
T3 Sandhi rules of different prosodic hierarchies

Abstract

This study conducts acoustic analysis on T3 sandhi of two characters across different boundaries of prosodic hierarchies. The experimental data partly support Chen (2000)'s view about sandhi domain that "T3 sandhi takes place obligatorily within MRU", and "sandhi rule can not apply cross intonation phrase boundary". Nonetheless, the results do not support his claim that "there are no intermediate sandhi hierarchies between MRU and intonation phrase". On the contrary, it is found that, although T3 sandhi could occur across all kinds of hierarchical boundaries between MRU and intonation phrase, T3 sandhi rules within a foot (prosodic word), or between feet without pause, or between pauses without intonation (phonology phrase) are very different in terms of acoustic properties. Furthermore, based on the facts that (1) T3 sandhi could occur cross boundary of pauses and (2) phrase-final sandhi could be significantly lengthening, it is argued that T3 sandhi is due to dissimilation of low tones, rather than duration reduction within MRU domain. It is also demonstrated that tone sandhi and prosodic hierarchies may not be equivalently evaluated in Chinese phonology. Prosodic hierarchies are determined by pause and lengthening, not by tone sandhi.

Key words: tone sandhi; prosodic hierarchies; boundary; Mandarin Chinese

1 Introduction

So-called T3 sandhi in mandarin Chinese has been widely discussed in Chinese Phonology. Mandarin Chinese has four tones: T1 (level 55), T2 (rising 35), T3 (low-rise 214), T4 (falling 51). Generally, when a T3 is followed by another T3, it turns into T2. The rule could be simply stated as: 214->35/ ___214. The reason why T3 sandhi has drawn extensive attention is that this rule involves complex interactions between prosodic features and syntactic structures. Discussions concentrate on two aspects: 1) organization of sandhi domain and the relation with syntax; 2) the motivation of T3 sandhi and its nature.

The interaction between T3 sandhi and syntax has been reported by many studies (e.g. Shih 1986, Shen 1994, Chen 2000). Leading view regards tone sandhi domain as an identical process with metric organization, both directly controlled by syntactic structure. The basic ideas for this view have been proposed in Shih (1986):

(1)Foot formation rules:

- a. Immediate Constituency: Link immediate constituents into disyllabic feet.
- b. Duple Meter: Scanning from left from right, string together unpaired syllables into binary feet, unless they branch to the opposite direction.
- c. Super-foot Construction: Join any leftover monosyllable to a neighboring binary foot according to the direction of syntactic branching.

(The rules were recast in Chen (2000) as: a. No straddling; b. left-to-right binary organize Minimal rhythmic units (MRU); c. metric-syntactic congruence constraint.)

Shen (1994) provided more detailed analysis on the impact of syntactic branching. T3 sandhi must occur on left-branching structure, but optionally on right-branching structure.

In this light, two questions may be raised: 1) could syntactic boundaries necessarily determine all sandhi domains? 2) Could sandhi domains reflect syntactic boundaries?

Chen (2000) gave negative answers to both of the above questions. For example

(Cited from Chen2000 pp373. Digits 1, 2, 3 represent the tonal categories of T1 T2 T3, respectively, and *s* stands for sandhi):

(2) head simple

[tou-nao] [jian-dan] “naïve, simple-minded”

2 3 3 1 base tone

(2 3) (3 1) i. MRU-internal TS not applicable

(2 s) (3 1) ii. TS across MRU

The four-syllable utterance is broken into two binary units. The successive T3 syllables “nao” and “jian” are separately organized in two units, but the boundary does not block the application of sandhi rule. It seems that prosodic phrase boundary has no constraint on sandhi rules. Chen therefore concluded that sandhi domain is not determined directly by syntax, and intermediate hierarchies between MRU and intonation phrase could be cancelled.

Our earlier investigation on T3 sandhi (Kuang 2005) partly supports Chen’s conclusion. For example, for a left-branching structure T3 string, there are two possible sandhi forms:

(3) exhibition hall inside crowded

[[[zhan-lan-guan] li] ji] “The exhibition hall is very crowded”

((((3 3 3) 3) 3)

i. (((s s s) s) 3)*

ii. (((s 3 s) s) 3)

iii. ((s s 3) s) 3)

If sandhi rules strictly obey syntactic condition, the output should be i. However, it is very rare in natural speech. More natural forms are ii and iii.

ii has the same sandhi form with unstructured T3 strings, which are naturally divided into several binary sandhi units (Feng1998 referred it as natural foot):

(4) wu. wu wu wu wu “five five five five five”

(s 3)(s s 3)

iii preferentially bounds IP constituents into a sandhi unit, and the two leftover syllables joint together as a binary foot.

Simply put,(1) sandhi rule could violate word boundary, but hardly exceed the length of two or three syllables; 2) within an intonation phrase, sandhi rule could occur across MRU (foot) and prosodic phrase boundaries.

Although Chen (2000) has proposed some explanation to the conditions of sandhi rules, some aspects are still left unexplained. For instance, are sandhi rules could be identically applied across all different hierarchical boundaries? If not, could intermediate prosodic hierarchies between MRU (foot) and intonation phrase be cancelled for sandhi rule? To understand the interaction between sandhi rules and prosodic factors, it turns out to be necessary to make a closer look at the sandhi process. Therefore, we conducted an acoustic experiment to test T3 sandhi across

boundaries of different prosodic hierarchies.

2 Experiment

2.1 Procedure

Purpose: to investigate phonetic properties of T3 sandhi across different prosodic boundaries.

Stimuli: We designed 150 clauses, in which a pair of successive T3 syllables is organized in separate two rhythmic units. We adjust the size of the rhythmic units from foot to intonation phrase, so that the pair of T3 syllables is on the boundaries of different hierarchies.

Subjects: a boy and a girl, both are native speakers of Beijing Mandarin.

Recording: The experiment is conducted in Phonetics laboratory of Peking University. Signals are collected from two channels (EGG and acoustic). Data is described by Matlab and Praat programs. The following spectrogram figures of attested T3 syllables are drawn by Praat. For the sake of revealing the tendency of F0 and boundary information at the same time, we use narrowband spectrogram. Some of the figures are also added intensity curves for necessary complement information.

We shall cite examples to describe our experimental results from small boundaries to

larger ones. The attested T3 syllables are underlined. For convenience, we do not translate long test sentences, and only mark the boundary and T3 characters.

2.2 Discussion

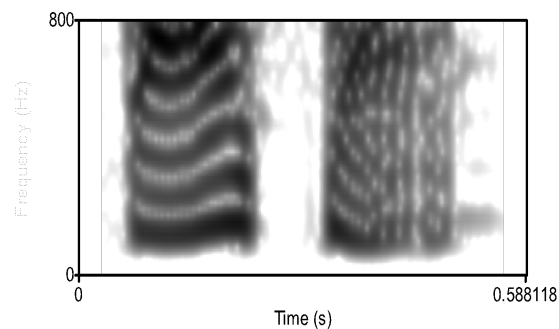
A. Within a standard binary foot (MRU)

Examples:

(5) yu-san (umbrella); mai-mi(buy rice); da-si(beat to death);da-san(hold the umbrella)

Results: T3 sandhi obligatorily takes place (no exception), and the two syllables are close join together; no pause and lengthening effect; F0 of the sandhi syllable rise sharply but the duration is short; intensity of the latter syllable is no larger than the sandhi one.

Figure 1: da-san(hold the umbrella)



B. Cross feet within one prosodic phrase

Examples:

(6) a. [shang-chang][guang-gao-bu](the advertisement department of the market);

Market the advertisement department

(1 s) (3 4 4)

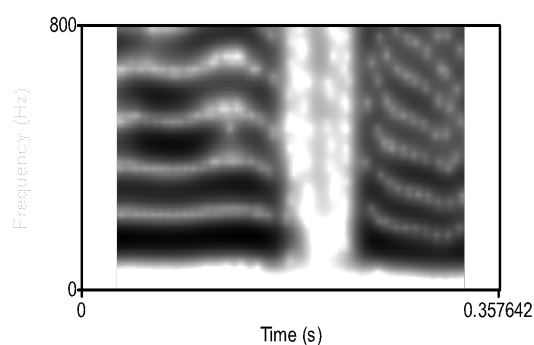
b. [Jing-**cai**] [**biao**-xian](wonderful performance)

Wonderful performance

(1 s) (3 4)

Results: T3 sandhi is likely to take place (with few exceptions); F0 of the sandhi syllable rises smoothly, and sandhi duration is longer; no obvious pause and lengthening between the two syllables; the intensity of the latter syllable is not stronger than the former.

Figure 2: [jing-**cai**][**biao**-xian] (wonderful performance)



C. Cross prosodic phrases within an intonation phrase

Since all we need are the sandhi characters on boundaries, for convenience, we would not translate the following long experimental utterances. We shall mark the T3 syllables and label the prosodic phrases.

Examples:

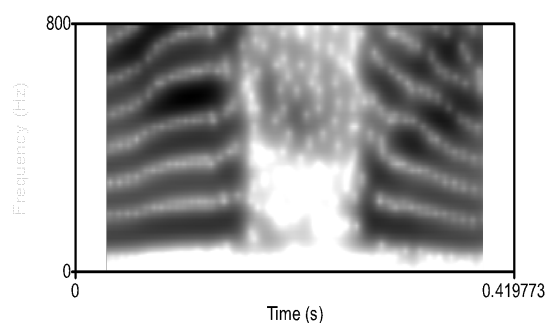
(7) a. [天边][一抹][火红的晚霞]

b. [用毛笔][写了个大字]

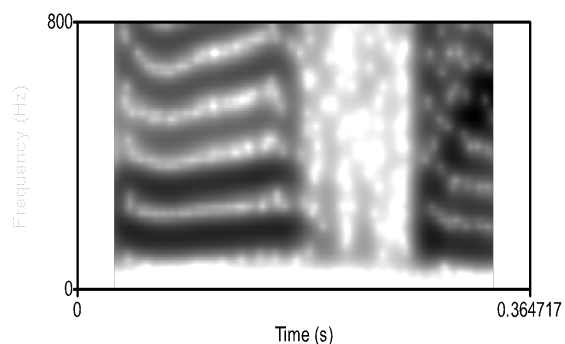
c. [从上海]、[北京来的旅客][到这里集合] (“上海” and “北京” are parallel components with a pause between them)

Results: T3 sandhi optionally takes place; the former syllable is obviously lengthened and its duration is much longer than the latter syllables; F0 of the former syllable rises and the rising part is obviously lengthened; small pauses of 0.1ms are allowed between the two syllables. That suggests tone sandhi could apply across pause and lengthening boundary.

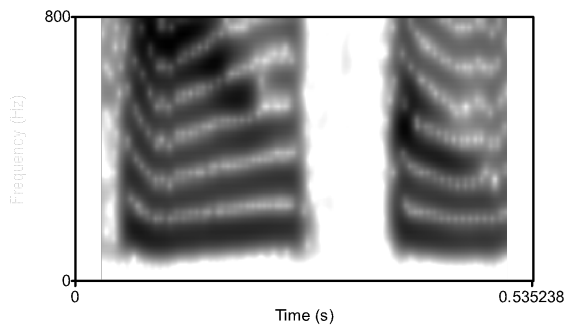
Figure 3: [天边][一抹][火红的晚霞]



[用毛笔][写了个大字]:



[从上海]、[北京来的旅客][到这里集合]



D. Cross intonation phrases

Example:

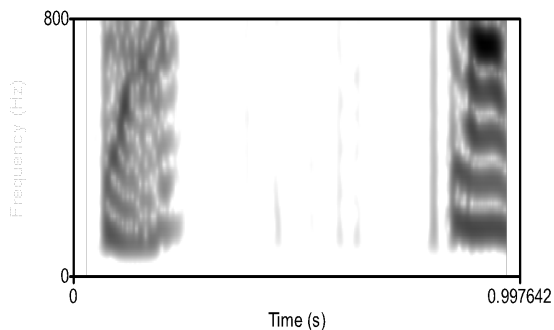
The sentences are constructed by two clauses.

(8) a. [小柳惆怅地想]: [哪个才是真正适合我的呢]

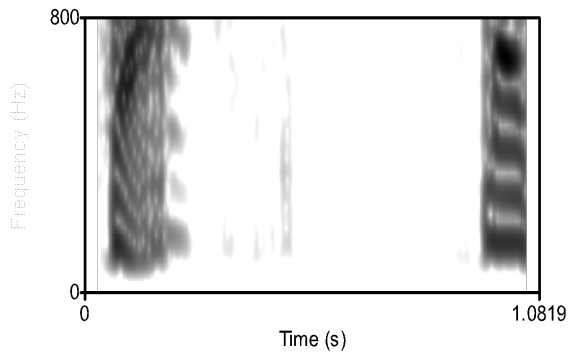
b. [不要买雨伞], [买皮球才划算]

Results: tone sandhi does not take place; there is a long pause between the two syllables; the former syllable is short and the intensity reduces quickly; pitch and intensity are reset in the latter syllable. Sandhi rules cannot apply across this kind of boundary.

Figure 4: [小柳惆怅地想]: [哪个才是真正适合我的呢]



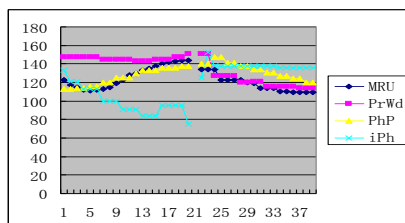
[不要买雨伞], [买皮球才划算]:



Summary:

The data above suggest that 1) Tone sandhi could take place in all the smaller boundaries than intonation phrase; 2) Only tone sandhi within foot is obligatory, and in larger boundaries it is optional; 3) T3 sandhi on the A, B, and C are different in phonetic representation (duration, intensity, pause and lengthening effect). We conclude the above F0 patterns of sandhi in the figure:

Figure 5:

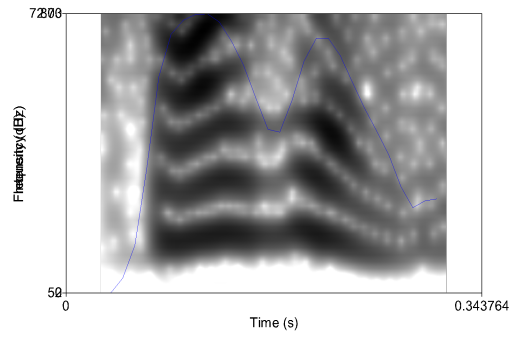


2.3 Minimal contrast test

We design a minimal contrast experiment to test the above summary. We posit the same T3-character sequence ”好很” on the all sizes of hierarchical boundaries.

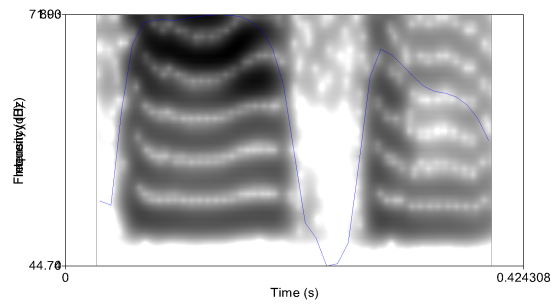
Within a foot:

(9) 这么改一改就[好很多]了。



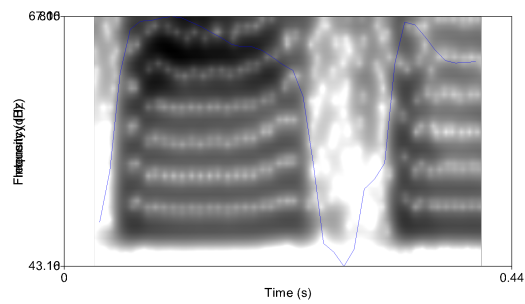
Cross feet:

(10)[配合好||很难]



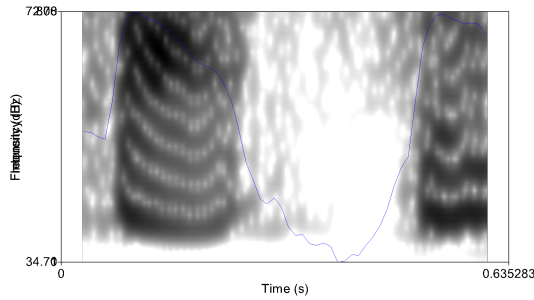
Cross prosodic phrases:

(11)[网吧开得好||很赚钱]



Cross intonation phrases:

(12)[大家好], [很高兴认识你们]



3 The phonological analysis

3.1 Motivation of T3 sandhi

Before moving to the formal discussion about the interaction between TS and prosodic hierarchies, we would like to briefly look into the understandings of the motivation and constraints for the sandhi rule. The results of our experiment shed a light on the controversial topic. Basically, debates usually arise from the following views:

3.1.1 Dissimilation or straightening

In the view of dissimilation, the distinctive feature of third tone sandhi rule in Mandarin Chinese is [+Low]. For a full third tone contour 214 (low-rise), the final rising part is a floating tone, which only fulfills in a single T3 syllable or as the final syllable in prosodic units. In other words, it only shows up in restricted environment. For most natural speech, it usually realizes as 21, a low tone. Thus, when two low tones are adjacent, the former one must change into a high tone. The rule of avoiding adjacent low tones has been demonstrated across languages.

Some researchers assume that the process of T3 sandhi is straightening the turning contour (Liu 2005, Fu2006). The departure of the theory is the theory of pitch target, which set forth by Xu (2000): Pitch range are what speakers actually intend to implement, but such implementation is constrained by their limitations of the articulators. If duration is not long enough, the pitch target cannot be fully realized. Straightening theory adopted the view that time limitation would constrain the implementation of T3 contour, and further asserted that the T3 sandhi actually is the articulation strategy, by which speakers tend to cancel the turning point of contour shape, straightening it from the start point to the end point. In a word, with the constraint of MRU's size, T3 sandhi is straightening 214 to 24.

Which of the assumptions is more reasonable to explain the motivation of T3 sandhi in Mandarin Chinese?

According to our experiment, T3 sandhi in Mandarin Chinese could not be explained with the straightening theory. The results suggest that tone sandhi could take place across small pause and lengthening boundaries. Especially, on the phrase boundary, which allows the effect of lengthening on the final syllable, the first T3 syllables have enough time to realize their underlying contour target; but they still change into High. On the contradictory, our experiment supports the assumption of dissimilation. No matter whether or not the two T3 syllables are in the same MRU; no matter whether the duration of the first T3 is long or short; no matter whether or not there is pause

between the two T3 syllables, the first T3 syllables are all likely to change into High tone. The point could be seen clearly in the minimal comparable pair:

“wonderful performance”	“wonderful performance”
(13)(a)[jingcai][biaoxian]	(b)[jing-cai] [biao-yan]
(1 3)(3 4)	(1 3) (3 3)
(1 s)(3 4)	(1 3)(s 3)

The two utterances have same syntactic as well as prosodic structure, in which, T3 syllable “cai” both posits at the boundary of the former unit. However, (a) changes into High whereas (b) stays as Low. The reason for the difference just lies in whether the second syllable of the latter unit is also Low. Therefore, it can be concluded that, rather than the time limitation of MRU, the successive emergence of low tones is the real necessary condition for T3 sandhi.

3.1.2 Whether stress is one of the main constraints of T3 sandhi

Whether or not Mandarin Chinese has stress is controversial. Typically, stress or accent may have accentual properties both in pitch range and duration. However, the trouble for Chinese is, in a binary foot, the former syllable has higher pitch and greater range whereas the latter syllable is longer. In other words, none of the part could possess all the typical phonetic properties of stress. Moreover, by far there is no clear perceptive experiment could confirm the position of stress. Of course, that does not mean Chinese have no stress difference at all. Here we refer to the most common expressions which rule out contrastive stress as well as neutralization in lexical

morphology. We would not go further about the question whether Chinese has phonological stress in this paper; we only care about the possibility of stress being as the main constraint for T3 sandhi.

To demonstrate stress is the main constraint of T3 sandhi, it should be confirmed that (1) sandhi tone could mark the position of stress, or (2) it could be clearly predicted by stress which position must change into [+High] . However, our experimental result negated the above assumptions.

Firstly, indeed under contrastive stress former syllable in T3 string is more likely to change into high. However, if it is not followed by another T3, no matter how emphasize on it, it certainly could not change.

Secondly, are high tones the position of stress? Our experiment proved that it is common for sandhi rule to take place at the word-final position which is considered as the unstressed position. Come back to our minimal pair (13) again. If the Head must be (or likely to be) H tones, why the sandhi representation (“biao”) is different at the same stress position? The reason again can only be attributed to the number of T3 syllables in a string.

Moreover, the fact that T3 sandhi could apply cross prosodic boundaries reveals that sandhi domains are not isomorphic with rhythmic units and they are under relatively

independent constraints. Therefore, it is not surprise that tone sandhi could not be predicted by metric constraints.

All in all, according to our experimental results, T3 sandhi is essentially motivated by dissimilation of low tones or OCP_L. The number of constituent syllables and the size of sandhi domain (two or three syllables long) are mainly responsible for the organization of T3 sandhi domains.

3.2 Discussion for interaction between tone sandhi and prosodic hierarchies

Now we are moving to our main topic: what is the relationship between TS and prosodic hierarchies, which decides which?

Our experiment has proved several conclusions in Chen (2000):1) MRU and intonation phrase are the ultimate limits of TS domain. MRU is the minimum boundary that impels TS preferentially takes place; while intonation phrase is the maximum boundary that necessarily cut off the spreading of TS. 2) TS within MRU is required, but optionally across MRUs.

However, does it follow that only two prosodic hierarchies are needed for sandhi rules and intermediate hierarchies could be cancelled? Could TS domains be regarded as prosodic hierarchies? To answer these questions, merely evaluating whether TS

occurs is far from enough. We should specifically consider the sandhi representations on different hierarchies. We shall persist that intermediate prosodic hierarchies should be kept for sandhi rules.

Firstly, pause and lengthening are definitive information for perception of different prosodic hierarchies, which has been proved by many perceptive experiments across languages. Mandarin Chinese is not exceptional. Speakers could perceive at least four levels of pause so that they could distinguish foot, small prosodic phrase, large prosodic phrase, and intonation phrase.

Secondly, our experiment reveals that the T3 sandhi on different hierarchical boundaries is different from each other. Sandhi syllables are short and F0 sharply rise in feet or MRUs, but longer and F0 smoothly rise between MRU and phrase boundaries. Besides, phrase-final position sandhi allows small pause and lengthening, which is also distinctive from the sandhi representation between feet. Referring to the preceding research on acoustic information of boundaries of prosodic units (Cao1999), it could be known that the differences of duration and pause in sandhi syllables exactly reveal the phonetic distinctiveness between prosodic hierarchies.

Furthermore, although between ultimate limits of feet and intonation phrase, tone sandhi rule all apply optionally; the possibility of TS is different from small to large boundaries. Statistical result suggests that it is more likely to occur on smaller

boundaries. That means the distance between two T3 syllables is responsible for the application of tone sandhi.

In summary, prosodic hierarchies in Mandarin Chinese are decided by pause and lengthening effect rather than tone sandhi. Sandhi domains and prosodic units are under different prosodic mechanisms. Moreover, prosodic boundaries could significantly constrain the tone sandhi domain, but tone sandhi cannot define the prosodic boundaries.

4 Conclusions

In this paper, the acoustic experiment provides more specific understanding of sandhi process. We have shown that sandhi rules could apply across different prosodic boundaries, but the phonetic properties are not identical. So the intermediate hierarchies between MRU and intonation phrase for sandhi rule cannot be cancelled. The fact that sandhi domains usually violate rhythmic boundary implicates that sandhi domain is a different prosodic process from rhythmic organization. Prosodic hierarchies in Mandarin Chinese are essentially determined by the perception of pause and lengthening on boundaries; and T3 sandhi is mainly motivated by dissimilation of adjacent low tones. The extent of pause and lengthening on boundaries can determine whether sandhi rules are able to apply across, but tone sandhi has no influence on organization of rhythmic units. From the relationship between sandhi rule and

rhythmic units, we tend to make the hypothesis that looseness or distance between syllables is one of the most important factors for prosodic organization.

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