

BAN PA LA-U SGAW KAREN TONES: AN ANALYSIS OF SEMITONES, QUADRATIC TRENDLINES AND COEFFICIENTS¹

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Abstract

Each dialect of the Sgaw Karen language has a different tonal system. Despite the different number of tones, all of the previous studies agree on the fact that all tones of Sgaw Karen are level tones. However, according to my phonological analysis of the tonal system of Ban Pa La-u Sgaw Karen, this dialect has a contour tone. The tonal system comprises four tones, i.e. /low/, /mid/, /high/ and /falling/ occurring in non-checked syllables. The high and low tones also have allotones in checked syllables. To confirm my analysis of the tonal system and the new finding of a contour tone in this Sgaw Karen dialect, an acoustic analysis of the tones occurring in citation forms was attempted. The analysis included three parts: (1) semitones to illustrate the pitch shape and height; (2) quadratic trendlines to indicate the direction and degree of pitch change; and (3) coefficients to show the

generalization of each tone and the discrimination among tones.

The fundamental frequencies in hertz of the four tones were measured and then converted into semitone values to help minimize the variations in the pronunciation of the six female speakers. In addition, time and semitone values were used to generate 2nd degree polynomial or quadratic equations and trendlines for which coefficients were plotted to model the pitch contour shapes.

The results revealed that: the low tone was mid-falling or low-falling with an obvious degree of pitch change and curved or linear pitch movement; the mid tone was mid level with a less obvious degree of pitch change and wide curved or linear pitch movement; the high tone was mid-high level with a lesser degree of pitch change and wide curved or linear pitch movement; and the falling tone was high-falling with an obvious degree of pitch change and curved pitch movement. In checked syllables, the low and high tones were realized as low-falling and high-falling respectively. The low tone had a greater degree of pitch change than the other; however, both had curved pitch movement.

1. Introduction

Sgaw Karen is a tonal language belonging to the Karenic branch, which is an affiliation within the Tibeto-Burman languages. Sgaw Karen speaking people outnumber those of the other Karenic languages spoken in Thailand, i.e. Pwo, Pa-O, Kayan, Kayah, and Kayaw. Sgaw Karen speaking people are widely distributed throughout the country. The Karen in Thailand are generally called “Kariang” which roughly refers to all

¹ This paper was presented at RGJ Seminar Series LXXXII on Southeast Asian Linguistics organized by the Research Institute for Languages and Cultures of Asia at Mahidol University. I am grateful to Dr. Chutamanee Onsuwan, the discussant of the session, for her comments and suggestions which have been useful for the revision.

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Karenic groups. At Ban Pa La-u, Tambon Huay Sat Yai, Amphoe Hua Hin, Changwat Prachuap Khiri Khan (a province in the western part of Thailand), some Karen identify themselves as “Kariang”, and others as “Karang”. Following the linguistic fieldwork, we found that Kariang is Pwo Karen while Karang is Sgaw Karen.

Each dialect of the Sgaw Karen language has a different number of tones. Previous studies have reported three to four tones in Sgaw Karen, i.e. /high/, /mid/ and /low/ (Jones 1961a, Ratanakul 1986b) or /mid/, /breathy high/, /breathy low/ and /creaky low/ (Dhananjayananda 1983³) or /mid high/, /mid/, /mid-low/ and /low/ (Lar Baa 2001) in non-checked syllables and two in checked syllables, i.e. /high/ and /low/. In addition we observed in a Linguistic Field Methods class (November 2010 – February 2011) that the Sgaw Karen dialect spoken at Ban Huay Mi in Amphoe Pay, Changwat Mae Hong Son (a province in the northern part of Thailand) has two tones, i.e. /low/ and /high/. Despite the different number of tones, all of the previous studies agree on the fact that all tones in Sgaw Karen are level tones. However, according to my phonological analysis of the tonal system of Ban Pa La-u Sgaw Karen, this dialect of

Sgaw Karen has a contour tone, i.e. a falling tone. The objectives of this research are to attest by acoustic study that the Sgaw Karen dialect spoken at Ban Pa La-u has four tones in non-checked syllables and two allotones in checked syllables and to investigate the acoustic cues to tonal discrimination. This research will provide a new finding about a contour tone in Sgaw Karen and prove the effectiveness of applying quadratic equations to analyze the acoustic characteristics of tones.

2. Phonological sketch of Ban Pa La-u Sgaw Karen

The Sgaw Karen dialect spoken at Ban Pa La-u has 23 consonant phonemes which occur in the initial position. Only / ʔ / can occur in the final position. There are 11 vowel phonemes: 9 monophthongs and 2 diphthongs. The vowel length is not contrastive. The tonal system comprises 4 tones, i.e. /low/, /mid/, /high/ and /falling/ occurring in non-checked syllables. There are allotones of the high and low tones in checked syllables. The high and low tones occurring in checked syllables are analyzed as allotones of those in non-checked syllables instead of tonemes, for they are conditioned by syllable type.

3. Methodology

I collected the data for phonological analysis in order to find a minimal set of tones to use as test words for acoustic study at Ban Pa La-u, Tambon Huay Sat Yai, Amphoe Hua Hin, Changwat Prachuap Khiri Khan. The test words were pronounced three times by six female native speakers of Sgaw Karen

³ The Sgaw Karen dialect spoken at Ban Huay Tom was originally reported by Dhananjayananda (1983) to have a tonal system comprising six contrastive tones. In this paper, I re-analyze the tonal system of Ban Huay Tom Karen to define four contrastive tones in non-checked syllables and two in checked syllables, i.e. the glottalized high and the glottalized low tones occurring in checked syllables have been re-analyzed as allotones of the high level and low level tones in non-checked syllables respectively, since they are conditioned by syllable type.

ranging in age from 23 to 43. The total number of test tokens was 108 (6 speakers x 6 words⁴ x 3 times). The speakers were asked to say the test words in the sentence frame⁵:

/tɛ wɛ ____ təʔ bə/
say COMP one time
'say the word ____ once'

The following are the test words of four lexical tones in non-checked syllables and two allotones in checked syllables:

Non-checked syllables

Low tone (Low) /lə/ 'play'
Mid tone (Mid) /lə/ 'down'
High tone (High) /lɔ/ 'deceive'
Falling tone (Falling) /lɔ/ 'straw'

Checked syllables⁶

Low tone (Low⁷) /nəʔ/ 'Ms (title)'

⁴ To avoid the influence of initial and final consonants on pitch, I used a minimal set, of which I could find only one set due to the time limitations of the fieldtrip, for non-checked syllables which have four tones, for acoustic analysis. Therefore, only six words including two analogous pairs in checked syllables were used.

⁵ There is no tone sandhi in this dialect of Sgaw Karen so this sentence frame can be used for eliciting the data.

⁶ Checked syllables with the initial consonant /l/ could not be found for the minimal set. Therefore /n/ was chosen because they are both voiced alveolar sounds.

⁷ The glottal stops (ʔ) are used to mark the allotones of the high and the low tones in checked syllables.

High tone (High?) /nɔʔ/ 'grass'

The Praat program version 5.2.11 was used for recording and F0 measurement. A high-quality desktop microphone was placed approximately 30 cm from the speakers. Mono recordings and a default sampling frequency of 44,100 hertz were selected. Regarding pitch analysis, the standard pitch range setting, which was from 75 to 500 hertz, was adapted as all of the speakers were female⁸. The floor was set to 100 hertz and the ceiling to 500 hertz.

Two F0 measurement tasks were done. The first was to analyze semitone values and the other to generate quadratic trendlines. Regarding the first F0 measurement task, the fundamental frequencies (F0) at 5 points of time for each vowel were measured at 0%, 25%, 50%, 75% and 100% from vowel onset to offset. Only 5 points of time, instead of 11 points, were measured because they did not show significant differences. Moreover, the elaborated pitch measurement was further done for the second F0 measurement task for which the fundamental frequency was measured every 0.01 second from vowel onset to offset.

The measured fundamental frequencies in hertz were converted into semitone values. In fact, there are a number of psycho-acoustic pitch scales, apart from semitones, such as mels, Bark and ERB-rate. Semitones were used in this study owing to their effectiveness. Nolan (2007) has done an experimental evaluation of pitch scales and the results reveal that semitones most

⁸ It was difficult to find male informants because they went out to work.

accurately reflect intuitions about the intonational equivalence of the subjects.

The formula was semitones = $3.32 \times 12 \times \text{LOG}(\text{Hz to be translated} / \text{Hz reference level})$. On account of the different purposes of converting hertz into semitones, the reference levels used for plotting the semitone-value line graph and the scatter plot for generating quadratic trendlines were different. The line graph of semitones was to illustrate the overview of the tone shapes and the comparison of the pitch height of all

tones, so the reference level in the case of the semitone line graph was the lowest pitch point among all tones which, in this study, was always that of the low tone in the non-checked syllable (as an example of Speaker 4 in Table 1). The fundamental frequencies were converted into semitones and the lowest pitch was subtracted to zero to help minimize the variation in the pronunciation of the six female speakers, showing the different pitch height and range between each tone produced by the individual speaker and among the other speakers.

Consonants

	<i>Bilabial</i>	<i>Alveolar</i>	<i>Palatal</i>	<i>Velar</i>	<i>Glottal</i>
<i>Plosive</i>	p b ph	t d th	c ch	k kh	ʔ
<i>Nasal</i>	m	n	ɲ	ŋ	
<i>Fricative</i>		s		x ɣ	h
<i>Trill</i>		r			
<i>Approximant</i>	w	l	j		

Vowels

<i>Monophthongs</i>	Front	Central	Back
high	i	ɨ	u
mid	e	ə	o
low	ɛ	a	ɔ
<i>Diphthongs</i>		ai au	

Tones /low/⁹ /mid/ /high/ /falling/

⁹ The low tone is produced with a breathy voice, but the breathy voice is not marked because it can be predicted and phonation type is not contrastive in this language.

The other purpose of converting hertz into semitones was to show the degree of pitch change in each tone. Thus the reference level was the lowest pitch point of each tone (as an example of Speaker 4 in Table 2). When the lowest pitch point from each pitch measurement of each tone was normalized to zero, the maximum pitch became equal to the degree of pitch change. The normalized semitones showed the total amount of pitch

change in each contour compared across tones and speakers. The scatter plots and the quadratic trendlines that best fitted the F0 measurements were generated by Microsoft Excel 2010. The 2nd degree polynomial or quadratic equation used to generate the trendline was $y = ax^2 + bx + c$. The a- and b-coefficients for each trendline were saved to create a model based on the relationship of the a- and b-coefficients from the equations.

Table 1 The semitone values of each tone produced by Speaker 4, prepared for a line graph. Zero was the reference level.

Semitones: Speaker 4						
Time	Low	Low?	Mid	High	High?	Falling
0%	4.782749	7.144141	2.657708	4.861412	7.349272	6.520224
25%	4.133223	6.862081	2.048872	4.651888	7.379556	6.263299
50%	3.209767	6.529904	1.560691	4.668621	7.272468	5.546492
75%	1.818102	5.560063	1.442503	4.473226	6.549445	3.430742
100%	0	3.208046	1.30989	4.140227	5.402263	2.37995

4. Results

4.1 Semitones

The semitones converted from the average fundamental frequencies of each tone produced by each Pa La-u Sgaw Karen speaker were plotted using line graphs illustrating the phonetic realization of the four lexical tones.

The six line graphs show the overview of the four tones in non-checked syllables and two in checked syllables. In spite of some differences in details among speakers, they reflect a similar pattern (see Figure 1).

In Figure 1, the result of the F0 measurements indicates that the four lexical

tones in Pa La-u Sgaw Karen can be categorized by pitch height and contour. To begin with the non-checked syllables, the generalization was that the *low tone* was mid-falling or low-falling. It began at mid or low range, and fell steadily to the lowest point of the semitone scale. The *mid tone* was mid level or low level beginning at the mid or low range and staying level or falling slightly. The *high tone* was mid-high level. It began with mid or mid-high pitch and stayed relatively level in that it rose or fell for not more than one semitone scale except for that of Speaker 1. Despite three semitone scales of pitch contour, the high tone of

Speaker 1 could be concluded to have a small amount of contour similar to the other

five speakers due to the widest pitch range. This is supported by the finding of Dilley (2005), suggesting that tone is relative in a dualistic way, one part of which is that tones are scaled relative to an individual's pitch range. Moreover, although the high tone of some speakers began at the mid range similar to the low and the mid tone, it was noted that the pitch of the high tone from 25% to 100% was always higher than the other two tones. The *falling tone* was high-falling. It began at a high range then either

fell to mid range (Speaker 1, 2 and 4) or rose to the highest point at 25% before falling to mid range (Speaker 3, 5 and 6). Furthermore, the pitch shapes of the allotones of the high and the low tones in the checked syllables were either falling or rising-falling. Although they shared a similar pitch contour, they were differentiated by the endpoint. The high tone always ended higher than the low tone.

Normalized Semitones : Speaker 4						
Time (sec)	Low	Low?	Mid	High	High?	Falling
0	3.905162	2.086838	1.061225	0.273398	1.858174	4.078882
0.01	3.819686	2.071617	0.911586	0.258577	1.736927	4.077479
0.02	3.632387	2.054405	0.514968	0.310423	1.617278	3.997847
0.03	3.477174	2.049013	0.336621	0.313052	1.514942	3.908419
0.04	3.337588	2.024117	0.363141	0.347427	1.408199	3.78989
0.05	3.043458	1.957536	0.267551	0.329549	1.291427	3.658584
0.06	2.814755	1.784974	0.232249	0.273675	1.124818	3.539144
0.07	2.635281	1.538286	0.121453	0.25557	0.790055	3.423321
0.08	2.554128	1.205144	0.104036	0.199834	0	3.261531
0.09	2.094947	0.717159	0.06911	0.125465		3.075494
0.1	1.914202	0	0	0.086418		2.781599
0.11	1.514439			0		2.41639
0.12	0.994252					1.9926
0.13	0.630345					1.560399
0.14	0					0.929184
0.15						0.588183
0.16						0.325644
0.17						0

Table 2 The semitone values of each tone produced by Speaker 4, prepared for a scatter plot to generate the quadratic trendline. The zeroes were the reference level of each ton

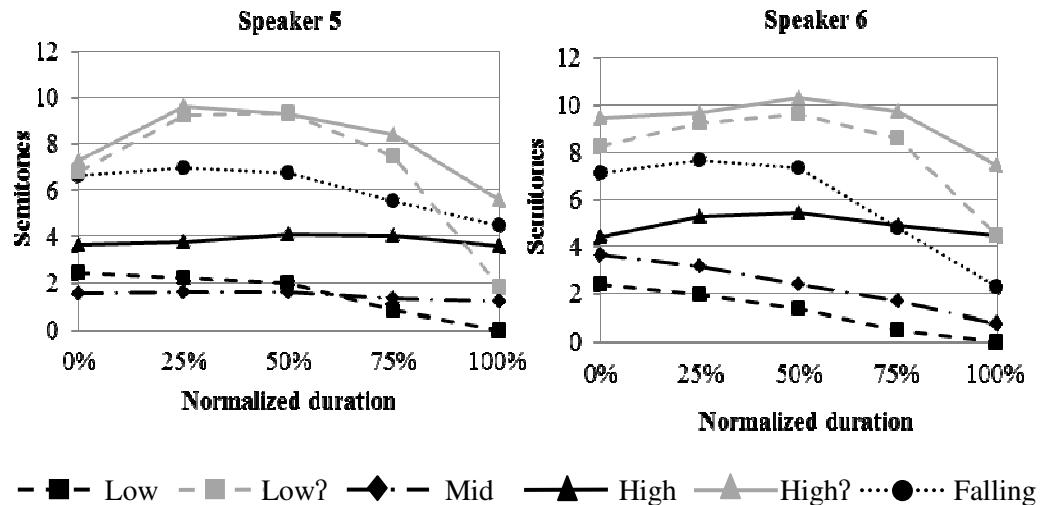


Figure 1 Semitones of the Pa La-u four lexical tones

According to the semitones of the four lexical tones in both non-checked and checked syllables, the phonetic characteristics of many tones, i.e. the low tones in both non-checked and checked syllables, the high tone in checked syllables, and the falling tone were of a falling or convex shape. Moreover, it was speculated that duration was relevant to tonal identity. Among the tones with phonetically falling shape, the tone with shorter duration would fall more steeply than the longer counterpart. Nevertheless, the different durations of the tones were ignored in the semitone line graph owing to the normalized duration represented by the x-axis. Therefore, it was interesting to use the method proposed by Andruski and Costello (2004) to investigate the pitch contour cues for tone discrimination in Pa La-U Sgaw Karen as the method revealed the details of pitch contour and the durations of tone in real time. Andruski and Costello (2004) noted that “in languages with a crowded tonal space, multiple tones

can have similar contours. Even in languages with few tones, details of contour shape may be used by listeners for tone identification.” They proposed the method of using polynomial equations to model pitch contour shape in lexical tones. Green Mong was used as a test case. In the paper, two kinds of polynomial equations, namely linear equations (1st degree polynomial equations) and quadratic equations (2nd degree polynomial equations) were used to test their hypothesis. It was found that discriminant analysis using the coefficients as predictor variables showed a greater effectiveness of using quadratic coefficients for tone classification than linear coefficients.

The method of using quadratic equations and trendlines to analyze lexical tones proposed by Andruski and Costello (2004) was adopted in this study in order to investigate the pitch contour cues for tone discrimination in Pa La-u Sgaw Karen.

4.2 Quadratic trendlines

A quadratic equation can be applied in order to analyze lexical tones, especially contour tones, in languages. The output of the quadratic equation is the trendline which can be used to describe and compare the details of contour shape across tones. The quadratic trendline shows the direction and the degree of pitch change, which pinpoints some interesting pitch contour cues compared with the semitone-value line graph. The information carried by the trendlines elaborates the phonetic realization of the lexical tones.

A quadratic equation is a polynomial equation of the second degree. The form of quadratic equation used in the study of Andruski and Costello (2004) was $y = a + bx + cx^2$. However, this current study followed the form of quadratic equation generally used in mathematic literature i.e. $y = ax^2 + bx + c$ where a and b are coefficients. Therefore, the a -coefficient in this study was the c -coefficient in Andruski and Costello's study. The trendline generated from a quadratic equation is a graph in the form of a parabola. The parabola can open either upward or downward as in Figure 2.

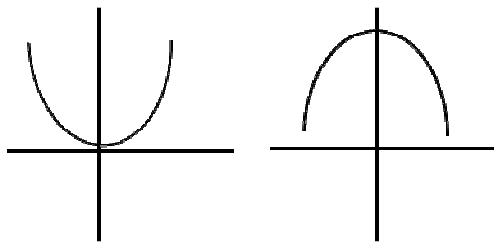


Figure 2 A parabola opening upward (left) and a parabola opening downward (right)

However in the case of analyzing tone or lexical pitch in languages, the quadratic trendline generated from the value of time and semitones is always half of the parabola. This is because the x -axis which represents time value is never negative.

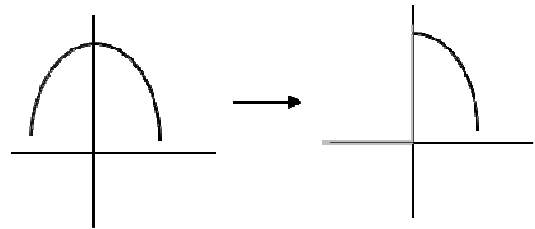


Figure 3 A half parabola due to the positive value of the x -axis representing duration

In this paper, the values of time and semitones were used to generate 2nd degree polynomial or quadratic equations and trendlines for each actual pitch contour. As in the example of Speaker 1 in Figure 4, the y -axis shows the semitone scale for interpreting the direction and degree of pitch change while the x -axis shows the duration in seconds.

In the case of Speaker 1's falling tone, the quadratic equation for generating this trendline was $y = -178.1x^2 - 12.90x + 6.867$ in the form $y = ax^2 + bx + c$. The y -axis of the line graph (left) represents the level of pitch height whereas the y -axis of the scatter plot (right) represents the degree of pitch change. The line graph indicates that the pitch height of the starting point of the falling tone produced by Speaker 1 was approximately 12 semitones and the lowest point at the end was approximately 6 semitones. This conforms to the information conveyed by the trendline of the scatter plot in that the y -axis indicated an amount of

pitch change of approximately 6 semitones. While the x-axis of the line graph represents the normalized duration, the other represents the real duration indicating a duration of approximately 0.17 second. The semitone-value line graph and the trendline both suggest a similar phonetic realization in

terms of the pitch shape of the falling tone produced by Speaker 1 in that the line graph illustrates the overall pitch shape of the falling tone as high falling and the trendline also shows the direction of the pitch movement as a convex or falling contour.

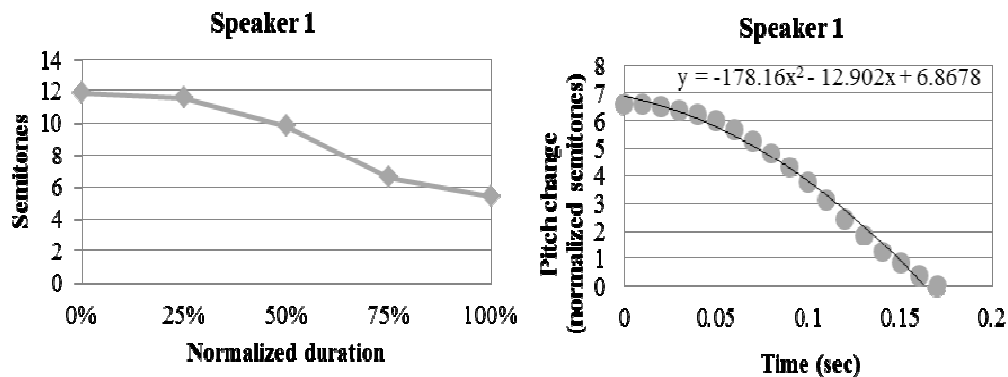


Figure 4 The comparison of the semitone-value line graph (left) and a quadratic trendline fitted to average fundamental frequencies of the falling tone (right) produced by Speaker 1

As in Figures 5-10, it is important to note that the y-axis of the quadratic trendline graph on the right does not represent the pitch height as it traditionally does in the line graph of hertz or semitone values but the degree of pitch change or contour. Besides, the x-axis of the quadratic trendline graph on the right represents real duration (seconds) instead of normalized duration (5 equidistant timepoints) as in the line graph of semitone values on the left.

The quadratic trendlines of the four lexical tones produced by 6 speakers can be classified into 3 groups based on the patterns. The main difference is the pitch movement of the high, mid and low tones in non-checked syllables.

The other tones, i.e. the falling tone in non-checked and the high and low tones in checked syllables, all had a convex pitch contour.

Pattern 1: Linear pitch movement (S1)

The uniqueness of the first pattern was that, except for the falling tone, all tones in non-checked syllables had a linear pitch movement. In other words, the pitch movement of the low, mid, and high tones in non-checked syllables was a straight line (see Figure 5).

As in Figure 5, the trendline on the right shows that the falling tone had the largest amount of pitch change and the mid tone

had the smallest. Although the low tone in non-checked syllables had the lowest starting point, illustrated by the semitone-value line graph on the left, the amount of pitch change was not the smallest. According to the trendlines, the pitch movement of the falling tone, the low, and the high tones in checked syllables was convex or falling. The pitch movement of the low tone, mid tone, and high tone in non-checked syllables was a straight line. This suggests that in spite of the contour shape of the low tone resembling the falling tone in the semitone-value line graph, the overall pitch movement was similar to that of the level tone. This was due to the different duration of the low and falling tones. The low tone had approximately 0.1

seconds of duration more than the falling tone. Longer duration caused the gradual pitch fall; consequently, the overall pitch movement was more like a level tone than a contour tone.

Pattern 2: Curved pitch movement (S2-S5)

All of the tones in the second pattern had a non-linear pitch movement. Like the other patterns, the falling tone and the two tones in checked syllables were convex. The low, mid, and high tones, in contrast to Pattern 1, had a curved pitch movement – both convex and concave. The different shape of curvature brought about an insignificant difference due to the small degree of pitch change (see Figures 6-9).

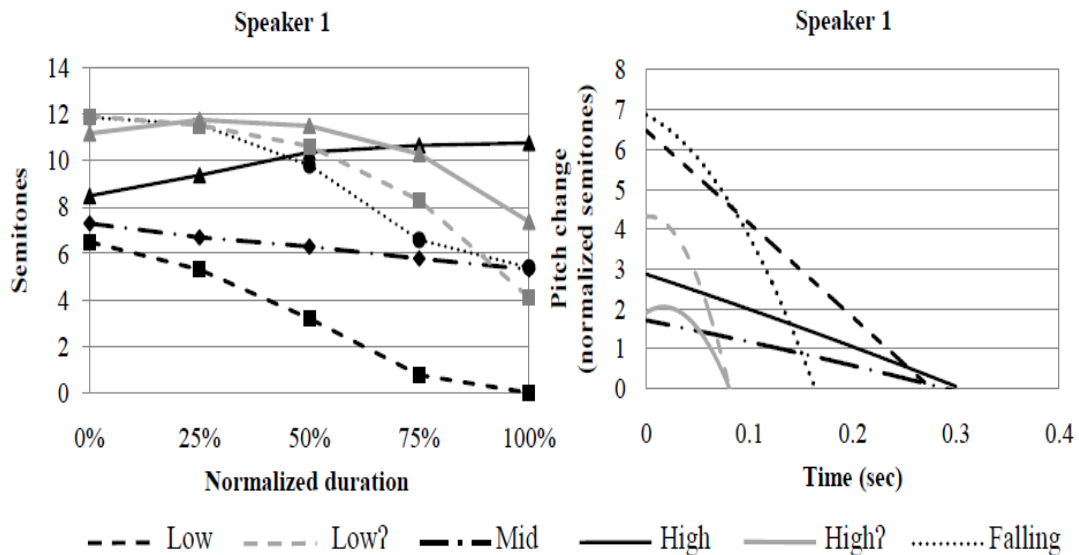


Figure 5 A comparison of semitones of the Pa La-u four lexical tones (left) and quadratic trendlines generated from semitones (right) produced by Speaker 1

As illustrated in Figures 6-9, the tones produced by Speakers 2 – 5 had nearly the same pitch-contour pattern. The trendlines illustrate that no tones had a pitch movement in an exact straight line. The semitone-value line graph shows that the overall tone shapes of the low tone and the falling tone in non-checked syllables were of a similar contour shape as for Speaker 1 in Figure 5. Nonetheless, unlike the linear trendline of Speaker 1's low tone, the trendlines showing the pitch movement of the low tones of this pattern were convex. With regard to the other tones in non-checked syllables, the pitch movement of the mid tone was a wide concave (S2,S3,S4) or a wide convex (S5); and that of the high tone was a wide convex (S2,4,5) or an extremely wide concave which resembled a straight line but not exactly. (S3). However, the degree of the pitch change was less than 1 semitone,

leading to an insignificant contour, and they were reasonably categorized as level tones conforming to the overall pitch shape in the semitone-value line graph. The falling tone was obviously realized as a falling contour. The pitch-change range was approximately 3-4 semitones except for Speaker 5. What differentiated Speaker 5's falling tone from the low tone, which had nearly the same amount of pitch change, was a rise-fall pitch contour and shorter duration causing a steeper contour. In checked syllables, both the semitone-value line graph and trendline showed that the low and high tones were falling and the low tone had greater degrees of pitch excursion.

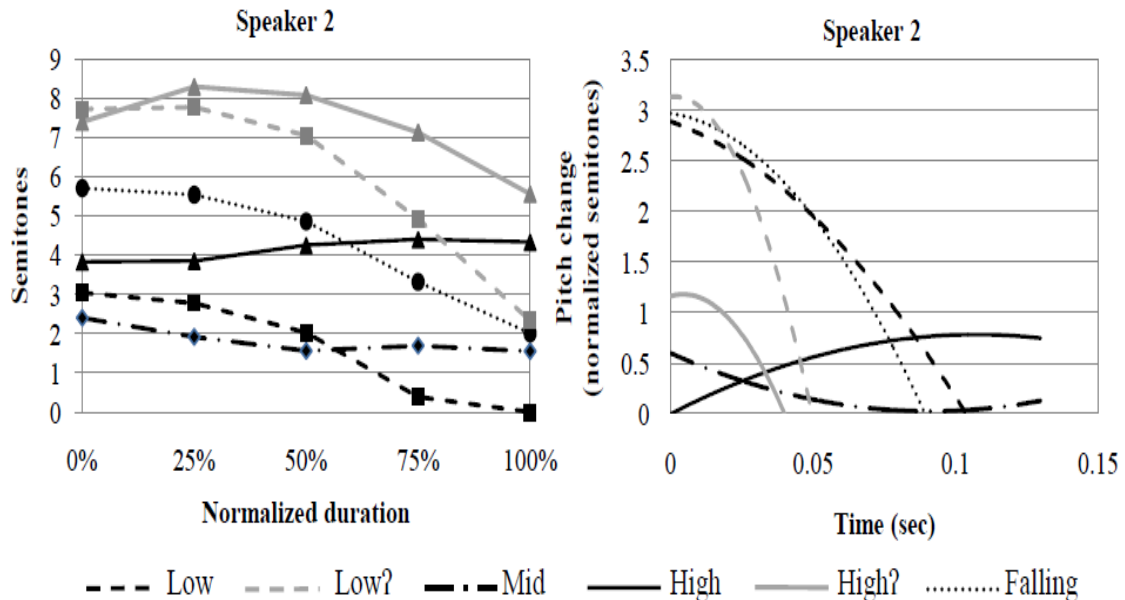


Figure 6 A comparison of semitones of the Pa La-u four lexical tones (left) and quadratic trendlines generated from semitones (right) produced by Speaker 2

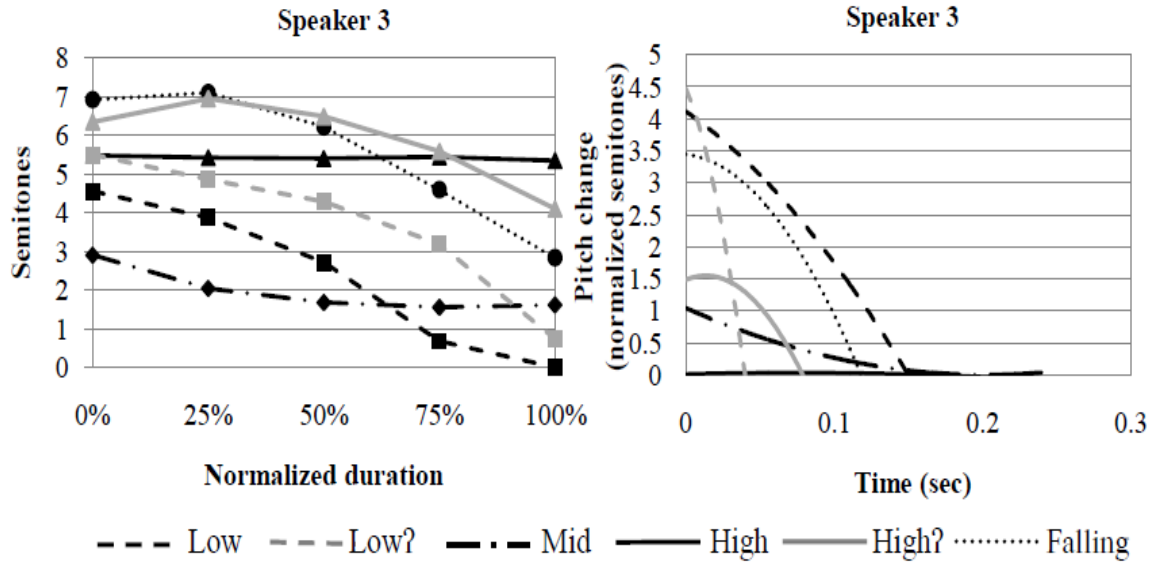


Figure 7 A comparison of semitones of the Pa La-u four lexical tones (left) and quadratic trendlines generated from semitones (right) produced by Speaker 3

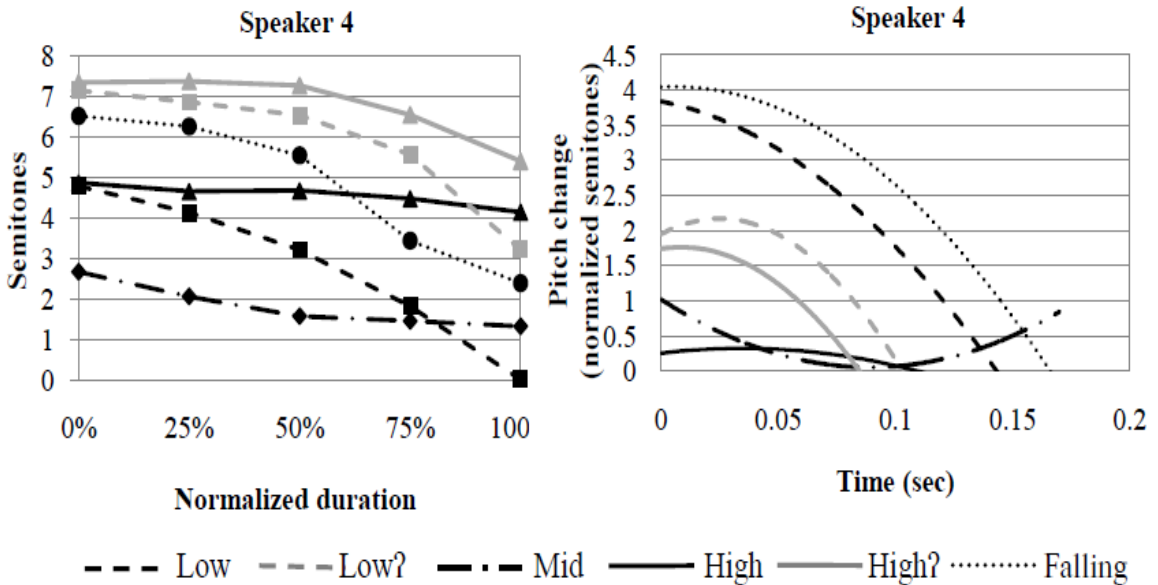


Figure 8 A comparison of semitones of the Pa La-u four lexical tones (left) and quadratic trendlines generated from semitones (right) produced by Speaker 4

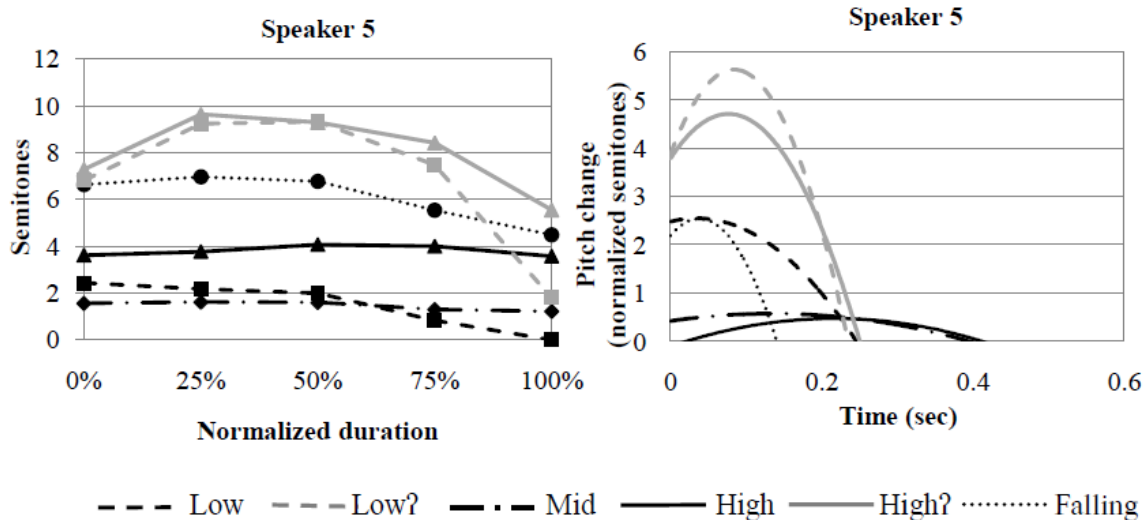


Figure 9 A comparison of semitones of the Pa La-u four lexical tones (left) and quadratic trendlines generated from semitones (right) produced by Speaker 5

Pattern 3: Mixed type (S6)

The last pattern combined Patterns 1 and 2 in that the mid and low tones in non-checked syllables had a straight-line pitch movement but the high tone in non-checked syllables had a curved pitch movement as shown in Figure 10.

As seen in Figure 10, the trendline of the falling tone shows the largest amount of pitch change and the pitch contour shape as high falling. Due to the small pitch change below 1 semitone and the relatively long duration compared to the other tones, the high tone was categorized as a level tone, conforming to the phonetic realization illustrated by the semitone-value line graph. The pitch movement of the low and mid tones in non-checked syllables was a straight line, suggesting the characteristics of a level

tone. In checked syllables, the low tone had much more pitch excursion than the high tone; both were realized as falling.

To sum up, the generalization is that in non-checked syllables, the low tones whose phonetic realizations were mid falling or low falling, as the line graphs showing the semitones on the left of Figures 5-10 indicate, had three characteristics of trendlines: (1) the pitch movement was a straight line similar to the level tone; (2) the pitch movement was convex with wide curvature nearly similar to a straight line; (3) the pitch movement was convex but less obvious than the falling tone, which was relevant to the longer duration of the low tone. This suggests that the characteristics of the low tone were fairly level, similar to the impressionistic description.

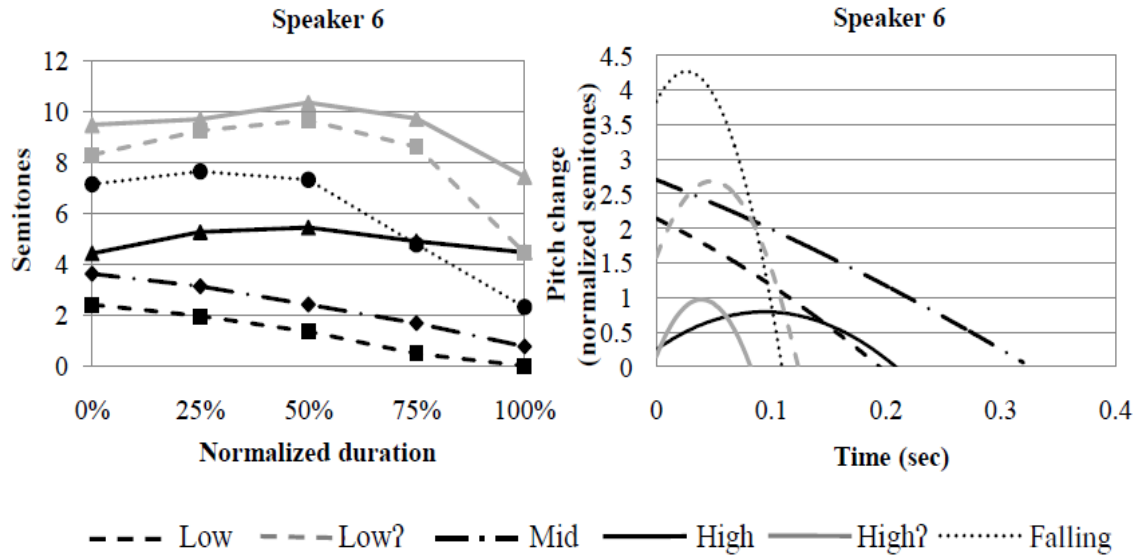


Figure 10 A comparison of semitones of the Pa La-u four lexical tones (left) and quadratic trendlines generated from semitones (right) produced by Speaker 6

The trendlines of the mid tone and the high tone, which were level tones, in non-checked syllables were not always a straight line. In spite of some curved trendlines, the range of the pitch change showing in semitones was narrow, resulting in a less obvious pitch contour. The contour was not significant when the degree of pitch movement was very little (not more than 1 semitone). Likewise, the results emphasize their realization as level tones. With regard to the falling tone, the semitone-value line graph together with the trendline unanimously confirmed the high-falling pitch contour.

In checked syllables the high tone and the low tone both had a falling pitch contour indicated by the direction and shape of the trendlines. The two tones were distinguished by the amount of pitch change. The pitch-change range of the low tones was larger

than the other. The results support the conclusion that the trendlines illustrate more detailed information about contour shape.

Table 3 shows the phonetic realization of the four lexical tones by synthesizing the information conveyed by both semitone-value line graph and quadratic trendline.

4.3 Coefficients

As the trendlines of tones across speakers were not identical, the line graphs cannot show the generalization and discrimination of tones well. Therefore, the a- and b-coefficients of the quadratic equations were further used to generate a scatter plot in order to create a model for tonal identity. The model reflects the generalization of each tone and discrimination among tones.

Table 3 Phonetic realization of the four lexical tones

Lexical tones	Overall shape	Starting point	Endpoint	Degree of pitch change	Duration	Pitch movement
Low	falling	mid/low	lowest	Obvious ¹⁰	long	linear / curved
Mid	level	mid	mid	less obvious	long	linear / wide curved
High	level	mid-high	high	less obvious	long	linear / wide curved
Falling	falling	high	low	obvious	short	curved
Low?	falling	high	higher than high?	more than high?	short	curved
High?	falling	high	lower than low?	less than low?	short	curved

This model based on the relationship of the a-and b-coefficients from the quadratic equations reflects the aspects of pitch contour shape distinguishing one tone category from another. The b-coefficient indicates the initial slope at the intercept. With the positive b-coefficient, the initial slope of the contour is upward, and the negative b-coefficient causes a downward initial slope (see Figure 11).



Figure 11 Information carried by the b-coefficients, the dotted circle indicating the initial slope

¹⁰ The criterion for identifying the “obvious” pitch change was a pitch-change degree of more than 3 semitones for linear pitch movement and more than 1 semitone for curved pitch movement

The a-coefficient indicates whether the pitch contour is concave or convex. A positive a-coefficient brings about a concave contour and a negative result in a convex contour. In addition, when the value of the a-coefficient is zero, its contour is a straight line. The amount of the absolute value of a-coefficients also indicates the size of the curvature. The larger the absolute value of a-coefficient, the steeper the pitch contour becomes (see Figure 12).

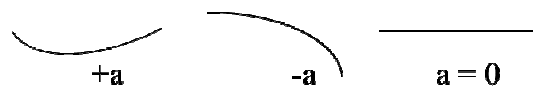


Figure 12 Information carried by the a-coefficients

The a- and b- coefficients from all trendlines were plotted in the scatter plot to show the clustering and scattering of the tones suggesting the generalization of each tone and discrimination across tones (see Figure 13).

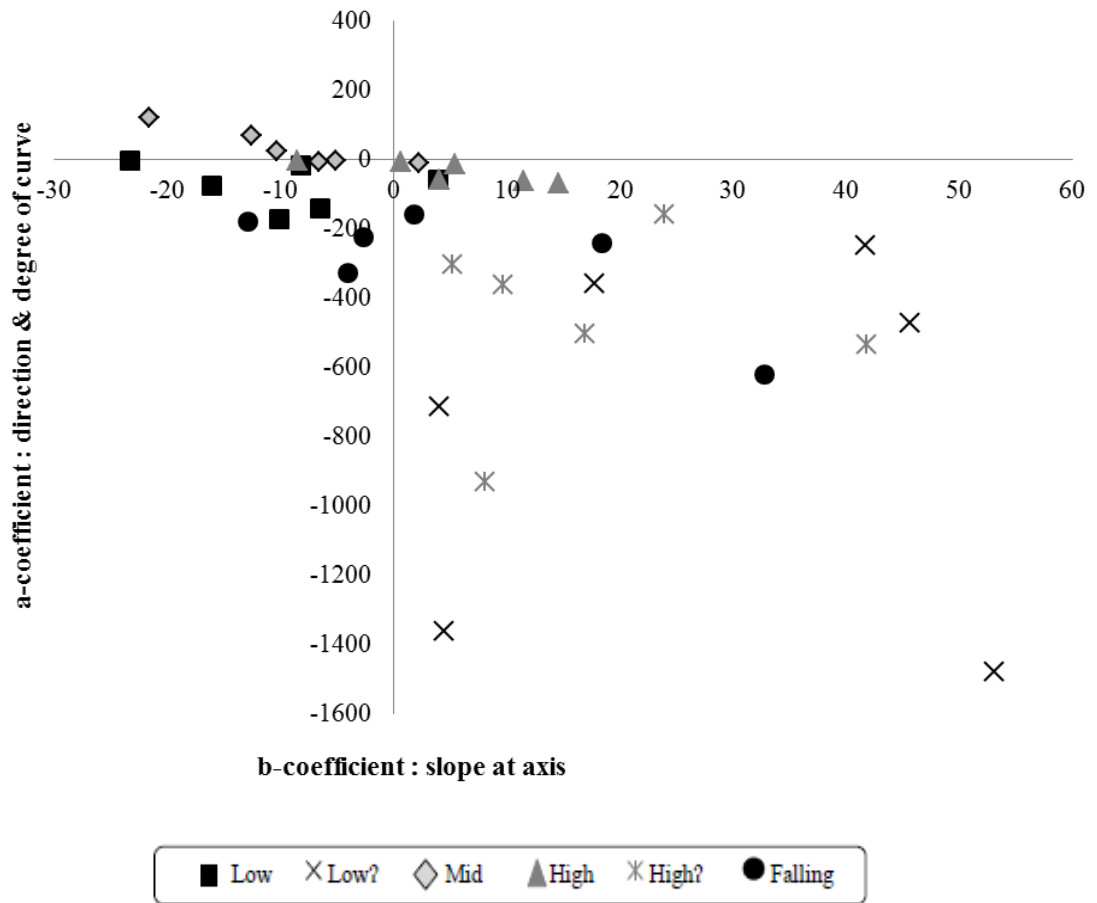


Figure 13 Relationship of the a- and b-coefficients from the quadratic equations

In Figure 13, the x-axis represents the b-coefficient, and the y-axis represents the a-coefficient. There are no tones in the upper right quadrant because positive a- and b-coefficients indicate a rising contour. The rising tone is not a phoneme in the tonal system of Pa La-u Sgaw Karen. Only the mid and high tones in non-checked syllables are level owing to the value of a-coefficients (y-axis) near zero. Although the high tone has a slightly upward initial slope whereas the mid tone has a slightly downward initial slope due

to the different positive/negative values of b-coefficient, they both are categorized as level tones since the contour is slight and their overall shapes are relatively straight lines.

The model reflects the different falling or convex shapes of the low (in non-checked syllables) and falling tones. The low tones have a progressive fall indicated by negative b-coefficient values. Although one token of the low tones has a positive b-coefficient value, the absolute value is so small that it

does not show a significant upward initial slope.

The falling tones have a rise-fall pattern and a steep fall. The rise-fall pattern is specified by a positive b-coefficient value. Compared to the low tones, all of the falling tones have larger absolute values of a-coefficients, pointing out the steeper contours. In addition, having smaller absolute values of a-coefficients, the majority of the low tones fall very close to the same space occupied by the mid and high tones in non-checked syllables. Therefore, some of the low tones have a contour shape resembling the level tone. These values reflect the fact that the falling tone has a more obvious contour pattern than the low tone in non-checked syllables.

Of all the tones, the low and high tones in checked syllables show the most obvious rise-fall pattern. All have positive b-coefficient values and most have extreme negative a-coefficient values. However, the low tones have steeper contours as the absolute values of a-coefficients are larger.

5. Conclusion and discussion

Acoustic analysis confirmed the characteristics of Pa La-u Sgaw Karen's four lexical tones consisting of three level tones and one contour tone. The line graph of semitones, the quadratic trendlines, and the model based on the relationships of coefficients indicate the complex of acoustic cues to tonal identity. Tones in the Pa La-u Sgaw dialect are well-defined by pitch shape, starting point, endpoint, degree of pitch change, duration, pitch movement, and slope.

This research supports the effectiveness of applying quadratic equations to analyze the acoustic characteristics of tones in language as suggested by Andruski and Costello (2004). In addition, the values of quadratic coefficients can further be plotted in a scatter plot to reflect the generalization of the individual tone together with the discrimination among tones by showing clustering and scattering in a particular area.

In fact, an acoustic analysis of the tones in connected speech was also performed but is not included in this paper because it did not show any significant pattern. The variability of the tones in connected speech could have resulted from different phonetic environments. Moreover, the data is too small and thus, inadequate for statistical analysis.

Acknowledgements

I would like to express my gratitude to Prof. Dr. Theraphan Luangthongkum for her supervision and comments. Financial support from the Thailand Research Fund through the Royal Golden Jubilee Ph.D. Program and the Faculty of Arts, Chulalongkorn University (Grant No. PHD/0201/2552) to Prof. Dr. Theraphan Luangthongkum and Sujinat Jitwiriyanont is acknowledged. My special thanks go to my friends in the Department of Linguistics and the Sgaw Karen at Ban Pa La-u.

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