Coronal contrasts in Anong

Ela Thurgood
Department of English
California State University, Chico
ethurgood@csuchico.edu

This study examines acoustic characteristics of a three-way distinction among a set of voiceless coronal fricatives and two sets of voiceless coronal affricates in Anong, an endangered Tibeto-Burman language. The study shows a lack of parallelism between the fricative and affricate series. The fricatives are well differentiated by spectral shapes and formant transitions of the following vowels, but not by the center of gravity. The affricates are well differentiated by the center of gravity, but not by spectral shapes nor by formant transitions of the following vowels. The study shows that /ʂ/ is acoustically a retroflex, while /tʂʰ tʂ/ are not.

1 Introduction

Anong is a Tibeto-Burman language on the edge of extinction, spoken in Fugong County in the Yunnan Province in China.[1] In 1995, there were 62 fluent speakers and about 300 semi-fluent speakers living in Mugujia village (Sun 2005b). The highly endangered nature of Anong is evident in bilingual contact situations. Anong is only used on that rare occasion when all the speakers are fluent in Anong, otherwise Lisu is the language of communication (Sun 2005b, G. Thurgood 2003).[2]

This acoustic study investigates the distinctions among the coronals, examining in particular the three-way distinction among the voiceless fricatives /s ʂ ɕ/, among the aspirated voiceless affricates /tsʰ tʂʰ tɕʰ/ and the unaspirated voiceless affricates /ts tʂ tɕ/. The fundamental question being asked is how the three-way distinction among the coronal fricatives and affricates is established acoustically. To answer this question, Anong coronals are examined in terms of their spectral properties, their gravity center frequencies and the formant frequencies of the following vowel.

The results of this study are compared with acoustic studies of coronal fricatives and affricates in other languages with a three-way distinction. Specifically, Anong is compared with Standard Chinese (Svantesson 1986; Ladefoged & Wu 1984), Polish (Halle & Stevens 1997; Nowak 2006), and Komi-Permyak (Kochetov & Lobanova 2007). Standard Chinese shares with Anong the same inventory of coronal fricatives and affricates; Polish and Komi-Permyak inventories are similar except there is only one series of voiceless affricates.

[1] This dying dialect of Anong is now quite distinct from related dialects spoken in Burma. In future work we hope to obtain data on those dialects for purposes of comparison and contrast.
[2] For a description of the northern dialect of Lisu, see Bradley (1994).

Journal of the International Phonetic Association (2009) 39/1
doi:10.1017/S002510030800368X

Table 1 Anong vowel inventory.

Sun (2005a: 33)			Thurgood (2007: 612)		
i (y)		u ɯ	i (y)	ɨ	u
e		o	e		o
ɛ	a	ɑ	ɛ		ɑ

Table 2 Anong consonant inventory (after Sun 2005a: 27).

	Bilabial	Alveolar	Retroflex	Alveolo-palatal	Velar	Glottal
Stop	pʰ p b	tʰ t d	ʈʰ ʈ ɖ		kʰ k g	ʔ
Fricative	f v	s z	ʂ ʐ	ɕ ʑ	x ɣ	h
Affricate		tsʰ ts dz	tʂʰ tʂ dʐ	tɕʰ tɕ dʑ		
Nasal	m̥ m	n̥ n	ɳ̊ ɳ	ɲ̊ ɲ	ŋ̊ ŋ	
Lateral						
fricative		ɬ				
approximant		l	ɭ			
Approximant		ɹ				

Additionally, the Anong retroflex fricative is compared with retroflex fricatives in Toda (Gordon et al. 2002) and in O'odham (Dart 1993).

1.1 Anong vowels and consonants

Sun (2005a) distinguishes eight main vowels plus /y/, a marginal vowel restricted to a handful of Chinese borrowings. Sun (2005a: 34) observes that the vowel /ɯ/ is more central than the symbol ɯ would lead one to expect, and, as the acoustic analysis of Anong vowels has shown (Thurgood 2007), a more appropriate IPA symbol for /ɯ/ would, in fact, be /ɨ/. Thurgood's study also shows that the vowel [a] can be analyzed as an allophonic variation of /ɑ/, reducing Sun's inventory by one. Table 1 presents a comparison of the two systems.

The consonant inventory of Anong is shown in table 2. This inventory has been undergoing some rapid changes, including the loss of the retroflex series /ʈʰ ʈ ɖ ɳ ɭ/, which became /tʰ t d n l/, respectively. Three observations about Anong coronals are particularly important for the present study. First, Sun (2005a: 28) describes the alveolo-palatal series /ɕ tɕʰ tɕ dʑ/ as laminal alveolo-palatals, articulated slightly back and sounding close to [ç cçʰ cç ɟj]. Second, Sun (2005a: 28) reports that the retroflex series /ʂ tʂʰ tʂ/ is phonetically similar to [ʃ tʃʰ tʃ]. Third, no lip rounding has been noted, something one would have expected Sun to have noticed and comment on were it present.

2 The present study

2.1 Data

The data used for the present study have been selected from recordings made by Sun Hongkai in 1999. Sun recorded one speaker, who at the time was over 60 years old. He was quite possibly one of the last fluent speakers of Anong. The recordings were made on a camcorder. The forms were elicited in isolation, each repeated twice in a row. The database used in this study consisted of 28 tokens of coronal fricatives (10 tokens of /s/, 10 tokens of /ʂ/, 8

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

Table 3 Word-list used to examine Anong coronal fricatives and affricates.

/s/	/ʂ/	/ɕ/
sɑ^{31}bɹɨ^{55} 'wild leek'	ʂɑ^{53}dʑɛ^{31} 'to pee'	ɕɑ^{55}bɛn^{35} 'to stride over'
sɑ^{53} 'earth, dirt, soil'	ʂɨ^{55}vɑ^{31} 'book'	tʰi^{33}ɕɑ^{55} 'one hundred'
ɑ^{31}sɑ^{53} 'earth, dirt, soil'	ʂɨ^{53} 'dove'	ɕu^{33} 'blood'
ɑ^{31}sɨ^{53} 'a comb'	dɑ^{31}ʂɨ^{53} 'dove'	ɕɛm^{31} 'knife'
ɑ^{31}sɨ^{31} 'a boat'	ʂu^{53} 'to winnow'	
/tsʰ/	/tʂʰ/	/tɕʰ/
tsʰɑ^{55} 'ten'	ɑ^{31}tʂʰɑ^{55} 'stride forward'	tɕʰɑ^{55} 'bird'
tsʰɑŋ^{31} 'person'	tʂʰɨ^{55} 'minority group'	tɕʰɑ^{55}mɑ^{55} 'child'
tsʰɨ^{31} 'rain'	tʂʰu^{55} 'to pick up'	ɑ^{31}tɕʰi^{53} 'to split'
tsʰɨ^{31} 'to cut out in sewing'	ɑ^{31}tʂʰu^{55} 'breast'	tɕʰim^{31} 'house'
ɑ^{31}tsʰu^{55} 'pointed (knife)'		tɕʰuŋ^{53} 'straight'
/ts/	/tʂ/	/tɕ/
tsɑ^{35}si^{55} 'become red'	tʂu^{55}dʑɛŋ^{55} 'siskin'	tɕɑ^{55}xom^{31} 'squirrel'
		tɕo^{55}bɑ^{55} 'barnyard millet'
		tɕi^{55}dzɨ^{31} 'to paint wall'

tokens of /ɕ/). The fricatives were analyzed in front of /ɑ/, /u/, and either /ɨ/ or /ɛ/. Twenty-eight tokens of the aspirated affricates were measured (10 tokens of /tsʰ/, 8 tokens of /tʂʰ/, 10 tokens of /tɕʰ/). Whenever possible, word-initial contexts were chosen. However, when the coronals occurred intervocalically, the results were inspected for possible positional variation (cf. Kochetov & Lobanova 2007). The aspirated affricates were analyzed in front of /ɑ/, /u/, and either /i/ or /ɨ/. For the unaspirated affricates /ts tʂ tɕ/, and in particular for /tʂ/, the data were sparse, something that Sun observed as early as in 1988 (see Sun 1988). In the available word-list (table 3), /ts/ occurs only before /ɑ/ and /tʂ/ only before /u/.

2.2 Measurements

Using SoundEdit 16 version 2, the recordings were downsampled to 22,050 Hz when measuring the consonants, and to 11,025 Hz when measuring the following vowel. The data were then analyzed using Scicon's Macquirer software system. A number of acoustic measurements were taken. First, FFT spectra were computed using a 1024-point frame (approximately 46 milliseconds) centered around the middle of each fricative and the fricative part of each affricate. Numerical spectra were then averaged together over the tokens of each consonant appearing in each environment. Second, following the method described in Gordon, Barthmaier & Sands (2002), the center of gravity was also calculated for each token and then averaged together for each coronal appearing in each context. Finally, the frequencies for the first three formants (F1, F2, F3) were measured at the onset and in the middle of the following vowel /ɑ/. The SPSS statistical package (version 11.0.3) was used to perform repeated measures of ANOVA and post-hoc comparisons.

3 Acoustic analysis of Anong coronal fricatives

3.1 Spectral properties

The averaged spectra of the three coronal fricatives are plotted in figures 1–3. For each fricative, the tokens are separated by the following vowels. In general, there is a considerable

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

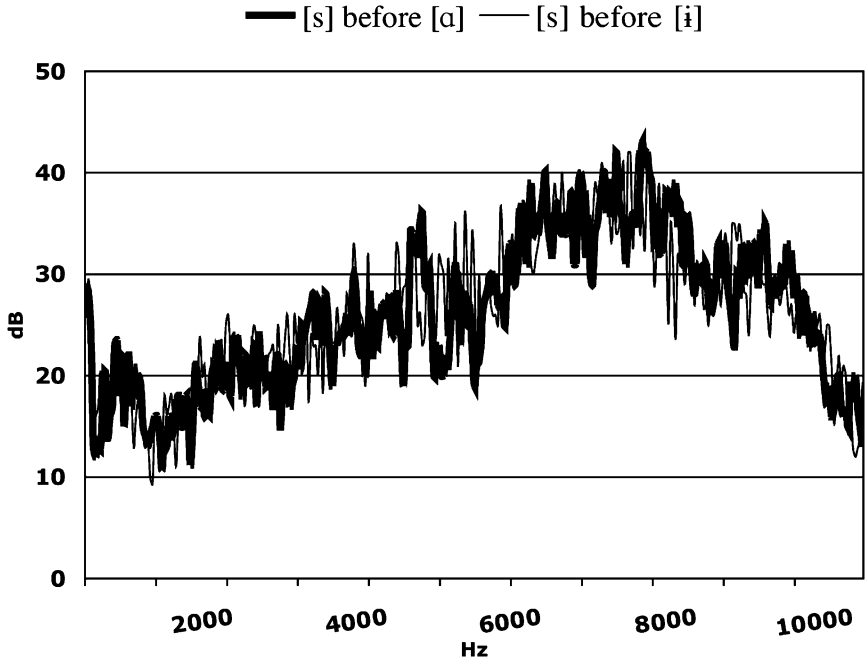

Figure 1 Averaged acoustic spectra for /s/ before two vowels.

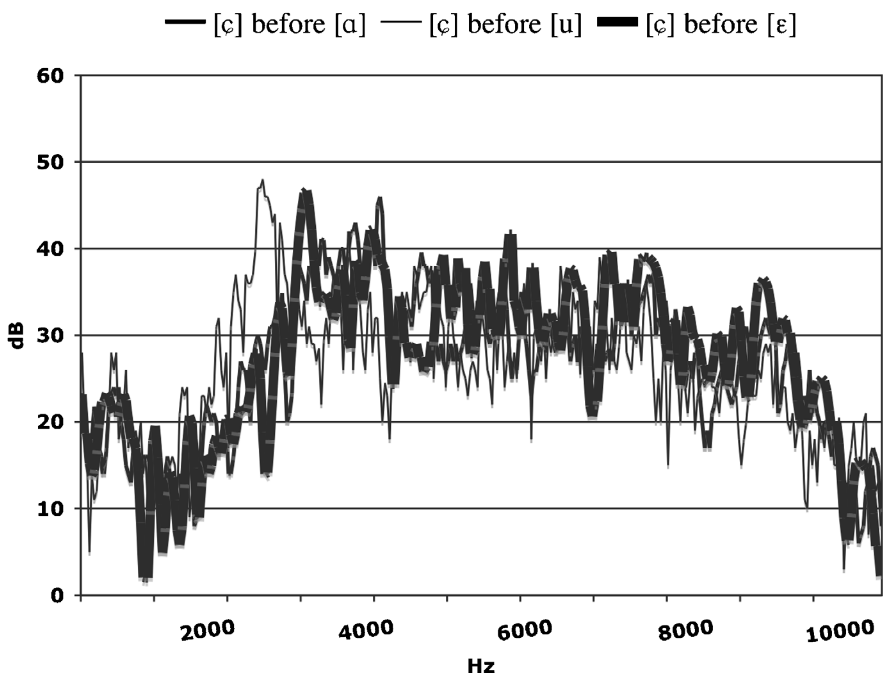

Figure 2 Averaged acoustic spectra for /ɕ/ before three vowels.

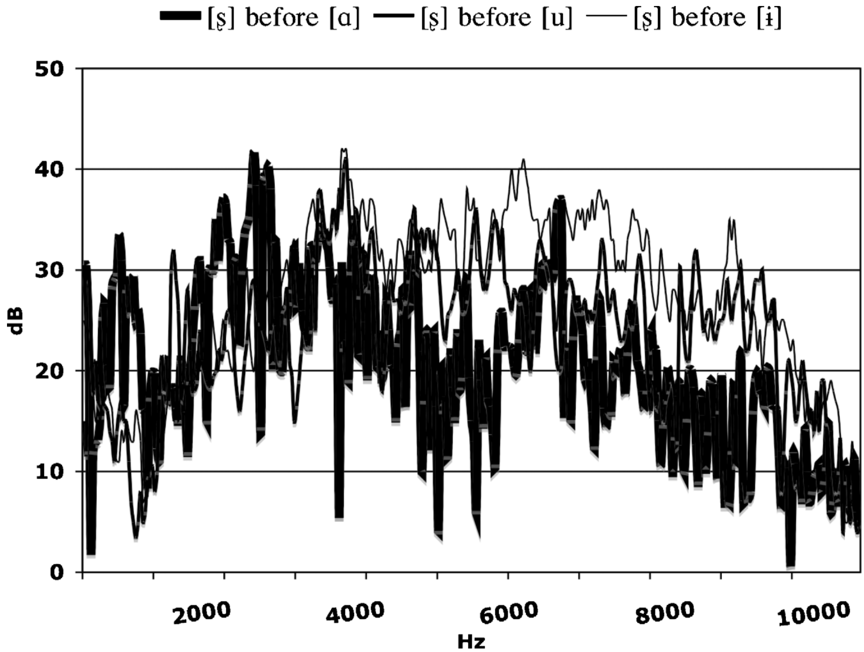

Figure 3 Averaged acoustic spectra for /ʂ/ before three vowels.

uniformity across the analyzed data in the spectral characteristics of the three coronal fricatives. Starting with /s/, spectra show a steady rise with the highest spectral peaks centered at approximately 7.2 kHz, at which point there is a steep decline in noise. Spectra for /ɕ/ show a very different display of noise distribution. The most pronounced peaks are between 2.4 kHz and 4 kHz. Before all three vowels, the noise displays a relatively flat spectrum between 4.1 kHz and 7.1 kHz and then a steep decline. Spectral peaks for /ʂ/ cluster in two locations. The most prominent peak cluster is between 2.2 kHz and 3.4 kHz, the less prominent peak cluster is between 5.1 kHz and 6.2 kHz.

The overall spectral shapes clearly differentiate the three coronal fricatives from each other. As an illustration, averaged spectra for /s ʂ ɕ/ occurring before /ɑ/ are plotted in figure 4. In this context, the amplitude peak of /s/ is at approximately 7.2 kHz. Before the amplitude peak, the intensity of /s/ is below the intensities of /ɕ/ and /ʂ/; following the amplitude peak, the intensity of /s/ is above the intensity of /ɕ/ and /ʂ/. The fricatives /ʂ/ and /ɕ/ display high noise at lower frequencies: /ʂ/ shows the greatest amplitude approximately at 2.4 kHz, /ɕ/ later at 4.1 kHz. The spectra for the two fricatives also differ in that /ʂ/ shows a secondary peak at ca. 6.2 kHz, while /ɕ/ shows a relatively flat spectrum between 4.1 kHz and 7.1 kHz and then a steep decline. The intensity of /ʂ/ is somewhat lower than that of /ɕ/.

3.2 Centers of gravity

Gravity center frequencies for Anong coronal fricatives before different vowels and averaged across these vowels are shown in figure 5. For /ʂ/ and /ɕ/, the gravity center frequencies were measured before /ɑ/, /ɨ/ and /u/. For /s/, the gravity center frequencies were measured only before a following /ɑ/ and /ɨ/. The center of gravity for /s/ is the highest; it is always greater than 6 kHz. The centers of gravity for /ʂ/ and /ɕ/, are always smaller than 5.5 kHz. An analysis of variance indicates that fricative type affects the center of gravity values ($F(2,23) = 43.513$,

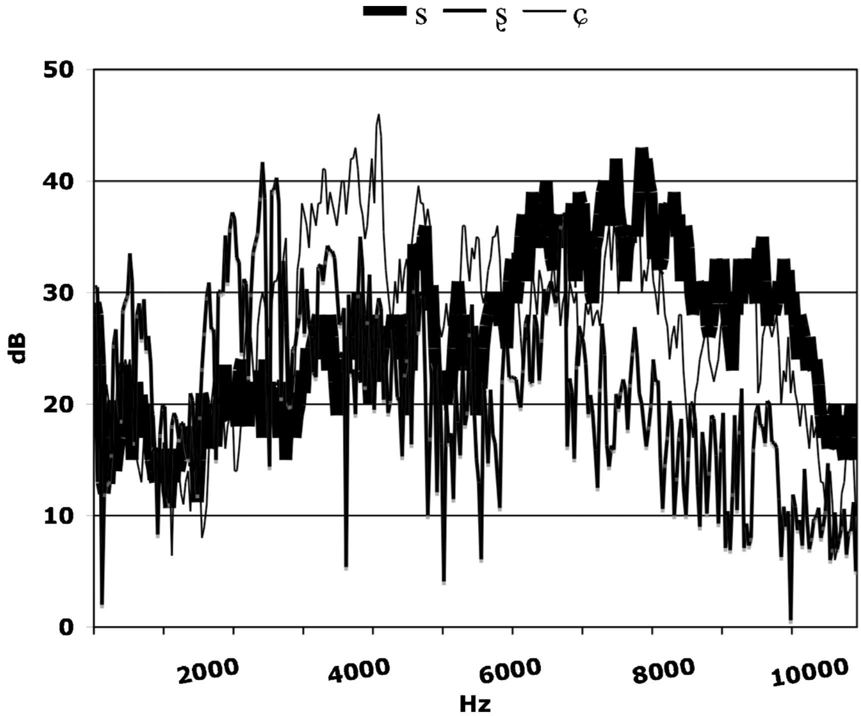

Figure 4 Averaged spectra of /s/, /ʂ/ and /ɕ/ before /ɑ/.

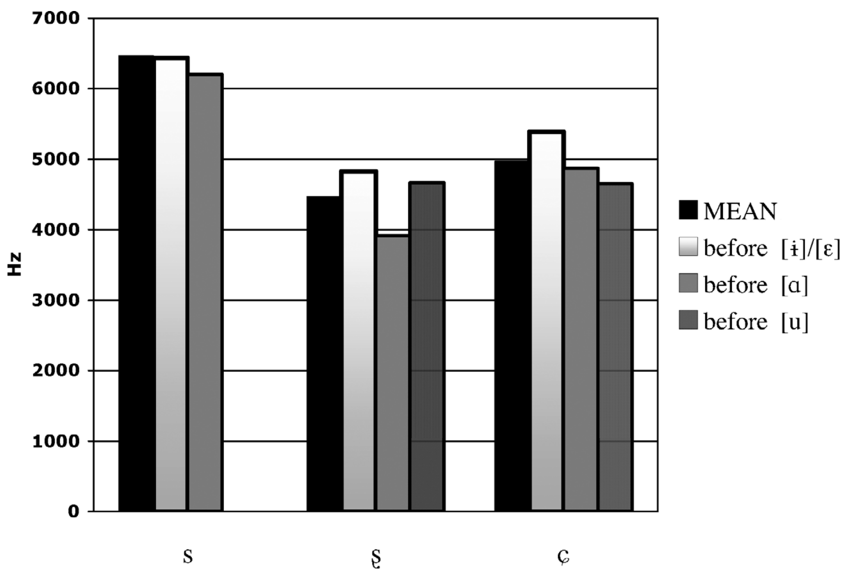

Figure 5 Gravity center frequencies for Anong coronal fricatives before different vowels and averaged across vowels.

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

Table 4 Averaged frequencies of /ɑ/.

	At the onset			In the middle		
	F1	F2	F3	F1	F2	F3
Following /s/	580	1124	2939	581	1086	2969
Following /ʂ/	424	1245	2373	567	922	2382
Following /ɕ/	455	1201	2749	461	1150	2794
Following a non-coronal (Thurgood 2007: 611)				600	1044	2739

$p < .0001$). Scheffe's post-hoc tests reveal the difference between /s/ and /ɕ/ and between /s/ and /ʂ/ to be significant ($p < .05$). Pairwise comparison between /ʂ/ and /ɕ/ does not reach statistical significance.

3.3 Formant frequencies of /ɑ/ following the fricative coronals

Formant values for the first three frequencies (F1, F2, F3) of /ɑ/ following /s/, /ʂ/, and /ɕ/, calculated at the onset and in the middle, are given in table 4. For comparison, the formant frequencies of /ɑ/ following a non-coronal (taken from Thurgood 2007) are also presented.

Following /ʂ/ and /ɕ/, the average F1 is lower at the vowel onset than following /s/. The lowering effect of the alveolo-palatal /ɕ/ on F1 persists into the middle of the vowel; the lowering effect of the retroflex /ʂ/ on F1 vanishes by the middle of the vowel. There is no difference in F1 values between the beginning and the middle of the vowel when the vowel /ɑ/ follows the alveolar /s/. The formant frequency values of /ɑ/ following /s/ pattern with the formant frequency values of /ɑ/ arrived at in the earlier study (Thurgood 2007). Turning to F2, the formant values are consistently higher not only at the onset but also in the middle of the vowel when /ɑ/ follows /ɕ/. In contrast, when /ɑ/ follows /ʂ/, even though the F2 is raised at the onset, it is not raised in the middle of /ɑ/. Turning to F3, the retroflex /ʂ/ triggers lowering of this formant. The effect of /ʂ/ on /ɑ/ persists well beyond the portion of the vowel immediately adjacent to the fricative. Neither /s/ nor /ɕ/ causes F3 lowering.

3.4 Discussion

All three Anong coronal fricatives /s ʂ ɕ/ are well differentiated by their spectral shapes. Among the three, the alveolar fricative /s/ is the most distinct. The most prominent spectral peaks for /s/ occur at higher frequencies than for /ʂ/ and for /ɕ/, at approximately 7.2 kHz. In contrast, the fricatives /ʂ/ and /ɕ/ display their most prominent spectral peaks at lower frequencies, between 2.2 kHz and 4 kHz depending on the following vowel. The spectra for the two fricatives differ in that /ʂ/ shows a less prominent, secondary peak cluster between 5.1 kHz and 6.2 kHz, while /ɕ/ shows a relatively flat spectrum following the most pronounced noise peak and then a steep decline.

The spectral shapes of Anong coronal fricatives /s ʂ ɕ/ parallel the spectral shapes of Polish coronal fricatives /s ʂ ɕ/ obtained by Nowak (2006). In Polish, as in Anong, the spectral shapes of the retroflex /ʂ/ are characterized by two clusters of spectral peaks. Depending on the following vowel, Polish spectral peaks cluster at frequencies between 2.8 kHz and 3.5 kHz and between 5.4 kHz and 5.7 kHz (Nowak 2006: 142). Two spectral peaks have also been reported for Mandarin Chinese /ʂ/ and Komi-Permyak /ʂ/. In Mandarin Chinese, the spectral peaks are located around 2.9 kHz and around 4.5 kHz (Ladefoged & Wu 1984: 273–274). In Komi-Permyak, they are located at lower frequencies, around 1.5 kHz and around 3.5 kHz (Kochetov & Lobanova 2007: 70).

Anong shares with Polish the spectral shapes of the alveolo-palatal /ɕ/. In both languages, the spectral peaks are followed by a relatively flat spectrum and then a steep decline. In

Polish, the spectral peaks are located close together at frequencies between 3.3 kHz and 3.9 kHz depending on the vowel context, the following flat part of the spectrum declines at frequencies higher than 6 kHz (Nowak 2006: 142). This spectral shape has not been observed for Komi-Permyak /ɕ/, where /ɕ/ spectra are not significantly different from /ʂ/ spectra (Kochetov & Lobanova 2007: 72–73).

All three Anong coronal fricatives /s ʂ ɕ/ are well differentiated by the formant frequencies of the following vowel. The alveolo-palatal /ɕ/ triggers a significant lowering of F1 and a slight raising of F2 in the following /ɑ/. These changes in formant frequency values parallel changes reported in other languages. For example, for Polish lower F1 and higher F2 of a vowel adjacent to an alveolo-palatal have been reported (Halle & Stevens 1997, Nowak 2006). However, what makes Anong fricative coronals different is that their influence on the formant frequency values is found not only at the onset but also into the middle of the vowel.

In Anong, the retroflex /ʂ/ triggers a significant lowering of F3 in the following /ɑ/. F3 lowering of a vowel adjacent to a retroflex fricative has been reported for other languages, for example for Toda (Gordon et al. 2002) and O'odham (Dart 1993). However, in Polish (Nowak 2006) and Komi-Permyak (Kochetov & Lobanova 2007), /ʂ/ does not trigger a lowering of F3. As suggested by Kochetov & Lobanova (2007: 73), the lack of F3 lowering can be explained by smaller curling of the tongue in the production of /ʂ/.

The gravity center frequencies have been found to differentiate /s/ from both /ʂ/ and /ɕ/ well, with /s/ showing significantly higher gravity center frequencies than those of /ʂ/ and /ɕ/. The high gravity center frequencies have been shown to correlate with the frontness of the constriction in articulation (Stevens 1998). This correlation is found cross-linguistically (Gordon et al. 2002). Likewise in Svantesson's (1986) study of Mandarin Chinese, high gravity center frequencies of /s/ differentiate it from lower gravity center frequencies of /ʂ/ and /ɕ/. The difference between Anong and Mandarin Chinese, however, is that while in Mandarin Chinese the center of gravity is higher for /ɕ/ than for /ʂ/, in Anong the difference between the two coronals does not reach statistical significance. A lack of significant differences between the gravity center frequencies of /ʂ/ and /ɕ/ has been observed for Polish /ʂ/ and /ɕ/ (Nowak 2006) and for Komi-Pemyak /ʂ/ and /ɕ/ (Kochetov & Lobanova 2007).

4 Acoustic analysis of Anong coronal affricates

4.1 Spectral properties of fricative components

Averaged spectra of the fricative components of /tsʰ/, /tʂʰ/ and /tɕʰ/ are plotted in figures 6–8. For each affricate, the spectra are separated according to the following vowel. The fricative component of /tsʰ/ has a relatively flat spectrum followed by the most prominent noise peak at about 5.6 kHz when followed by [u] and at about 6.8 kHz when followed by [ɨ]. Before [ɑ], the flat spectrum is first followed by a fall and only then by a rise with a peak at about 6.7 kHz. Regardless of the following vowel, the highest spectral peaks of /tsʰ/ are centered at higher frequencies.

The spectral characteristics of /tɕʰ/ differ depending on the following vowel. When followed by a high vowel, /tɕʰ/ displays most pronounced peaks at lower frequencies followed by a slow decline in noise. When followed by the low vowel /ɑ/, the spectrum shows a cluster of secondary, less prominent peaks at higher frequencies. The spectra of /tʂʰ/ show a very similar display of noise distribution.

For a clearer view of the two types of affricates pattern together, averaged spectra for /tʂʰ/ and /tɕʰ/ occurring before the low vowel and before the non-back high vowel are plotted in figures 9 and 10. For both affricate types before the low vowel, a secondary cluster of peaks occurs between 5.7 kHz and 6.4 kHz. For both affricate types before the non-back high vowel, a relative flat spectrum occurs between 4.9 kHz and 7.9 kHz and then there is a decline.

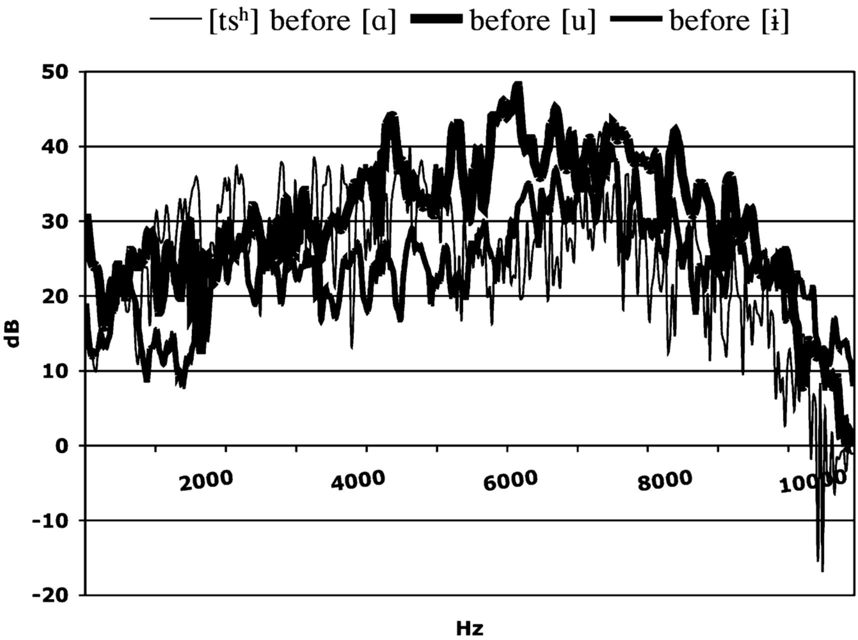

Figure 6 Averaged acoustic spectra for /tsʰ/ before three vowels.

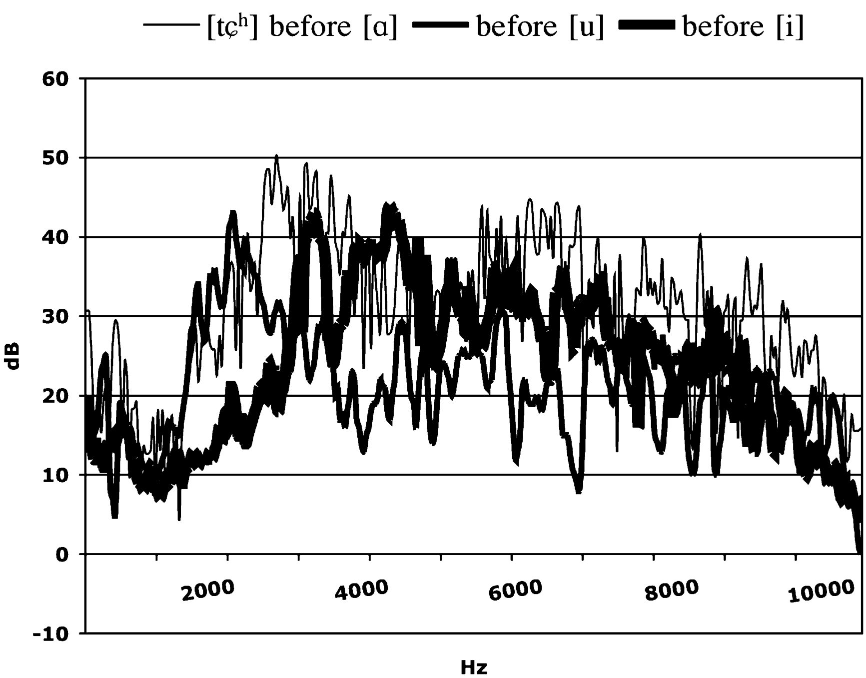

Figure 7 Averaged acoustic spectra for /tɕʰ/ before three vowels.

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

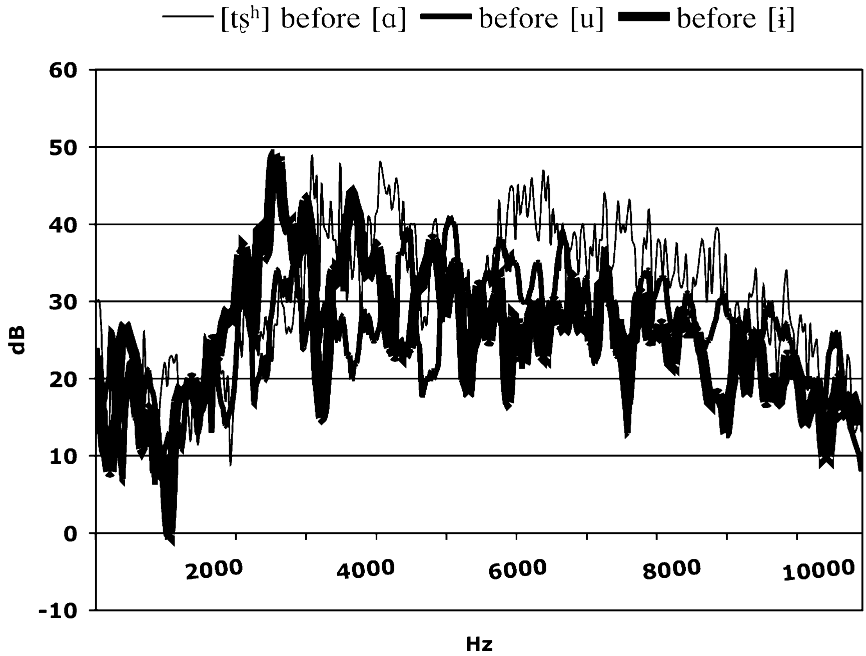

Figure 8 Averaged acoustic spectra for /tʂʰ/ before three vowels.

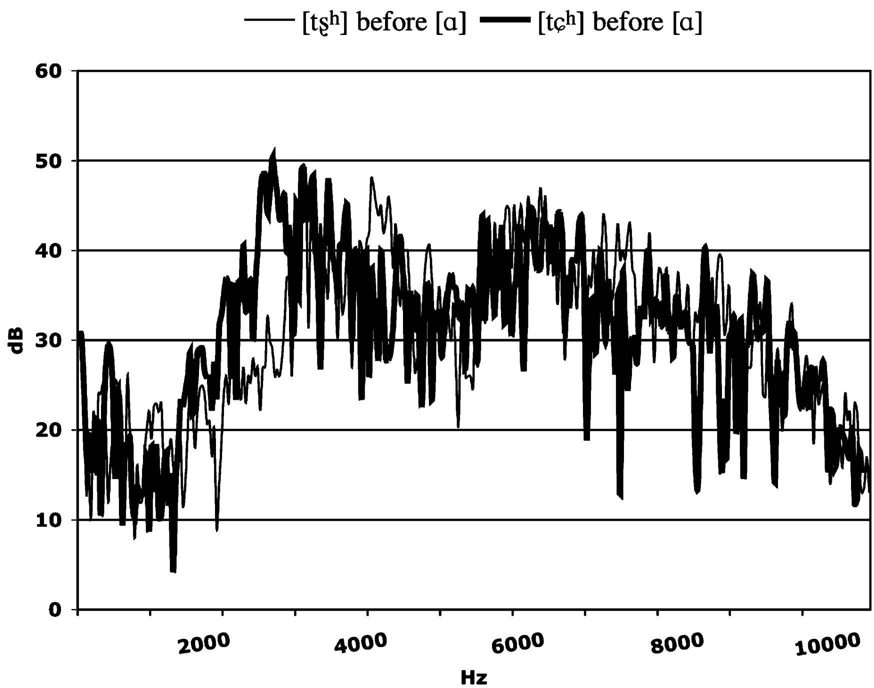

Figure 9 Averaged acoustic spectra for /tʂʰ/ and /tɕʰ/ before the low vowel.

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

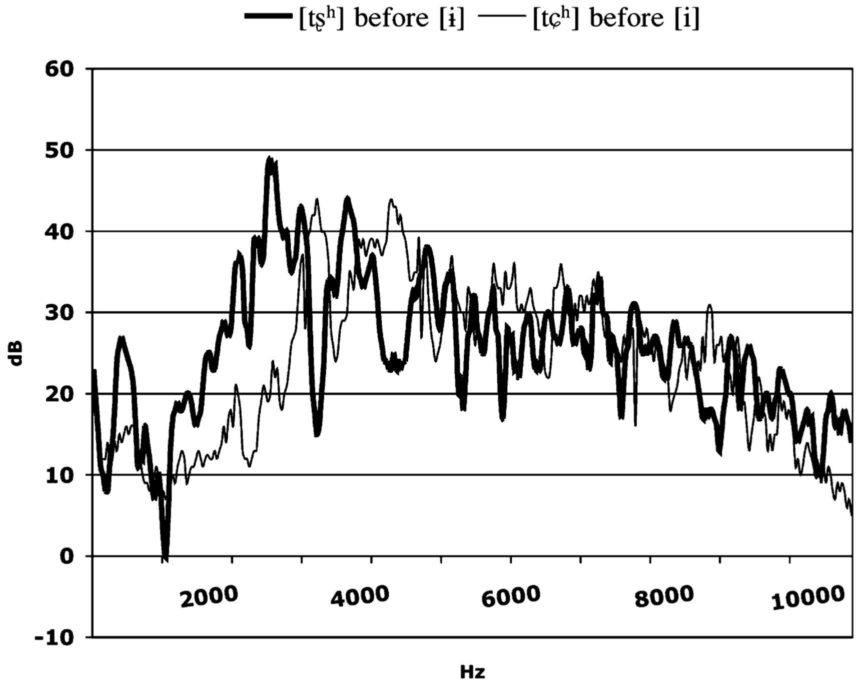

Figure 10 Averaged acoustic spectra for /tʂʰ/ and /tɕʰ/ before a non-back high vowel.

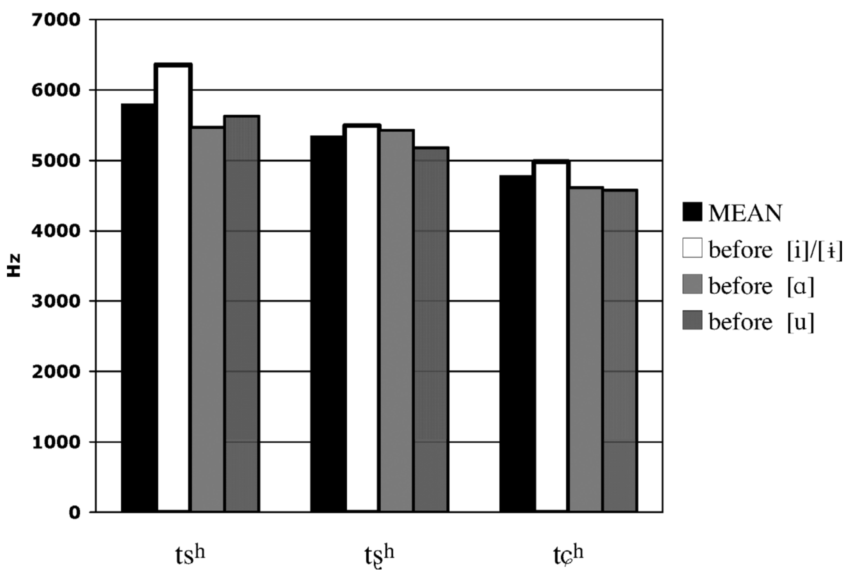

Figure 11 Gravity center frequencies for aspirated coronal affricates before different vowels and averaged across the vowels.

4.2 Centers of gravity

Gravity center frequencies for Anong coronal affricates before different vowels and averaged across the vowels are shown in figure 11. An analysis of variance indicates that affricate

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

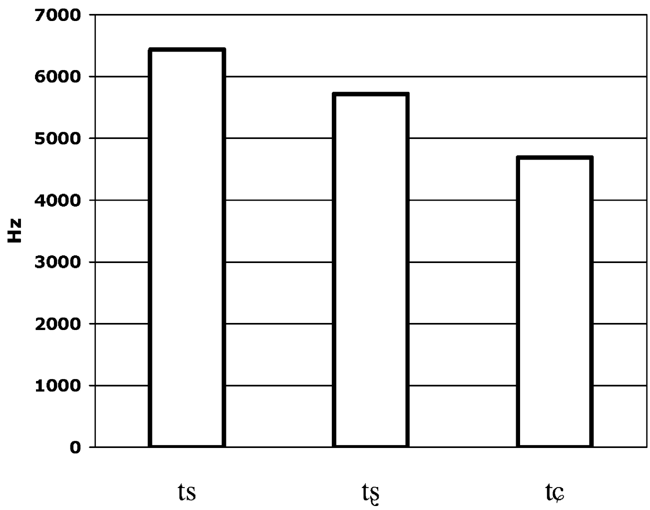

Figure 12 Gravity center frequencies for the fricative component of unaspirated affricates averaged across vowels.

Table 5 Average frequencies of /ɑ/ following a coronal affricate.

	At the onset			In the middle		
	F1	F2	F3	F1	F2	F3
Following /ts/ and /tsʰ/	541	1281	2825	573	1085	2847
Following /tʂʰ/	398	1216	2699	457	1071	2693
Following /tɕ/ and /tɕʰ/	388	1230	2788	443	1036	2721
Following a non-coronal (Thurgood 2007: 611)				600	1044	2739

type affects the center of gravity values ($F(2,21) = 18.613$, $p < .0001$). Before all vowels, the alveolar /tsʰ/ has the highest gravity center values, while the alveolo-palatal /tɕʰ/ has the lowest gravity center values. Pairwise post-hoc comparisons involving /tsʰ/, /tʂʰ/ and /tɕʰ/ show a significant difference at minimally $p < .05$.

For the unaspirated affricates, the comparison is more restricted. However, even though the data are limited in the number of tokens available, the gravity center frequencies of unaspirated /ts/, /tʂ/ and /tɕ/ pattern in the same way as the gravity center frequencies of aspirated /tsʰ/, /tʂʰ/ and /tɕʰ/. The alveolar affricate /ts/ has the highest gravity center values, while the alveolo-palatal affricate /tɕ/ has the lowest, with the gravity center values of the retroflex affricate /tʂ/ placed in between (see figure 12).

4.3 Formant frequencies of /ɑ/ following a coronal affricate

Formant frequency values at the onset and in the middle of /ɑ/ following the three coronal affricates are given in table 5. There is no significant difference in formant frequencies between the /ɑ/ following the unaspirated /ts/ and /tɕ/, and the /ɑ/ following their aspirated counterparts, /tsʰ/ and /tɕʰ/. In table 5, formant frequencies of /ɑ/ from aspirated and unaspirated counterparts are collapsed. For comparison, the formant frequencies of /ɑ/ following a non-coronal (taken from Thurgood 2007) are presented.

As table 5 shows, the formant values of /ɑ/ following alveolar affricate /ts/ measured in the middle of the vowel do not differ from the formant values of /ɑ/ given in Thurgood

https://doi.org/10.1017/S002510030800368X Published online by Cambridge University Press

(2007). F1 is lowered when /ɑ/ follows either the retroflex or the alveolo-palatal affricate. A lowering effect of both types of affricates occurs not only at the onset but also in the middle of /ɑ/. Additionally, the retroflex affricate has not been found to trigger lowering of F3 in the following vowel. As a result, the retroflex and the alveolo-palatal do not reliably differ in their effect on F1, F2 and F3 of the following vowel.

4.4 Discussion

The results show that of the three acoustic measurements used in this study, the best differentiation among the three coronal affricates is achieved by the gravity center frequencies. Gravity centers for alveolar /tsʰ ts/ are highest. Their relatively high frequency center of gravity is shared with high gravity centers for Mandarin Chinese /tsʰ ts/ (Svantesson 1986). However, the gravity centers of the remaining two types of affricates do not pattern in the same way. In Anong, the alveolo-palatals /tɕʰ tɕ/ are characterized by the lowest gravity centers. In Mandarin Chinese, retroflex /tʂʰ tʂ/ have the lowest gravity centers.

Spectral shapes of the fricative component of /tsʰ/ are similar to spectral shapes of the corresponding fricative /s/, with both their spectral peaks located at higher frequencies. Spectra for /tɕʰ/ and for /tʂʰ/ show a very similar display of noise distribution with the most pronounced peaks between 2 kHz and 4 kHz. For both affricate types before the non-back high vowel, the spectral peaks are followed by a relatively flat spectrum and then a decline. However, before the low vowel, the spectra of /tɕʰ/ and for /tʂʰ/ are characterized by secondary peaks between 5.7 kHz and 6.4 kHz. Before the non-back high vowel, the spectral shapes of /tɕʰ/ and /tʂʰ/ are similar to the spectral shape of /ɕ/. Before the low vowel, the spectral shapes of /tɕʰ/ and /tʂʰ/ are similar to the spectral shape of /ʂ/.

The fricative component of /tʂʰ/ does not trigger lowering of F3 in the following vowel. Instead, it patterns with /tɕʰ/ in triggering a lower F1 in /ɑ/. A lower F1 reflects a longer constriction not characteristic of a retroflex (Halle & Stevens 1997, Stevens 1998). It again points to /tʂʰ/ being more like /tɕʰ/.

5 Conclusions

The study has examined the acoustic characteristics of Anong coronal fricatives and affricates, focusing on the three-way distinction among the voiceless fricatives /s ʂ ɕ/, the voiceless aspirated affricates /tsʰ tʂʰ tɕʰ/, and the voiceless unaspirated affricates /ts tʂ tɕ/. The study has shown a lack of parallelism between the coronal fricatives and affricates. With the fricatives, the spectral shapes and the formant frequencies of the following vowel display a three-way distinction among the fricatives /s ʂ ɕ/, but the gravity center frequencies only provide a two-way distinction, between /s/, on the one hand, and /ʂ/ and /ɕ/ on the other. However, with the affricates, the spectral shapes and the formant frequencies of the following vowel do not differentiate /tsʰ tʂʰ tɕʰ/ well; these acoustic measurements only show a two-way distinction, between /tsʰ/, on the one hand, and /tʂʰ/ and /tɕʰ/ on the other. However, the gravity center frequencies do preserve a three-way distinction.

As for retroflexes in Anong, the spectral shapes of /ʂ/ and the formant frequencies of the following vowel show that /ʂ/ is acoustically a retroflex. First, the spectral shape of /ʂ/ with its two spectral peaks not only differentiates it well from the remaining two coronals /s/ and /ɕ/, but it also patterns well with the spectral shapes of the retroflex fricatives in other languages (Komi-Permyak, Mandarin Chinese, Polish). Second, Anong /ʂ/ triggers a significant lowering of F3 in a following /ɑ/, a feature that has been associated with the presence of retroflexion. It is of interest that in Anong the effect of /ʂ/ on the following vowel is observed not only at the vowel onset but also into the middle of the vowel. In contrast, the /tʂʰ/, termed retroflex by Sun, is not a typical retroflex acoustically. First, the fricative part of /tʂʰ/ does not consistently pattern with the fricative /ʂ/. Second, the spectral peaks of /tʂʰ/ are not different from those of /tɕʰ/. Third, the vowel /ɑ/, when it follows /tʂʰ/, does not show a lowered F3, but a lowered F1 instead. Thus, in the speech of the one of the last fluent speakers of Anong, the retroflex affricate /tʂʰ/ has been lost along with other retroflex series. In contrast, the retroflex fricative /ʂ/ is still preserved.

Acknowledgements

I would like to thank Sun Hongkai for making this study possible. My thanks are also due to Graham Thurgood, David Bradley, Adrian Simpson, and an anonymous reviewer for their helpful comments. This work was supported by NSF Grant #606232 Endangered Languages in China.

References

Bradley, David. 1994. *A dictionary of the Northern Dialect of Lisu (China and Southeast Asia)* (Pacific Linguistics Series C–126). Canberra: The Australian National University.

Dart, Sarah. 1993. Phonetic properties of O'odham stop and fricative contrasts. *International Journal of American Linguistics* 59(1), 16–37.

Gordon, Matthew, Paul Barthmaier & Kathy Sands. 2002. A cross-linguistic acoustic study of voiceless fricatives. *Journal of the International Phonetic Association* 32(2), 141–174.

Halle, Morris & Kenneth N. Stevens. 1997. The postalveolar fricatives of Polish. In Shigeru Kiritani, Hajime Hirose & Hiroya Fujisaki (eds.), *Speech production in language: In honor of Osamu Fujimura*, 177–193. Berlin: Mouton de Gruyter.

Kochetov, Alexei & Alevtina Lobanova. 2007. Komi-Permyak coronal obstruents: Acoustic contrasts and positional variation. *Journal of the International Phonetic Association* 37(1), 51–82.

Ladefoged, Peter & Ian Maddieson. 1996. *The sounds of the world's languages*. Oxford: Blackwell.

Ladefoged, Peter & Zongji Wu. 1984. Places of articulation: An investigation of Pekingese fricatives and affricates. *Journal of Phonetics* 12, 267–278.

Nowak, Paweł M. 2006. The role of vowel transition and friction noise in the perception of Polish sibilants. *Journal of Phonetics* 34(2), 139–152.

Stevens, Kenneth N. 1998. *Acoustic phonetics*. Cambridge, MA: MIT Press.

Sun, Hongkai. 1988. Notes on Anong, a new language. *Linguistics of the Tibeto-Burman Area* 11(1), 27–63.

Sun, Hongkai. 2005a. *A description of Anong* [in Chinese] (New Found Minority Languages of China). Beijing: Institute of Minority Studies.

Sun, Hongkai. 2005b. The Anong language: Studies of a language decline. *International Journal of the Sociology of Language* 173, 143–157.

Svantesson, Jan-Olof. 1986. Acoustic analysis of Chinese fricatives and affricates. *Journal of Chinese Linguistics* 14(1), 53–70.

Thurgood, Ela. 2007. Phonetic variation in Anong vowels. In Jürgen Trouvain & William J. Barry (eds.), *16th International Congress of Phonetic Sciences*, 609–612. Saarbrücken.

Thurgood, Graham. 2003. The causatives in Sun Hongkai's Anong: Language death and rapid restructuring. In Paweł M. Nowak, Corey Yoquelet & David Mortensen (eds.), *Twenty-Ninth Annual Meeting of the Berkeley Linguistics Society* (*BLS* 29), 463–471.