

# The effects of speaking rate and intonation on the duration of tones in Mandarin Chinese

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## Abstract

This study investigates the effects of speaking rate and intonation on the duration of tones in Mandarin Chinese. My previous study found that the effect of intonation on the duration of tones is tone-dependent, i.e., the final falling tone is longer in question intonation than in statement intonation, whereas the final rising tone has similar duration for the two intonation types. In this study, the effects of intonation on the duration of sentence-final tones with different speaking rates (normal, fast, and slow) are examined. The results show that tonal targets and tone-bearing units have orthogonal or independent effects on the duration of tones. The results also suggest that the effect of changing tonal targets on the duration of tones is not speaker-controlled, i.e., the process of changing tonal targets is blind to its effect on tonal duration.

**Index Terms:** tone, intonation, duration, Mandarin Chinese

## 1. Introduction

More than half the world languages are tone languages [1]. Tone is realized on and synchronized with its tone-bearing unit. On the one hand, the duration of a tone-bearing unit is affected by many contextual and situational factors such as vowel identity and speaking rate. On the other hand, tone as an articulatory event has an intrinsic duration. For example, it takes longer time to realize a rising tone than a falling one over the same pitch range, because the maximum speed of pitch change is slower for pitch rising than pitch falling [2, 3]. How do the two aspects of duration of tones interact, is one more basic than the other? How is the duration of tones determined in speech production with respect to these two aspects? This study attempts to answer these questions by investigating the effects of speaking rate and intonation on the duration of tones in Mandarin Chinese.

It is observed that long vowels and sonorant rimes are more likely to carry contour tones [4]. The phonological and phonetic accounts for the distribution of contour tones have made different assumptions, explicitly or implicitly, about which is more basic in determining the duration of a tone, the tone itself or its tone-bearing unit. Duanmu (1994) argued against the existence of contour tones in phonology [5]. In his proposal, a contour tone occupies two moras hence longer. Akinlabi and Liberman (2001) made a similar proposal to explain the distribution of falling tones in Yoruba, in which a falling tone is associated with two tonal positions [6]. These accounts seem to suggest that tone-bearing units are more basic in determining tonal duration. Yu (2010) argued that the durational properties of contour tones could be better explained in terms of the interplay of articulatory and perceptual effects in tone realization [7]. It takes longer time to realize a contour tone, and the speakers also need longer time to perceive a contour tone. For example, if a falling  $F_0$  is very short, it will be heard as a level tone. This explanation

seems to assume that tonal targets, dynamic or static, are more basic in determining their duration. Zhang (2000) proposed an optimality-theory account for the interaction between tonal targets and tone-bearing units with respect to duration [8]. In his proposal, there are two faithfulness constraints: one is that tonal targets must be realized in the output, and the other is that the duration of the tone-bearing unit must be preserved in the output. If there is a conflict between the two constraints, then the rankings between them will determine whether to lengthen the tonal bearing unit, or to simplify the tonal targets from a contour tone to a level tone.

There are four lexical tones in Mandarin Chinese, referred to as Tone1, Tone2, Tone3 and Tone4. The  $F_0$  contours of the tones in isolation are high level, rising, low dipping (or just low) and falling, respectively. Pike (1948) differentiated two tonal systems: level-pitch register systems and gliding-pitch contour systems [9]. Mandarin belongs to the latter in this typological classification. Although there has been a long debate in phonology about whether the contour tones in Mandarin Chinese should be treated as sequences of high or low targets [e.g., 10, 11, 12], phonetic studies have mainly found evidence for the presence of unitary contours in Chinese tonal representation [13, 14, 15]. Tone2 is longer than Tone4 in Mandarin Chinese [16, 17, 18]. This is consistent with the finding that pitch rising takes longer time than pitch falling [2, 3]. But on the other hand, Tone2 has a smaller pitch range than Tone4 (Tone2 is transcribed as “35” and Tone4 is “51” in the 5-scale tone notation system). Therefore, the underlying rising and falling targets might not be adequate to explain the duration difference between the two tones. Besides tonal targets, speaking rate and intonation also affect the duration of tones. Yuan (2004) found that Tone4 in question intonation is longer than in statement intonation, whereas Tone2 has similar duration in the two intonation types [15].

This study investigates how speaking rate and intonation affect the duration of tones in Mandarin Chinese. Intonation may change tonal targets. Yuan (2004, 2006) argued that one mechanism of question intonation in Mandarin Chinese is to change the slope of contour tones, i.e., to flatten the final falling tone and to steepen the final rising tone [15, 19]. The speaking rate effect is, on the other hand, more on the tone-bearing units, i.e., the tone-bearing units become longer or shorter due to a slower or faster speaking rate. By investigating the effects of speaking rate and intonation on the duration of tones, we may answer questions about how the two aspects, the tonal targets and the tone-bearing units, interact in determining the duration of tones in speech production.

## 2. Method

A corpus of 26 sentences was created for the study. The sentences were minimal pairs contrasting on intonation type (statement, question) and tone of the last syllable (Tone2, Tone4), for example:

礼拜五罗燕要买羊。(Li3bai4wu3 Luo2yan4 yao4 mai3 yang2.)  
 礼拜五罗燕要买羊?(Li3bai4wu3 Luo2yan4 yao4 mai3 yang2?)  
 “Luo2Yan4 will buy a goat Friday. / ?”

礼拜五罗燕要买鹿。(Li3bai4wu3 Luo2yan4 yao4 mai3 la4.)  
 礼拜五罗燕要买鹿?(Li3bai4wu3 Luo2yan4 yao4 mai3 la4?)  
 “Luo2Yan4 will buy a deer Friday. / ?”

(The sentences are transcribed in *Pinyin* romanization with a digit at the end of each syllable indicating the tone of the syllable.)

The sentences, in Chinese characters, were presented one by one on a computer display to the speakers in a randomized order. The speakers were asked to speak the sentences as a question if there is a question mark at the end and as a statement if there is a period at the end. The procedure was repeated three times. Each time the speakers were asked to speak the sentences in a particular speaking rate: normal, fast, and slow, respectively. Thirty native Mandarin speakers, fifteen male and fifteen female, participated in the recordings. The speakers were college students aged 20 to 31 years who studied at Beijing University and spoke Standard Chinese in their daily lives. The recordings were conducted in a soundproof booth in the phonetics laboratory at Beijing University.

The 780 utterances (30 speakers and 26 utterances per speaker) were first segmented using the Penn Phonetics Lab Forced Aligner (<http://www.ling.upenn.edu/phonetics/p2fa>). The boundaries of the last syllables were then manually checked and corrected, and the durations of the last syllables were analyzed.

### 3. Results

The effects of speaking rate on the duration of sentence-final Tone2 and Tone4 in statement intonation are shown in Figure 1. We can see from the figure that speaking rate has similar effects on Tone2 and Tone4. Both Tone2 and Tone4 become longer when speaking rate is slower. We can also see that Tone2 is longer than Tone4 at all speaking rates, and the duration difference between the two tones remains the same magnitude across different speaking rates. This result suggests that the effects of speaking rate and tonal targets on the duration of tones are orthogonal and independent.

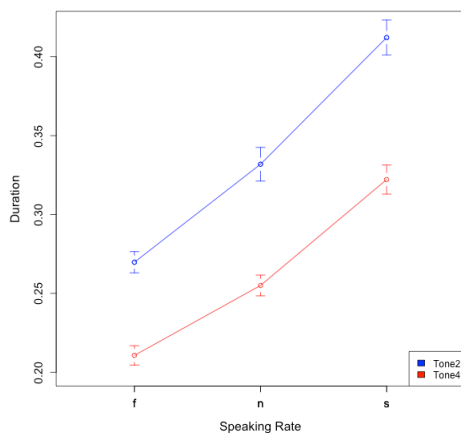


Figure 1. The effects of speaking rate on the duration of sentence final Tone2 and Tone4.

The effects of intonation on the duration of sentence-final Tone2 and Tone4 at different speaking rates are shown in Figure 2. The figure shows that the final Tone4 is longer in question intonation than in statement intonation whereas the final Tone2 has similar duration in the two intonation types. This pattern is the same across all speaking rates. This result suggests that the speaking rate effect is orthogonal and independent to the effect of intonation on the duration of tones. The mechanism of question intonation on sentence-final Tone2 and Tone4 is, as argued in Yuan (2004, 2006), to change the tonal targets, i.e., to flatten the final falling tone and to steepen the final rising tone [15, 19]. This mechanism seems to be, however, blind to its consequence on the duration of tones, because across different speaking rates sentence-final Tone4 becomes longer in question intonation whereas sentence-final Tone2 does not.

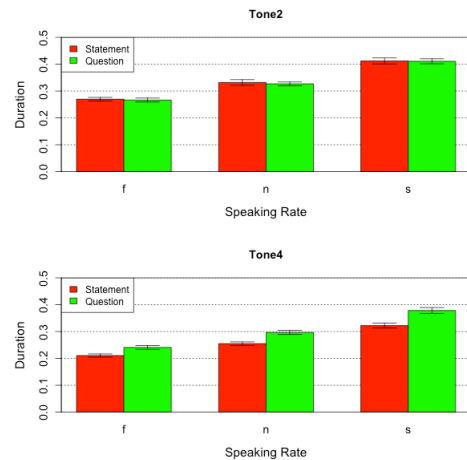


Figure 2. The effects of intonation on the duration of sentence final Tone2 and Tone4 at different speaking rates.

### 4. Conclusions

Both Tone2 and Tone4 become longer when speaking rate is slower. However, the duration difference between the two tones remains the same magnitude across different speaking rates. The effect of question intonation on the duration of sentence-final tones also remains the same across different speaking rates. These results suggest that the effects of speaking rate and tonal targets (both the phonological targets of tones and the change of tonal targets by intonation) are orthogonal and independent.

Question intonation has different effects on the duration of sentence-final Tone2 and Tone4. Sentence-final Tone4 is longer in question intonation than in statement intonation whereas sentence-final Tone2 has similar duration in the two intonation types, and furthermore, this pattern is the same across different speaking rates. This result suggests that the change of tonal targets by intonation is blind to its consequence on the duration of tones.

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