The production of aspirated fricatives in Sgaw Karen

Hugo Salgado, Jessica Slavic & Ye Zhao

University of North Carolina at Chapel Hill
asalgado@live.unc.edu, jslavic@live.unc.edu, zhaoye@live.unc.edu

Aspirated fricatives are rare sounds cross-linguistically. This study focuses on the phonetic description of the aspirated coronal fricative /sʰ/ in Sgaw Karen. Our phonetic study found that aspiration in /sʰ/ is significantly shorter than aspiration in aspirated stops in Sgaw Karen. However, it behaves analogously to aspiration in stops in that it is significantly longer than in its unaspirated counterpart. Nevertheless, an important difference is found: while aspiration duration in stops is not affected by the height of the following vowel, aspiration in /sʰ/ significantly decreases as the height of the following vowel increases. Our research suggests that high vowels lengthen frication duration in /sʰ/, which then shortens aspiration duration. This indicates that friction and aspiration compete in the total segment duration, and that frication dominates aspiration duration. The competition between friction and aspiration may account for the rarity of aspirated fricatives cross-linguistically, since aspiration is subject to significant reduction to accommodate contexts that lengthen frication duration. When this reduction occurs, aspiration after Sgaw Karen fricatives in certain contexts is comparable to voice onset time of unaspirated stops, which means aspiration in these instances may be hard to distinguish perceptually. As a result, these aspirated fricatives may be more likely to merge with their unaspirated counterparts by losing their aspiration, as attested in modern Burmese.

1. Introduction

The Karen family of languages is a branch of the Tibeto-Burman subfamily of the Sino-Tibetan languages (Benedict 1972, 127). As the

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most widely spoken of the Karen languages, Sgaw Karen has approximately 1,480,000 speakers in Myanmar and Thailand (Ethnologue 2012). Typologically speaking, like other members of the Tibeto-Burman family, Sgaw is a tonal language with a system of probably 6 contrasting tones and an isolating morphology. In terms of syntax, the Karen languages are noteworthy within Sino-Tibetan for changing the almost canonical Sino-Tibetan SOV word order into an SVO word order (Manson 2009). Sgaw Karen also possesses a rare and understudied two-way phonemic contrast in voiceless coronal fricatives: unaspirated /s/ and aspirated /\textipa{\textit{\text{sh}}}/, along with a more cross-linguistically represented three-way phonemic contrast in stops: voiced, voiceless unaspirated, and voiceless aspirated. This study focuses on the phonetic description and properties of the rare aspirated coronal fricative /\textipa{\textit{\text{sh}}}/ in Sgaw Karen.

2. Aspirated fricatives

Aspiration has been defined as the interval of aperiodic noise of glottal origin that follows the release of some obstruents (Johnson 1997). Aspiration is most common in stops. As can be seen in Figure 1 below, aspirated stops in Sgaw Karen feature an interval of aspiration between the release of the stop (signaled by the short stop burst in the spectrogram) and the beginning of the following vowel (signaled by the onset of periodic waves in the spectrogram); in contrast, unaspirated stops in Sgaw Karen show little or no aspiration at all between the stop release and the beginning of the vowel.

![Figure 1. Spectograms and Waveforms of /t/ (left) and /\textipa{\textit{\text{sh}}} (right) Showing Aspiration](image-url)
On the other hand, the articulation of aspirated fricatives in Sgaw Karen comprises two types of aperiodic noise: a frication phase of coronal origin, characterized in the waveform and spectrogram by high amplitude noise and high resonant frequencies, and an aspiration phase of glottal origin, characterized in the waveform and spectrogram by noticeably lower amplitudes and resonant frequencies (see Appendices 2 and 3 for minimal and near-minimal pairs featuring /s/ and /sʰ/).

![Image](image_url)

**Figure 2. Frication in /s/ (left) and Frication and Aspiration in /sʰ/ (right)**

Aspirated fricatives are rare sounds cross-linguistically. Jacques (2011) reports that only three out of 451 languages in the UPSIP database, and a few additional languages reviewed elsewhere, feature /sʰ/, the most common aspirated fricative. Aspirated fricatives share some typological traits (Jacques 2011): 1) all languages with aspirated fricatives, excluding Korean (see Chang 2013), also have plain unaspirated counterparts in their phonological inventories, 2) aspirated fricatives never appear in initial clusters, and 3) if a language has only one aspirated fricative, it is always the aspirated coronal fricative /sʰ/. Our fieldwork in Sgaw Karen confirms that these criteria are true of the aspirated fricative in this language.

Aspirated fricatives, though somewhat common within the Sino-Tibetan language family, are still very rare and poorly studied among the world’s languages (Jacques 2011). Blevins (2004) proposes two main reasons to account for the rarity of particular sound patterns: a) no or few diachronic pathways can lead to their creation, or b) the processes of sound change render these sounds susceptible to elimination. Jacques (2011) outlines eight cross-linguistic diachronic pathways leading to the creation of aspirated fricatives, thus arguing that these sounds are rare because of the instability of the aspiration in fricatives, which makes it difficult to maintain the distinction between the aspirated and plain fricative. Confirming this theory, Wheatley (2003) provides evidence that in Burmese, younger speakers tend to lose the contrast of aspirated and unaspirated coronal fricatives by merging the two sounds together into the unaspirated fricative /s/. However, no serious phonetic study as to the
characteristics of aspiration in fricatives has been published to back up Jacques’ (2011) idea as to now. Sgaw Karen features this rare and understudied two-way phonemic contrast in voiceless unaspirated and aspirated coronal fricatives /s/ and /sʰ/, thereby offering a gateway to explore the phonetic characteristics of aspiration in aspirated fricatives.

3. Research questions

As a phonetics study in an under-documented language, the guiding research question for this project is broadly: *what is the behavior of the aspiration feature in Sgaw Karen coronal fricative /sʰ/?*

Additionally, we wanted to know how the aspiration feature in Sgaw Karen compares typologically to other languages with aspiration in obstruents, so we included a control study on its aspirated and unaspirated stops. This would also show whether aspirated fricatives in Sgaw Karen compare to their unaspirated counterparts analogously to the way aspirated stops compare to their unaspirated counterparts. Furthermore, we wanted to make sure that any anomalies found in fricative aspiration were not characteristic of aspiration in all Sgaw Karen obstruents, but rather unique to the fricatives. The following questions therefore formed subsequent guidelines in our plan of research: *How does aspiration in fricatives compare to aspiration in stops? What is the relationship between aspiration and frication duration? How does aspiration behave in stops and fricatives according to word and vowel context?*

3.1 Methodology

3.1.1 Stimuli sets

The sounds targeted in the set of stimuli included the aspirated and unaspirated coronal fricatives /s sʰ/, and a control set of aspirated and unaspirated stops /p t k pʰ tʰ kʰ/.

Words were collected from a Sgaw Karen dictionary that represented these eight sounds in three vowel contexts: followed by [a], [o], and [u], and with each target consonant-vowel sequence situated in three word positions: absolute initial (word- and phrase- initial), word-medial, and phrase-medial (sound occurs word-initially, but preceded by a word ending in a schwa-like vowel). The words were inserted into two frame sentences according to the target word-context, where ‘X’ is the token word:

* Absolute initial and word-medial: X [ʔi me lə ma pʰla], meaning “X is a word”
Word initial/phrase medial: [jə sɔ kɔ mɔ] X [ʔi me lɔ ma pʰla], meaning “I think X is a word”

The sets of token sentences were then randomized twice and filler sentences were added to the beginning and end of each set, resulting in two sets of 74 sentences.

3.1.2 Participants

The data used in this research was gathered from elicitation sessions with one male and one female native speaker consultant of Sgaw Karen, both of whom served as consultants for the Linguistic Field Methods class taught by David Mora-Marin at UNC - Chapel Hill. The male native speaker consultant was 37 years old, born and raised in Burma. He also had lived in Thailand and moved to the United States ten years prior. At the time of recording he resided in Chapel Hill, North Carolina. He speaks Burmese, some Thai, and English. The female native speaker consultant was 50 years old, moved to the United States six years ago from Burma, and had resided in Chapel Hill ever since. She also speaks English, Po Karen, Burmese, and some Thai. During elicitation sessions, some dialectal and pronunciation variation between the consultants was observed.

3.1.3 Presentation of stimuli

Native speaker consultants were shown a PowerPoint presentation of each randomized set of stimuli. The consultant was shown one sentence at a time on a laptop display, and then read the Sgaw Karen sentence aloud. Before each recording, the consultants familiarized themselves with the format of the experiment by responding to practice slides. An experimenter who was present during the recordings controlled the PowerPoint sequence.

3.1.4 Recording

Recording sessions took place in a sound proof chamber and in a quiet office setting. A Sennheiser ME66 shotgun microphone was used along with a digital recording device, which recorded at a sampling rate of 44.1 kHz.

3.1.5 Acoustic analysis

Acoustic analysis was performed on the sound files using the Praat software, version 5.3.32.
To analyze the recordings, measurements were collected for voice onset time (VOT) of stops and fricatives, for frication duration of all fricatives, and for total duration of aspirated fricatives. In this discussion, the VOT of aspirated segments is synonymous with ‘aspiration duration,’ and the terms will be used interchangeably. The images above show the waveforms and spectrograms for fricatives in Praat. For frication duration, measurement commences with the onset of aperiodic noise with high amplitude in the waveform and the presence of high resonant frequencies in the spectrogram, and ends either with the onset of periodic noise and appearance of vowel formants, or with the significant reduction in amplitude and change in appearance of resonance frequencies in the spectrogram. Measurement of aspiration in fricatives commences at the visible decrease in amplitude of the aperiodic waveform, along with the appearance of low resonance frequencies in the spectrogram. The VOT of unaspirated fricatives was measured from the cessation of frication to the onset of voicing in the following vowel. Likewise for aspirated and unaspirated stops, the VOT was measured from the stop release to the onset of voicing in the following vowel.

4. Results

We found several significant results through statistical analysis of the data. In the charts below, we use 95% confidence intervals, represented by the black I-beams above the bars. The confidence intervals indicate that there is a 95% probability that the calculated confidence interval encompasses the true value of a given parameter. If the confidence intervals in two given bars do not overlap, we can be 95% confident that there is a
significant (p < 0.05) difference between the values. When the black I-beams do overlap, the values are not significantly different (p > 0.05).

4.1 Overall Voice Onset Time

For overall VOT, values from both speakers are averaged together for this discussion. However, the male speaker VOT values were generally higher than the female speaker values, and both speaker values trended similarly. As can be seen in Figure 4, the overall average VOT in the coronal aspirated fricative /s^h/ (around 40 ms) is significantly shorter than in stops (around 90 ms), while still being significantly longer than the VOT in unaspirated stops (20 ms).

![Overall Average VOT, Stops and Fricatives](Image)

*Figure 4. Overall Voice Onset Time (VOT) for Stops and Fricatives*

4.2 Aspiration by word context

Aspiration was analyzed according to word-context. Figure 5 illustrates that there is no significant difference in aspiration duration in fricatives due to word-context, whereas there does appear to be a significant difference in some of the values for the aspirated stops.
These findings are not surprising, as prior research on aspiration duration according to word context demonstrates that in English, stop aspiration and /h/ are longer word-initially than word-medially (Davis & Cho 2003). Stops in Sgaw Karen are consistent with Davis and Cho’s (2003) findings in that word-initial stop aspiration is significantly longer than word-medial aspiration. And although there is not a significant difference in fricative aspiration duration, we can see that fricatives at least trend with stops when analyzed according to word-context.

4.3 Aspiration by vowel context

However, when aspiration in fricatives and stops was analyzed by vowel context, we found a striking difference in the behavior of their duration, as can be seen in the confidence intervals in Figure 6. While there is no significant difference in aspiration duration for stops, there is a significant difference in the aspiration duration of the fricative according to following vowel context: the higher the following vowel, the shorter the aspiration duration in the fricative. Figure 6 shows that, for the aspirated fricative, aspiration before the high vowel [u] is significantly shorter than before the low vowel [a].

Figure 5. Aspiration Duration by Word Context
Previous research on languages such as English (see Yavaş 2009 for an account of the literature on the subject) suggests that aspiration in aspirated stops tends to be longer when followed by high vowels and shorter when followed by low vowels. It has been proposed (Yavaş 2009) that this is motivated by the high position of the tongue during the stop closure stage that is assumed in anticipation of the following high vowel, which results in a less abrupt pressure drop that boosts the length of aspiration. As the pressure drop is more abrupt when followed by low vowels, given their more open articulation, aspiration duration in stops is shorter in this context. For these reasons, the attested shortening effect of high vowels on aspiration duration in the aspirated fricative, being the opposite of what was described in the literature for stops, was unexpected and ought to be explained.

5. Discussion

What could cause this difference in behavior in aspiration between aspirated stops and fricatives? We would like to suggest that frication duration may be the reason for this phenomenon. Previous research on fricatives in English (Jongman et al. 2000) and Greek (Chaida et al. 2009, 31) has found that frication duration is correlated with the height of the following vowel: fricatives are longer before high vowels and shorter before low vowels. This is phonetically motivated: the open vocal tract configuration of low vowels makes it harder to sustain the consonantal
constriction required for fricatives, therefore reducing frication duration; on the other hand, frication is easier to sustain before high vowels, which require a more constricted vocal tract (Chang 2013, 14).

We analyzed frication duration of both the aspirated and the unaspirated fricatives in Sgaw Karen and, as we can see in Figure 7, frication duration in both aspirated and unaspirated fricatives in Sgaw Karen is significantly longer after high vowel [u] than after low vowel [a].

![Figure 7. Frication Duration by Following Vowel Context](image)

We can now attest that vowel height has exactly the opposite effect on frication duration as on aspiration duration. Could these two phenomena be related?

Studies on the interaction between aspiration and frication duration in fricatives are almost non-existent. However, Chang’s (2013, 14) recent study on Korean, a language with a coronal fricative having aspiration as a non-phonemic feature, demonstrates that longer frication duration is linked to a significant decrease in aspiration duration, which is the same pattern we see in Sgaw Karen, a language in which aspiration is contrastive in fricatives. This led us to ask how strongly frication and aspiration duration are related in Sgaw Karen.

In order to test the correlation between aspiration duration and frication duration in Sgaw Karen aspirated fricatives, we ran a Pearson’s r linear
correlation comparing the values of frication duration and aspiration duration in each individual token featuring /sʰ/. Results are shown in Figure 8.

<table>
<thead>
<tr>
<th></th>
<th>Frication Duration</th>
<th>Aspiration Duration</th>
</tr>
</thead>
</table>
| Frication Duration | Pearson Correlation 1  
|                  | Sig. (2-tailed) | -.382 |
|                  | N                  | 36  |
| Aspiration Duration | Pearson Correlation | -.382  |
|                  | Sig. (2-tailed) | .022 |
|                  | N                  | 36  |

*. Correlation is significant at the 0.05 level (2-tailed).

**Figure 8. Correlation between Aspiration and Frication Duration in Fricatives**

Each row and column in the table corresponds to one variable. The cells at the middle row and right column and bottom row at the middle column represent the correlation of frication duration and aspiration duration in /sʰ/. In these cells, the top number is the Pearson correlation coefficient: -0.382, a negative correlation. The middle number is the significance of this correlation. If the **Sig. (2-tailed)** value is less or equal to 0.05, as is the case in this correlation, there is a statistically significant correlation between the two variables of aspiration duration and frication duration. The bottom number N is the number of observations that were used to calculate the Pearson correlation coefficient.

As predicted, the correlation results show that frication and aspiration duration have a significant negative correlation. This supports an interesting indirect effect of vowel height on aspiration: the higher the following vowel, the longer the frication duration, which, in turn, shortens aspiration.

Moreover, an additional argument is put forward if we compare the total duration (i.e. measuring aspiration and frication duration combined) of both aspirated and unaspirated fricatives. Indeed, as we can see in Figure 9, with overlapping confidence intervals, both sounds have similar overall duration.
These results suggest that aspiration and frication compete in aspirated fricatives to occupy the same articulatory space: frication, with the lengthening effect of vowel contexts, prevails over aspiration.

Indeed, in Sgaw Karen, aspiration in aspirated fricatives has been demonstrated to be significantly shorter than in aspirated stops. Moreover, we have found that aspiration and frication in fricatives seem to compete for the same articulatory space, with aspiration being subject to the shortening effect of frication duration, which has been shown to shorten it to an average similar to that found in unaspirated stops of about 20 milliseconds. As explained by Johnson (1997, 119), the VOT boundary between aspirated and unaspirated stops has been cross-linguistically estimated at about ±30 milliseconds: a shorter VOT would make it harder to perceive the distinction between aspirated and unaspirated fricatives.

Our research on Sgaw Karen would seem to predict that the quality of aspiration in aspirated fricatives would tend to make aspirated fricatives merge with their unaspirated counterparts by losing their aspiration. As reported by Jacques (2011, 2), this has been attested in modern spoken Burmese, a language with both an aspirated and an unaspirated coronal fricative: younger Burmese speakers have lost the distinction between /s/ and /sʰ/ by merging both sounds into /s/. We believe this may be evidence that aspirated fricatives are rare because their aspiration is difficult to maintain and easily neutralized by sound change, although this is only one example. More research on other languages with aspirated fricative is needed to attest whether this pattern is common cross-linguistically.
6. Conclusions

In this study, we found that in Sgaw Karen aspirated fricatives have significantly shorter aspiration duration than aspirated stops. While they pattern like aspirated stops in that they have significantly longer VOT than their unaspirated counterparts, we found a fundamental difference in aspiration duration between stops and fricatives by the quality of the following vowel context. For aspirated fricatives, the height of the following vowel has a negative effect on aspiration duration: the higher the following vowel, the shorter the aspiration duration of the fricative. On the other hand, vowel height has no significant effect on aspiration in aspirated stops. We found that frication duration can account for this behavior in aspiration duration. Indeed, as in other languages, frication duration in Sgaw Karen is significantly longer before high vowels in both aspirated and unaspirated fricatives. We ran a correlation and found that in aspirated fricatives aspiration and frication duration are significantly negatively correlated. Moreover, we measured the total duration (aspiration plus frication duration) of both fricatives and found that they have very similar durations on average. This situation points to the fact that aspiration and frication in aspirated fricatives must occupy the same articulatory space, with frication prevailing over aspiration. Thus, an important effect of vowel height on aspiration duration in aspirated fricatives is attested: Sgaw Karen shows that high vowels lengthen frication duration, which in turn shortens aspiration duration in aspirated fricatives.

We hypothesize that this data from Sgaw Karen offers an explanation as to why aspirated fricatives are so rare cross-linguistically. Aspirated fricatives already feature shorter aspiration duration. The added hampering effect of vowel height, which shortens aspiration duration to an average closer to unaspirated stops, may cause aspirated fricatives to become perceptually hard to distinguish from unaspirated fricatives, thus making the distinction harder to sustain, and making aspirated fricatives merge with their unaspirated counterparts by losing their aspiration, as hypothesized by Jacques (2011, 12). However, more research on other languages with aspirated fricatives is needed to support such an assertion.

REFERENCES


**APPENDICES**

Appendix 1: “Data for statistical analysis” (Spreadsheet, .xlsx format)

Appendix 2: “Aspirated [sʰa] ‘soundness’ and [sʰo] ‘to stop’ pronounced by the two native speaker consultants” (Audio, .wav format)

Appendix 3: “Unaspirated [saku] ‘bow’ and [so] ‘generation’ pronounced by the two native speaker consultants” (Audio, .wav format)