COARTICULATION OF MANDARIN TONE 3

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ABSTRACT
This paper investigates how Mandarin Tone 3 changes when speaking rate and tonal context are varied. Data were collected from one female and one male graduate student both native speakers of Mandarin with four lexical tones. The test phrase consisted of three [ma]s in a row which were put in a sentence to provide a natural context. The second [ma] was always Tone 3, preceded and followed by Tone 1, Tone 2, Tone 3 or Tone 4 resulting in 16 different combinations. The subjects were asked to read the sentences at two rates: slow and fast. The F0 of each [ma] was measured at the onset and the offset of its vowel. In addition, F0 of the second [ma] was measured at midpoint. The duration of the vowel was also measured. The results from the preliminary study suggest that in general, the F0 variations for Tone 3 can be explained in terms of speaking rate and tonal context. This study supports these observations with an attempt to quantitatively predict the F0 value for Tone 3 from the duration and F0 of preceding and following syllables.

1. INTRODUCTION
The present study investigates the fundamental frequency of Mandarin Tone 3 in different tonal and rate contexts and further examines the following questions:

A. Is the F0 of Tone 3 contextually influenced by its neighbors?
B. If so, how is that influence expressed?
C. Does speech rate change the F0 of Tone 3?
D. If so, what is the nature of that rate dependence?
E. Is there tonal undershoot?

2. METHODOLOGY

2.1 Language and Speakers
The target language is Mandarin spoken in Taiwan. Taiwan Mandarin has four lexical tones and one neutral tone. In this study, only the four lexical tones will be discussed. Tone 1 is high and level, Tone 2 is mid-rising, Tone 3 is falling-rising (or falling-dipping), and Tone four is high-falling. Data were collected from one female speaker and one male speaker. Both are native speakers of Taiwan Mandarin and are graduate students in the Department of Linguistics at the University of Texas at Austin (UT).

2.2 Speech Sample
The test phrase consists of three [ma]s in a row. The second [ma] is always the third tone. It is preceded and followed by Tone 1, Tone 2, Tone 3, or Tone 4. These three [ma]s are inserted in a sentence in order to provide a natural context for their utterance. The consonant [m] of the test word [ma] maximally exhibits the sonorant and nasal features, so it is very vowel-like.
Therefore, it is possible to determine the value of F0 even while the consonant is being articulated. The focus of this paper is on F0 changes during [a].

![Diagram of sequence of tones in Mandarin](image)

**Figure 1.** Schematic representation of the sequences of tones in this study. Different tone combinations are provided in 16 sentences.

<table>
<thead>
<tr>
<th>Mandarin:</th>
<th>媽</th>
<th>馬</th>
<th>嗎</th>
<th>怎 麼 寫？</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPA:</td>
<td>[ma]</td>
<td>[ma]</td>
<td>[ma]</td>
<td>[tsan]</td>
</tr>
<tr>
<td>Tone</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Translation:</td>
<td>mother</td>
<td>horse</td>
<td>a phrase final particle used in questions</td>
<td>how to write</td>
</tr>
<tr>
<td>English:</td>
<td>How do you write “mother,” “horse” and “a phrase final particle used in questions”?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 2.3 Recording

Recording was done in a sound treated room at the Phonetics Laboratory in the Department of Linguistics at UT. 16 written sentences were presented to two subjects. The two subjects read the sentences at a slow and a fast rate. For the slow rate, they produced the sentences as slow as possible without introducing pauses. For the fast rate, the sentences were produced without sacrificing tone distinctions.

### 2.4 Measurement

There are 16 sixteen logically possible combinations of [ma], [ma], and [ma] when the first and third elements in the phrase can take any of the four tones, as shown in Figure 1 and exemplified in Table 1. As Figure 2 shows, the F0 of each [ma] was measured at the onset and offset of its vowel. F0 of the second vowel was also measured at midpoint. The F0 of each [ma]
at onset and offset were measured by placing the cursor at a visually determined midpoint of the first identified cycle and the last identified cycle of the vowel in the waveform.

Vowel 1
[a]

Vowel 2
[a]

Vowel 3
[a]

F0 Onset  F0 Offset  F0 Onset  F0 Midpoint  F0 Offset  F0 Onset  F0 Offset

Figure 2. Measurement points of the three vowels

3. RESULTS

3.1 The effect of context
The results of this study show that, when Tone 3 in vowel 2 is preceded and followed by different tones, the F0 of Tone 3 in Vowel 2 contours are varied. F0 of Tone 3 in vowel 2 changes with the context. The illustrations are given in figures 3 and 4. When Tone 3 was preceded by Tone 2 in the slow rate, the slope decreased considerably from V2 onset to V2 midpoint. A similar pattern was not observed when Tone 3 is preceded by Tone 4.

Figure 3. The F0 contour of vowel 2 in Tone 3 varies with its context in slow rate.

3.2 The effect of rate
Another factor which affects the F0 contour of vowel 2 in Tone 3 is rate. Four distinct phenomena related to the effects of rate were found in this study. These are undershoot (Figure 5), rate adjustment (Figure 6), asynchrony between segment timing and tonal contour (Figure 7), and temporal compression (Figure 8). Figure 5 demonstrates undershoot. The frequency difference between V2 onset to V2 midpoint and V2 midpoint to V2 offset in fast rate
is smaller than those in slow rate. The rate adjustment that occurred between fast and slow rates is shown in Figure 6. Examination of the points between V2 onset and V2 midpoint in Figure 6 under the two rate conditions shows that the slope between V2 onset and V2 midpoint is steeper in fast speech than in slow. In Figure 7, Tone 3 shows a falling pattern from onset to offset in fast speech. However, the pattern is not similar to that found in slow speech within the same context. Figure 8 illustrates that the F0 of V2 onset, midpoint, and offset in slow and fast speech show a similar range: approximately 80 - 100 (Hz). The only difference between the slow and fast is duration. Within Tone 3 in slow speech, the onset, midpoint, and offset are farther apart, while they are closer in fast speech i.e. temporal compression.

![Tone sequences 234 and 432 in fast speech from a female speaker](image)

**Figure 4.** The F0 contour of vowel 2 in Tone 3 varies with context in fast rate

![Tone sequence 134: Tone 3 in V2 in slow and fast speech from a female speaker](image)

**Figure 5.** Undershoot occurs while the speech rate changes in different tonal contexts.
Figure 6. Rate Adjustment: the example illustrates rate adjustment of Tone 3 in Vowel 2 is preceded by Tone 2 and followed by Tone 1 in two speech rates.

Figure 7. Asynchrony between segmental timing and tonal contour
4. SUMMARY
In the introduction, a number of questions were raised. In response, we note that F0 of Tone 3 is sensitive to both context and rate. We observed several processes e.g., undershoot, rate adjustment, temporal compression, and asynchrony between segment timing and tonal contour. An attempt will be made at the conference to report on a quantitative model that captures those effects.