Contextual Variability of Third-Tone Sandhi in Taiwan Mandarin

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Abstract

This study investigates the phonetic property of Third-Tone Sandhi in Taiwan Mandarin and the effects of contextual variability. The goal of this study is to provide empirical evidence for the description of Tone 2 (T2) and Tone 3 (T3) in Taiwan Mandarin and further to account for the phonetic features of T2 and T3 in Third-Tone Sandhi Contexts. The results show that isolated T2 is different from isolated T3 in Taiwan Mandarin. Interestingly, the phonetic *T2* (</T3/) derived from Third-Tone Sandhi Rule in Sandhi Context has more raising effect than the underlying T2 in the same Sandhi Context. The greater raising effect of the T3 (> *T2*) in Sandhi Context was supported by its longer vowel duration. Third-Tone Sandhi Rule turns **T3**T3 into *T2*T3, and anticipatory dissimilation enhances the raising effect on the Sandhi.

1. Introduction

There are four lexical tones in Mandarin Chinese, which are Tone 1, Tone 2, Tone 3 and Tone 4. Neutral tone is an atonic syllable. A tone is often described in terms of its pitch height, and the pitch shape it has over the duration of the syllable. Although the shift and muddle of Tone 2 (Mid-High) and Tone 3 (Low) in Taiwan Mandarin has been mentioned in Chen [1], her results are based on personal observation or perception. As a result, how Tone 2 and Tone 3 in Taiwan Mandarin differ phonetically has not been well studied, and the production of the Sandhi variation is not clear yet. It is important to note that phonetic contexts do affect the realization of prosody in Mandarin. For instance, the notable phenomenon of Third-Tone Sandhi does occur in both spontaneous speech and citation, at normal and fast rate of speech. In Third-Tone Sandhi context, it is natural to produce predictable Sandhi (T3T3 > *T2*T3) patterns; whereas when each tonal syllable is placed in isolation, Sandhi does not occur. The present study focuses on the contextual prosodic variation of Third-Tone Sandhi and the factors that contribute to the phonetic realization of Third-Tone Sandhi. The study aims to provide empirical evidence for the description of T2 and T3 in Taiwan Mandarin and further to account for the phonetic features of T2 and T3 in Third-Tone Sandhi Contexts. Physical measures of T2 and T3 in different contexts were made to capture the tonal identity of Taiwan Mandarin and the variability of Third-Tone Sandhi.

2. Background of Third-Tone Sandhi

Mandarin Third-Tone Sandhi is generally predictable, and the application of Third-Tone Sandhi rule is phonological obligatory, when only two third-tone syllables are strung together. The phonetic realization of the Third-Tone Sandhi becomes more complicated when more than two third-tone syllables come together. Cheng [2] claims that all third-tone syllables except the last one may change when many T3 syllables appear, and the various possible changes depend on speech tempo.

Thus far, phonological status of Third-Tone Sandhi Rule is ascertained, whereas the phonetic realization of Third-Tone Sandhi may vary.

2.1. Mandarin Third-Tone Sandhi Rule

In Sandhi Contexts, T3 alternates with T2 when another T3 follows. In other words, Third-Tone Sandhi Rule turns a low T3 into a rising tone when followed by another T3. But a T2 (rising tone) tone does not change its phonetic property when followed by another T2. Earlier studies [3][4] provide phonological account for sandhi domain, and Chen [4] further proposes stress-foot as sandhi domain in diverse Chinese dialects. Mandarin Third-Tone Sandhi Rule was treated as a dissimilation process on a register level [5]. When two syllables with identical tones come together, the first one changes. Shih [3][6] proposes that three-syllable structures function similarly to disyllabic feet. No matter whether the added syllable is to the right or to the left, Third-Tone Sandhi Rule applies without fail. Coster and Kratochvil [7] have investigated T3 Sandhi in connected speech and claimed that the occurrence of tone sandhi in spontaneous speech is not governed by the phonological tone sandhi rule, either in its conventional form or in its restricted form.

Phonetically, Shih's [6] study captures a significant phonetic distinction between T2 and T3: T3 stays low much longer than a T2; in the beginning of a rhyme, the pitch of a T2 typically falls slightly as well, giving it an overall falling-rising shape; however, by the time T2 begins to rise, T3 still remains low and continues to fall, reaching a lower level than a T2 and then rises. However, the phonetic property of T2 and T3 in Sandhi contexts was not investigated in her study. In the present study, both isolated and connected T2 and T3 in Third Tone Sandhi Context were examined.

2.2. The Effect of Contextual Tonal Variation

The magnitude and directional has been important issues in the study of contextual tonal effect. Gandour *et al.* [8] have found that Thai tones were more influenced by carry-over coarticulation than by anticipatory coarticulation. Carry-over coarticulation affected a greater number of Thai tones and extended farther into adjacent tones. On the other hand, the findings on Mandarin tonal variation have been mixed. Anticipatory and carryover effects were found to be comparable in magnitude of effect, and it was concluded that the bi-directional effects are symmetric [9][10]. It was also observed that tonal coarticulation in Mandarin was unidirectional, and each tone in Mandarin was affected either by a carry-over effect, or by an anticipatory effect [11]. Furthermore, data from Mandarin and Thai suggest that the anticipatory tonal influence is dissimilatory rather than

assimilatory [8][11][12]. The anticipatory effect (also called anticipatory raising or regressive H-raising) is that f0 height of a tone is raised when followed by a low tone [8][13]. Anticipatory raising effect may in fact be the real mechanism underlying downstep [11]. Xu [11] concludes that anticipatory effects are mostly dissimilatory: a low onset value of a tone raises maximum F0 value of a preceding tone.

Anticipatory raising effect may be a factor for the dissimilatory phenomena of *T2* (</T3/) in Third-Tone Sandhi Context. In the present study, all the target words were placed preceding a T3 with a low onset. Under the controlled phonetic environment, it was expected that the maximum F0 (usually offset) of a *T2* would be raised by its following T3 (low onset). Particularly, one of the main concerns of the present study is to know whether the raising effect of T3 is significant in the tonal context of *T2*T3 (</T3T3/) with the application of Third-Tone Sandhi Rule. Namely, whether the *T2* derived from Third-Tone Sandhi Rule has greater raising effect than the controlled T2 in the same context without the application of T3 Sandhi Rule. The italic *T2* is the product of Third-Tone Sandhi Rule, whereas T2 is a controlled one.

2.3. Rate Factor in Mandarin Speech

Shih [3] has noted that internal structures of three-syllable phrases are ignored or 'flattened' out in fast and casual speech. In allegro speech, for instance, three-syllable phrases are treated as internally unstructured sequences of syllables. This indicates speech rate affects the identification of a prosodic foot and the application of the T3 Sandhi rule in three-syllable phrases. In Xu's [14] instrumental study, it was found that duration at slower rate is longer and that the duration of the R (Rising) tone is the longest. It is clear that speech rate reduces the duration of a syllable. However, whether speech rate directly affects the phonetic realization of Third-Tone Sandhi needs further investigation.

In the present study, speech rate was considered as one of the parameters in the physical measures of F0 contour, one of the major phonetic correlates of the third-tone Sandhi features.

3. Production of variability

It has been predicted in the present study that *T2* derived from Third-Tone Sandhi Rule is distinct from the controlled T2, due to various factors such as phonetic contexts and speech rates. Sandhi context may produce the variability of *T2*.

3.1. Design of the Experiments

The independent factors in this study are (i) Tone: underlying /T2/ and /T3/; (ii) Position: isolation and Sandhi Context. Isolation position will retain the form of underlying /T2/ and /T3/, whereas Sandhi Context will result in the surface form *T2*, which may be a reflex of either /T2/ or /T3/; (iii) Speech Rate: normal and fast. Fast rate may cause more tonal coarticulation or neutralize the surface forms of *T2* or *T3*.

On the other hand, dependent factors are as follows. (i) onset; (ii) offset; (iii) pitch contour; and (iv) vowel duration. Offset f0 values are usually the maximum f0 in T2 (rising). Pitch contour is obtained from the difference between Onset and Offset (Offset-Onset). If the f0 value is larger than zero, it is a rising contour; whereas a f0 value less than zero indicates a falling contour. Duration was measured from the vowel portion. For instance, in the CV syllable [mei], duration was measured from the portion of the diphthong [ei].

Four groups were designed. Two are experimental, and two are controlled. Experimental groups are T3 in Tone Sandhi Context and T2 in Tone Sandhi Context. Controlled groups are Isolated T2 and T3. Each group is consisted of 30 tokens. Tokens in each group were produced at fast and normal rates. The total number of the tokens is 480 (N= 480).

In Mandarin, lexical items are monosyllabic. Each monosyllable is divided into a consonant initial and a rhyme (a single vowel, diphthong or a vowel plus a nasal coda). Vowel height was not controlled in the study, because the three-syllable phrases must be grammatical, and the thirty grammatical phrases per condition could not be formed by only an identical vowel height. Tone Sandhi Contexts are three-syllable phrases, with first or second-syllable T3, fixed last-syllable T3, and the target T2 or T3 inserted into the initial or the middle of the template to form a grammatical phrase. Target tonal syllables are in the form of T2 or T3 CV, in which C is a nasal, a lateral, or a glide. A target syllable **X** is placed at the first or second position of an internal prosodic foot in a three-syllable phrase context **X T3 T3** or **T3 X T3**, in which the application of Third-Tone Sandhi Rule is obligatory. Experimental groups 1 and 2 are illustrated below.

* Group 1: T3 in Third-Tone Sandhi Context
    jing3 **yu3** ni3 *'the policeman and you'*
* Group 2: T2 in Third-Tone Sandhi Context
    jing3 **yu2** ni3 *'the policeman entertained you'*

Controlled groups 3 and 4 are shown below.

* Group 3: T3 in isolation
    yu3 *'rain'*
* Group 4: T2 in isolation
    yu2 *'fish'*

Two female native speakers of Taiwan Mandarin ages 25-28 participated in this study. None of them had hearing impairment history. Recording was conducted in a sound treated booth in the Department of Linguistics, University of Texas at Austin. Materials were randomized and presented to the subjects in a printed list in Chinese characters. None of the target words was marked or underlined. Subjects were instructed to read aloud each phrase or syllable at a normal rate. Then they were asked to read the list again at their fastest rate. The data recorded on the digital tapes was sampled at 20,000Hz using the Macquirer software.

Physical measures are vowel duration, f0 at onset and offset points, and pitch contour. Vowel duration was measured from each target syllable. Pitch contour (rising or falling) was obtained by subtracting onset from offset (Pitch Contour = f0 at Offset – f0 at Onset). Separate analyses of variances (ANOVAS) were performed on the f0 values at onset and offset, contour, and vowel duration to evaluate the extent of anticipatory effects in 480 tokens.

3.2. The Correspondence of Offset and Pitch Contour

The results of f0 values at onset and offset points of each condition are given in Figure 1. F0 values at offset are higher than that at onset, except for T3 in isolation, and T3 in Sandhi Context has greater raising effect than T2 in Sandhi Context, indicated by the raising slope. There is not much pitch contour difference between T2 in Sandhi Context and T2 in isolation. There is, however, significant pitch contour difference between T3 in Sandhi Context and T3 in isolation ($p < 0.0001$). ANOVAs indicate a significant difference in f0 at offset of T3 and T2 in Sandhi Contexts [$F_{(3, 236)} = 135.94$, $p < 0.0001$]. The correspondence between offset and pitch contour is clear.

A t-test was conducted to confirm the contour distinction between T3 and T2 in Sandhi Contexts. Pitch contour of T3 in Sandhi Context has significant difference [df=118, t=3.139, p<0.001] from T2 in Sandhi Context. T3 in Sandhi Context has more raising effect. The greater raising effect is significant [F (3, 236)=175.42, p<0.0001]. Pitch contour indicates the raising effect, because it was obtained from the subtraction.

The results indicate isolated T2 is different from isolated T3 in Taiwan Mandarin. The phonetic *T2* (</T3/) derived from Third-Tone Sandhi Rule in Sandhi Context has more raising effect than the underlying T2 in the same Sandhi Context.
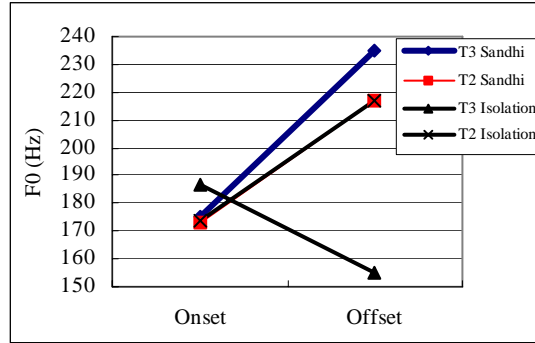

Figure 1: *F0 at Onset and Offset at Normal Rate*

3.3. Duration in Isolation and Sandhi Context

Earlier study has found that a rising tone has longer duration [14]. In the present study, if T3 in Sandhi Context has greater raising effect, presumably, it has longer duration.

The duration of T3 in Sandhi Context has significantly longer duration [F (3, 236)=93.604, p<0.0001] than that of T2 in the same Third-Toe Sandhi Context. As shown in Figure 2, T3 in Third-Tone Sandhi Context has longer duration than the tonal tokens in the other conditions.
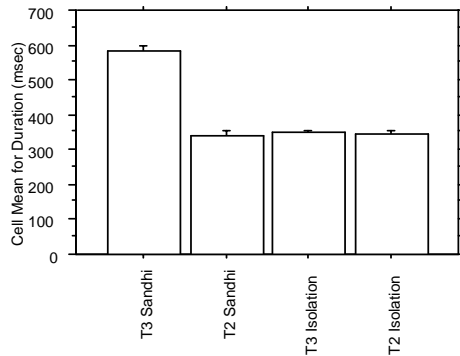

Figure 2: *Vowel Duration at Normal Rate*

The actual mean duration of the tonal tokens in each condition is given in Table 1.

Table 1: *Mean duration (msec) in each condition*

Condition	Duration (msec)
T3 Sandhi	584
T2 Sandhi	340
T3 Isolation	348
T2 Isolation	342

Note that the duration of T3 in Sandhi Context is the longest, much longer than the T2 tokens in the same Sandhi Context. It is clear that the greater raising effect of the T3 in Sandhi Context was supported by its longer vowel duration.

3.4. Speech Rate Affects Raising Effect

At fast speech rate, the distinction between T3 and T2 in Sandhi Contexts becomes less salient and not significant. F0 values at onset and offset points at fast rate were illustrated in Figure 3. Though the offset of T3 in Sandhi Context is slightly higher than that of T2 in Sandhi Context, the difference is not significant (p=0.2175). This indicates speech rate affects raising effect, though it does not change the falling or rising pitch contour of the tonal tokens.
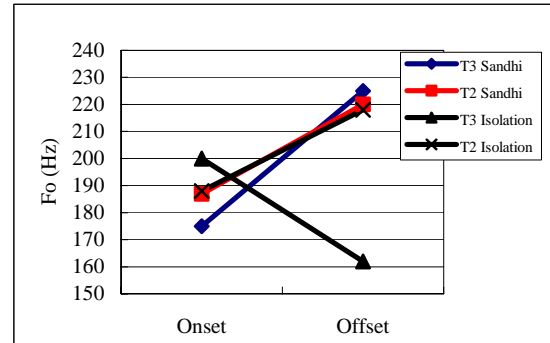

Figure 3: *F0 at Onset and Offset at Fast Rate*

4. Contextual effects

Sandhi Context provides the application of Third-Tone Sandhi Rule. Pitch tracks of the isolated T2 and T3 [ma] tokens in the present study are given in Figure 4, whereas pitch tracks of T2 and T3 [ma] in Sandhi Context are given in Figure 5. Vowel duration in the figures was normalized.
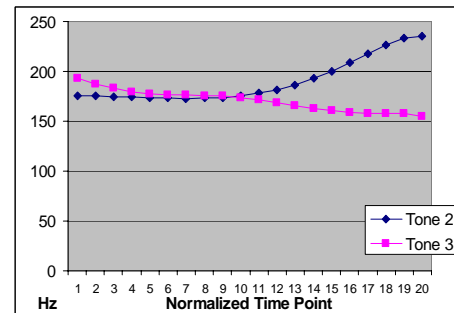

Figure 4: *Pitch Tracks of Isolated T2 and T3 [ma]*

As shown in Figure 4, T3 falls from the middle of the duration and has minimum f0 at offset point, whereas T2 rises and has the maximum f0 at offset point. On the other hand, both T2 and T3 in Sandhi Context have high f0 values at offset, as shown in Figure 5. The comparison between T3 in isolation and T3 in Sandhi Context indicates Sandhi Contexts trigger the application of Third-Tone Sandhi Rule in Mandarin and turn the underlying T3 into the phonetic *T2*. Isolated T2, T2 and T3 in Sandhi Context have rising pitch contour, whereas isolated T3 is a slightly falling tone or a low tone. It is clear that Sandhi Context is the prerequisite for the application of

Third-Tone Sandhi Rule, and phonetic contexts do affect the phonetic realization of T2 and T3 in Taiwan Mandarin.
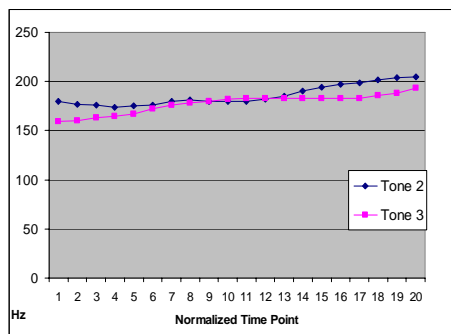

Figure 5: *Pitch Tracks of T2 and T3 [ma] in the Sandhi Context*

5. The relation between Third-Tone Sandhi and anticipatory dissimilation

It has been found in the present study that if the speaker distinguished isolated T2 and T3, *T2* derived from Third-Tone Sandhi Rule in three-syllable phrases may have more raising effect than the T2 in the same context without the application of Third-Tone Sandhi Rule. In a study of tones of Mandarin spoken in Taiwan (Taiwan Mandarin), Shih [3] notices that T3 seems to raise a high tonal target in the preceding tone. According to her observation, the high values of both T2 and T4 were higher when followed by T3 than by other tones. Though Shih [3] does not make any claim about contextual tonal effect, Xu [11] re-examined her data and found similar trend in other cases that not only do T2 and T4 have higher f0 values before T3 but also T1. Shen [9] also notices that T1 and T2 have the highest overall tonal values when preceding T2 and T3. It seems quite consistent among earlier studies that T3 raises the tonal values of its preceding tone, and Xu [11] has claimed that the phenomenon is due to anticipatory dissimilation. It has been investigated in the present study that both phonological Third-Tone Sandhi Rule and tonal contexts enhance the raising effect on the Third-Tone Sandhi, and the raising effect of Sandhi Context is due to anticipatory dissimilation.
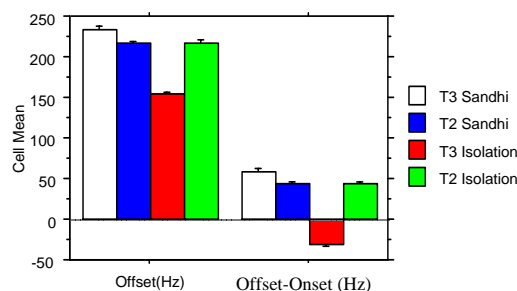

Figure 6: *F0 at offset and Offset-Onset*

In the present study, when phonetic contexts are controlled, T3 tokens in Sandhi Context at normal rate have significantly higher offset than their counterparts of T2 in Sandhi Context and T2 in isolation, as shown in Figure 6.

While no significant difference was found in the onsets of T2 and T3 in Sandhi Context, higher offset and raising pitch contour are the direct evidence for the claim that *T2* alternated with /T3/ due to Third-Tone Sandhi Rule has extra raising effect, given the same phonetic environment where anticipatory dissimilatory effect occurs. Phonological, **T2**T3 (T3T3 > **T2**T3) due to Third-Tone Sandhi Rule is identical to underlying **T2**T3. Phonetically, however, derived **T2**T3 (T3T3 > **T2**T3) is distinct from underlying **T2**T3, because of the robust anticipatory raising effect in Sandhi Context, as well as the contextual variability of Sandhi. Third-Tone Sandhi Rule turns **T3**T3 into **T2**T3, and the anticipatory dissimilation enhances the raising effect on its preceding tone.

Speech rate, described in earlier studies as a 'tempo' [2], has found to be a factor for the phonetic realization of T3 in Sandhi Context. At fast rate, the raising effect of T2 and T3 in Sandhi Context did not show significant difference. Therefore, it is proposed in this study that fast speech rate reduces anticipatory raising effect in T3 Sandhi Context. It is not the case in this study that the occurrence of Tone Sandhi in fast speech is not governed by the phonological Tone Sandhi rule. Rather, the interaction between speech rate and anticipatory dissimilation is the account for the loss of robust raising effect.

6. References

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