TONAL MOVEMENTS IN THAI

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ABSTRACT

This paper investigates the acoustics of the five Thai tones with respect to the constraints for contour tone perception proposed by House [5]. A comparison with the production model which compares a tonal contour to the response of a step-input of a second order linear system [2], [7], [8] is given. The phonological representation of Thai contour tones is suggested. Finally, 'the optimal range' of tonal movements for contour tone perception is discussed.

INTRODUCTION

House [5] finds three perception constraints for contour tones as movement contour features-- a minimal vowel duration of 100 ms., contour movement onset in synchrony with vowel onset, and contour movement occurring during spectral stability. When these criteria are not met, the tone is perceived as tonal level. These perception constraints do not apply to tonal excursions which do not fall within a certain 'optimal range' which is yet to be defined. House notes that the tonal contours in his studies range between 3-8 semitones per 100 ms. Such an optimal rate of tonal movement serves to distinguish the perception of contour tone features, e.g. Rise, Fall, from level tone features, e.g., High, Low. He further invites studies on both production and perception of various tonal languages for verification.

This paper investigates the five tones in Thai traditionally described as three levels, High, Mid, Low, and two contours, Fall and Rise. The perception and representation of the Thai contour tones is controversial [1], [3], [4], [10], [11] while High, Mid, and Low are well agreed upon to be single level tones [9]. Phonetically, modern Mid and Low tones fall slightly whereas High tone rises. The acoustic inspection in this study focuses on the direction and rate of F0 change, and duration and onset of F0 change. All were examined in synchrony with an observation of the spectral pattern.

MEASUREMENTS

Subjects are ten native Thai speakers, 5 males and 5 females ages 19-33 years. The recordings were made on isolated [aa] syllables in all five tones, 5 tokens per tone, 25 tokens per subject. The F0 and time measurements were made on a PC computer using Kay Elemetrics CSL 4300 programs.

F0 end-points for each contour movement were measured at the beginning and end of the rise or fall. Such measurements define the total interval of the tone. The velocity of F0 change was calculated from the mid 75% portion of the entire contour for each slope [6]. This is the 'response' slope where the maximal rate of pitch change occurs [6]. The contour movement onset was measured beginning at the voicing onset of the vowel to the time where the F0 begins to change direction, either rising or falling. The same measurements were applied to all tones. A few tokens with discontinuous F0 pattern were disregarded. Both the total and the response intervals were normalized to semitones and the velocity of the response slope ($\Delta F0/\Delta time$) to semitones per second.

RESULTS

For both males (tbl.1) and females (tbl.2), only Low tone has the beginning of the falling F0 within 50 ms. after the vowel onset, i.e., having the beginning of the tonal contour synchronized with the vowel onset [5]. For the vowel duration, all tones have the tonal slope span over a period of ± 200-300 ms. during which there is spectral stability, with an average of ± 200 ms. for Fall, Rise, and ± 300 ms. for High, Mid, Low (tbls. 1 & 2). Combining the contour movement onset and interval time (tbls. 1 & 2), the approximate vowel duration is 350-400 ms. for all tones.

For the tonal interval (fig. 1), High, Mid and Low have an average interval of ≤ 3 semitones whereas Fall and Rise span an interval of 5-7 semitones.

The tones were grouped in two groupings according to the direction of the tonal excursions; Falling pattern with Fall, Low and Mid, and Rising pattern with Rise and High. A correlation was calculated between the response interval and response velocity of pitch change, and between the response interval and response duration for each tone separately, and for each tonal group. The velocity and the interval are found to be highly correlated ($p < .005$) for each tone, and for each tonal group (tbl. 4). The duration and interval, however, do not correlate for most tones for both males and females, with an exception of Fall (females) and Mid (males) (tbl. 3). For the tonal groups, the duration inversely correlates with the interval size (tbl. 3).

DISCUSSIONS

The only tone that meets all the three criteria for the contour feature perception [5] is Low. However, Low is categorized as a level tone in Thai. Two possible determining factors seem to be the rate of F0 change and the interval size.

The correlation between the velocity of F0 change and the interval size for all tones ($p < .005$) for both males and females, with no correlation found for the interval and the duration for most tones except for Fall in females and Mid in males (tbl. 3) seem to indicate a time constant in the pitch control mechanism, [2], [7], [8], [10], [11]. Such data advocates for a directional, interval dependent default rate of F0 transition which is automatically generated, with sequences of level tones as the representations (comparable to the step-input of a linear system). Moreover, the correlation between the velocity and the interval ($p < .005$) for both tonal groups (tbl. 4) seems to indicate that the same mechanism for tonal movements is being applied to all tones with the same direction of tonal change; Fall, Low and Mid, and Rise and High.

Since velocity is not distinctive for Low tone, the factor for level tone categorization seems to be narrowed down to the interval size. Interestingly, High, Mid and Low have an average interval of 3 semitones (fig. 1).

For Mid, the contour movement onset criteria is not met. Neither is High. In all, it seems that the level tone category is attributed to its interval threshold of 3 semitones when the vowel duration is 350-400 ms. regardless of the contour movement onset.

For both Fall and Rise, the contour movement onset criteria is not met. However, based on the production model derived from the correlations discussed above [10], [11], the tones are suggested to be represented as sequences of levels, High-Low for Fall, and Low-High for Rise.

Finally, the correlations found for the tonal groups (tbls. 3 & 4), especially with regard to duration, seem to indicate time adjustments made between Thai 'level' and 'contour' tone productions.

Table 1. Average Contour Movement Onset, Total Interval Size and Total Interval Time for the five Thai tones from combined male speakers.

Tones	Contour Movement Onset (ms.)	Total Interval (s)	Interval Time (ms.)
Mid (n=21)	82 (s.d.=78.54)	2.53 (s.d.=1.12)	269 (s.d.=88.26)
Fall (n=23)	99 (s.d.=41.38)	7.38 (s.d.=2.01)	237 (s.d.=45.23)
High (n=24)	70 (s.d=75.83)	2.99 (s.d.=1.21)	263 (s.d.=70.87)
Rise (n=16)	142 (s.d.=51.04)	6.05 (s.d.=1.17)	203 (s.d.=48.18)
Low (n=17)	48 (s.d.=24.19)	1.51 (s.d.=0.81)	316 (s.d.=50.18)

Table 2. Average Contour Movement Onset, Total Interval Size and Total Interval Time for the five Thai tones from combined female speakers.

Tones	Contour Movement Onset (ms.)	Total Interval (s)	Interval Time (ms.)
Mid (n=21)	114 (s.d.=135.46)	2.46 (s.d.=0.74)	310 (s.d.=103.51)
Fall (n=25)	208 (s.d.=66.21)	6.88 (s.d.=1.43)	200 (s.d.=41.81)
High (n=25)	102 (s.d.=97.06)	2.99 (s.d.=0.87)	286 (s.d.=111.23)
Rise (n=25)	229 (s.d.=54.47)	5.22 (s.d.=1.32)	190 (s.d.=36.16)
Low (n=21)	25 (s.d.=20.84)	2.71 (s.d.=0.81)	309 (s.d.=83.15)

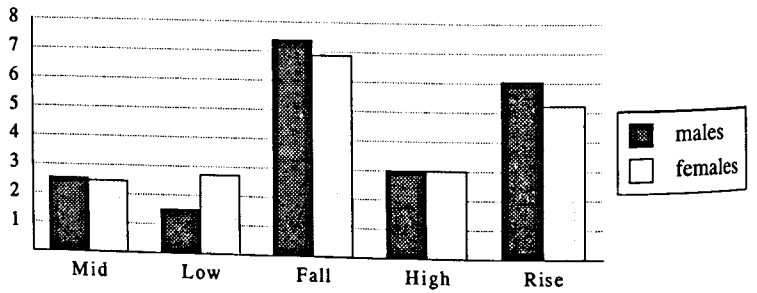

Figure 1. Average Total Interval for the five Thai tones (in Semitones).

Table 3. Correlation between Response Interval vs. Duration for Thai tones (p = .05)

	M	L	F	H	R	F, L &M	H &R
females	r = .23 n.s.	r = .27 n.s.	r = .52 p < .005	r = -.20 n.s.	r = -.04 n.s.	r = -.42 p < .005	r = -.44 p < .005
males	r = -.59 p < .005	r = -.31 n.s.	r = .33 n.s.	r = -.04 n.s.	r = -.11 n.s.	r = -.35 p < .01	r = -.39 p < .01

Table 4. Regression & Correlation between Response Interval and Response Velocity of Thai tones in two groupings; Fall, Low & Mid, and Rise & High.

Tones	Y = a + bX	Correlation (r)	Significance (p)
Falling Pattern: Fall, Low & Mid			
males	Y = -.06 +5.72X	0.9531	< .005
females	Y = -2.37 +6.89X	0.9426	< .005
Rising Pattern: Rise & High			
males	Y = -2.58 +7.36X	0.8849	< .005
females	Y = -5.72 +8.56X	0.8976	< .005

SUMMARY

Implications from this study are: first, the rate of F0 transition is the same, interval dependent default rate for all tones with the same direction of F0 movement. Second, the difference between Thai 'level' and 'contour' tones is in the interval size, ± 3 semitones is the threshold for level tones. Contour tones span an interval of 3-8 semitones. Also, there seems to be some time adjustments between 'level' and 'contour' tone productions. Third, Thai Rise and Fall do not meet House's constraints on contour feature perception. Rather, the correlation between the velocity and the interval, and the time constant for each tone favors the representation as a sequence of levels. Finally, the 'optimal range' of contour tone perception in House's studies (3-8 s/ ≥100 ms.) includes a rate which is faster than the 'optimal' or 'default' production rate defined within this study. Whether the contour perception 'optimal range' contains the production rate awaits further verification.

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