Trisyllabic Tone Sandhi in Tianjin Mandarin

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Abstract

Tianjin Mandarin is known for its complex tone sandhi patterns over bisyllabic constituents and the conflicting directionality as well as the possible iterative application of sandhi rules over trisyllabic constituents. Previous studies on Tianjin tone sandhi, especially those on sandhi in trisyllabic sequences, have been mainly based on impressionistic descriptions. In this paper, we argue that tone sandhi in Tianjin Mandarin is much simpler than what the literature suggests. First, only three bisyllabic tonal combinations in Tianjin introduce sandhi changes: T1+T1, T4+T1, and T3+T3. Furthermore, tone sandhi in Tianjin Mandarin does not involve the change of one lexical tone into another. Second, in trisyllabic sequences, these bisyllabic sandhi rules do not apply consistently, as claimed in the literature. Specifically, T1+T1 and T4+T1 only introduce sandhi changes when they are right-aligned. Iterative sandhi application was only observed over T3+T3+T3 sequence where sandhi must have been applied from the left edge. Conjointly, we argue that there is no experimental evidence to support the so-called “paradox” in Tianjin tone sandhi (Chen, 2000).

Index Terms: tone sandhi, Tianjin Mandarin, production

1. Introduction

Tianjin Mandarin is known for both its complex tone sandhi patterns over bisyllabic constituents and the conflicting directionality as well as the possible iterative application of the sandhi rules over trisyllabic constituents [e.g., 1, 2, 3]. Most of the previous studies on Tianjin tone sandhi have been based on impressionistic descriptions. To understand the underlying mechanism of these sandhi patterns, we will show that it is important to first obtain objective data on the acoustic realization of the bisyllabic sandhi patterns and their application in trisyllabic sequences. We will show that tone sandhi in Tianjin Mandarin is not as complex as described in the literature, and the so-called “paradox” in Tianjin tone sandhi, as described in [3], does not seem to exist, at least in speakers of younger generations.

There are four lexical tones in Tianjin Mandarin. Tone 1 is a low-falling tone; Tone 2 is a high-rising tone; Tone 3 is a dipping tone; Tone 4 is a high-falling tone. Both T1 and T4 are falling, but T1 is realized in a lower register while T4 in a relatively higher one. Figure 1 illustrates the $f_0$ realization of the lexical tones in isolation.

When two tones are combined, the first one undergoes sandhi changes [3]. The general consensus is that there are four sandhi rules in this dialect [e.g., 1, 3, 4, 5, 6, 7, 8]. Rules a-c in (1) have been attributed to tonal dissimilation due to the Obligatory Contour Principle. Rule d has been proposed to undergo changes due to Tonal Absorption [3].

(1)
\[ a. T1 \rightarrow T3. \quad b. T3 \rightarrow T2. \quad c. T4 \rightarrow T1/ T4. \quad d. T4 \rightarrow T2/ T1 \]

[2] argues that there are two more sandhi rules in Tianjin Mandarin, where T3 changes to T1 before either T2 or T4.

Of all the 64 tonal combinations of trisyllabic sequences, 27 combinations have been claimed to involve sandhi based on the four bisyllabic sandhi rules in (1) [1, 3, 8; but see 2 for more combinations that undergo sandhi changes]. Among the 27 combinations, 20 refer to simple application of one bisyllabic sandhi rule, which have been argued to apply consistently, regardless of the directionality of how the syllables are grouped. For example, sandhi applies over the T1+T1 combination in the context of both T1+T1+T2 and T2+T1+T1.

The other seven cases involve more complex sandhi changes concerning both the directionality and iterativity of rule applications, known as the Tianjin sandhi “paradox” (Chen, 2000). For example, in some trisyllabic sequences, more than one sandhi rule has been claimed to apply over the sequence, sometimes due to a new sandhi context created by the first application of one sandhi rule. This is known as the chain effect [3]. A good case in point is the T3+T1+T1 sequence. The first T1 can change to T3, which results in T3+T3+T1 where T3+T3 is again a possible sandhi context. Some other sequences might provide two possible sandhi contexts such as in T1+T1+T1. This tonal sequence has been reported to be realized as T1+T3+T1, which has been taken as evidence that the sandhi rule must have been applied from the right edge of the constituent.

In (2-8), we summarized the seven such complex trisyllabic tone sandhi patterns reported in the literature [1, 2, 8]; (2) and (3) have been argued to apply tone sandhi from the left edge and (4) – (8) from the right, among which, (2) – (5) have been claimed to involve the chain effect.

(2) $T3+T3+T3 \rightarrow T2+T3+T3 \rightarrow T2+T3+T3$
(3) $T4+T4+T1 \rightarrow T1+T4+T1 \rightarrow T1+T4+T1$
(4) $T4+T4+T4 \rightarrow T4+T4+T4 \rightarrow T4+T4+T4$
(5) $T3+T3+T1+T3 \rightarrow T3+T3+T1+T3$
(6) $T1+T4+T1+T4+T3 \rightarrow T3+T1+T4+T3$
(7) $T1+T1+T1+T1 \rightarrow T3+T1+T1+T3$
(8) $T4+T4+T1 \rightarrow T4+T4+T1$

Various theoretical attempts have been made to explain the sandhi patterns in Tianjin Mandarin [2, 3, 4, 5, 6, 8], but no consensus has been reached.

Worth noting is that all studies on trisyllabic sequences in Tianjin Mandarin have been based on impressionistic observations. Recent experimental studies on bisyllabic sandhi patterns in Tianjin Mandarin suggest that the actual sandhi
patterns may be different from descriptions based on auditory impressionistic data. For example, [9] has found that in bisyllabic constituents, T4 may not be changed to T1 before another T4. [10] has also confirmed the non-application of this rule as “obsolete”. It is therefore very likely that the actual realization of trisyllabic combinations might also differ from those described in previous studies. As we set out to understand Tianjin tone sandhi better, we take it as our primary goal in this paper to investigate, with well-controlled experiments, the tonal realization of trisyllabic sequences in Tianjin Mandarin. Two specific questions were addressed:

1) Do bisyllabic tone sandhi patterns apply consistently in trisyllabic sequences across all sandhi contexts?

2) Can we observe the chain effect described in the literature with experimental data?

2. Method

2.1. Materials

Our stimuli included all 64 trisyllabic combinations of the four lexical tones in Tianjin Mandarin. As a control for further comparison, 16 bisyllabic combinations were also included.

2.2. Subjects

Six speakers (three males and three females) participated in the experiment. All were in their twenties, born and raised in the urban areas of Tianjin. They were paid for their participation but naïve of the purpose of the experiment.

2.3. Recording

Recordings were conducted in a quiet room. All subjects followed the same procedure. Each sequence was elicited with a carrier sentence “… shi” “… (gloss: … is …)” as response to a pre-recorded question. For example,

QUESTION: Nar3 shi4 yi1 kuai4 bu4 mao2 zhi1 di4?

“Where is a barren land?”

ANSWER: Sha1 hui1 la1 shi1 yi1 kuai4 bu4 mao2 zhi1 di4.

“Sahara is a barren land.”

Subjects were requested to respond to the question with the sentence presented on the computer screen. In total, 384 trisyllabic items (4 initial tones * 4 middle tones * 4 final tones * 6 words) were elicited from six participants with two thirds of the constituents repeated twice. 96 bisyllabic items (4 initial tones * 4 final tones * 6 words) were elicited from six participants with four repetitions.

2.4. $f_0$ extraction

The data were manually segmented in Praat [11]. A custom-written script was used for $f_0$ extraction and smoothing. $f_0$ contours were obtained by taking 20 points (in Hertz) in each syllable and averaged across words and repetitions of the same tonal combination. The data were averaged across speakers after being transformed into semitones with the following formula:

\[ st = 12 \times \log_{2}(f_0 / f_{ref}) \]  

(st: semitone; $f_0$: raw f0 value in Hz; $f_{ref}$: the reference frequency with 100 Hz for females and 50 Hz for males)

3. Results

3.1. Bisyllabic sandhi patterns

Figure 2 shows the actual $f_0$ contours of the four commonly recognized patterns which are claimed to undergo sandhi changes in the literature (bisyllabic sandhi realization; hereafter referred as BS pattern), listed in (1). These $f_0$ contours were plotted in dark gray. In addition, each pattern can be compared to the realization of the tonal sequences that have been claimed to be the targeted realization of the tonal sequences (i.e., bisyllabic target realization; hereafter referred as BT pattern). These $f_0$ contours were plotted in light gray. Note that if indeed the bisyllabic sequences undergo tone sandhi and there is complete neutralization of the sandhi realization (BS) and the targeted realization (BT), as claimed in the literature, we would expect merged $f_0$ contours.

3a. T1+T1 vs T3+T1

3b. T3+T3 vs T2+T3

3c. T4+T4 vs T1+T4

3d. T4+T1 vs T2+T1

Figure 2: $f_0$ realization of the four bisyllabic sandhi patterns. Thick lines indicate the mean $f_0$ of the bisyllabic sandhi realization (dark gray areas for ±1 standard error of mean); thin lines indicate the mean $f_0$ of the bisyllabic targeted realization (light gray areas for ±1 standard error of mean). Normalized time.

In T1+T1 (Figure 2a), the first T1 was realized with a dipping contour comparable to that of T3. Although the contour of the first tone does suggest a sandhi change, it is not fully neutralized with the $f_0$ realization of T3+T1.

In T3+T3 (Figure 2b), the first dipping T3 was realized with a rising contour, very comparable to that of T2, and two contours were almost neutralized.

In T4+T4 (Figure 2c), the first high-falling T4 was realized with an $f_0$ contour, comparable to that of T1, but in a much higher $f_0$ register. We know that T1 and T4 are both falling tones, differing mainly in register. When the onset is not a sonorant, as in the case of the bisyllabic data here, T4 is typically realized with an $f_0$ contour that falls from the very beginning, just like T1, but in a higher register. Therefore, we think the first T4 in T4+T4 remains to be T4 rather than being changed into T1.

In T4+T1 (Figure 2d), the preceding T4 was realized with a rising $f_0$ but again, it is not fully neutralized with the contour of its targeted T2, as we would have expected if there was a sandhi change of T4 to T2.

In short, Figure 2 shows that, among the four sandhi patterns described in the literature, except for T3+T3 (Figure 2b) whose sandhi realization is almost neutralized with its targeted realization (T2+T3), none of the other sandhi patterns
were realized with an \( f_0 \) that is similar to their targeted realizations. Specifically, T1+T1 (Figure 2a) and T4+T1 (Figure 2b) do seem to undergo sandhi changes, but their sandhi realization is still very different from their targeted realization (i.e., T3+T1 and T2+T1 respectively). The tonal sequence T4+T4 does not seem to undergo sandhi at all.

While our main focus is on the four well-known bisyllabic sandhi patterns, we also noted in passing additional change of T3 to T1 before either T2 or T4, where the dipping T3 is realized as a low falling tone, without a salient rising \( f_0 \) tail, very similar to the realization of T3 in Beijing Mandarin.

### 3.2. Sandhi application in trisyllabic sequences

In Figures 3-6, the actual \( f_0 \) realization of the trisyllabic sequences (i.e., trisyllabic sandhi realization; hereafter referred as TS pattern) was plotted in dark gray. Each combination is compared to the realization of the trisyllabic sequences that have been claimed to be the targeted realization of the trisyllabic sandhi sequences (i.e., trisyllabic targeted realization; hereafter referred as TT pattern), plotted in light gray. Furthermore, those plotted on the left have the sandhi context in the first two syllables; and those on the right have the sandhi context in the last two syllables. Like in bisyllabic data, merged \( f_0 \) contours are also expected if tone sandhi is indeed applied, as claimed in the literature.

**Figure 3: trisyllabic sandhi patterns containing T1+T1 sequences.** Thick lines indicate the mean \( f_0 \) patterns of the trisyllabic sandhi realization (dark gray areas for ±1 standard error of mean) and thin lines indicate the mean \( f_0 \) patterns of the trisyllabic targeted realization (light gray areas for ±1 standard error of mean). Normalized time.

For the simple sandhi cases where no directionality is involved, the main question here is whether all the four rules apply consistently in trisyllabic sequences whenever there is a sandhi context. Figure 3 examines the T1+T1 sequence in different contexts. When T1+T1 is left-aligned (i.e., T1+T1+Tx, in Figures 3a-d, 1), tone sandhi cannot have applied, because we would have expected that the first one should be realized with a rising \( f_0 \) contour (see Figure 2a). In fact, however, the tonal sequence is realized as two consecutive falling tones, except for Figure 3a-1 where T1 is realized as a rising contour due to the sandhi change over the last two T1 syllables (see Figure 3a-2). When T1+T1 is right-aligned (i.e., Tx+T1+T1, in Figures 3a-d, 2), the sequence is always realized with a rising \( f_0 \) contour, comparable to that of T3+T1, without complete neutralization.

Figure 4 examines the T3+T3 sequence in different contexts. We see that in both T3+T3+Tx and Tx+T3+T3, the first T3 is always realized with a rising \( f_0 \) contour that is comparable to T2, as found in the bisyllabic data (Figure 2b), suggesting that the application of this sandhi rule is rather consistent.

**Figure 4: trisyllabic sandhi patterns containing T3+T3 sequences.** Thick lines indicate the mean \( f_0 \) patterns of the trisyllabic sandhi realization (dark gray areas for ±1 standard error of mean) and thin lines indicate the mean \( f_0 \) patterns of the trisyllabic targeted realization (light gray areas for ±1 standard error of mean). Normalized time.

Figure 5 illustrates the \( f_0 \) patterns of T4+T4 sequences. We know from Figure 2c that in bisyllabic sequences, there is no sandhi applied over the sequence. Here, again, no evidence of
sandhi application is observed over T4+T4 no matter if it is left-aligned or right-aligned.

Figure 5: trisyllabic sandhi patterns containing T4+T4 sequences. Thick lines indicate the mean $f_0$ patterns of the trisyllabic sandhi realization (dark gray areas for ±1 standard error of mean) and thin lines indicate the mean $f_0$ patterns of the trisyllabic targeted realization (light gray areas for ±1 standard error of mean). Normalized time.

Figure 6: trisyllabic sandhi patterns containing T4+T1 sequences. Thick lines indicate the mean $f_0$ patterns of the trisyllabic sandhi realization (dark gray areas for ±1 standard error of mean) and thin lines indicate the mean $f_0$ patterns of the trisyllabic targeted realization (light gray areas for ±1 standard error of mean). Normalized time.

Given what we have observed in the simple cases of trisyllabic sandhi application in Figures 3-6, we know that in (10) and (12), no change should be expected since the T4+T4 sandhi rule does not apply. Because of the directional constraint of T4+T1 and T1+T1, we expect only one-step sandhi change from the right edge in (9), (13), and (14). This is indeed what we observed in the data.

The remaining interesting cases are (8) and (11). Here, the actual realizations of these two trisyllabic sequences were plotted in dark and the $f_0$ patterns of their targeted realization, as predicted by the so-called chain effect, were plotted in light gray.

In (11), sandhi can only be initiated from the right edge (T1+T1), but the derived context (T3+T3+T1) may lead to another sandhi application, resulting in T2+T3+T1. If T1 indeed changes to T3 and if there is indeed the so-called chain effect, the $f_0$ patterns in Figure 7 suggest that the sandhi rule indeed applied from the right-edge, but no chain effect is observed, as the contour of the first syllable here is clearly a T3 realization, without resemblance to a T2 realization, as predicted in (11).
In (8), both T2+T2+T3 and T3+T2+T3 are possible outputs, where a chain effect is expected if the sandhi rule is applied from the left-edge, as shown in (8). The \( f_0 \) patterns in Figure 8a confirm the chain effect of T3+T3 rule application and suggests that the application of this rule must be from the left-edge.

![Figure 7: actual \( f_0 \) realization of T3+T1+T1 compared to that of T2+T3+T1. Thick lines indicate the mean \( f_0 \) patterns of the trisyllabic sandhi realization (dark gray areas for \( \pm 1 \) standard error of mean) and thin lines indicate the mean \( f_0 \) patterns of the trisyllabic target realization (light gray areas for \( \pm 1 \) standard error of mean). Normalized time.](image)

![Figure 8: actual \( f_0 \) realization of T3+T3+T3 compared to two possible targeted realizations. Thick lines indicate the mean \( f_0 \) patterns of the trisyllabic sandhi realization (dark gray areas for \( \pm 1 \) standard error of mean) and thin lines indicate the mean \( f_0 \) patterns of the trisyllabic targeted realization (light gray areas for \( \pm 1 \) standard error of mean). Normalized time.](image)

4. Discussion and conclusion

Results of this study confirmed three of the bisyllabic sandhi patterns reported in the literature: T3+T3, T1+T1, T4+T4. Our results thus agree with findings of [10] as well as our own, reported in [9]. Contra to the received wisdom in the literature, the T4+T4 sequence does not undergo sandhi changes, T4+T4 has long been taken as one of the sandhi patterns. In our data, the first T4 falling contour in the context of T4+T4 resembles that of T1 in isolation, partly due to the fact that the tone-bearing syllables in our data have obstruent onsets, leading to the impression that T4 has been changed to T1. It is clear from our figures that T4 was realized in a much higher register, suggesting no change of T4 to T1. [10] argues that this rule is “obsolete”, due to the influence from Beijing Mandarin, where there is no tone sandhi on T4+T4 sequences. Our conjecture is that the T4+T4 sandhi rule may have never existed in Tianjin Mandarin. Of course, more convincing evidence would come from the investigation of older generations of Tianjin speakers. If the T4+T4 sandhi rule did exist, we then expect that the first falling contour should be realized with a much lowered register to realize the derived T1.

Previous studies have also proposed two additional sandhi rules [2]: T3→T1/ T2 and T3→T1/ T4, in which the preceding dipping T3 is realized as low falling tone. We think this is very similar to the half low tone realization in Beijing Mandarin where the final rise of the dipping T3 is always absent in non-prepausal position [12]. Supporting evidence comes from [13], which shows that there is no neutralization of T3+T2 versus T1+T2 or T3+T4 versus T1+T4. Listeners can reliably detect the acoustic differences in differentiating the pairs. Therefore, we believe that the so-called sandhi change over the T3+T2/T4 sequences are due to contextual realizations of T3, without involving any tonal sandhi changes.

Among the three sequences which do undergo sandhi changes, our results show that only the sandhi-derived T3+T3 (Figure 2b) shows an \( f_0 \) pattern which is close to that of T2+T3, the claimed targeted realization of T3+T3 in the literature. In contrast, despite clear evidence of sandhi realization in T1+T4 and T4+T1, their \( f_0 \) patterns show little resemblance to that of their claimed targeted realization (i.e., T3+T1 and T2+T4 respectively), suggesting that tone sandhi in Tianjin Mandarin can not be considered as the change of lexical tone to another. Given the large body of literature on tone sandhi in Tianjin Mandarin, whose theoretical claims are often contingent upon the misconception that tone sandhi in Tianjin changes one lexical tone to another [1, 2, 3, 4, 5, 6, 7, 8], we believe our findings are of important empirical significance, which should be taken seriously in any attempt to understand the tone sandhi mechanism in general.

Moving onto trisyllabic tonal sequences, two important observations have been made. The first one concerns the consistency of sandhi application. In all impressioin descriptions, the bisyllabic sandhi rules summarized in (1) were reported to consistently apply in trisyllabic sequences whenever there is a sandhi context [1, 2, 3, 8]. Our data, however, showed clearly that consistent application was only found over the sequence T3+T3. The sandhi application over T1+T1 and T4+T1 sequences is only possible when these bisyllabic sequences are right-aligned to the trisyllabic constituents. It is not yet clear to us why these two sandhi rules apply only on the right edge. What we do notice is that they also do not show neutralization effect at all. Instead, there seems to be more variabilities in the output sandhi realization.

Another important observation is that among the seven trisyllabic more complex sandhi patterns, listed in (8) – (14), we did observe different constraints on the directionality of sandhi application but no chain effect due to derived tone sandhi context. All the patterns involving T4+T4 sequences, e.g., (10) and (12), are not confirmed. As for T1+T1 and T4+T1, we know that sandhi only applies when they are right-aligned. The \( f_0 \) patterns for (9), (13) and (14) further confirm the restricted application of tone sandhi.

The change in (11) (i.e. T3+T1+T1→T2+T3+T1) was not confirmed in our data. What we found, instead, is an \( f_0 \) contour that is more comparable to that of the sequence T3+T3+T1. In other words, despite the fact that T3+T3 can be applied consistently, the sandhi change over T1+T1 does not trigger the change of the initial T3, suggesting further that T1 does not change to T3 before another T1.

The only pattern confirmed in our data is the one described in (8) where T3+T3+T3 was realized with an \( f_0 \) contour comparable to that of T2+T2+T3. Despite the fact that T3+T3 sandhi can be applied either right- or left- aligned. Our data (Figure 8) suggest that over a trisyllabic sequence, the sandhi application must have been initiated from the left edge and applied iteratively from left to right, as otherwise, the application would have created a blocking context (i.e., T3+T2+T3, as in Figures 8b).

In sum, over trisyllabic sequences, we observed similar patterns of tone sandhi as those in bisyllabic sequences, but under some constraints. First, while T3+T3 can be applied consistently regardless of the alignment in the sequence, sandhi change over T1+T1 and T4+T1 is only observed when
they are right-aligned. Second, in the sequence of T3+T3+T3, sandhi applies only from the left-edge but is iterative, leading to some kind of chain effect.

Taking together our findings in the tonal realization of bisyllabic and trisyllabic sequences, we conclude with a much more simplified picture of tone sandhi in Tianjin Mandarin. First, we propose there are only three sandhi rules for T1+T1, T4+T1, and T3+T3, respectively. We believe that sandhi in Tianjin Mandarin does not involve the change of one lexical tone to another. There is a clear difference between the so-called underlying sequence vs. the targeted sandhi sequence in T1+T1 vs. T3+T1 and T4+T1 vs. T2+T1, although the difference between T3+T3 vs. T2+T3 is indeed very subtle. Second, these bisyllabic sandhi rules do not apply consistently in trisyllabic contexts. While sandhi over T3+T3 is more prevalent, the application of sandhi in T1+T1 and T4+T1 is restricted to the right-edge only. Last but not least, the complex sandhi applications reported in the literature, known as the paradoxical tone sandhi, do not seem to be justified. The only complex pattern we observed is over T3+T3+T3 where sandhi has to be applied from the left edge. The remaining research question, which we leave for future research, is to further understand the mechanism that explains Tianjin tone sandhi, the difference between Tianjin Mandarin and Beijing Mandarin, as well as the implication of such a mechanism for language changes in general.

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6. References