔM, pɔBrH, pɔBrL, puGH, peGL, tɛM, tɛBrH, tɛBrH, toGH, toGL/.*

| VOT (ms) | M | BrH | BrL | GH | GL |
|---|---|---|---|---|---|
| p$^{h}$ | 121 | 98 | NA | 130 | 126 |
| t$^{h}$ | 112 | 85 | NA | 119 | 115 |
| p | 6 | 2 | 3 | 8 | 8 |
| t | 9 | 5 | 4 | 10 | 9 |

In Table 4, it can be seen that (1) the vowel onset in /t$^{h}$ɛM/ is breathier than in /tɛM/; (2) /t$^{h}$ɛM/ has a less breathy vowel than /tɛBrH/ does, especially in the second half of the vowel, but /t$^{h}$ɛM/ shows a breather vowel onset than /tɛBrH/ does; (3) the vowel in /tɛBrH/ is breathier than in /tɛM/ through the entire vowel; (4) the second half of the vowel in /tɛBrH/ is breathier than the first half; (5) /t$^{h}$ɛBrH/ is generally breathier than /tɛBrH/ but is not clear that whether breathiness is stronger in the first or second half of the vowel in /t$^{h}$ɛBrH/; and (6) /t$^{h}$ɔGH/ is less creaky at the vowel onset than /tɔGH/ is. When onset aspiration occurs, the following vowel onset becomes breathy or less creaky. Thus, consonant aspiration does leads to vowel breathiness at the beginning of the vowel. The consonant breathiness is stronger than the tone breathiness only at the vowel onset. As the vowel production continues, tone breathiness increases but consonant breathiness decreases (e.g., /t$^{h}$ɛM/ and /tɛBrH/). Breathy High Tone is characterized with a production of breathiness on the latter part of the vowel. Therefore, consonant and tone breathiness differ in timing and degree of breathiness. Consonant breathiness concentrates at the vowel onset, while vowel breathiness is produced primarily on the second half of the vowel. When onset aspiration and tonal breathiness co-occur in /t$^{h}$ɛBrH/, breathiness is produced from the vowel onset to the offset to a greater extent. However, whether the second half of the vowel has primary breathiness is less clear. If the cue of a breathy tone is the increase of breathiness along with the vowel duration, C$^{h}$V̤ is a less salient environment for the identity of the breathy tone in terms of providing the cue.

Another observation related to consonant identity can be made based on VOT variations in different tonal environments, as shown in Table 5. Comparing /t$^{h}$BrH, phBrH/with / t$^{h}$M, phM/, the VOT values in the breathy tone conditions are less (25ms average) than in the modal tone condition. The breathy tone conditions also exhibit shorter VOT (31ms average) than creaky tone conditions (/t$^{h}$GH, phGH, t$^{h}$GL, phGL/).Yet, modal tone and creaky tone conditions do not have obvious difference in VOT (5ms average) of /t$^{h}$, p$^{h}$/. Onsets /t, p/ exhibit the same pattern that breathy tones are associated with shorter VOT. And /t, p/ have slightly longer VOT (1.25ms average) with a creaky tone than with a modal tone. Without sufficient data, it is difficult to determine whether the VOT difference in breathy tone condition is significant, but the tendency is clear that aspirated onset is associated with shorter VOT when there is a breathy tone.

## 5 Conclusion and Discussion

In S'gaw Karen, C$^{h}$V̤ combinations are actively avoided in the phonology. There are uncommon cases of C$^{h}$V$^{BrH}$ and no case of C$^{h}$V$^{BrL}$, but aspirated onsets can co-occur with the modal and creaky tones. This phonotactic constraint is related to the contrast between consonant breathiness and tone breathiness. By examining aspiration noise around the third formant and H1-H2 values, it is found that onset aspiration spreads breathiness to the first half of the vowel while tone breathiness occurs in the latter part of a vowel. At the vowel onset position, consonant breathiness is greater than the tone breathiness merely, but the tone breathiness increases considerably at and after the midpoint of the vowel. Therefore, consonant breathiness and vocalic breathiness are distinguishable at the vowel onset and within the second half of the vowel.

In the rare C$^{h}$V$^{BrH}$ words, the production of breathiness is carried throughout the entire vowel to a greater extent than in C$^{h}$V and CV$^{BrH}$ words. However, it is unclear where the breathiness starts and which half of vowel is relatively breathier. Comparing the C$^{h}$V and CV$^{BrH}$ conditions, the timing cue is therefore less available in the $C^hV^{BrH}$ environment. The gap of $C^h\underset{..}{V}$ might be a result of avoidance of ambiguity between vowel breathiness and the breathiness overlap from the aspirated onset.

It is also found that there is a difference in VOT as a function of phonation. The VOT is shorter when the onset consonant is followed by a breathy vowel. The shortening effect is more obvious for the aspirated onset, as the VOT in breathy tone conditions is approximately 25ms shorter than in the modal tone condition and 30ms shorter than in creaky tone conditions. Considering long VOT is crucial for producing an aspirated stop, the dispreference of shortened VOT in S'gaw Karen limits the distribution of the aspirated consonants and breathy tones.

These findings indicate that the identity of breathiness as well as VOT status may have an effect on the phonotactics in S'gaw Karen. Since it has been reported that aspirated stops have a restricted distribution in Takhian Thong Chong, as they can only be the onsets of modal vowels (DiCanio, 2009), this phonotactic phenomenon might have a phonetic basis. From a phonological perspective, an aspirated onset involves the [+spread glottis] feature docking on the following vowel and a breathy tone also provides a [+spread glottis] on the vowel. It can be hypothesized that a vowel can only hold one [+spread glottis] in S'gaw Karen.

The the nonexistence of $C^hV^{BrL}$ could be a result of a thorough application of the phonotactic rule. However, it is possible that historical change occurred to the aspirated onset: $*C^ɦ > \mathring{C}^h$. The voiced aspirated onset initiated the breathy phonation with low pitch. When the breathy low tone maintained in the phonology, the voiced aspirated consonants merged with voiceless aspirated consonants. Since aspirated voiced consonants were found to be the source of low breathy tones in Hmong languages (Kong, 1993; Esposito et al., 2012), future investigation on the historical change of the Breathy Low Tone in S'gaw Karen will be conducted. Furthermore, production data from additional participants will be evaluated in the future.

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