

## Effects of Prosodic Position and Tonal Context on Taiwanese Tones\*

Shu-hui Peng  
peng@ling.ohio-state.edu

**Abstract:** The present study investigates the effects of prosodic position and following tone on duration and fundamental frequency of voicing (F0) pattern for the Taiwanese tones. The results showed that Taiwanese tones were acoustically influenced by prosodic position and to a certain extent by tonal context. Prosodic position had strong effects on both the F0 and duration of tones. Final lengthening and final lowering were found in the utterance-final and to a somewhat lesser extent in phrase-final positions. Pitch range was substantially affected by prosodic position, but in general, the tone shape was not changed. Tone sandhi in Taiwanese was not only defined by syntactic phrase but also by prosodic phrase. Anticipatory tonal coarticulation affected the F0 offsets of Taiwanese tones without affecting syllable duration. Assimilation occurred between contour tones and the following tone. Dissimilation was found between the high-level tone and the following tone. Pitch range in general was not affected by tonal context; however, some subject-dependent variation was found.

### Introduction

It has been found that durations of syllables and segments in sentences are conditioned by prosodic position. For example, syllables at the end of utterances are longer than those in non-utterance-final positions (Fonagy & Magdics, 1960). This phenomena is known as pre-pausal lengthening of syllables. A study of vowel duration in a connected discourse (Klatt, 1975) indicates that a vowel is longer not only at the end of an utterance but also at the end of a prosodic phrase. Klatt also found that the lengthening of vowels at the end of utterances is not greater than that in the end of a phrase. A descriptive model of segment duration by Lindblom and Rapp (1973) suggests that segments in the final syllables of a phrase are longer than in non-final syllables, since segments in the middle of a phrase are temporally more compressed than those in other positions of the phrase.

The intonation of utterances is shaped by prosodic position. Liberman & Pierrehumbert (1984) found that the fundamental frequency (F0) of the last accent of an utterance is lower than that of the non-final accent in the same position in a longer utterance. This effect of phrasal position on the F0 of utterances is known as final-lowering. Final-lowering also exists in tone languages. A study by Shih (1988) comparing the same Mandarin tone in different positions of an utterance showed that the F0 of the tone in utterance-final position was lower than in

---

\* I thank Mary Beckman, Marjorie Chan and Keith Johnson for their helpful comments. I am also grateful to Sun-Ah Jun and Jennifer Venditti for their help on an earlier version of this paper and Sook-Hyang Lee for her assistance with the analysis of variance.

utterance-initial and utterance-medial positions. It is in the initial position that the target tone has the highest value of F<sub>0</sub>.

For tone languages, in addition to prosodic position, tonal context is another factor that may affect the F<sub>0</sub> of tones. In some tone languages, there are regular phonological rules (tone sandhi) for tones which change one tone into another tone. However, in all tone languages some tonal coarticulation is expected. Tonal coarticulation, namely the phonetic influence of one tone on another tone, occurs between adjacent tones due to their close specification. According to the direction in which coarticulation applies, tonal coarticulation can be classified into two different types: anticipatory and perseveratory. Anticipatory coarticulation occurs when the F<sub>0</sub> pattern on one syllable is influenced by the tonal features of the syllable following it. Perseveratory coarticulation is the carry-over of the tonal features of a preceding syllable.

In Mandarin (Shih, 1988; Shen, 1990), tonal coarticulation is bi-directional: anticipatory and perseveratory. Shih (1988) has analyzed tones according to pitch levels, and thus distinctive tones in Mandarin are represented with different tonal targets which correspond to the pitch levels of the tones. For instance, the rising tone (tone 2) is represented as mid-high (MH). The relative F<sub>0</sub> values and timing of tonal targets might be shifted due to tonal coarticulation. Shih (1988) found that the rising tone (tone 2) ends higher when the following target is low, but ended lower when before high tonal target. The rising tone followed by a high target ends lower due to the shift of the final high target of the rising tone to the following high target. Conversely, the rising tone followed by a low target was not affected by the following low target.

Moreover, a later Mandarin study by Shen (1990) found that in addition to onsets and offsets of tones, the overall tonal height (pitch ranges) of tone contours are also affected by neighboring tones. The overall pitch ranges of tones following high-offset tones are higher than those of tones following low-offset tones. However, the directions of tone contours were not shifted by neighboring tones. That is, in general, tone shape was constant while onset and offset values and the overall tone height vary depending on neighboring tones. It would be interesting to see whether these effects of prosodic position and tonal context are language-specific phonetic processes in Mandarin or whether they also exist in a related tone language like Taiwanese.

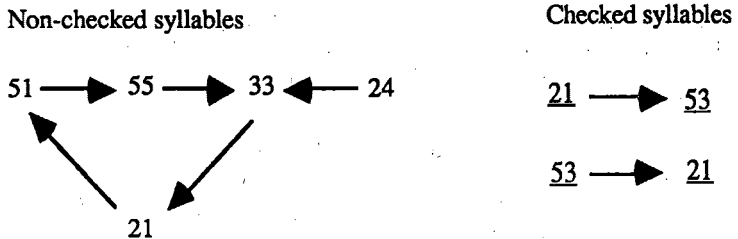
The Taiwanese tonal system is different from the Mandarin one in two ways. First, there are more phonologically distinctive tones in Taiwanese. Second, in Taiwanese, tone sandhi is not conditioned by tonal context but only by prosodic position; all but the last syllables of tonal phrases change to sandhi forms. Given these differences, we might expect a different pattern of tonal coarticulation in Taiwanese.

The purpose of the present study is to examine the effect of prosodic context and tonal context on Taiwanese tones using the measurements of duration and F<sub>0</sub>. There are seven phonologically distinctive tones in Taiwanese Amoy. Two of them are in checked syllables—i.e. syllables which end with stop consonants. Five of them are in non-checked syllables—syllables which do not end with stop consonants. Descriptions and transcriptions of the Taiwanese tones using the traditional 5-point numeric scale (Chao, 1930) are listed in Table 1.

**Table 1.** Qualitative descriptions and numeric scales of Taiwanese tones (Checked tones are underlined.)

| Description          | Numeric scale | example                                   |
|----------------------|---------------|---|
| High-level           | 55            | /lu <sup>55</sup> / "to push"             |
| Mid-level            | 33            | /lu <sup>33</sup> / "to consider"         |
| Mid-rising           | 24            | /lu <sup>24</sup> / "to be like"          |
| Mid-falling          | 21            | /lu <sup>21</sup> / "to scrape"           |
| High-falling         | 51            | /lu <sup>51</sup> / "woman"               |
| Mid-falling checked  | <u>21</u>     | /lut <sup><u>21</u></sup> / "to rub away" |
| High-falling checked | <u>53</u>     | /lut <sup><u>53</u></sup> / "rule"        |

**Table 2.** Taiwanese tone sandhi rules. One tone changes into another when followed by another tone in the same tonal phrase.



**Examples:**

| before tone sandhi  | after tone sandhi                       | meaning         |
|---|---|-----------------|
| /tsa <sup>51</sup> / "early" /tɿ <sup>21</sup> / "meal"         | [tsa <sup>55</sup> tɿ <sup>21</sup> ]   | "breakfast"     |
| /tiɔŋ <sup>55</sup> / "middle" /tau <sup>21</sup> / "daytime"   | [tiɔŋ <sup>33</sup> tau <sup>21</sup> ] | "at noon"       |
| /aŋ <sup>24</sup> / "red" /hwe <sup>55</sup> / "flower"         | [aŋ <sup>33</sup> hwe <sup>55</sup> ]   | "red flower"    |
| /tau <sup>33</sup> / "bean" /liŋ <sup>55</sup> / "milk"         | [tau <sup>21</sup> liŋ <sup>55</sup> ]  | "soy bean milk" |
| /pai <sup>21</sup> / "to worship" /gɔ <sup>33</sup> / "five"    | [pai <sup>51</sup> gɔ <sup>33</sup> ]   | "Friday"        |
| /sit <sup>21</sup> / "to lose" /le <sup>51</sup> / "politeness" | [sit <sup>53</sup> le <sup>51</sup> ]   | "Excuse me!"    |
| /lut <sup>53</sup> / "law" /su <sup>55</sup> / "expert"         | [lut <sup>21</sup> su <sup>55</sup> ]   | "lawyer"        |

Like many other similar tone languages, Taiwanese has tone sandhi rules. Each Taiwanese tone undergoes tone sandhi when followed by another syllable in the same tonal phrase. The changes of tones are systematic and predictable and are conditioned by prosodic position, but not by the presence of a specific tone as

Mandarin tone sandhi rules. Each tone is changed into another tone regardless of the tone quality of the tone following it (Cheng, 1968). These changes form a Tone Sandhi Chain, as shown in Table 2. The tone in final position of a tonal phrase or followed by a final neutral tone stays unchanged, i.e. does not undergo tone sandhi. Tones preceding the final syllables of tonal phrases are changed by tone sandhi rules. For example, /bi<sup>51</sup>/ “beautiful” and /lu<sup>51</sup>/ “woman” become /bi<sup>55</sup> lu<sup>51</sup>/ when they form a noun phrase “beautiful woman”.

It has been demonstrated that tonal phrasing is closely related to syntactic phrasing in Taiwanese (Cheng, 1968; 1973; Chen, 1987). Syllables in phrases and sentences are grouped into tonal phrases based in large part on syntactic structure. However, there are some exceptions to the formation of tonal phrases due to rhythmic structure (Hsiao, 1990). For example, /taŋ<sup>55</sup>/ “east”, /sai<sup>55</sup>/ “west”, /lam<sup>24</sup>/ “south” and /pak<sup>21</sup>/ “north” become [taŋ<sup>33</sup> sai<sup>55</sup> lam<sup>33</sup> pak<sup>21</sup>], when they are read in a sequence. The first two syllables and the last two syllables form separate rhythmic feet. Only the first tone of each foot is changed. In addition to these phonological changes created by tone sandhi, phonetic variations caused by tonal context and prosodic position are also expected.

The present study investigated five distinctive Taiwanese tones in different prosodic positions: phrase-initial, phrase-medial, phrase-final and utterance-final as well as the coarticulatory effects of the following tone. It reports results from two pilot studies using only one talker and a larger main study using four talkers. The first pilot study was designed to see whether Taiwanese high-level and high-falling tones are influenced by prosodic position and the following tone. Also, it investigated whether the influence on different target tones follows the same overall pattern. Results indicated that prosodic position affected both the F0 and duration of the high-level tone, but only the F0 of the high-falling tone. The F0 and duration of the high-level tone also varied depending on tonal context. A dissimilation-like effect on F0 was found between the target tone and the following tone. In order to examine the effect of following tone even further, the second pilot study focused on the high-level tone followed by five distinctive tones in phrase-medial and phrase-final positions. Very similar results were found in the measurements of duration and F0.

The main study then included all five Taiwanese tones in non-checked syllables followed by tones with various F0 onset values: high-level tone, mid-level tone or mid-falling tone in the same four prosodic positions used in the first pilot study. The results showed that prosodic position affected the F0 and duration of Taiwanese tones more strongly than did following tone. Anticipatory tonal coarticulation was found. These findings contradict the results of Lin's (1988) study in which Taiwanese tonal coarticulation was found to be only perseveratory coarticulation.

## First Pilot Study

### Method

#### *Materials*

The corpus used in this experiment is shown in Appendix 1. The target syllable which was either high-level tone [kɔ<sup>55</sup>] or high-falling tone [kɔ<sup>51</sup>] was

placed in four different prosodic positions: tone-phrase-initial, tone-phrase-medial, tone-phrase-final and utterance-final. When the high-level target tone was not utterance-final, it was followed by a syllable which either had high-level tone or mid-level tone except that in phrase-initial position it did not occur before mid-level tone. The syllable following the high target tone started with a voiceless unaspirated stop consonant (except for one case in which it was voiced). The high-falling target tone was followed by a syllable with high-level tone and starting with a voiceless unaspirated stop consonant.

Each target tone was embedded in three five-syllable sentences and one three-syllable phrase as shown in Table 3. Each sentence contained two tonal phrases. The phrasal boundary was after the second syllable in the first of the three sentences. Here the target tone was in the initial position of the second phrase (phrase-initial case). The phrasal boundary was after the third syllable in the other sentences. The target tone was at the medial position (phrase-medial case) or the final position of the first phrase (phrase-final case). In addition, a three-syllable utterance was used. The target tone was at the final position of this utterance (utterance-final case).

**Table 3.** Schematization of corpus 1 utterances for different prosodic positions with the target tone (syllable) underlined. Square brackets indicate the boundaries of tonal phrases.

| Prosodic positions | schematized utterances |
|--------------------|------------------------|
| phrase-initial     | [σ σ] [ <u>σ</u> σ σ]  |
| phrase-medial      | [σ <u>σ</u> σ] [σ σ]   |
| phrase-final       | [σ σ <u>σ</u> ] [σ σ]  |
| utterance-final    | [σ σ <u>σ</u> ]        |

There were eleven utterances in total. Each of them was read five times. Therefore, there were fifty-five tokens. Nine filler tokens were used. Tokens were arranged in random order.

### *Subject*

One female native Taiwanese speaker (HS) who also speaks Mandarin and English fluently participated the present experiment.

### *Recording & Acoustic Measurements*

The subject was asked to read the tokens in a normal, fluent speaking style. The productions of the subject were recorded using a TEAC V-427C stereo cassette deck in a sound-proof booth in the Ohio State University Linguistics Laboratory.

Durations and fundamental frequencies of target tones were measured. Durations of target tones were analyzed with wide-band spectrograms using the Kay DSP 5500. The duration of each target tone was measured from the release of

the initial stop consonant to the offset of the vowel. In addition, each sentence or phrase was digitized and its fundamental frequency contours analyzed with the *waves*™ signal editor (Entropic Research Laboratory, INC., 1993) on a Sun Sparcstation. The F0 of each high target tone (55) was measured at 3 points along the frequency contour for the syllable: onset, mid-point and offset of the F0 contour. For each high-falling target tone (51), only onset and offset of the F0 contour were measured. Mean duration and F0s of each target tone were calculated. Because the tone preceding the target tone was not controlled in the present experiment, all onset values of F0 contours were only used to show the general pitch range of pitch contours. The test sentence in which the high target tone at the phrase-initial position is followed by the mid-level tone was deleted due to a design error.

## Results

A two-way analysis of variance (ANOVA) (prosodic position x tonal context) was done for each target tone. The effect of prosodic position on duration of the high target tone is significant, [ $F(3, 26) = 70.02, p < 0.01$ ]. Figure 1 shows the overall mean measurements of the high-level target tone pooled over the two following tone contexts at phrase-medial, phrase-final and utterance-final positions. Three F0 values are plotted: the point at time zero representing the onset F0 of the syllable, the next point representing the F0 in the middle of the syllable and the last point representing the F0 at the end of the syllable

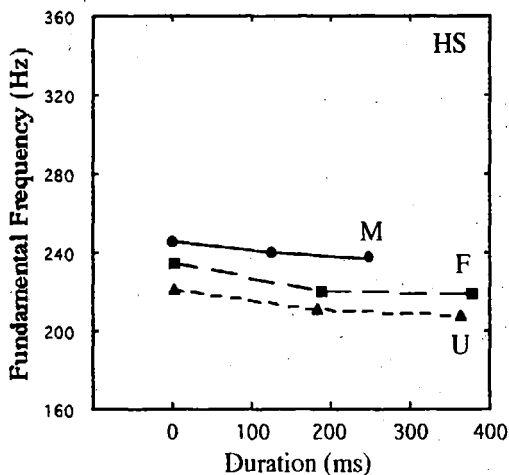


Fig. 1. Mean durations and F0s of the high target tone (55) in different prosodic positions in the first pilot study. Means pooled over the two tonal contexts. M = phrase-medial, F = phrase-final, U = utterance-final.

Table 4. Mean durations and F0s of the high target tone followed by high-level tone (55) in different prosodic positions. F0 is measured at three different points along the pitch contour: onset, mid-point and offset.

| prosodic position | duration (ms) | F0 (Hz) |           |        |
|-------------------|---------------|---------|-----------|--------|
|                   |               | onset   | mid-point | offset |
| phrase-initial    | 254.4         | 242.92  | 232.82    | 233.3  |
| phrase-medial     | 230.8         | 230.88  | 231.04    | 236    |
| phrase-final      | 392.4         | 228.1   | 208.2     | 207.2  |
| utterance-final   | 362.2         | 220.8   | 210.76    | 207.74 |

(and the abscissa showing mean syllable duration). As the figure shows, durations of the high-level tone in phrase-final and utterance-final positions are longer than in phrase-medial position. Since the target syllable in phrase-initial position occurred only before 55, we can only compare all four prosodic contexts only in that tonal context. Mean durations and F0 measurements of the high target tone followed by 55 are listed in Table 4. The duration of the high-level tone in the phrase-initial position is somewhat longer than in phrase-medial position but much shorter than in phrase-final and utterance-final positions. The effects of prosodic position on the F0 values of the high-level tone are significant at mid-point and offset [ $F(3, 26) = 7.88; 11.7, p < 0.01$ ] and are marginally significant at onset [ $F(3, 26) = 3.82, P < 0.05$ ]. Mean F0 values are lower in phrase-final position than in phrase-initial and phrase-medial positions and lower still in utterance-final position.

Figure 2 shows the mean measurements pooled over prosodic positions common to the two tonal contexts. The duration of the high-level tone does not vary according to following tone. However, the effect of following tone on the height of F0 is significant at all measurement points [ $F(1, 20) = 18.78; 32.81; 14.51, p < 0.01$ ]. A dissimilation-like effect of the following tone level was found: F0 of the high-level tone is higher when followed by mid-level tone than when followed by another high-level tone.

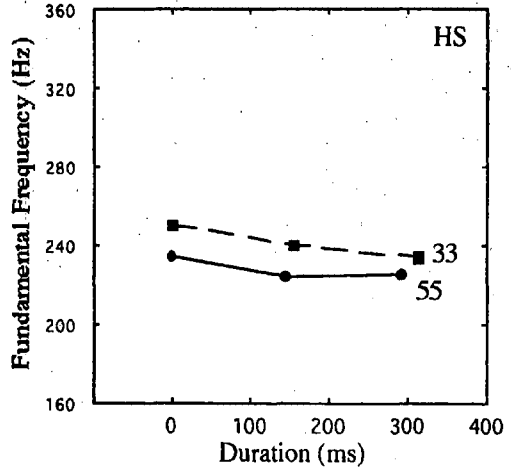


Fig. 2. Mean durations and F0s of the high target tone (55) followed by different tones in the first pilot study. Means pooled over all non-initial tokens.

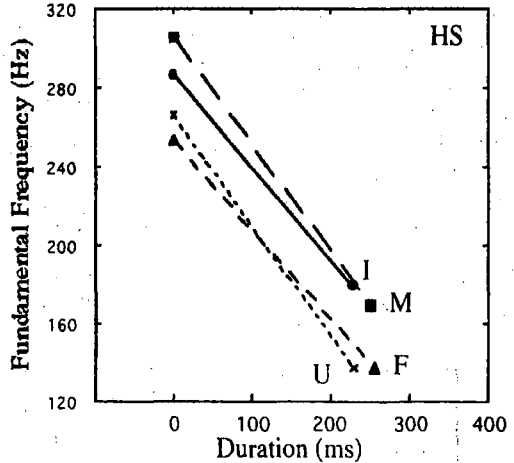


Fig. 3. Mean durations and F0s of the high-falling tone (51) in different prosodic positions. I = phrase-initial, M = phrase-medial, F = phrase-final, U = utterance-final.

As shown by Figure 3, the duration of the high-falling tone is not significantly changed by prosodic position, [ $F(3, 16) = 2.96, p > 0.05$ ], but the pitch range of F0 is, [ $F(3, 16) = 22.6; 15.54, p < 0.01$ ]. Mean values are lower in the phrase-final and utterance-final positions than in the phrase-initial and phrase-medial positions.

## Second Pilot Study

The aim of this pilot experiment is to examine the effects of the following tone and phrasal position even further by adding more tonal contexts to the target tone and focusing on two phrasal positions: phrase-medial and phrase-final.

## Method

### Materials

The corpus used in this pilot experiment is listed in Appendix 2. A syllable with high-level tone [po<sup>55</sup>] was the target syllable. It was placed either in phrase-medial position or in the phrase-final position, and was followed by any of the five tones found in open syllables. However, there was no final target in the context of the rising tone, because here the following syllable began the next phrase and the rising tone as a surface form only appears in phrase-final position because of its unique status in tone sandhi cycle as shown in Table 2. The prosodic structure of the sentences was the same as those in the first pilot study (shown in Table 3). Thus there were nine different sentences in total: five for phrase-medial position and four for phrase-final position. Each of the sentences was read six times. Eighteen filler sentences were added to the fifty-four test sentences. Tokens were read in random order.

### Subject

The same subject who participated the first pilot study also participated this experiment.

### Recording and Acoustic Measurements

The same methods of recording and measurement used in the first pilot study were followed. Only five of the six repetitions of each sentence and phrase which showed complete pitch contours were selected to be measured for duration and fundamental frequency.

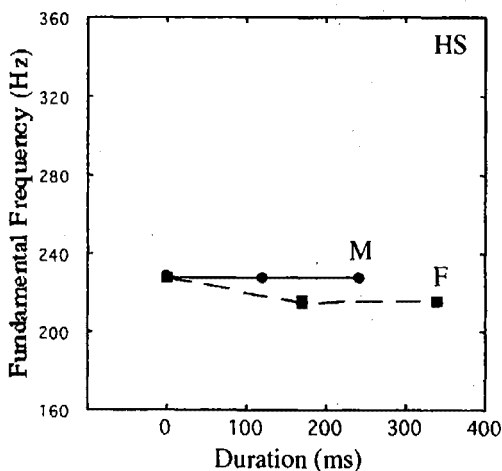


Fig. 4. Mean durations and F0s of the high target tone (55) in the phrase-medial position (M) versus the phrase-final position (F) pooled over tonal context.



## Results

As in the first pilot study, the effect of prosodic position on the duration of the high-level tone is bigger than its effect on fundamental frequency (Figure 4). The mean duration of the high-level tone in phrase-final position is significantly longer than at phrase-medial position,  $[F(1, 32) = 125.7, p < 0.01]$ . The effect of prosodic position on F0 of the high-level tone is significant at both the mid-points,  $[F(1, 32) = 9.16, p < 0.01]$  and the offsets of the F0 contours,  $[F(1, 32) = 12.33, p < 0.01]$ .

Figure 5 shows the mean durations and F0 measurements of the target syllable followed by different following tones. Duration of the high-level tone does not significantly vary according to following tone, but F0 does. The effect of following tone on F0 of the high-level tone is significant at the offset of the F0 contour,  $[F(3, 32) = 8.57, p < 0.01]$  and marginally significant at the mid-point of F0 contour,  $[F(3, 32) = 4.14, p < 0.05]$ . As in the first pilot study, there was a dissimilation-like effect: the F0 values were higher when followed by syllables with low onsets (mid-falling or rising tone) than by syllables with mid or high onsets (high-level tone, mid-level tone or high-falling tone).

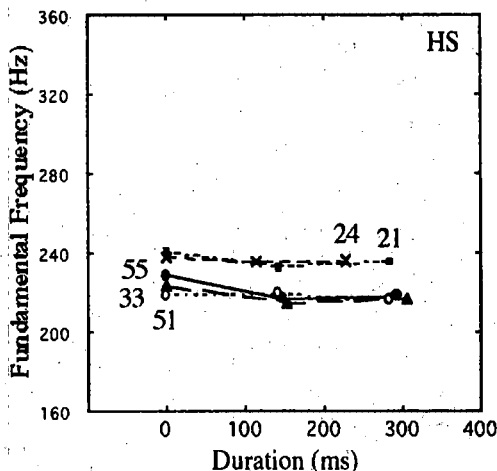


Fig. 5. Mean durations and F0s of the high target tone (55) followed by different tones and pooled over prosodic position.

## Main Study

The main experiment then was designed to investigate the issues raised in the pilot studies further by analyzing the productions of four subjects including all five Taiwanese tones occurring in non-checked syllables as targets in four prosodic positions and three tonal contexts.

## Method

### Materials

The corpus is shown in Appendix 3. Five target tones were investigated: [kaw<sup>55</sup>], [kaw<sup>33</sup>], [kaw<sup>21</sup>], [kaw<sup>51</sup>] and [kaw<sup>24</sup>]. Each of the target syllables was followed by high-level tone (55), mid-level tone (33) or mid-falling tone (21), and was placed in four different prosodic positions: phrase-initial, phrase-medial, phrase-final and utterance-final positions except that [kaw<sup>24</sup>] could occur only in

final position see Table 2. The utterances used in this study were five-syllable sentences and phrases and had the same prosodic structures used in the pilot studies.

There were forty-four utterances in total used in this study. Each of the sentences and phrases were read ten times. There were forty-four filler sentences mixed into the test sentences and phrases.

### *Subjects*

Four native Taiwanese speakers participated the test: two male and two female. They also speak Mandarin and English. None of them was the subject in the pilot experiments.

### *Recording and Acoustic Measurements*

The methods of recording and measurements were the same as used in the pilot studies except that each subject took one or two ten- to fifteen-minute breaks during the session. Eight of ten repetitions of each sentence and phrase which showed complete pitch contours were selected to be measured for duration and fundamental frequency.

## **Results**

### *Effects of prosodic position on syllable duration*

Figures 6~9 show the mean durations and F0 values of each target tone according to prosodic position and following tone for each of the four subjects. A two-way ANOVA (prosodic position x tonal context) indicated that the main effects of prosodic position on duration were significant in the productions of the majority of subjects. Table 5 shows all the statistics for the main study. Final-lengthening was found in utterance-final and/or phrase-final position. In general, final syllables were longer than non-final syllables, although speakers differed in whether only absolute utterance-final syllables showed the effect or both utterance-final and phrase-final syllables. It is also clear that the effect of final-lengthening was stronger in the utterance-final position than in utterance medial phrase-final position, except the case of subject RY's productions (Figure 8) where the effects in these two positions were equally strong.

There was an interaction between prosodic position and target tone type. The effects of prosodic position on the durations of the two falling tones were much smaller than the three non-falling tones (i.e., the high- and mid-level tones and the rising tone). The main effects of prosodic position on the durations of syllables with the mid-falling tone were significant in the productions of two subjects HL and RY. (Although curiously RY's utterance-final syllables were shorter than his phrase-final ones.) The effects for syllables with the high-falling tone were significant in the productions of HL, RY and SH (although again with the curious short utterance-final syllables for RY) and was marginally significant in the production of subject MT. Some final-lengthening effect in the utterance-final position the were shown in the productions of subjects SH (Figure 7) and HL

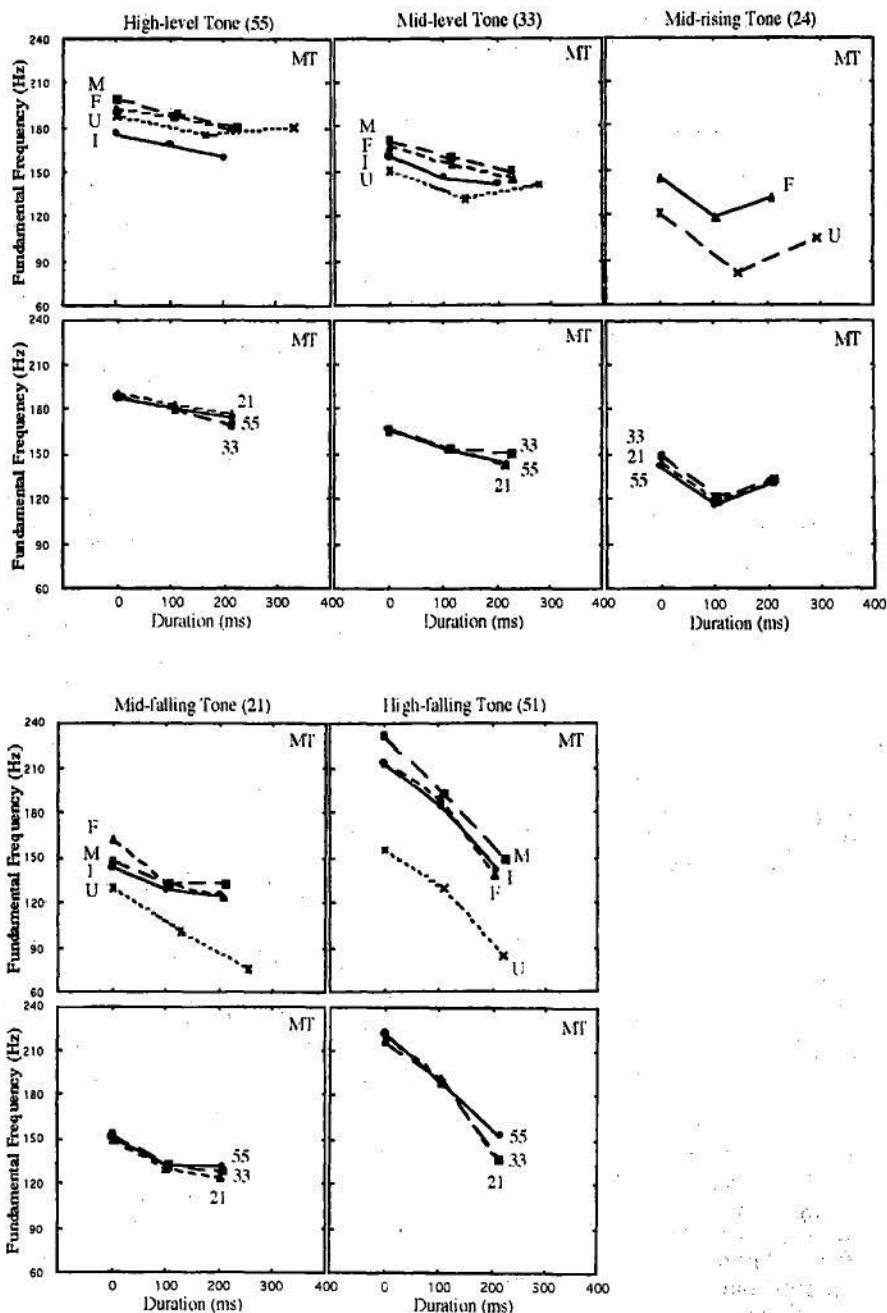


Fig. 6. Mean durations and F0s of each target tone followed by different tones in different prosodic positions. Subject MT. I = phrase-initial, M = phrase-medial, F = phrase-final, U = utterance-final.

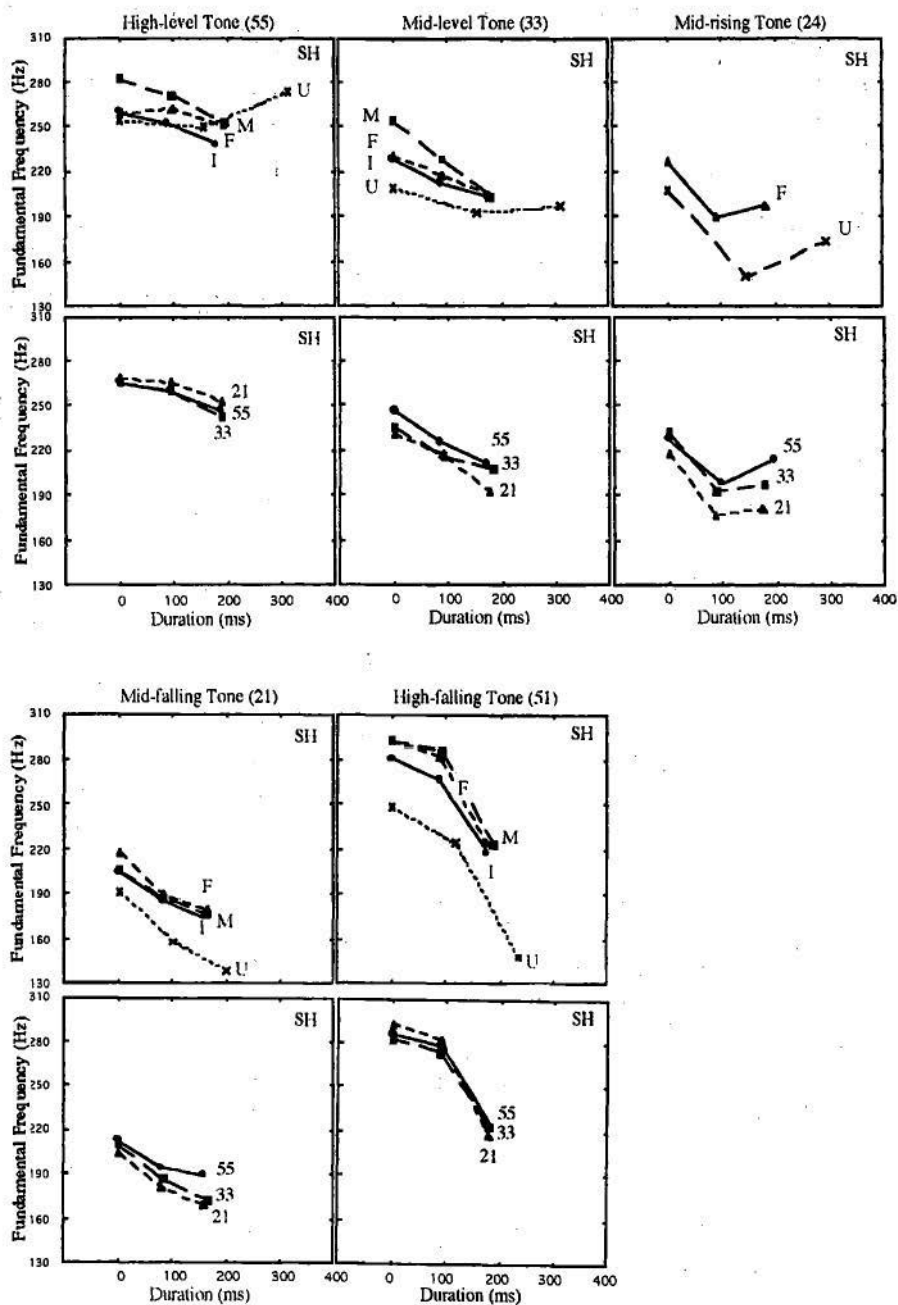


Fig. 7. Mean durations and F0s of each target tone followed by different tones in different prosodic positions. Subject SH. I = phrase-initial, M = phrase-medial, F = phrase-final, U = utterance-final.

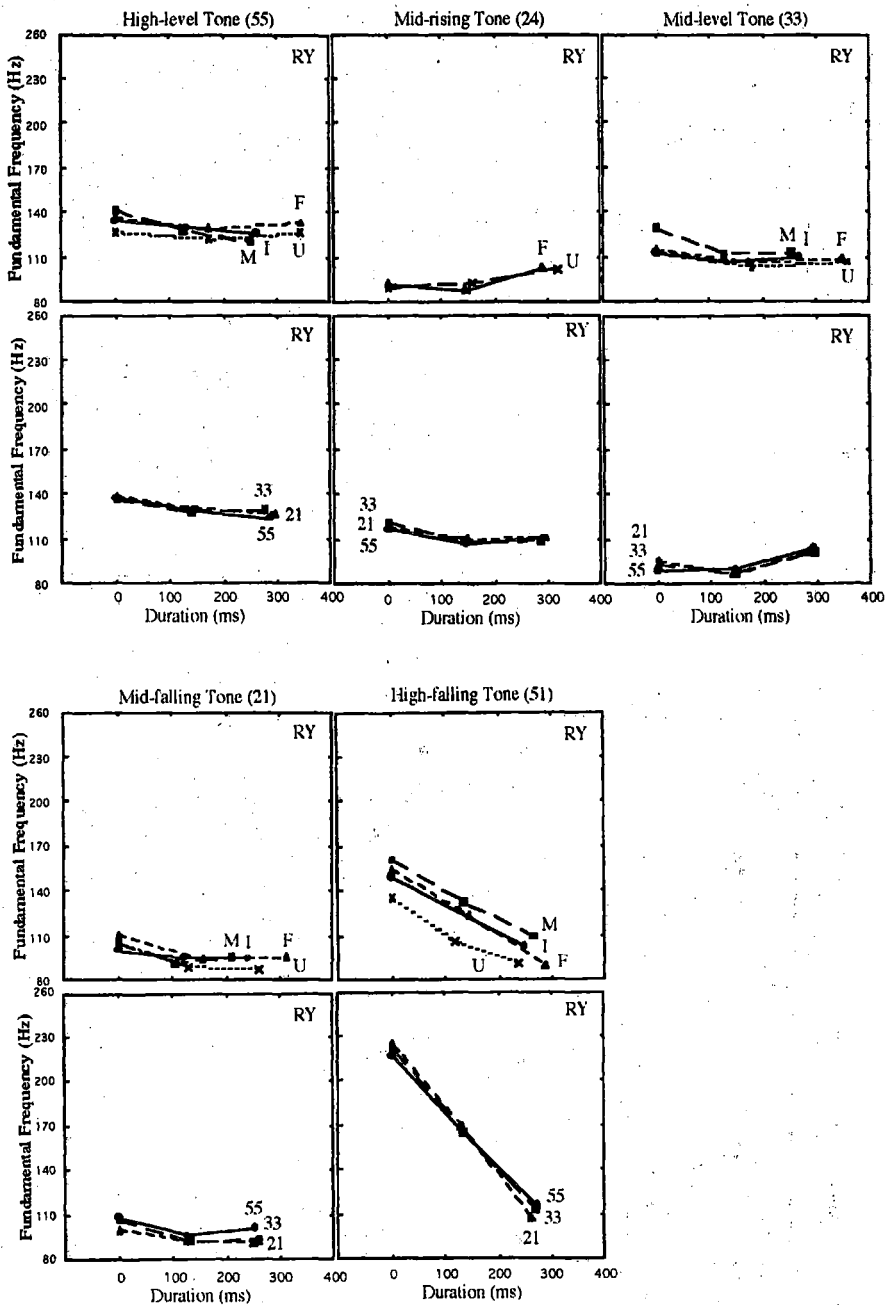


Fig. 8. Mean durations and F0s of each target tone followed by different tones in different prosodic positions. Subject RY. I = phrase-initial, M = phrase-medial, F = phrase-final, U = utterance-final.

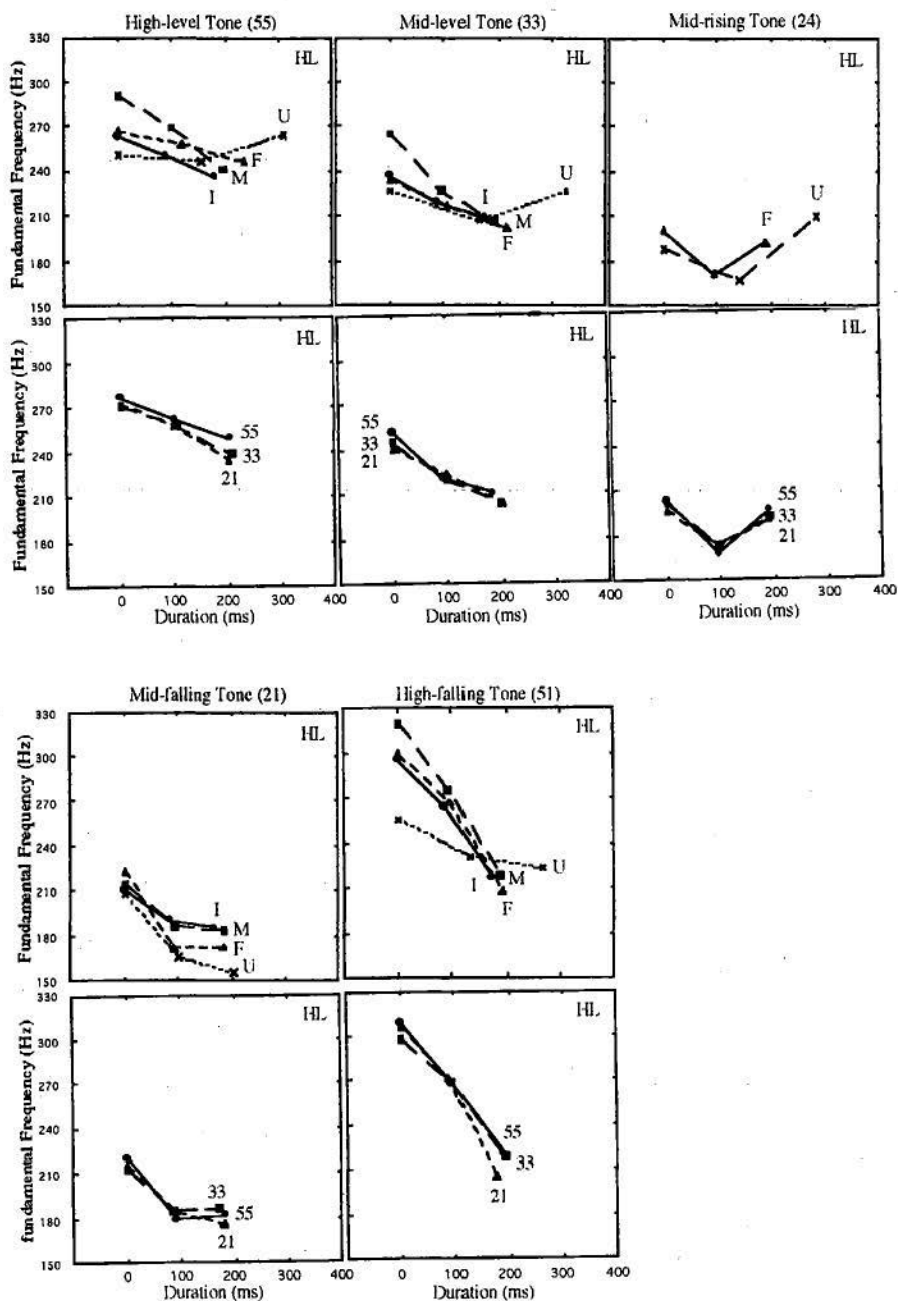


Fig. 9. Mean durations and F0s of each target tone followed by different tones in different prosodic positions. Subject HL. I = phrase-initial, M = phrase-medial, F = phrase-final, U = utterance-final.

**Table 5.** F values for the main experiment. Prosodic position (pos.): df = (2, 66), following tone (fol.): df = (2, 63), Prosodic position X following tone: df = (4, 63). \*\* = p < 0.01, \* = p < 0.05.

|    |          | MT       |         |             | SH      |         |             |
|----|----------|----------|---------|-------------|---------|---------|-------------|
|    |          | pos.     | fol.    | pos. X fol. | pos.    | fol.    | pos. X fol. |
| 55 | duration | 7.59**   | 0.06    | 2.87*       | 9.15**  | 0.05    | 3.08*       |
|    | F0 onset | 28.77**  | 0.29    | 1.06        | 26.44** | 0.39    | 0.33        |
|    | mid      | 26.99**  | 0.69    | 1.71        | 15.71** | 2.25    | 0.36        |
|    | offset   | 33.23**  | 3.55*   | 0.46        | 8.18**  | 3.45*   | 1.14        |
| 33 | duration | 9.39**   | 3.12    | 3.95**      | 1.42    | 3.89*   | 2.21        |
|    | F0 onset | 9.56**   | 0.19    | 0.33        | 53.13** | 14.41** | 4.92**      |
|    | mid      | 14.11**  | 0.34    | 2.15        | 29.02** | 11.05** | 2.73*       |
|    | offset   | 4.39*    | 5.08**  | 3.30*       | 0.06    | 4.43*   | 2.11        |
| 24 | duration | —        | 0.45    | —           | —       | 6.68**  | —           |
|    | F0 onset | —        | 1.29    | —           | —       | 4.34*   | —           |
|    | mid      | —        | 1.09    | —           | —       | 12.87** | —           |
|    | offset   | —        | 0.07    | —           | —       | 19.91** | —           |
| 21 | duration | 1.80     | 0.43    | 3.26*       | 1.36    | 2.29    | 1.64        |
|    | F0 onset | 34.47**  | 1.80    | 4.45**      | 8.77**  | 3.18*   | 0.93        |
|    | mid      | 2.36     | 1.04    | 1.94        | 0.68    | 7.93**  | 2.86*       |
|    | offset   | 8.88**   | 6.29**  | 1.91        | 1.12    | 21.29** | 1.22        |
| 51 | duration | 3.61*    | 0.28    | 0.08        | 8.28**  | 0.29    | 5.56**      |
|    | F0 onset | 15.74**  | 0.99    | 2.24        | 5.51**  | 3.65*   | 3.34*       |
|    | mid      | 2.97     | 1.09    | 0.62        | 14.53** | 2.64    | 0.71        |
|    | offset   | 5.78**   | 15.41** | 2.06        | 2.92    | 3.24*   | 6.26**      |
|    |          | RY       |         |             | HL      |         |             |
|    |          | pos.     | fol.    | pos. X fol. | pos.    | fol.    | pos. X fol. |
| 55 | duration | 84.79**  | 3.15*   | 0.20        | 40.05** | 0.98    | 3.81**      |
|    | F0 onset | 4.75*    | 0.38    | 0.43        | 15.73** | 2.45    | 0.63        |
|    | mid      | 0.54     | 0.98    | 0.70        | 9.33**  | 1.61    | 0.81        |
|    | offset   | 18.17**  | 4.07*   | 2.47        | 3.62*   | 10.57** | 12.65**     |
| 33 | duration | 66.77**  | 0.49    | 6.57**      | 42.12** | 8.21**  | 4.21**      |
|    | F0 onset | 32.36**  | 2.41    | 0.50        | 65.03** | 7.66**  | 9.45**      |
|    | mid      | 11.74**  | 2.48    | 3.96**      | 10.03** | 1.12    | 1.56        |
|    | offset   | 1.82     | 0.64    | 7.32**      | 3.24*   | 3.20*   | 1.05        |
| 24 | duration | —        | 0.41    | —           | —       | 0.03    | —           |
|    | F0 onset | —        | 2.03    | —           | —       | 0.57    | —           |
|    | mid      | —        | 1.15    | —           | —       | 0.71    | —           |
|    | offset   | —        | 0.26    | —           | —       | 1.73    | —           |
| 21 | duration | 90.24**  | 1.06    | 1.06        | 10.36** | 1.73    | 2.06        |
|    | F0 onset | 11.19**  | 6.48**  | 1.24        | 8.53**  | 2.34    | 0.20        |
|    | mid      | 4.37*    | 5.75**  | 3.59*       | 5.22**  | 0.61    | 0.52        |
|    | offset   | 0.08     | 4.69*   | 1.40        | 5.22**  | 4.66*   | 0.94        |
| 51 | duration | 23.51**  | 2.75    | 0.50        | 9.29**  | 4.92*   | 2.32        |
|    | F0 onset | 14.83**  | 1.98    | 0.57        | 23.35** | 3.91*   | 1.86        |
|    | mid      | 16.11**  | 1.37    | 1.18        | 5.59**  | 0.49    | 1.03        |
|    | offset   | 136.33** | 5.17**  | 1.43        | 6.08**  | 10.88** | 3.19*       |

(Figure 9). Final-lengthening of the falling tone in the phrase-final position only occurred in the productions of subject RY (Figure 8) and subject HL (Figure 9).

### *Effects of prosodic position on F0*

Analysis of variance showed that the effect of prosodic position on F0s of target tones was significant for both the mid-points and offsets of F0 contours with only one exception—the offset of the mid-level tone produced by subject SH (Figure 7). Final-lowering of F0 occurred in utterance-final position and very weakly in phrase-final position. The effect on contour tones was stronger than that on level tones. The mid-points and offsets of the contour tones in the utterance-final position were lower than those in the other positions. In fact, the changes of mid-points and offsets of F0 contours also caused the pitch range of the contour tones to shift down. Figures 6~9 indicate that pitch ranges of contour tones in the utterance-final position, especially in the productions of subjects MT (Figure 6) and SH (Figure 7), were mostly lower than in other positions. Final-lowering in the phrase-final position was only found in the offsets of the high-falling tone in the production of subjects RY (Figure 8) and those of both falling tones in the productions of subject HL (Figure 9). The offsets of the high-falling tone in the phrase-medial position produced by subjects MT and RY and that of the mid-falling tone produced by MT were higher than those in the other positions. For the high-level tone and the mid-level tone, final-lowering was found in mid-point values in the utterance-final position. The offsets of the high-level tone and the mid-level tone in the utterance-final position were not lower than in other positions due to the change of tone shape except the mid-level tone shown in Figure 8 which was slightly lower than in phrase-medial position.

The level tones showed some change of tone shapes in the utterance-final or phrase-final positions. Tone shapes of contour tones: mid-falling, high-falling and rising tones were more constant. The only change found was in the high-falling tone in the utterance-final position produced by subject HL.

### *Effects of tonal context on syllable duration*

The effect of following tone on durations of target tones was much smaller than that of prosodic position. Generally, syllable duration was constant regardless of the tonal context except for small differences in the productions of subject SH between mid-level tone vs. rising tone context (Figure 7), subject RY for high-level tone vs. high-falling tone contexts (Figure 8) and, subject HL for mid-level tone vs. high-falling tone context (Figure 9).

### *Effects of tonal context on F0*

F0 values of target tones varied significantly according to following tones, although the effect was smaller than that of prosodic position. The main effect of following tone on F0 offsets was stronger than on mid-point F0s. Tonal assimilation occurred between the falling tones (51 & 21) and the following tones in the productions of all the subjects. The offset of the target tone was higher when followed by high-onset tone (55) than when followed by low-onset tone (21). This assimilatory effect was also found in the level tones (Figures 7 & 9) and in the rising tone (Figure 7). On other hand, the mid-point values were mostly constant except some small variation found in the productions of subjects SH and RY. A dissimilation-like effect of following tone was shown in the two level tones. The



F0 offset of the high-level tone or the mid-level tone in the context of the mid-level tone was higher than those in the context of the high-level tone (Figures 6 & 8). The F0 offset of the high-level tone in the context of the mid-falling tone was higher than that in the context of the mid-level tone (Figures 6 & 7).

## Discussion

As found in previous studies for other languages, durations of syllables varied according to prosodic position. Pre-pausal lengthening was the feature shared by all subjects. Duration of syllables was longer in the utterance-final position than in any other position probably due to the fact that speech speed was gradually reduced toward the post-utterance pause to signify the termination of the utterance. Consequently, syllables were lengthened utterance-finally. Klatt's study of connected discourse indicated that the duration of a vowel at the end of an utterance was not greater than at the end of a phrase. Nevertheless, he also predicted that when sentences are produced separately, the result may be different. Phrase-final lengthening was also present in the current study; however, the effect was not as strong as pre-pausal lengthening. It was consistently found only in the production of two subjects (HS and RY).

Lindblom and Rapp's (1973) prediction that segments in phrase-medial position would be shorter than those in phrase-initial and phrase-final position only partially agreed with the result found in the present study. Syllables in the phrase-medial position were shorter than in phrase-final position in the productions of most of the subjects. They were generally as long as syllables in phrase-initial positions with some variation. It seemed that the difference among syllables in these three phrasal positions could be appropriately interpreted by the substantial lengthening of syllables in the phrase-final position to signify the separation of phrases, although in fast speech the difference of the syllable duration in different phrasal positions might be accounted for by the speed of the utterance. Syllable duration was not influenced by the following tone except in very few cases showing small effects of following tone which were much weaker than the effect of prosodic position. That is, tonal context which varied the fundamental frequency did not temporally influence the duration of syllables.

The effect of prosodic position on duration of syllables was not equally great for all target tones. The durations of falling tones, especially the high-falling tone, were more constant than those of the two level tones and the rising tone. The temporal constancy of syllables with a falling tone indicated that the rate of F0 fall was probably important for the listeners to identify the quality of the tone. A study of perception of Taiwanese tones (Lin & Repp, 1989) showed that in addition to F0, duration of syllables also contributed to the distinction of falling and non-falling tones. Syllables with falling tone were found to be shorter than those with other tones in Taiwanese (Lin, 1988) as well as in Mandarin (Ho, 1976).

Mid-point and offset F0 values and the overall pitch range of tone were affected by both the prosodic position and the following tone. Final-lowering occurred in the utterance-final position as well as in the phrase-final position. However, the strongest effect was found in the utterance-final position. It is fairly possible that, in addition to the reduction of speech speed, the lowering of pitch also contributed to the cueing of utterance termination. The influence of phrasal position seemed to be stronger at the end of the syllable than at the middle of the syllable. The lowering of the offsets was greater than the mid-points. The

lowering of both mid-point values and offset values led to the lowering of the overall pitch range. The pitch ranges of tonal contours were shifted down in the utterance-final position regardless of the quality of the target tone. However, the lowering was greater for contour tones than level tones. It was probably due to the closer specification of register height for the level tones than for the contour tones. If the lowering of the F0 of the high-level tone (55) was too much, then the high-level tone was likely to be indistinguishable from the mid-level tone. Similarly, if the F0 of the mid-level tone was over-lowered, it would be difficult to distinguish it from the mid-falling tone which was sometimes analyzed as low tone (22 or 11). The lowering of the F0 height of falling or rising tones, on the contrary, was less likely to create this problem.

Phrase-final lowering was found in the production of some subjects, but it showed more variance and less effect than the lowering of F0 in the utterance-final position. The difference between the two final positions in the effect of final lowering was probably due to the fact that the F0 height in the phrase-final (non-utterance-final) could not be too low, since there needed to be some indication that the utterance will continue. Another reason was that given the short interval between prosodic phrases, the process of falling needed to be finished in a short period of time. Consequently, the F0 height could not be lowered as much as in the utterance-final position. F0 values of syllables in phrase-medial position and in phrase-initial position were higher than in final positions. The difference between the phrase-medial position and phrase-initial position found in very few cases was much less than the difference between non-final positions and final positions and showed much more variance. In these cases, F0 of tones in general was slightly higher in phrase-medial position than in phrase-initial position. This was different from what has been shown for Mandarin (Shih, 1988) where F0 is higher in utterance-initial position than in other positions in the utterance. This difference was probably caused by the slight difference in the prosodic position of the target tone. The target tone in the phrase-initial position used in the present study was not utterance-initial.

Unlike pitch range, tonal shape only showed very small and limited differences. The shape of some tonal contours in the utterance-final position were changed. All of them had the F0 which were raised at the offsets of the tonal contours. This phenomenon was found in the productions of four out of five subjects. The subject who participated the pilot studies did not show this change. The difference was possibly caused by the fact that the utterances used for the utterance-final case were all noun phrases in the pilot study and were imperative sentences (in some cases) in the main study. The subject whose production did not show change of tonal shape read the noun phrases as if naming objects. In the main study, subjects who raised their pitch at the end of the utterance (high boundary tone) read the imperative sentences in the way that meant to persuade someone to do something, instead of ordering someone to do something. (Higher pitch—or the lack of final lowering—sounds less like a declarative direct order.)

F0s of syllables were also affected by following tone, but the degree of the influence of the following tone was smaller than that of the prosodic position. As was seen in the effects of prosodic position, the offsets of the tonal contours showed a larger change than mid-points of F0s. Also, non-falling tones were slightly more stable across tonal contexts than were falling tones. The rising tone was the most stable tone. An assimilation effect was found between falling tones and tones following them. The offset values of falling tones change according to the height of the following tone. When the following tone was a high-onset tone,

the offset of the target tone was higher. It was lower when followed by a low-onset tone. A similar assimilatory effect was also found in anticipatory and perseveratory tonal coarticulation of Mandarin (Shih, 1988; Shen, 1990): tone 3 (214) starts higher when following a high tonal target corresponding to a high offset than a low tonal target corresponding to a low offset. However, Shen found this effect to be the general trend for tonal coarticulation in Mandarin. In contrast, the results of the current study on Taiwanese showed also a dissimilation-like effect between level tones and tones following them. The F0 of a level tone was higher when followed by a low-onset tone, but was lower when followed by a high-onset tone. A similar effect was found in Shih's (1988) Mandarin study: tone 2 (245) ended higher when the following tonal target was low, but lower when the following tonal target was high. Shih accounted for this phenomenon in Mandarin as an artifact of target deletion and not of target value per se. She posited a rule that deletes the final high tonal target of tone 2 when the following tonal target is high so that the measured value is in the transition from the preceding mid to a high in the following syllable. By contrast, the anticipatory dissimilation of the offset of target tone in the present study occurred in level tones and cannot be explained by a shift in timing of tonal target. It seems to be a contrast effect occurring between tones with different onset and offset values either to enhance perceptual cues of the following tone or to preserve the contrast between the high-level tone and the high-falling tone.

Pitch range and tone shape of tones were less affected by the following tone than by prosodic position. The change of overall pitch level caused by the F0 height of the following tone was only found in the high-level tone produced by subject HS. This minor change of pitch range of tone by tonal context was similar to that found in Lin's Taiwanese study (1988), but differed from the pattern found in Mandarin which showed change of pitch range of tones depending on the tonal context except for the high-falling tone only affected at the offset. In the production of HS, not only the offsets of tones but also the mid-point F0s were affected by the following tone. As found in Mandarin (Shen, 1990), tone shape was generally constant regardless of different following tones except a small change found in the production of subject HS.

## Conclusion

Taiwanese tones are acoustically influenced by prosodic position and to a certain extent by tonal context. Prosodic position has strong effects on both the F0 and duration of tones. Final-lengthening and final-lowering of F0 were found in the utterance-final and to a somewhat lesser extent in phrase-final positions. Pitch range was substantially affected by prosodic position, but in general, the tone shape was not changed. On the other hand, anticipatory tonal coarticulation affects the F0 offsets of tones without affecting syllable duration. A dissimilation-like effect occurs between level tones and the following tone. The F0 offset of a level tone was higher when the onset of the following tone was low than when it was high. Assimilation occurs between contour tones and the following tone. Some assimilatory effects were also found in level tones. The F0 offset of a contour tone was higher when followed by a high-onset tone than when followed by a low-onset tone. Tone shape of Taiwanese tones is not affected by tonal context. Pitch range in general is not affected by tonal context; however, some subject-dependent variation was found.

Given the effects of prosodic position and tonal context on duration and the F0 contours of tones, it would be interesting to see how duration and F0 contribute to listener identification of the prosodic position and the quality of the following tone. What are the relative contributions of the temporal information and the F0 cuing the termination or continuation of an utterance? Can the quality of a tone be predicted from the preceding tone?

## References

- Chao, Y. R. (1930) A system of tone letters. *Le Maitre Phonétique*, 30, 24-27.
- Chen, M. Y. (1987) The syntax of Xiamen tone sandhi. *Phonology Yearbook*, 4, 109-149.
- Cheng, R. (1968) Tone sandhi in Taiwanese. *Linguistics*, 41, 19-42.
- Cheng, R. (1973) Some notes on tone sandhi in Taiwanese. *Linguistics*, 100, 5-25.
- Entropic Research Laboratory, INC. (1993) *Waves+ 5.0*. AT & T Bell Laboratories. Washington, D. C..
- Fonagy, I. & Magdics, K. (1960) Speed of utterance in phrases of different lengths. *Language and Speech*, 3, 179-192.
- Ho, A. T. (1976) The acoustic variation of Mandarin tones. *Phonetica*, 33, 353-367.
- Hsiao, Y. E. (1990) The Bermuda triangle of syntax, rhythm and tone. *ESCOL '90*, 112-123.
- Klatt, D. (1975) Vowel lengthening is determined in a connected discourse. *Journal of Phonetics*, 3, 129-140.
- Liberman, M. & Pierrehumbert, J. (1984) Intonational invariance under changes in pitch range and length. In *Language Sound Structure*. (M. Aronoff & R. T. Oehle, editors), pp. 157-233. Cambridge, MA; MIT Press.
- Lin, H.-B. (1988) *Contextual Stability of Taiwanese Tones*. Doctoral dissertation, University of Connecticut.
- Lin, H.-B. & Repp, B. (1989) Cues to the perception of Taiwanese tones. *Language and Speech*, 32(1), 25-44.
- Lindblom, B. & Rapp, K. (1973) Some temporal regularities of spoken Swedish. *Papers from the Institute of Linguistics, University of Stockholm, Publication 21*.
- Shen, X. (1990) Tonal coarticulation in Mandarin. *Journal of Phonetics*, 18, 281-295.
- Shih, C. (1988) Tone and intonation in Mandarin. *Working Papers of the Cornell Phonetics Laboratory*, 3, 83-109.

**Appendix 1—Corpus for first pilot study**

[kə<sup>55</sup>] followed by high-level tone (55)

- [t<sup>h</sup>en<sup>33</sup> po<sup>51</sup>][kə<sup>55</sup> təŋ<sup>55</sup> tiam<sup>21</sup>] “TAN PAW” antique shop.  
 [twa<sup>21</sup> kə<sup>55</sup> təŋ<sup>55</sup>] [bo<sup>33</sup> lai<sup>24</sup>] The great shareholder did not come.  
 [tam<sup>33</sup> hiü<sup>33</sup> kə<sup>55</sup>] [kau<sup>55</sup> kin<sup>55</sup>] There are nine Chinese pounds of fresh mushrooms.  
 [tam<sup>33</sup> hiü<sup>33</sup> kə<sup>55</sup>] fresh mushrooms

[kə<sup>55</sup>] followed by mid-level tone (33)

- [te<sup>33</sup> kə<sup>55</sup> bi<sup>33</sup>] [tsin<sup>33</sup> taŋ<sup>33</sup>] This has a strong smell of a kettle.  
 [tam<sup>33</sup> hiü<sup>33</sup> kə<sup>55</sup>] [tʰi<sup>33</sup> tʰi<sup>33</sup>] Fresh mushrooms are slightly sweet.  
 [tam<sup>33</sup> hiü<sup>33</sup> kə<sup>55</sup>] fresh mushrooms

[pə<sup>51</sup>] followed by high-level tone (55)

- [si<sup>51</sup> tsio<sup>51</sup>] [pə<sup>51</sup> kau<sup>55</sup> tswa<sup>33</sup>] At least nine rows are planted.  
 [t<sup>h</sup>sa<sup>33</sup> pə<sup>51</sup> pi<sup>55</sup>] [taŋ<sup>51</sup> tsʰi<sup>24</sup>] Sewing clothes is a way to earn some money.  
 [tsen<sup>33</sup> t<sup>h</sup>sai<sup>51</sup> pə<sup>51</sup>] [kan<sup>55</sup> tan<sup>55</sup>] It is easy to fry some dried radish.  
 [tsen<sup>33</sup> t<sup>h</sup>sai<sup>51</sup> pə<sup>51</sup>] To fry some dried radish.

**Appendix 2—Corpus for second pilot study**

[pə<sup>55</sup>] in the phrase-medial position with five different following tone

- [twa<sup>21</sup> pə<sup>55</sup> to<sup>55</sup>] [tsin<sup>33</sup> lai<sup>33</sup>] The big valuable knives are very sharp.  
 [twa<sup>21</sup> pə<sup>55</sup> ten<sup>33</sup>] [p<sup>h</sup>ai<sup>55</sup> k<sup>h</sup>i<sup>51</sup>] Large precious temples are hard to build.  
 [twa<sup>21</sup> pə<sup>55</sup> kiam<sup>21</sup>] [si<sup>51</sup> kwi<sup>21</sup>] The big precious sword is most expensive.  
 [twa<sup>21</sup> pə<sup>55</sup> tia<sup>51</sup>] [kia<sup>55</sup> hwe<sup>55</sup>] The big precious caldron is not fire-proof.  
 [twa<sup>21</sup> pə<sup>55</sup> k<sup>h</sup>im<sup>24</sup>] [tat<sup>21</sup> tsi<sup>24</sup>] Big precious pianos are worth a lot.

[pə<sup>55</sup>] in the phrase-final position with four different following tone

- [bo<sup>33</sup> laŋ<sup>33</sup> pə<sup>55</sup>] [k<sup>h</sup>ə<sup>55</sup> lien<sup>24</sup>] It is depressing to be praised by nobody.

|  |   |
|--|---|
| [ŋ <sup>51</sup> laŋ <sup>33</sup> po <sup>55</sup> ] [tsin <sup>33</sup> t <sup>h</sup> sam <sup>51</sup> ] | It is awful to expect praise from people.     |
| [u <sup>21</sup> laŋ <sup>33</sup> po <sup>55</sup> ] [si <sup>5</sup> ho <sup>51</sup> ]                    | It is good to be praised by some people.      |
| [ai <sup>51</sup> laŋ <sup>33</sup> po <sup>33</sup> ] [kio <sup>51</sup> kak <sup>21</sup> ]                | It is hopeless to be always eager for praise. |
| ([σ σ *po <sup>33</sup> ] [σ <sup>24</sup> σ] missing since 24 occurs only in final position--see Table 2)   |   |

### Appendix 3—Corpus for main experiment

#### [kau<sup>55</sup>] in the phrase-initial position

|  |   |
|--|---|
| [lɔŋ <sup>55</sup> tsɔŋ <sup>51</sup> ] [kau <sup>55</sup> taŋ <sup>55</sup> puā <sup>21</sup> ] | In total, there are nine and a half barrels.        |
| [lɔŋ <sup>55</sup> tsɔŋ <sup>51</sup> ] [kau <sup>55</sup> kin <sup>33</sup> puā <sup>21</sup> ] | In total, there are nine and a half Chinese pounds. |
| [lɔŋ <sup>55</sup> tsɔŋ <sup>51</sup> ] [kau <sup>55</sup> p <sup>5</sup> puā <sup>21</sup> ]    | In total, there are nine and a half pounds.         |

#### [kau<sup>55</sup>] in the phrase-medial position

|   |   |
|---|---|
| [be <sup>55</sup> kau <sup>55</sup> kin <sup>55</sup> ] [bo <sup>33</sup> kau <sup>51</sup> ] | It is not enough to just buy nine Chinese pounds. |
| [be <sup>55</sup> kau <sup>55</sup> p <sup>5</sup> ]  | It is not enough to just buy nine pounds.         |
| [be <sup>55</sup> kau <sup>55</sup> te <sup>21</sup> ] [bo <sup>33</sup> kau <sup>51</sup> ]  | It is not enough to just buy nine pieces.         |

#### [kau<sup>55</sup>] in the phrase-final position

|   |  |
|---|--|
| [siū <sup>33</sup> ban <sup>21</sup> kau <sup>55</sup> ] [kiam <sup>55</sup> ke <sup>21</sup> ] | The price will be reduced if it is turned in late.     |
| [siū <sup>33</sup> ban <sup>21</sup> kau <sup>55</sup> ] [ka <sup>33</sup> k <sup>5</sup> ]     | The payment will be increased if it is turned in late. |
| [siū <sup>33</sup> ban <sup>21</sup> kau <sup>55</sup> ] [po <sup>21</sup> li <sup>21</sup> ]   | The interest will be low if it is turned in late.      |

#### [kau<sup>55</sup>] in the utterance-final position

|  |                         |
|--|-------------------------|
| [m <sup>21</sup> t <sup>h</sup> aŋ <sup>33</sup> siū <sup>33</sup> ban <sup>21</sup> kau <sup>55</sup> ] | Do not turn it in late. |
|--|-------------------------|

#### [kau<sup>33</sup>] in the phrase-initial position

|  |   |
|--|---|
| [tsi <sup>21</sup> kai <sup>51</sup> ] [kau <sup>33</sup> kau <sup>55</sup> pa <sup>21</sup> ] | Nine hundred dollars is paid each time.       |
| [tsi <sup>21</sup> kai <sup>51</sup> ] [kau <sup>33</sup> te <sup>33</sup> puā <sup>21</sup> ] | Nine and a half bags are submitted each time. |

- [tsi<sup>21</sup> kai<sup>51</sup>] [kau<sup>33</sup> pō<sup>55</sup> puā<sup>21</sup>]      Nine and a half pounds are submitted eachtime.
- [kau<sup>33</sup>] in the phrase-medial position
- [kh<sup>51</sup> kau<sup>33</sup> kh u<sup>55</sup>] [sam<sup>51</sup> pō<sup>33</sup>]      (He goes) to the suburbs to take a walk.
- [kh<sup>51</sup> kau<sup>33</sup> kwu<sup>33</sup>] [sam<sup>51</sup> pō<sup>33</sup>]      (He goes) to the outskirts of the city to take a walk.
- [bo<sup>33</sup> kau<sup>33</sup> tai<sup>21</sup>] [to<sup>33</sup> tsau<sup>51</sup>]      (He) left without leaving a message.
- [kau<sup>33</sup>] in the phrase-final position
- [tso<sup>51</sup> siū<sup>33</sup> kau<sup>33</sup>] [ph ai<sup>55</sup> pau<sup>55</sup>]      If (the skin of a dumpling) is made too thick, it will be hard to seal.
- [tso<sup>51</sup> siū<sup>33</sup> kau<sup>33</sup>] [kia<sup>55</sup> ke<sup>55</sup>]      If (the coat) is made too bulky, it will be inconvenient.
- [tso<sup>51</sup> siū<sup>33</sup> kau<sup>33</sup>] [ph ai<sup>55</sup> pau<sup>55</sup>]      If (the skin of a dumpling) is made too thick, it will weigh a lot.
- [kau<sup>33</sup>] in the utterance-final position
- [m<sup>21</sup> thəŋ<sup>33</sup> tso<sup>51</sup> siū<sup>33</sup> kau<sup>33</sup>]      Do not make it too thick.
- [kau<sup>21</sup>] in the phrase-initial position
- [nai<sup>21</sup> iōŋ<sup>33</sup>] [kau<sup>21</sup> tiā<sup>55</sup> kwa<sup>21</sup>]      durable thick lids of cookers
- [nai<sup>21</sup> iōŋ<sup>33</sup>] [kau<sup>21</sup> pō<sup>33</sup> le<sup>24</sup>]      durable thick glass
- [nai<sup>21</sup> iōŋ<sup>33</sup>] [kau<sup>21</sup> te<sup>21</sup> pan<sup>51</sup>]      durable thick floor
- [kau<sup>21</sup>] in the phrase-medial position
- [iō<sup>21</sup> kau<sup>21</sup> paŋ<sup>55</sup>] [lai<sup>33</sup> kh am<sup>21</sup>]      (We should) cover it with a thick piece of wood.
- [iō<sup>21</sup> kau<sup>21</sup> ph we<sup>33</sup>] [lai<sup>33</sup> kh am<sup>21</sup>]      (We should) cover it with a thick comforter.
- [iō<sup>21</sup> kau<sup>21</sup> pō<sup>21</sup>] [lai<sup>33</sup> kh am<sup>21</sup>]      (We should) cover it with a thick cloth.
- [kau<sup>21</sup>] in the phrase-final position
- [be<sup>21</sup> bo<sup>33</sup> kau<sup>21</sup>] [kiam<sup>55</sup> th an<sup>21</sup>]      Less money was earned due to fewer materials being on sale.
- [tsia<sup>21</sup> bo<sup>33</sup> kau<sup>21</sup>] [tiŋ<sup>33</sup> kio<sup>21</sup>]      If it is not enough to eat, (you should) order more.

|   |  |
|---|--|
| [ten <sup>33</sup> bo <sup>33</sup> kau <sup>21</sup> ] [ten <sup>33</sup> tsi <sup>51</sup> ]                                | Fewer fish were caught due to the lack of electricity. |
| [kau <sup>21</sup> ] in the utterance-final position  |  |
| [t <sup>h</sup> sin <sup>33</sup> t <sup>h</sup> si <sup>51</sup> tsi <sup>21</sup> bo <sup>33</sup> kau <sup>21</sup> ]      | It does not seem to be enough to eat.                  |
| [kau <sup>51</sup> ] in the phrase-initial position   |  |
| [tsi <sup>21</sup> t <sup>h</sup> iau <sup>21</sup> ] [kau <sup>51</sup> tiŋ <sup>55</sup> kuan <sup>24</sup> ]               | (He) jumped right to the top.                          |
| [tsi <sup>21</sup> t <sup>h</sup> iau <sup>21</sup> ] [kau <sup>51</sup> tu <sup>33</sup> tiŋ <sup>51</sup> ]                 | (He) jumped right to the top of the closet.            |
| [tsi <sup>21</sup> t <sup>h</sup> iau <sup>21</sup> ] [kau <sup>51</sup> p <sup>h</sup> we <sup>221</sup> tiŋ <sup>51</sup> ] | (He) jumped right to the top of the comforter.         |
| [kau <sup>51</sup> ] in the phrase-medial position  |  |
| [bo <sup>33</sup> kau <sup>51</sup> ti <sup>55</sup> ] [p <sup>h</sup> ai <sup>55</sup> tsi <sup>21</sup> ?                   | If it is not sweet enough, it will not be delicious.   |
| [bo <sup>33</sup> kau <sup>51</sup> tiŋ <sup>33</sup> ] [p <sup>h</sup> ai <sup>55</sup> tsi <sup>21</sup> ?                  | If it is not firm enough, it will not be tasteful.     |
| [bo <sup>33</sup> kau <sup>51</sup> k <sup>h</sup> wi <sup>21</sup> ] [p <sup>h</sup> ai <sup>55</sup> tsi <sup>21</sup> ?    | If (he) is not satisfied, (he) will not give up.       |
| [kau <sup>51</sup> ] in the phrase-final position   |  |
| [gi <sup>21</sup> tsap <sup>21</sup> kau <sup>51</sup> ] [tam <sup>55</sup> gan <sup>51</sup> ]                               | The eyes (of the statue) will be painted on the 29th.  |
| [gi <sup>33</sup> tsap <sup>21</sup> kau <sup>51</sup> ] [k <sup>h</sup> wi <sup>33</sup> tsi <sup>51</sup> ]                 | The result of the lottery will be known on the 29th.   |
| [gi <sup>33</sup> tsap <sup>21</sup> kau <sup>51</sup> ] [taŋ <sup>21</sup> kaŋ <sup>55</sup> ]                               | The construction will begin on the 29th.               |
| [kau <sup>51</sup> ] in the utterance-final position  |  |
| [læŋ <sup>21</sup> pa <sup>21</sup> gi <sup>33</sup> tsap <sup>21</sup> kau <sup>51</sup> ]                                   | Two hundred and twenty-nine.                           |
| (kau <sup>24</sup> cannot occur in phrase initial or medial position see Table 2)   |  |
| [kau <sup>24</sup> ] in the phrase-final position   |  |
| [hit <sup>53</sup> tsi <sup>51</sup> kau <sup>24</sup> ] [kau <sup>55</sup> kwai <sup>21</sup> ]                              | That monkey is nasty.                                  |
| [hit <sup>53</sup> tsi <sup>51</sup> kau <sup>24</sup> ] [t <sup>h</sup> au <sup>33</sup> tsi <sup>33</sup> ]                 | That monkey ate without permission.                    |
| [hit <sup>53</sup> tsi <sup>51</sup> kau <sup>24</sup> ] [p <sup>h</sup> o <sup>33</sup> kia <sup>51</sup> ]                  | That monkey is carrying her baby.                      |



[kau<sup>24</sup>] in the utterance-final position

[k<sup>h</sup>wā<sup>51</sup> tio<sup>21</sup> hit<sup>53</sup> tsia<sup>51</sup> kau<sup>24</sup>]

(I) saw that monkey.