

Directionality of disyllabic tone sandhi across Chinese dialects is conditioned by phonetically-grounded structural simplicity

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This study examines structural simplicity and phonetic naturalness of tone sandhi patterns across seventeen Chinese varieties. We show that tone sandhi systems triggered purely by phonetic environment are overwhelmingly uni-directional (i.e. structurally simple), regardless of their phonetic naturalness. Crucially, uni-directionality is largely right-dominant, which could be attributed to the left tone's inability to bear contour tones. We argue that for the purely phonetic tone sandhi, the patterns tend to be structurally simple, keeping a uni-direction, but the directionality is phonetically grounded, preferring right-dominant patterns. When tone sandhi systems are sensitive to grammatical categories, there is a strong structural bias towards keeping a single direction for each grammatical category, supporting the structural simplicity hypothesis. We show that our tone sandhi analysis incorporating the structural simplicity and the phonetic naturalness can better account for sandhi patterns which were argued to lack phonetic or cognitive motivation.

Keywords: Tone sandhi, structural simplicity, phonetic naturalness, Chinese

1. Introduction

Tone sandhi refers to the alternation of phonetic tone shape conditioned by adjacent tones or by prosodic or morphosyntactic position (Chen, 2000). There has been various work in Chinese tone sandhi research including language-specific pattern descriptions (Rose, 1990; Lin, 1996; Zhu, 2006; Zhang and Liu, 2011), typological observations and theoretical analyses (Yue-Hashimoto, 1987; Yip, 1990; Bao, 1999; Chen, 2000; Zhang, 2007), and work on the underlying mechanisms of sandhi patterns (Zhang and Lai, 2010; Zhang, 2016). As to the basis of tone sandhi, there have been work to identify the phonetic underpinning of tone sandhi patterns. One proposal is that tonal duration in a nonfinal syllable position should be reduced where contour tone bearing ability is lacking: For tonal duration, tones with greater pitch excursion requires a longer duration than those with smaller pitch excursion. A rising tone requires a longer duration than a falling tone of equal pitch excursion. Also, tones with more pitch targets require a longer duration than those with less pitch targets (Zhang, 2002). In the case of Mandarin tone sandhi, for instance, the third tone is dipping-rising in isolation and word-finally, but it is dipping when preceding the other three tones, the pattern of which can be explained by its phonetic motivation: the left (non-final) syllable has insufficient duration to carry the third tone with three pitch targets (Zhang, 2002). Another phonetic motivation concerns the interaction between tone and prosodic prominence. A high register tone is preferred over a low register tone in prosodically prominent (head)

positions, and a low register tone is preferred over a high register tone in prosodically weak (non-head) positions (Lin, 2012). For instance, in Pingyao, a mid-high tone remains unchanged on the left syllable in left-dominant tone sandhi patterns but the mid-high tone changes to a mid-low or a low-mid on the left syllable in right-dominant patterns, because lower register tone is preferred and more natural in non-head positions (Lin, 2012). As noted by Zhang (2014), such phonetic factors seem to be relevant to the description of some tone sandhi patterns (e.g. contour tone simplification in Beijing Mandarin and Tianjin). Experimental work also supports the claim that tone sandhi patterns grounded on phonetics are better learned or generalized than those that are not (Zhang and Lai, 2010; Zhang and Liu, 2016). Despite supporting evidence for the phonetic motivation of tone sandhi patterns, both theoretically and empirically, it is almost impossible to account for tone sandhi universally based on phonetic grounds alone (Zhang, 2014).

Our proposal in the present paper is that patterns of tone sandhi found among Chinese dialects are seemingly very complex, but can be better understood when the concept of ‘structural simplicity’ is taken into consideration together with phonetic naturalness. Specifically, structural simplicity in this paper refers to a tendency to prefer uni-directional sandhi patterns to bi-directional ones (See Section 2 for the details). For example, disyllabic sandhi patterns found in the Tianjin dialect are systematically left-dominant (Zhang and Liu, 2016), and thus are structurally simple; Disyllabic sandhi patterns in the Changting dialect are bi-directional (Chen, 2000), and are thus complex. We examine tone sandhi systems across seventeen Chinese varieties to show how structural simplicity plays a role in forming tone sandhi patterns. The Chinese varieties considered include Mandarin, Tianjin, Boshan, Kunming, Wuyi, Xiamen, Fuzhou, Yudu, Chengdu, Dongkou, Changzhou, Huojia, Shanghai, Tangxi, Chaoyang, Pingyao and Changsha, classified into six Chinese dialectal groups (Northern, Wu, Min, Hakka, Xiang and Jin). The 17 dialects cover a wide geographic region: the north (e.g. Beijing, Tianjin, Shanxi), northeast (e.g. Shandong), southeast (eg. Shanghai, Fujian, Jiangsu), southwest (e.g. Sichuan, Yunnan) and central (e.g. Changsha, Henan) areas of China.

We examine two types of sandhi patterns: ‘phonetic tone sandhi’ and ‘phonetic-grammatical tone sandhi’ following the tone sandhi categorization by Chen (2000). ‘Phonetic tone sandhi’ refers to the patterns conditioned by pure phonetic environment, such as a neighboring tone. For example, in Tianjin, a high-mid tone changes to a high-level when it is followed by a low-level tone, regardless of the grammatical structure of the word (Zhang and Liu, 2016). ‘Phonetic-grammatical tone sandhi’ refers to the patterns that are sensitive to both phonetic environment and grammatical structure of the word. In Chaoyang, for instance, a high-mid tone changes to a mid-low when it is preceded by any tone in resultative verbal complements and numeral phrases. However, the high-mid tone remains unchanged when it is preceded by any tone in noun phrases, verb phrases, pronouns and certain noun classifiers (Zhang, 2007). We will show that dialects with only phonetic tone sandhi often apply sandhi rules in a certain direction, governed largely by structural simplicity. For the dialects with phonetic-grammatical

tone sandhi, on the contrary, sandhi patterns usually apply in both directions. We will show further that once we identify types of grammatical structures, however, tone sandhi within each grammatical category largely applies in a specific direction, conforming to the structural simplicity hypothesis.

For the 17 Chinese dialects, the phonetic naturalness of tone sandhi will be analyzed, following the definitions of phonetic naturalness of tone sandhi in Zhang (2002) and Lin (2012): the reduction of tonal duration at a nonfinal syllable position (Zhang, 2002) and the pitch heights in relation to prosodic prominence (head vs. non-head) positions (Lin, 2012). We show that in the 17 Chinese dialects, phonetically unnatural sandhi patterns are actually frequent, suggesting the insufficiency of phonetic naturalness to account for the sandhi patterns. However, we cannot crudely state that phonetic naturalness does not have any effect on tone sandhi patterns. This paper shows that when tone sandhi is triggered purely by phonetic environment, the directionality of tone sandhi is largely uni-directional, but crucially its directionality is phonetically grounded. Specifically, the directionality of tone sandhi patterns shows a skewed distribution toward right-dominant sandhi, which can be accounted for by the left tone’s lack of contour tone bearing ability. When tone sandhi is conditioned by grammatical structures, however, a purely structural simplicity governs the directionality of tone sandhi patterns, exhibiting primarily a single direction within a grammatical category concerned, thus resulting in no directional asymmetry.

Despite various descriptive works on tone sandhi across Chinese dialects (See Chen (2000) for an extensive data description), and a collection of studies on the phonetic underpinning of tone sandhi by Zhang (2010, 2011, 2014, 2016), there is no single resource using a systematic tone system which also compares structural and phonetic underpinnings of tone sandhi patterns across various Chinese dialects, both of which are extensively discussed as properties of tone sandhi. This paper aims to provide a complete description of the disyllabic tone sandhi patterns accompanied by real world examples from various resources, using a single system of tone representations. In the following sections, we rely on Chao’s (1948) five-point scale tone letters to describe tones, where “1” and “5” represent the lowest to highest pitches. Table 1 below is an example of the four tones of Mandarin Chinese in Chao tone letter system. The tone descriptions (Duanmu, 2007) along with their representative pitch tracks (adapted from van de Weijer and Sloos, 2014) are provided in Table 1 and Figure 1 to aid understanding.

Mandarin Tones	Chao tone letters	Tone descriptions
Tone 1	55	High-level
Tone 2	35	High-rising
Tone 3	213	Dipping-rising
Tone 4	51	High-falling

Table 1. Mandarin four tones in Chao tone letters

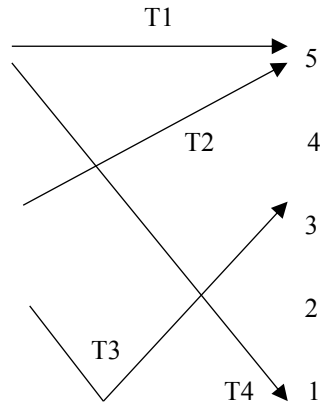


Figure 1. Pitch tracks of Mandarin four tones

2. *Dialects with phonetic tone sandhi*

This section examines dialects with phonetic tone sandhi including data from 12 Chinese dialects. We show that among the dialects with disyllabic phonetic tone sandhi, the majority of sandhi patterns are right-dominant. Right-dominant tone sandhi preserves the citation tone on the final (right) syllable in a sandhi domain, which is common in Northern, Min, and Southern Wu dialects. In contrast, left-dominant sandhi preserves the tone on the initial (left) syllable (Zhang, 2014). As the data show, right-dominant sandhi often involves local substitution and neutralization and left-dominant sandhi often involves rightward extension, concurring with Zhang’s (2007) tone sandhi observations. As far as the data shows, only one dialect with pure phonetic tone sandhi has sandhi in both directions.

2.1 *Right-dominant tone sandhi systems*

*Beijing Mandarin*¹ Beijing Mandarin has four citation tones: 55, 35, 213 and 51. As for the tone sandhi, there are three patterns, which involves the third-tone sandhi (Zhang and Lai, 2010) and the fourth-tone sandhi (Lin, 1992), as shown below.

(1) Beijing Mandarin

- a. 213 → 35 / __ 213
xau213 - tejou213 → xau35 - tejou213 “good wine”
- b. 213 → 21/ __ {55, 35, 51}
xau213 - k^han51 → xau21 - k^han51 “good-looking”
- c. 51 → 53/ __ 51
fan51 - teja51 → fan53 - teja51 “have holidays”

As seen in the above three patterns, Beijing Mandarin tone sandhi is right-dominant, since sandhi tones are on the left syllable and tones on the right syllable remain unchanged. Tone sandhi patterns *b* and *c* are phonetically grounded, as tonal duration is reduced in non-final positions (Zhang and Lai, 2010; Lin, 1992), from a

¹ Real word examples of Mandarin tone sandhi are transcribed in IPA from Zhang (2010).

dipping-rising tone to a low falling tone in pattern *b* and from a high-low tone to a high-mid tone in pattern *c*. However, the phonetic basis for pattern *a* is weak, because it involves raising of the pitch in a non-final position (Zhang and Lai, 2010), from a low dipping tone to a mid-high tone. Therefore, based on tonal duration, the tone sandhi pattern lacks phonetic motivation. Regardless of their phonetic grounds, Beijing Mandarin disyllabic tone sandhi patterns are consistently right-dominant.

*Tianjin*² Tianjin tone sandhi is also right-dominant, with some patterns lacking phonetic motivation. According to Shi's (1990) transcription, this Northern dialect has four citation tones: 11, 55, 24 and 53. According to Zhang and Liu (2016), Tianjin has six tone sandhi patterns, which are described below.

(2) Tianjin

- a. 11 + 11 → 24 + 11
fei11 - ji11 → fei24 - ji11 “airplane”
- b. 24 + 24 → 55 + 24
xi24 - lian24 → xi55 - lian24 “wash one’s face”
- c. 53 + 11 → 55 + 11
ren53 - zhen11 → ren55 - zhen11 “earnest”
- d. 53 + 53 → 11 + 53
jing53 - zhong53 → jing11 - zhong53 “net weight”
- e. 24 + 55 → 11 + 55
shen24 - yang55 → shen11 - yang55 “Shenyang” (place name)
- f. 24 + 53 → 11 + 53
hao24 - xiao53 → hao11 - xiao53 “funny”

All six patterns preserve the tone on the left syllable, supporting the structural simplicity hypothesis of tone sandhi directionality. However, they differ in the strength of their phonetic motivation. In patterns *e* and *f*, the rising tone 24 alternates to a low-level tone on the left syllable, which involves contour reduction in non-final positions. Pattern *c* changes a high-mid tone to a high-level tone, which also reduces pitch contours. However, pattern *a* is a contouring process, which substitutes a low-level tone to a rising tone, thus it cannot be easily explained by phonetic factors (Zhang and Liu, 2016). In addition, the phonetic basis of patterns *b* and *d* is not as strong as patterns *c*, *e*, and *f*. Considering the interaction between tone and prosodic prominence, pattern *b* increases pitch height in a prosodically weak (non-head) position. Moreover, patterns *b* and *d* cannot be easily interpreted as phonetically-motivated dissimilation, since coarticulatory dissimilation typically raises a high tone before a low tone (Zhang and Liu, 2016). Taken together, only some tone sandhi patterns in Tianjin have a strong phonetic motivation but the direction of all sandhi patterns is right-dominant.

² Real-world examples of Tianjin tone sandhi are transcribed in pinyin from Chen (2000) and Wee (2004).

*Boshan*³ Disyllabic sandhi in Boshan is also right-dominant. Boshan is a northern dialect spoken in Shandong Province with three citation tones: 214, 55 and 31. There are four disyllabic sandhi patterns in Boshan (Lin, 2004).

(3) Boshan

- a. 214 → 55/ __ 214
chun214 - fen214 → chun55 - fen214 “the spring equinox”
- b. 55a⁴ → 53/ __ 55
qi55a - ma55 → qi53 - ma55 “horse-riding”
- c. 55b → 214/ __ 55
tan55b - bai55 → tan214 - bai55 “to confess”
- d. T⁵ → 24/ __ 31
cheng55 - shi31 → cheng24 - shi31 “city”

Patterns *a*, *b* and *c* are motivated by the OCP (Obligatory Contour Principle) (Yip, 2002). As shown, they disallow identical tones in adjacent positions. However, the three patterns cannot be interpreted as phonetically-motivated dissimilation, because coarticulatory dissimilation typically raises a high tone before a low tone (Zhang and Liu, 2016). Moreover, pattern *b* substitutes a high-level tone for a high-mid tone and pattern *c* changes a high-level tone to a dipping-rising tone. The two patterns involve a contouring process in non-final positions, which is not predicted from phonetic naturalness. Pattern *d* is a process of neutralization: all tones are neutralized to 24 before 31. Neutralization reduces the number of sandhi tones, which simplifies the tone sandhi system (Li, 2004). However, when 55 and 31 are neutralized to 24 in initial position, tonal durations are increased, which is phonetically unnatural. Therefore, the tone sandhi patterns in Boshan cannot be attributed to phonetic naturalness *per se*, but they consistently preserve the tone on the right syllable.

*Kunming*⁶ Kunming is a dialect of Southwestern Mandarin Chinese. It has four citation tones: 44, 31, 53, and 11. According to data from Lin (2019), Kunming has two tone sandhi patterns.

(4) Kunming

- a. 44 → 35/ __ {31, 53, 11}
ti44 - t^həw31 → ti35 - t^həw31 ‘to lower the head’
tsã44 - tswi53 → tsã35 - tswi53 ‘to open one’s mouth’
fã44 - fu11 → fã35 - fu11 ‘to instruct’
- b. 53 → 55/ __ T
ei53 - xwã44 → ei55 - xwã44 ‘to like’
tiã53 - thəw31 → tiã55 - thəw31 ‘to nod’

³ Real-world examples of Boshan tone sandhi are transcribed in pinyin from Chen (2000).

⁴ 55 has two historical sources. 55a comes from Middle Chinese lower register *ping* tone and 55b is from Middle Chinese rising register *shang* tone.

⁵ In this paper, T represents any tone of the dialect.

⁶ Real-world examples of Kunming tone sandhi are transcribed in IPA from Lin (2019).

phaw53 - thwi53 → phaw55 - thwi53 ‘to run an errand’
 kã53 - ɕjɛ11 → kã55 - ɕjɛ11 ‘to thank’

Kunming tone sandhi is clearly right-dominant, as the two sandhi tones occur on the left syllable. In terms of phonetic motivation, pattern *b* changes a high-mid tone to a high-level tone, which reduces pitch contours. However, pattern *a* changes a level tone to a rising tone on a syllable with insufficient duration, which cannot be explained through the phonetic motivation of reducing tonal duration on non-final positions. Therefore, there exists a tone sandhi pattern in Kunming that is phonetically arbitrary.

*Wuyi*⁷ Wuyi tone sandhi is also right-dominant. Wuyi is a Southern Wu dialect, which has six citation tones: 24, 213, 53, 31, 55 and 13. According to Zhang (2007), there are two neutralization tone sandhi processes in Wuyi.

(5) Wuyi

- a.* 24, 213, 53 → 55/ __ T
 teiŋ24 - tsu55 → teiŋ55 - tsu55 “clear”
 fi-ʔuəi213 - kua24 → fi-ʔuəi55 - kua24 “go home”
 teiŋ53 - bu31 → teiŋ55 - bu31 “progress”
- b.* 31, 55, 13 → 11/ __ T
 die31 - ʔnəŋ24 → die11 - ʔnəŋ24 “electric lamp”
 kau55 - ɕi53 → kau11 - ɕi53 “exam”
 fiy13 - suo55 → fiy11 - suo55 “umbrella”

The two patterns in Wuyi both substitute contour tones for level tones in the initial position. Pattern *b* can be explained by the interaction between tone and prominence, because pitch height is reduced in prosodically weak (non-head) positions. The mid-low tone, high-level tone, and low-mid tone become a low-level tone. However, pattern *a* is the opposite of pattern *b*. The low-mid tone 24 and low-dipping tone 213 become a high tone 55, which increases pitch height in the non-head position. Therefore, pattern *a* cannot be easily explained by phonetic naturalness, but both of the tone sandhi patterns preserve the tone on the right syllable.

*Xiamen*⁸ Xiamen tone sandhi, which represents a typical ‘tone circle’ in Southern Min, is also right-dominant. Xiamen has five full tones 44, 24, 22, 21, and 53 and two checked tones⁹ 4, and 32. In Xiamen disyllabic tone sandhi, the tone on the right syllable remains unchanged, while the full tone on the left syllable undergoes a circular change as shown below (Chen, 1987).

(6) Xiamen

⁷ Real-world examples of Wuyi tone sandhi are transcribed in IPA from Fu (1984).

⁸ Real-world examples of Xiamen tone sandhi are transcribed in IPA from Chen (1987).

⁹ Checked tones only occur on checked syllables (syllables with a stop coda).

- a. 24 → 22/ __ T
 we24 - tua21 → we22 - tua21 “shoe laces”
- b. 22 → 21/ __ T
 tua22 - hai53 → tua21 - hai53 “big ocean”
- c. 21 → 53/ __ T
 ts^hu21 - tiŋ53 → ts^hu53 - tiŋ53 “roof top”
- d. 53 → 44/ __ T
 k^hi53 - ts^hu21 → k^hi44 - ts^hu21 “build a house”
- e. 44 → 22/ __ T
 p^haŋ44 - tsui53 → p^haŋ22 - tsui53 “fragrant water”

The checked tones on the left syllable undergo alternations as well, the pattern of which is distinctive from the tone circle in (6a)-(6e) (Chen, 1987).

- f. 4 → 21/ __ T
 lip4 - k^hao53 → lip21 - k^hao53 “entry point; import”
- g. 32 → 4/ __ T (when the checked syllable ends with /p, t, k/)
 bat32 - li22 → bat4 - li22 “literate”
- h. 32 → 53/ __ T (when the checked syllable ends with /ʔ/)
 aʔ32 - nŋ22 → aʔ53 - nŋ22 “duck egg”

Analysis of the ‘tone circle’ pattern is beyond the scope of the current paper. As for the phonetic motivation of the sandhi patterns in Xiamen, 24 → 22 in pattern *a*, 53 → 44 in pattern *d*, 44 → 22 in pattern *e*, 32 → 4 in pattern *g* have their phonetic basis: 24 → 22 changes a mid-high tone to a mid-level tone; 53 → 44 substitutes a high-mid tone to a high-level tone; 32 → 4 changes a mid-falling tone to a mid-level tone, which all involve contour reduction processes in the non-final position. 44 → 22 changes a high-level tone to a low-level tone, which also reduces pitch height in the initial position and follows the interaction between tone and prominence. However, 22 → 21 in pattern *b* and 4 → 21 in pattern *f* lack phonetic motivations, because they alternate level tones with a falling tone on the left syllable which lacks contour-tone bearing ability. Moreover, 21 → 53 in pattern *c* and 32 → 53 in pattern *h* cannot be simply attributed to phonetic naturalness. They change a low tone 21 or a mid tone 32 to a high-mid tone 53, which increases pitch height in non-head positions, contrary to what the interaction between tone and prominence would predict. To summarize, in Xiamen, half of the sandhi patterns lack a phonetic motivation, but the tones on the right syllable remain consistently stable.

*Fuzhou*¹⁰ Fuzhou, an Eastern Min dialect, also has a right-dominant paradigmatic tone sandhi system. The dialect has seven citation tones, five of which are full tones. Table 2 (adapted from Zhang, 2014) illustrates Fuzhou tone sandhi (full tones), with the leftmost column showing tones on the left syllable and the top row showing tones on the right syllable.

¹⁰ Real-world examples of Fuzhou tone sandhi are transcribed in IPA from Chan (1998).

(7) Fuzhou

	44 H	53 HL	242 LHL	212 L	32 M
44	<i>a.</i> 44- Tσ2		<i>b.</i> 53- Tσ2		
212					
242					
53	<i>c.</i> 44-Tσ2	<i>d.</i> 32- Tσ2	<i>e.</i> 21- Tσ2	<i>f.</i> 32- Tσ2	
32	<i>g.</i> 21- Tσ2		<i>h.</i> 44- Tσ2	<i>i.</i> 24- Tσ2	

Table 2. Fuzhou tone sandhi

Examples:

pattern *b*: ei212 - kien212 → ei 53 - kien 212 “opinion”

thien44 - khei212 → thien53 - khei212 “weather”

pattern *e*: ki53 - kuai212 → ki21 - kuai212 “strange”

pattern *f*: peiŋ53 - iu32 → peiŋ32 - iu32 “a friend”

pattern *h*: thu32 - tei242 → thu44 - tei242 “land”

The table shows that tones on the right syllable (Tσ2) remain unchanged. As citation tones 44, 212 and 242 in the leftmost column demonstrates (patterns *a* and *b*), Fuzhou tone sandhi involves the neutralization of the three tones on the left syllable. Although neutralization reduces the number of sandhi tones, some sandhi processes lack phonetic motivations. The change from a dipping-rising tone 212 and a rising-falling tone 242 to either a level tone 44 or a falling tone 53 reduces pitch contours, hence it is phonetically motivated. Moreover, the change from a high-mid tone 53 to a high-level tone 44 (pattern *c*), a mid tone 32 (patterns *d* and *f*) or a low tone 21 (pattern *e*) is also phonetically natural, because the tonal duration and pitch height is reduced in non-final position. In addition, 32 → 21 (pattern *g*) reduces pitch height and 32 → 44 (pattern *h*) reduces pitch contour, which can be attributed to phonetic naturalness. However, 44 → 53 in pattern *b* increases pitch contour in nonfinal position, since the high-level tone alternates with a high-falling tone. The 32 → 24 in pattern *i* changes a mid-falling tone to a low-rising tone, which also increases tonal duration on the left syllable. Therefore, two sandhi patterns in Fuzhou are phonetically unnatural, but the tone sandhi patterns systematically preserve tones on the right syllable.

*Yudu*¹¹ Yudu, a Hakka dialect spoken in Jiangxi Province, has a right-dominant tone sandhi system with five citation tones on non-checked syllables: 31, 35, 44, 22, and 42. According to Zhang (2007), Yudu has two sandhi patterns in which the second syllable always preserves its tone.

(8) Yudu

a. 35 → 31/ __ T

siɔ35 - hɿ44 → siɔ31 - hɿ44 “rivulet”

b. 22 → 44/ __ T

¹¹ Real-world examples of Yudu tone sandhi are transcribed in IPA from Xie (1992).

k^h522 - p^{hi}ã42 → k^h544 - p^{hi}ã42 “see a doctor”

In Yudu, Tone 31 does not undergo sandhi and Tone 35 neutralizes to 31 on the initial syllable. Tone 44 also does not change and Tone 22 neutralizes to 44 on the left syllable. The second syllable always preserves its tone. Pattern *a* is phonetically motivated, because it substitutes a rising tone with a falling tone, which reduces tonal duration. However, pattern *b* replaces a low register tone to a high register tone in the prosodically weak position, which is the opposite direction predicted for the interaction between tone and prosodic prominence.

2.2 Left-dominant tone sandhi systems

*Chengdu*¹² Chengdu, a dialect of Southwestern Mandarin Chinese, provides evidence for left-dominant sandhi with local substitution. According to Lin (2015), Chengdu has four citation tones: 45, 31, 55, and 13. Tone 31 never undergoes tone sandhi. For the other three tones, there are three sandhi patterns.

(9) Chengdu

- a.* 45 → 44 / T__
tso31 - t^{hi}en 45 → tso31 - t^{hi}en 44 “yesterday”
- b.* 55 → 53 / __]
fu13 - mu55 → fu13 - mu53 “parents”
- c.* 13 → 11 / T__
tsau55 - fan13 → tsau55 - fan11 “breakfast”
- (“]” = phrase final boundary)

In Chengdu, the left syllable always preserves its tone, and the tone on the right syllable undergoes sandhi. In pattern *a*, a high-rising tone is replaced by a high-level tone on the right syllable; and in pattern *c*, a low-rising tone changes to a low-level tone on the right syllable. The two patterns follow the interaction rule between tone and prosodic prominence, because the tones are simplified in non-head position. However, pattern *b* is the opposite of patterns *a* and *c*. In pattern *b*, a high-level tone is replaced by a contour tone in the non-head position. In sum, this dialect has a left-dominant tone sandhi system and a pattern lacking phonetic motivation.

*Dongkou*¹³ A left-dominant sandhi system with default insertion is also attested in Dongkou, a Xiang dialect (Zhang, 2007). It has five citation tones: 44, 112, 21, 24 and 13. In disyllabic tone sandhis, the tone on the first syllable remains intact, while the tone on the second syllable always changes to 21. The neutralization processes reduce the number of sandhi tones. On phonetic grounds, the change from rising tones 112, 24, and 13 to a falling tone 21 reduces tonal duration in final position. Additionally,

¹² Real-world examples of Chengdu tone sandhi are transcribed in IPA from Lin (2015).

¹³ No examples of Dongkou tone sandhi were provided in Zhang (2007). We do not have access to Tang (1960), which possesses the original data.

the change from a high-level tone 44 to a low-falling tone 21 decreases tone register in non-head position, which can be explained by the interaction between tone and prominence. However, the phonetic motivation is weak considering contour-tone bearing ability, because the final position has enough duration to carry contour tones (Zhang, 2002).

*Changzhou*¹⁴ A solely left-dominant sandhi system is found in Changzhou, a Northern Wu dialect, as well. Its purely phonetic tone sandhi system involves left-dominant rightward extension. Changzhou has five citation tones on non-checked syllables: 55, 13, 45, 523, and 24. In disyllables, the tone on the first syllable is extended to the following tone (Zhang, 2007). For instance, if the first syllable has a dipping tone 523, then the disyllabic word has a dipping melody. Changzhou disyllabic sandhi patterns are shown below.

(10) Changzhou

- a. 55 → 33 - 33
tʰɿu 55 → tʰɿu 33 - po33 “mop”
- b. 13 → 11 - 13
zo13 → zo11 - tʰi13 “yesterday”
- c. 45 → 45 - 55
ŋɛ45 → ŋɛ45 - li55 “tear”
- d. 523 → 55 - 23
tʰa523 → tʰa55 - hiaŋ23 “sun”
- e. 24 → 11 - 24
zaŋ24 → zaŋ11 - xai24 “Shanghai” (name of a city)

Left-dominant rightward extension sandhi patterns have phonetic grounds. They reduce a contour tone to lesser contours on each syllable in the domain and reduce pitch differences across syllable boundaries (Zhang, 2007). Moreover, they can be accounted for through the Perception-Map hypothesis (Steriade, 2008), since an output with rightward extension will be perceptually more similar than leftward extension to the input (Zhang, 2007). However, a question may be raised on the generalization that Changzhou tone sandhi extends the initial tone rightward, as the mapping of the initial tone onto the disyllabic word seems to be inconsistent. For example, in pattern *c*, the rise surfaces in the first syllable. But in pattern *e*, the rise surfaces in the second syllable. This phenomenon also exists in many other Northern Wu dialects. The absence of any analysis for the nuances of the sandhi patterns is due to the fact that the tonal transcriptions provided were based merely on auditory impressions (Zhang, 2007).

2.3 Bi-directional tone sandhi system

¹⁴ Real-world examples of Changzhou tone sandhi are transcribed in IPA from Wang (1988).

*Huojia*¹⁵ Huojia is a Jin dialect spoken in Henan Province, which represents one notable exception among phonetic tone sandhi systems. Its tonal inventory on non-checked syllable is 31, 53, 13, and 33. It has a bi-directional tone sandhi system with three sandhi patterns (Zhang, 2007).

(11) Huojia

- a. T1-T2 → 31-T2
- b. T1-T2 → T1-13
- c. T1-T2 → 31-13

In Huojia tone sandhi, the pattern to which a disyllabic word belongs to has to be lexically listed. For example, disyllabic words such as 厂长 “factory director”, 老虎 “tiger”, 老鼠 “mouse” have the same tonal input 53-53, but their tonal outputs are 31-53, 31-13, and 53-13, respectively (He, 1979). In terms of phonetic naturalness, the change from a low-rising tone 13 to a falling tone 31 on the left syllable is natural, because tonal duration is reduced in non-final position. However, the change from a level tone 33 to a contour tone 31 on the first syllable is unnatural, as it increases the pitch contour in a position lacking contour-tone bearing ability. Besides, the change from 53 to 31 on the left syllable also lacks phonetic motivation, since the pitch excursion is the same after tone sandhi. Therefore, tone sandhi in Huojia involves some unnatural sandhi patterns and is bi-directional. The system cannot be directly explained by phonetic naturalness or structural simplicity.

In general, eight out of the twelve Chinese dialects with phonetic tone sandhi have right-dominant local substitution sandhi systems. Three dialects with phonetic tone sandhi have left-dominant sandhi systems. And they show either a local substitution or a rightward extension. An exception is the Huojia dialect, which has a bi-directional sandhi system. Where the phonetic groundings of tone sandhi patterns are concerned, excepting Changzhou, all the other dialects with pure phonetic tone sandhi have at least one sandhi pattern which is phonetically unnatural. And a half of sandhi patterns are unnatural in Tianjin, Boshan, Kunming, Wuyi, Xiamen, Yudu, Dongkou and Huojia. Beijing, Tianjin, Boshan, Kunming, Xiamen, Fuzhou, Dongkou and Huojia have sandhi patterns which cannot be attributed to the phonetic motivation of reducing pitch duration in non-final positions. Tianjin, Wuyi, Xiamen, Yudu and Chengdu have sandhi patterns which cannot be explained by the interaction between tone and prominence. However, phonetic factors still play a crucial role in the tone sandhi systems, as evidenced by the asymmetry in the general preference for right-dominant sandhi patterns. The right-dominant tone sandhi is phonetically motivated by a syllable’s contour tone bearing ability. The left syllable has relatively insufficient duration (Zhang 2007), thus contour tones on the left syllable tend to undergo alternations. Therefore, in the tone sandhi patterns conditioned purely by adjacent tones, phonetics is indeed important. However, structural simplicity concerning the direction of tone sandhi

¹⁵ No phonetic transcription of Huojia was provided in the original source; examples are provided in characters.

should be incorporated to account for (a) a general preference for uni-directionality of sandhi patterns and (b) the tendency that patterns lacking phonetic underpinning are likely to show only uni-directional sandhi patterns. Considering the patterns examined here, we propose that phonetically-grounded structural simplicity (i.e., uni-directionality specifically toward right-dominant patterns) can account for an overwhelming number of sandhi patterns in phonetic tone sandhi systems. Table 3 below summarizes tone sandhi directionality and number of unnatural patterns of the 12 dialects with phonetic tone sandhi.

Chinese dialects	Tone sandhi directionality	Number of unnatural sandhi patterns
Beijing Mandarin	Right-dominant	1 out of 3
Tianjin	Right-dominant	3 out of 6
Boshan	Right-dominant	4 out of 4
Kunming	Right-dominant	1 out of 2
Wuyi	Right-dominant	1 out of 2
Xiamen	Right-dominant	4 out of 8
Fuzhou	Right-dominant	2 out of 11
Yudu	Right-dominant	1 out of 2
Chengdu	Left-dominant	1 out of 3
Dongkou	Left-dominant	3 out of 4
Changzhou	Left-dominant	0 out of 5
Huojia	Bi-directional	8 out of 16

Table 3. Summary of phonetic tone sandhi systems

3. *Dialects with phonetic-grammatical tone sandhi*

A number of Chinese dialects have tone sandhi in both directions. At first glance, these dialects' tone sandhi patterns seem structurally complex. However, when the lexical items undergoing tone sandhi are placed into different grammatical structures, tone sandhi largely applies in a specific direction within each type of grammatical category.

*Shanghai*¹⁶ Shanghai is a Northern Wu dialect. Shanghai has five citation tones, of which three are non-checked tones 53, 34, 13 and two are checked tones 55, 12 (Zhang and Meng, 2016). Tone sandhis in Shanghai are applied in both directions. The left-dominant tone sandhi patterns are illustrated in Table 4. Left-dominant sandhi in Shanghai involves rightward extension, as the left tone is spread across the disyllabic word.

(12) Shanghai

¹⁶ Real-word examples of Shanghai tone sandhi are transcribed in IPA from Zhang and Meng (2016).

	53	34	13	55	12
53	<i>a.</i> 55-31			55-22	
34	<i>b.</i> 33-44			33-44	
13	<i>c.</i> 22-44			22-44	
55	<i>d.</i> 33-44			33-44	
12	<i>e.</i> 11-13			11-33	

Table 4. Shanghai left-dominant tone sandhi patterns

Examples:

Pattern *a*: ɕiã53 - kã34 → ɕiã55 - kã31 “Hong Kong”

Pattern *b*: tiŋ34 - bã13 → tiŋ33 - bã44 “ceiling”

Pattern *c*: dʁ13 - tɕiã53 → dʁ22 - tɕiã44 “soy milk”

Pattern *d*: poʔ55 - dziʔ12 → poʔ33 - dziʔ44 “North Pole”

Pattern *e*: voʔ12 - tsã53 → voʔ11 - tsã13 “clothing”

Shanghai also has three right-dominant tone sandhi patterns, all of which involve local substitution and neutralization:

f. 53, 34, 55 → 44/ __ T

sɔ53 - tsɕ34 → sɔ44 - tsɕ34 “to cook dishes”

pʰɔ34 - zo13 → pʰɔ44 - zo13 “to steep tea”

tʰəʔ55 - faʔ55 → tʰəʔ44 - faʔ55 “to lose hair”

g. 13 → 33/ __ T

fiŋ13 - tɕiã34 → fiŋ33 - tɕiã34 “to accept an award”

h. 12 → 22/ __ T

zəʔ12 - səʔ55 → zəʔ22 - səʔ55 “to color”

The application of sandhi from left-to-right or right-to-left direction is dependent on the morphosyntactic structure of words in Shanghai (Zhang and Meng, 2016). Left-dominant sandhi applies to closely connected words; modifier-noun combinations can only undergo left dominant sandhi. Whereas right-dominant sandhi applies to loosely connected words or phrases (verb-object, subject-verb, verb-modifier, and coordinated structures). For example, when 头痛 means “headache” as a compound, left-dominant sandhi is applied; when it means “(my) head aches” as a subject-predicate phrase, right-dominant sandhi is applied (Yan, 2016). As for phonetic motivation, the phonetic basis for left-dominant rightward extension has been mentioned in Section 2 Changzhou. For Shanghai right-dominant sandhi, pattern *f* changes a high-mid tone 53, a mid-high tone 34 and a high-level tone 55 to a high-level tone 44, which reduces pitch contour or pitch height in non-final position. Pattern *g* replaces a low-rising tone 13 to a mid-level tone 33 on the first syllable, which is a levelling process. Pattern *h* substitutes a low-rising tone 12 to a low-level tone 22 on the left syllable, which is also a process of contour

reduction. Therefore, all the right-dominant patterns in Shanghai are phonetically motivated.

*Tangxi*¹⁷ Similarly, the Wu dialect of Tangxi has both left and right dominant sandhis. Tangxi has three citation tones on non-checked syllables: 33, 51, 24. Left-dominant rightward extension sandhi is associated with modifier-noun compounds as shown below (Zhang, 2007).

(13) Tangxi

- a. 33 - T → 33 - 33
pən33 - sə51 → pən33 - sə33 “ice-water”
- b. 51 - T → 53 - 31
ka51 - sə33 → ka53 - sə31 “rockery”
- c. 24 - T → 22 - 44
du24 - sə33 → du22 - sə44 “large mountain”

Right-dominant sandhi in Tangxi applies to verb-noun phrases (Zhang, 2007). The pattern involves local substitution and neutralization.

- d. 33, 51, 24 → 22/ __ T
so33 - tʰaŋ33 → so22 - tʰaŋ33 “cook soup”
ma51 - miə24 → ma22 - miə24 “buy noodles”
ma24 - tsö51 → ma22 - tsö51 “sell wine”

For phonetic naturalness, the left-dominant rightward extension patterns reduce a contour tone to lesser contours in the sandhi domain, thus they are classified as natural. Moreover, the right-dominant pattern has a strong phonetic basis. A mid-level tone 33, a high-falling tone 51, and a mid-high tone 24 surface as a low-level tone 22, thus tonal duration or pitch height is reduced on the initial syllable.

*Chaoyang*¹⁸ The Southern Min dialect of Chaoyang has six citation tones: 33, 313, 11, 55, 31, and 53. According to Zhang (2007), Chaoyang has two left-dominant sandhi patterns.

(14) Chaoyang

- a. 33, 313, 55, 31 → 11/ T __
au55 - ta33 → au55 - ta11 “thirsty”
hĩ313 - laŋ55 → hĩ313 - laŋ11 “deaf”
- b. 53 → 31/ T __
naŋ55 - mō53 → naŋ55 - mō31 “sick”

Chaoyang has four right-dominant sandhi patterns as follows (Zhang, 2007).

¹⁷ Real-world examples of Tangxi tone sandhi are transcribed in IPA from Kennedy (1953).

¹⁸ Real-world examples of Chaoyang tone sandhi are transcribed in IPA from Zhang (1979).

- c. 313, 11 → 33/ __ T
 tsɿŋ313 - lak55 → tsɿŋ33 - lak55 “try one’s best”
 ts^hiu11 - bue53 → ts^hiu33 - bue53 “treetop”
- d. 55 → 11/ __ T
 ts^ha55 - ts^hau53 → ts^ha11 - ts^hau53 “firewood”
- e. 31 → 55/ __ T
 ts^hu31 - p^hĩ33 → ts^hu31 - pĩ33 “neighbor”
- f. 53 → 31/ __ T
 ĩ53 - tiau55 → ĩ31 - tiau55 “bench”

The choice of right-dominant vs. left-dominant sandhi patterns largely relies on the grammatical structure of the word. Right-dominant sandhi applies to noun phrases, verb phrases, pronouns, and certain noun classifiers. Left-dominant sandhi is associated with resultative verbal complements and numeral phrases (Lee, 2002). In Chaoyang, both left and right dominant sandhi patterns involve paradigmatic substitution and neutralization. For left-dominant tone sandhi patterns, tone registers are decreased in non-head positions. In pattern *a*, tones 33, 313, 55 and 31 change to a low-level tone 11; and in pattern *b*, a high-mid tone 53 is replaced by a mid-low tone 31. Therefore, the two left-dominant patterns can be explained by the interaction between tone and prominence, since the tone register is lowered in prosodically weak position. For right-dominant sandhi patterns, pattern *c*, the change from a falling-rising tone 313 to a mid-level tone 33 reduces pitch contour in non-final position, which is phonetically motivated. Moreover, pattern *d* replaces a high-level tone 55 to a low-level tone 11, which reduces tone register in non-head position, thus it is classified as natural. Pattern *f* changes a high-mid tone 53 to a mid-low tone 31, which also reduces pitch height in non-head position, hence it can be explained by phonetics. However, in pattern *e*, the change from a low-level tone 11 to a mid-level tone 33 increases pitch height in non-head position, which is the opposite of what the interaction between tone and prominence would predict. Besides, pattern *e* substitutes a lower-register tone 31 with an upper-register tone 55 in prosodically weak position, which is also not predicted by the interaction between tone and prominence. Taken together, Chaoyang tone sandhi system is structurally simple within each grammatical category, but it has some phonetically unnatural sandhi patterns.

*Pingyao*¹⁹ The tone sandhi system in Pingyao, a Jin dialect spoken in Shanxi Province, is also bi-directional. The direction of sandhi is conditioned by the grammatical structure of a disyllabic word (Lin, 2012). Pingyao has three citation tones: 13, 53 and 35. When the grammatical construction is subject-predicate or verb-object, tone sandhi patterns are right-dominant as shown below.

(15) Pingyao

- a. 13 + 35 → 31 + 35 a

¹⁹ Real-world examples of Pingyao tone sandhi are transcribed in pinyin from Lin (2012).

- jia13 - bai35 → jia31 - bai35 “the family is broken up”
- b. 13 + 53 → 35 + 53 b
zheng13 - yan53 → zheng35 - yan53 “eyes are open”
- c. 35 + 13 → 13 + 13 c
yuan35 - shen13 → yuan13 - shen13 “the yard is deep”
- d. 35 + 35 → 31 + 35 d
shou35 - qi35 → shou31 - qi35 “to be bullied”
- e. 53 + 53 → 35 + 53 e
er53 - ruan53 → er35 - ruan53 “easy to be persuaded”

In the five right-dominant sandhi patterns, tones on the left syllable alternate and tones on the right syllable remain unchanged. For phonetic naturalness, patterns *a*, *c* and *d* can be explained by phonetics. Patterns *a* and *d* both change a rising tone to a falling tone on the left syllable, which reduces tonal duration on the position lacking contour-tone bearing ability. Pattern *c* replaces a mid-high tone to a low-mid tone in non-head position, which reduces pitch height and can be attributed to the interaction between tone and prominence. However, pattern *b* increases pitch height from a low-mid tone 13 to a mid-high tone 35 in prosodically weak position, which violates the interaction rule between tone and prominence. Meanwhile, pattern *e* cannot be easily explained by phonetics either. It substitutes a falling tone with a rising tone, which increases duration on the initial position.

When the grammatical constructions are modifier-head, conjunction, verb-complement construction, or reduplicate noun, tone sandhi patterns are largely left-dominant as shown below.

- f. 13 + 35 → 13 + 13
kai13 - kai35 → kai13 - kai13 “can be opened”
- g. 35 + 13 → 35 + 53
xiong35 - di13 → xiong35 - di53 “brothers”
- h. 35 + 35 → 35 + 53
zhen35 - jia35 → zhen35 - jia53 “true and false”
- i. 13 + 13 → 31 + 35
da13 - men13 → da31 - men35 “main door”
- j. 13 + 53 → 31 + 53
bing13 - tong53 → bing31 - tong53 “illness”

It is obvious that patterns *f*, *g* and *h* are examples of left-dominant tone sandhi. However, there are two exceptions in this grammatical category: pattern *i* involves tonal alternation on both left and right syllables; and pattern *j* alternates the tone on the left syllable. In other words, tone 13 is allowed to change on the left syllable when it is followed by 53 and another 13. According to Lin (2012), the low register tone 13 is not stable in the head position, due to the interaction between tone and prominence. Therefore, tone 13 sometimes alternates on the left position can be accounted for

through phonetics. Pattern *f* also can be explained by the interaction between tone and prominence, since the tone register is reduced from an upper register tone to a lower register tone in the non-head position. However, pattern *g* does not follow this rule, because a low register tone is substituted by a high register tone in the non-head position. Besides, pattern *h* does not change tone register and it changes a rising tone to a falling tone in the final position, which lacks phonetic motivation.

In the above 4 dialects with phonetic-grammatical tone sandhi, left and right-dominant patterns apply to different grammatical categories. However, there are some exceptions. Tone sandhi patterns of some dialects are still bi-directional within each grammatical category.

*Changsha*²⁰ Changsha, a Xiang dialect spoken in Hunan Province, has bi-directional sandhi patterns within each grammatical category. Changsha has six citation tones: 23, 13, 42, 45, 11, and 24. Firstly, in subject-predicate, verb-object, and verb-complement constructions, there are eight sandhi patterns (Lin, 2011).

(16) Changsha

- a. 23 → 33/ __ T
kai23 - deng23 → kai33 - deng23 “turn on the light”
- b. 23 → 33/ {13, 11} __
pa13 - shan23 → pa13 - shan33 “climb mountain”
- c. 42 + 42 → 33 + 55
sa42 - shou42 → sa33 - shou55 “let go one’s hand”
- d. 42 → 33/ __ 45
tao42 - zhang45 → tao33 - zhang45 “ask for debt”
- e. 45 → 55/ __ {23, 13, 11, 24}
pao45 - cha13 → pao55 - cha13 “make tea”
- f. 45 + 42 → 55 + 33
chen45 - zao42 → chen55 - zao33 “as early as possible”
- g. 45 → 33/ __ 45
bao45 - yuan45 → bao33 - yuan45 “complain”
- h. 42 → 33/ 24 __
qu24 - huo42 → qu24 - huo33 “reduce internal heat”

For the direction of tone sandhi, patterns *a*, *d*, *e*, *g* are right dominant. Patterns *b* and *h* are left dominant. Patterns *c* and *f* involve tonal alternation on both the left and right syllables. Therefore, Changsha tone sandhi is structurally complex in the first grammatical category, but it is largely right-dominant. For phonetic naturalness, the eight patterns all replace contour tones with level tones. However, patterns *b* and *h* do not have strong phonetic motivations, since the final position has sufficient duration to carry contour tones.

²⁰ Real-world examples of Changsha tone sandhi are transcribed in pinyin from Lin (2011).

Secondly, in modifier-head and conjunction constructions, there are eight sandhi patterns (Lin, 2011).

- i.* 23 → 33/ T ____
fei23 - ji23 → fei23 - ji33 “airplane”
- j.* 13 → 33/ {13, 42, 11, 24} ____
zao42 - chen13 → zao42 - chen33 “morning”
- k.* 42 → 33/ 45 ____
liao45 - jiu42 → liao45 - jiu33 “cooking wine”
- l.* 45 → 55/ {23, 13, 45, 11, 24} ____
jia23 - ju45 → jia23 - ju55 “furniture”
- m.* 42 + 45 → 33 + 55
ye42 - shou45 → ye33 - shou55 “beast”
- n.* 42 → 44/ ____ 11
jie42 - mei11 → jie44 - mei11 “sisters”
- o.* 24 → 33/ {13, 45, 11, 24} ____
zhi45 - fu24 → zhi45 - fu33 “uniform”
- p.* 42 + 24 → 44 + 33
jiu42 - xi24 → jiu44 - xi33 “feast”

For the direction of tone sandhi in the second grammatical category, patterns *i, j, k, l, o* are left-dominant. Pattern *n* is right-dominant. Patterns *m* and *p* alternate tones on both the first and the second syllables. Thus, Changsha tone sandhi is also structurally complex in the second grammatical category, but it is largely left dominant. Similar to sandhi patterns in the first grammatical category, the eight patterns all involve levelling processes. However, patterns *i, j, k, l, o* do not have strong phonetic motivations, because pitch contours in the final position do not need to be reduced.

In general, tone sandhi patterns are largely uni-directional in different grammatical categories. Therefore, we can still argue that structural simplicity also plays a role in the dialects with phonetic-grammatical tone sandhi. However, exceptions do exist. Changsha is structurally complex within each grammatical category, meaning multiple tone sandhi directions are attested within each grammatical category. In terms of phonetic naturalness, Shanghai and Tangxi sandhi patterns can be accounted for through a phonetic basis. However, about half of the sandhi patterns in Chaoyang, Pingyao and Changsha are unnatural. While we see the asymmetry of directionality in phonetic tone sandhi systems, there is no asymmetrical preference for right-dominant patterns among phonetic-grammatical tone sandhi systems. When tone sandhi systems are conditioned by grammatical structures, the structural simplicity component seems to govern the direction of tone sandhi. Table 5 below summarizes tone sandhi directionality and phonetic naturalness of the 5 dialects with phonetic-grammatical tone sandhi.

Chinese dialects	Tone sandhi directionality	The number of unnatural sandhi patterns
Shanghai	Right-dominant in one category, and left-dominant in another category	0 out of 13
Tangxi	Right-dominant in one category, and left-dominant in another category	0 out of 4
Chaoyang	Right-dominant in one category, and left-dominant in another category	2 out of 6
Pingyao	Right-dominant in one category, and largely left-dominant in another category.	5 out of 10
Changsha	Bi-direction in each grammatical category	7 out of 16

Table 5. Summary of phonetic-grammatical tone sandhi systems

4. Discussion and Conclusion

Based on a survey of 12 Chinese dialects with phonetic tone sandhi systems and 5 Chinese dialects with phonetic-grammatical tone sandhi systems, we conclude that the directionality of tone sandhi among disyllables is overwhelmingly uni-directional either throughout the tone sandhi system or within grammatical categories. The analysis of each sandhi pattern from the 17 dialects showed that a large number of patterns are phonetically unnatural. However, we cannot simply conclude that phonetic naturalness is irrelevant. We propose that the concept of ‘structural simplicity’ should be incorporated with phonetic naturalness to better capture tone sandhi patterns. Specifically, the uni-directionality (structural simplicity) of phonetic tone sandhi systems has a phonetic underpinning, as shown in the frequent right-dominant tone sandhi patterns. Additionally, when we look into the interaction between directionality and phonological processes, right-dominant sandhi often involves local substitution and neutralization and left-dominant sandhi often involves rightward extension, supporting again phonetic grounds of tone sandhi patterns. Tone sandhi patterns among phonetic-grammatical tone sandhi systems are largely governed by structural simplicity, because the preference for a single direction of sandhi per each grammatical category is strong, which results in relatively balanced distributions of right vs. left-dominant patterns.

The current structure-based account for tone sandhi patterns agrees with previous phonetic-based and cognition-based arguments. Our findings show that right-dominant tone sandhi systems are most frequent in the dialects with phonetic tone sandhi. In the right-dominant systems, some patterns could be attributed to a syllable’s contour tone bearing ability (Zhang, 2002), because they reduce pitch contours on the left syllable. Some patterns could be explained by the interaction between tone and prominence, since they increase tone register on the right syllable (head positions) or reduce register on the left syllable (non-head positions) (Lin, 2012). Moreover, the right-dominant local substitution sandhi patterns can be captured by Temporal Sequence (i.e. left-to-right rule application in speech planning) (Chen, 2000), because the substitutions are firstly applied on the left syllable. The structure-based account proposed here can

explain sandhi patterns which lack phonetic or cognitive motivation as well. Based on the survey of 17 Chinese dialects, when phonetically natural patterns are found in a dialect, it is highly likely that the opposite pattern can be found as well. For example, in Tianjin, a natural pattern $24 + 55 \rightarrow 11 + 55$ reduces pitch contours on the left syllable which lacks contour tone bearing ability, but it has the opposite pattern $11 + 11 \rightarrow 24 + 11$ which increases pitch contours on the left syllable. Moreover, the cognition-based account (i.e. Temporal Sequence) for right-dominant local substitution patterns cannot account for left-dominant local substitution patterns such as Chengdu tone sandhi. However, the phonetically or cognitively less motivated patterns could still largely be captured by structural simplicity in the directionality of tone sandhi.

When formal constraints previously proposed for tone sandhi are concerned, they are based either on the phonetic or structural components. For example, the markedness constraint *CONTOUR_i-NONFINAL penalizes a contour tone in non-final positions (Zhang, 2002). Another example is the faithfulness constraint IDENT-IO-T-L or IDENT-IO-T-R (Lin, 2006; 2008), capturing the left/right-dominance, respectively. This paper goes with the idea behind these proposed constraints, in that it considers the interactive effect of the structural simplicity with phonetic motivation to account for tone sandhi patterns.

To conclude, among the seventeen dialects from six dialectal groups in Chinese, structural simplicity seems to be a main factor behind disyllabic sandhi patterns. Structural simplicity largely governs the majority of sandhi directionalities in the 12 dialects with pure phonetic tone sandhi, as evidenced by the overwhelming uni-directionality of sandhi patterns, regardless of their phonetic grounds. Crucially, the uni-directionality is largely right-dominant, which could be attributed to the left tone's lack of contour tone bearing ability. Therefore, we propose a phonetically-grounded structural simplicity to account for tone sandhi triggered purely by phonetic environment. Furthermore, sandhi patterns in the 5 dialects with phonetic-grammatical tone sandhi are largely uni-directional within each grammatical category. Crucially, there is no directionality asymmetry skewed toward right-dominant patterns, primarily because each grammatical category prefers to have one direction of tone sandhi, distinctive from other grammatical category. The directionality of tone sandhi patterns here, therefore, is governed primarily by grammatical requirements. The role of 'structural simplicity' has been widely confirmed in segmental phonology. The bias towards segmental patterns with simpler featural descriptions has been reflected by natural-language typology and laboratory studies (as summarized by Moreton and Pater, 2012a). So far, only a few studies have investigated the bias in suprasegmental phonology (e.g. Pater, 2012) and no study has investigated its role in tone sandhi. This paper fills the gap in suprasegmental phonology by introducing structural simplicity to tone sandhi. Future research involves the investigation of the role of structural simplicity in tone sandhi learning.

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