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Anticipatory tonal coarticulation in Thai noun compounds*

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It is commonly known that speech sounds are subject to influences from adjacent sounds which alter their phonetic manifestation. This phenomenon is called *coarticulation*. Of particular interest is *anticipatory* or *look ahead* coarticulation, which involves one speech sound being influenced by subsequent sounds, and *perseverative* or *carryover* coarticulation, which involves one speech sound being influenced by preceding sounds.

In consonants and vowels, coarticulatory effects are bidirectional, which means that both anticipatory and perseverative effects are found to occur in languages of the world. In tones, coarticulatory effects occur in much the same way as they do between consonants and vowels. Ladefoged (1982) has suggested that coarticulation between tones tends to be perseverative rather than anticipatory.

Acoustic phonetic studies of tonal coarticulation are scarce. In Vietnamese, Han and Kim (1974) found that the six lexical tones vary in both height and slope. Perseverative effects were greater than anticipatory. Shen (1990) reported that the four Mandarin tones vary in height but not slope. Anticipatory and perseverative influences, however, were comparable in magnitude of effect. Palmer (1969) found that the five Thai tones vary in height and slope. Perseverative effects were predominant. Abramson (1979) provided a few more examples of tonal coarticulation in Thai.

Due to methodological limitations in these earlier studies on tonal coarticulation, it is difficult to determine to what extent coarticulatory effects are symmetric or asymmetric across tone languages, and to what extent both F_0 height and slope vary as a function of preceding or following

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tones. What is needed is a quantitative procedure that will make it possible to determine both the nature and extent of coarticulatory influences into adjacent tones across languages. In a preliminary study of Thai tonal coarticulation, Gandour, Potisuk, Dechongkit, and Ponglorpisit (1992) have proposed a quantitative method for assessing coarticulatory effects on fundamental frequency (F_0) height and slope. Their preliminary investigation was limited to perseverative effects in six disyllabic utterances. Within their limited sample, lexical tones did not vary in height as a function of the preceding tone. The slope of the mid tone, however, did vary depending upon the preceding tone, rising in the beginning portion when following a low tone, falling when following a falling tone.

The aim of this study is to apply Gandour et al.'s methodology to an investigation of anticipatory effects between Thai tones in bisyllabic noun compounds. As such, it is part of a larger series of studies designed to explore tonal coarticulation in Thai brain-damaged patients with unilateral left hemisphere and right hemisphere lesions. Both young and old normal speakers are included to permit us to distinguish whether differences in tonal coarticulation are to be attributed to the normal aging process rather than neurological lesions.

I. Method

1. Subjects

Twenty adult speakers of Thai participated in the study: 11 'young' adults and 9 'old' adults. Except for one additional young adult, these speakers were the same as those who participated in a previous study on tonal coarticulation in Thai (Gandour et al., in press). All 11 speakers in the young group were male and had completed 13 years of formal education; the average age of the young group was 26.4 (*SD* = 2.7). Four of the speakers in the old group were male, five were female; all had completed 4 years of formal education; the average age of the old group was 56.9 (*SD* = 2.3). All speakers had spent their entire lives in the Bangkok metropolitan area. Two different age groups as well as female speakers in the old group were included for purposes of comparison in a larger project on tonal coarticulation in Thai brain-damaged adults.

2. Speech Materials

A set of five bisyllabic noun compounds was chosen to investigate anticipatory tonal coarticulation (see Table 1). The first syllable was identical both phonemically and tonemically across the five noun compounds. The falling tone occurred on the first syllable. The second

syllables were similar phonemically, each beginning with a voiceless aspirated velar stop and ending with a sonorant. Each of the five Thai tones occurred on these second syllables: mid, low, falling, high, and rising. Thus, we were able to assess the influence of following tones on preceding tones in an otherwise relatively homogeneous phonetic context.

Table 1

Test Stimuli

tônkhɛɛ	'Sesbania tree'
tônkhàa	'galangal bush'
tônkhâaw	'rice stalk'
tônkhɔ́ɔ	'Ceylonese oak'
tônkhĕm	'ixora tree'

3. Recording Procedure

All noun compounds were printed in large Thai script on 3" x 5" cards. A total of 50 cards (5 noun compounds x 10 tokens) was presented in random order to subjects. They were instructed to read the noun compounds at a comfortable speaking rate. To avoid start and end effects, extra cards were placed at the top and bottom of the deck. To avoid list reading effects, a sufficient pause was provided between items to ensure that subjects maintained a uniform speaking rate. Subjects' utterances were recorded in a reasonably quiet room in a single session using a Sony ECM-66B microphone and a Marantz PMD-420 taperecorder.

4. Listening Procedure

Each subject's utterances were presented in random order to the second author for assessment of the correctness of the consonants, vowels, and tones in the noun compounds. He was instructed to indicate whether subject's productions were "correct" or not. Test tapes were played on a Marantz PMD420 taperecorder, and the signal was presented through TDH-39 headphones at a comfortable listening level.

5. Measurement Procedure

A total of 988 utterances were low-pass filtered at 4 kHz and digitized at a 10 kHz sampling rate for speech analysis using ILS (Interactive

Laboratory System, Signal Technology, Inc.) programs implemented on a Zenith 386 PC-AT computer. F_0 contours were extracted using a cepstral method of analysis. To minimize effect of consonantal perturbations at the beginning of F_0 contours, changes in F_0 that were 10 Hz or greater across a 10 ms time frame were excluded. Cepstral analysis sometimes failed to extract an F_0 contour from an obviously periodic audio waveform or from an audio waveform with lengthy stretches of aperiodicity. Because of such measurement problems, 3% and 5% of utterances produced by young and old speakers, respectively, were eliminated from the corpus.

6. Data Analysis

Of the remaining 951 utterances, only those utterances which were identified correctly by the second author, a native speaker of Thai, were retained for analysis. By this criterion, all of the remaining utterances of both young and old speakers were retained for data analysis.

Because all tokens of each tone were not of equal duration, the F_0 contours were equalized for duration on a percentage scale. Because the mean and variance of nontransformed measures of F_0 tends to be correlated, the F_0 contours were also normalized on a *z* score scale (cf. Rose, 1987). By such normalization, F_0 contours may be compared across speakers.

Average F_0 contours do not provide any indication of intraspeaker token-to-token variation in tonal production. Unless we quantify intraspeaker variation, it is difficult to assess inter- and intraspeaker variability in the production of Thai tones. To compare the point-to-point variability of F_0 contours for all tokens of each tone, an ensemble-averaging approach was taken (cf. Atkinson, 1976, pp. 441-442). All tokens of a tone made up an ensemble of F_0 contours for that tone by that speaker. The ensemble mean and standard deviation were determined at each 10% interval. The ensemble mean can be considered as the target F_0 contour for a particular tone and the ensemble standard deviation as a measure of the random perturbations that result in deviations from the target contour.

To assess changes in F_0 height and slope of the preceding syllable as a function of the tonal category of the following syllable, six measurement intervals and measurement points, respectively, were selected in the preceding syllable. In the case of F_0 height, there were six different time intervals varying in duration. Starting from the end of the preceding syllable, these six time intervals provided measures of average F_0 height over 10%, 20%, 30%, 40%, 50%, and 100% of the total duration. Similarly, in the case of F_0 slope, there were six different points of measurement. Starting from the end of the preceding syllable, these six time points provided measures of F_0 slope at 10%, 20%, 30%, 40%, 50%, and 100% of the total duration. The normalized F_0 contour of each syllable was fitted