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Directionality in Chengdu Tone Sandhi*

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This paper examines tone sandhi in Chengdu, which is a southwestern Mandarin dialect spoken in Sichuan Province, China. The investigation of the tone sandhi phenomena reveals some rather interesting properties of Chengdu. First, in tri-tonal strings, both left-to-right and right-to-left tone sandhi operation directionalities are observed; nonetheless, the operation directionalities appear to be ungoverned. Second, in quadri-tonal strings, morphosyntactic structures, which are completely functionless in predicting tone sandhi in tri-tonal strings, start to be respected. In this paper, I argue that the tone sandhi operation directionality in tri-tonal sandhi is by no means ungoverned. Normally tone sandhi operates from right to left for identity reasons, unless marked forms would be generated. In that case, tone sandhi operates reversely from left to right. Thus, the seemingly unpredictable tonal operation directionality in tri-tonal strings is naturally captured by the interaction of the identity and the markedness constraints. As for why morphosyntactic structure starts to take a role in quadri-tonal sandhi, I argue that Chengdu has an upper limit on the size of the tone sandhi domain, which is three syllables. When the strings exceed the upper limit of the domain size, they are divided into independent domains to avoid generating oversized ones. The division of the strings into different domains is not *ad hoc*, but is sensitive to morphosyntactic structures.

Key words: Chengdu, tri-tonal sandhi, quadri-tonal sandhi, directionality, Optimality Theory

1. Introduction

In research on tone sandhi, the best studied phenomenon is Beijing Mandarin tone sandhi (Cheng 1973, Shih 1986, Hung 1987, Zhang Z. 1988, Zhang N. 1997, Lin 2000b, 2001, 2004a, among others). Beijing Mandarin tone sandhi represents the kind of phenomenon where the operation of tone sandhi is sensitive to, though not necessarily isomorphic to, morphosyntactic structures. In this type, tone sandhi applies from the inner morphosyntactic constituent outwards. Thus, rule application directionality is generally governed by morphosyntactic structures.[1] There is another

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[1] Tone sandhi in strings of lexical words of Beijing Mandarin is governed by morphosyntactic structures. Tone sandhi in strings that contain function words, however, is not. For details, please refer to Shih (1986), N. Zhang (1997) and Lin (2001, 2004a, 2005b).

type of tone sandhi, referred to as *directional tone sandhi* (following Hyman and VanBik (2004)), where the operation of tone sandhi is blind to morphosyntactic structures. Tone sandhi observed in Tianjin (Chen 1987b, 2000, Hung 1987, Tan 1987, Zhang 1987, Lin 2002, 2003, 2005b), in Boshan (Chen 2000, Lin 2004b), and in Hakha-Lai (Hyman and VanBik 2004, Lin 2005a), for instance, belong to directional tone sandhi. In those languages, tone sandhi must operate in the direction of left to right to derive certain outputs and in the direction of right to left to derive others. Nonetheless, the rule operation directionality is not governed by morphosyntactic structures. Due to the lack of a general principle to govern tone sandhi operation, directional tone sandhi has raised some problems for current phonological theories. As argued in Chen (2000, 2004:800), Chen et al. (2003) and Hyman and VanBik (2004:845), neither the rule-based Derivational Theory nor the standard constraint-based Optimality Theory can successfully account for language data that involve directional tone sandhi.

Chengdu, which is a southwestern Mandarin dialect spoken in Sichuan Province, China, also displays directional tone sandhi. In tri-tonal strings of Chengdu, both left-to-right and right-to-left tone sandhi operation directions are observed, but the directions are not governed by morphosyntactic structures. In accounting for Chengdu tone sandhi, it is true that Derivational Theory still fails; nonetheless, I will show that an OT analysis not only properly accounts for the language data, but also discloses the motivation behind the seemingly unpredictable directions. I argue that the right-to-left tone sandhi operation directionality in Chengdu tri-tonal strings is triggered by an *Identity Effect*. In Chengdu, tonal outputs tend to be identical to the tonal bases to which they prosodically correspond. This is captured by an Output-to-Output (OO) correspondence constraint. The satisfaction of the constraint causes tone sandhi to operate from a right-to-left direction. However, if the correspondence of the two output forms (i.e., the output and the base) would result in highly marked forms, which are prohibited by the markedness constraint, tone sandhi would operate in the reverse direction. Thus, the tone sandhi operation directions are naturally predicted by the interaction of the OO correspondence constraint and the markedness constraint, where the latter must dominate the former.

In quadri-tonal strings, strangely, morphosyntactic structures, which are completely functionless in predicting tone sandhi in tri-tonal strings, are respected. I argue that the reason why tone sandhi starts to pay respect to morphosyntactic structures in quadri-tonal strings is that Chengdu has an upper limit on the size of the tone sandhi domain, which is three syllables. Thus, when the word strings exceed the upper limit of the domain size, they are divided into independent feet. The division of word strings into different feet is not *ad hoc*, but is sensitive to morphosyntactic structures.

2. Tri-tonal sandhi

2.1 Basic tonal facts

Chengdu has four citation tones. They are *yinping* MH, *yangping* ML, *yinshang* HM and *yinqu* LM. With the exception of ML, the citation tones undergo tone sandhi when adjacent to other tones. The combinations that involve tonal changes are listed below.[2] (Sandhi tones are in boldface hereafter)

(1)

	Input	Output	Example[3]	Tone Sandhi Rules	
a.	MH.LM	MH.**L**	*zong jiao* 'religion'	(A) LM→ L/ T ___	
b.	ML.LM	ML.**L**	*xi guan* 'habit'	(T = Any tone)	
c.	LM.LM	LM.**L**	*shi jie* 'world'		
d.	HM.ML	**H**.ML	*cai hong* 'rainbow'	(B) HM→ H/ ___ T	
e.	HM.HM	**H**.HM	*zuo shou* 'left hand'		
f.	MH.MH	MH.**M**	*jin tian* 'today'	(C) MH→ M/{MH, ML}___	(E) MH→[+level, α mid]/[-α mid]___
g.	ML.MH	ML.**M**	*zuo tian* 'yesterday'		
h.	LM.MH	LM.**H**	*mian bao* 'bread'	(D) MH→ H/ LM ___	
i.	HM.LM	**H.L**	*zao fan* 'breakfast'	(B) and (A)	
j.	HM.MH	**H**.**M**	*cao gu* 'straw mushroom'	(B) and (E)	

[2] In Chengdu, verbs are free from tone sandhi. For example, while nouns with an underlying MH.MH sequence such as *jin*MH *tian*MH 'today' would undergo tone sandhi and change to *jin*MH *tian***M**, verbs with the same underlying tonal sequence such as *chang*MH *ge*MH 'sing' would stay unchanged.

[3] The bi-tonal and tri-tonal examples in the present study were gathered from fieldwork conducted in Taiwan during November 2003 with my informants, Qi, qi (aged 37 in 2003) and Mrs. Chang (aged 24 in 2003). Both Mrs. Qi and Mrs. Chang are Mainland Chinese brides who married to Taiwanese husbands. Both of them were new comers to Taiwan in Nov. 2003. They had not left Chengdu for more than 15 months at the time of fieldwork sections. The quadri-tonal examples were gathered from fieldwork sections in Taiwan during April and June, 2005 with Qi, qi.

The tonal changes in Chengdu can be captured by the tone sandhi rules on the right hand side of the column. Rule (1A) captures the tonal fact that the rising tone LM changes to low level tone **L** when preceded by any tone. (ref. (1a-1c and 1i)). Rule (1B) captures the fact that the falling tone HM changes to high level tone **H** when followed by any tone. (ref. (1d, 1e, 1i and 1j)). Unlike LM and HM tones that assume only one sandhi form, MH has two sandhi forms: **M** and **H**. It changes to **M** when preceded by MH and ML, and to **H** when preceded by LM. The tonal changes are captured by rules (1C) and (1D). But, the two rules can actually be combined and rewritten more generally as (1E). Because it is clear that what sandhi form MH turns to depends solely on whether its preceding tone ends in mid or non-mid tones. Thus, when MH is preceded by MH and ML, which end with *non-mid* tones, it changes to **M**, which begins with *mid* tone; and when it is preceded by LM, which ends with *mid* tone, it changes to **H**, which begins with *non-mid* tone. This is a kind of OCP effect that prevents similar forms from occurring in adjacent positions. It is worth noting that in Chengdu, except for the HM.T sequence, it is the right tone, rather than the left tone of a sequence, that undergoes tone sandhi. This is different from other Chinese dialects such as Beijing Mandarin, Southern Min, Tianjin, Sixian-Hakka and Boshan, which tend to maintain the identity of the rightmost tone while allowing tones to change in other positions. In the literature, languages like Beijing Mandarin are referred to as right prominent languages while languages like Chengdu are referred to as left prominent languages. (Chen 2000, Hyman and VanBik 2004, among others)

Based on what we have observed so far, it is clear that the Chengdu tone sandhi rules are driven by the output constraints below.

(2) IDENT-IO-T-L: The leftmost tone of an utterance[4]/a foot is identical to its input correspondent.[5]

(3) *RISE: No rising tones.

(4) FALL]u: Falling tones are utterance final.

[4] An isolation pronunciation is an utterance. Thus, every isolation string discussed in the present study forms a prosodic utterance. This can be captured by constraints such as WRAP which requires every isolation string to be wrapped into a prosodic utterance. In the present paper, the prosodic utterances are left unmarked for the sake of simplicity.

[5] Notice that in structures that contain recursive feet (e.g. (T_1(T_2 T_3))), the IDENT-IO-T-L refers to the leftmost tone of the *outmost* foot (that is, T_1 but not T_2) because IDENT-BOT (to be proposed below in §2.4), which requires the tones (including the tone at the left edge) in a bound form of foot to be identical to those in their corresponding free form, would have functioned to govern the identity of the tones at the left edge of the embedded foot. Restricting the leftmost tone to the outmost foot in IDENT-IO-T-L can avoid unnecessary duplication.

(5) PARSEML: Preserve underlying ML tones.

(6) OCP: Avoid adjacent H's or M's in intersyllabic positions.

(7) *POLAR: Intersyllabic contours should be no more than 50% of the pitch range apart. [i.e., L and M and M and H can occur adjacently in the intersyllabic position (e.g. M**L.M** and L**M.H**), but **L** and **H** can not (e.g. M**L.H**).][6]

The first constraint IDENT-IO-T-L is a positional faithfulness constraint. It captures the fact that Chengdu is a left prominent language. The second constraint *RISE captures the fact that the two rising tones, LM and MH, change to level tones, **L** and **M**/**H**, in sandhi positions. As rising tones at the left edge of an utterance never undergo changes, we can say IDENT-IO-T-L >> *RISE. For underlying HM.T sequences, the sandhi forms (i.e. **H**.T) clearly violate IDENT-IO-T-L as the tones on the left have undergone tone sandhi. One could suggest a markedness constraint *FALL (which prohibits falling tones from surfacing) and the ranking *FALL >> IDENT-IO-T-L to ensure that HM tones at the left edge of an utterance would undergo tone sandhi. However, the unrestrained *FALL would refrain all HM tones from surfacing. But HM does surface at the right edge of an utterance (e.g. ML.HM). This paper proposes instead the positional markedness constraint FALL]u.[7] The FALL]u constraint in (4) enables HM at the right edge of an utterance to preserve its tone and at the same time forces non-utterance-final HM to change.[8] The change of HM at the left edge of an utterance would of course violate IDENT-IO-T-L. Hence FALL]u must dominate IDENT-IO-T-L. It is worth noting that HM is not the only falling tone in Chengdu. There is another falling tone in Chengdu, ML, which never undergoes

[6] This constraint is inspired by the constraints Space-100% and Space-50% proposed by Yip (2002), which are used to determine the tonal inventories. The constraints require that the space of the tones should be some given percentage of the pitch range apart. Clearly, the constraints are perceptually based. Perceptually, the wider the space of the tones, the easier it is to distinguish the tones. The constraint *POLAR, on the other hand, is articulatorily based. The motivation is clear. The wider the spacing between intersyllabic tonemes, the harder it is for speakers to produce them. In a talk given by Chen in 2003 at National Chiao Tung University about Changting Hakka tone sandhi, Chen mentions that abrupt changes between tonal values, such as L and H, is more marked than smoother changes such as between M and H or M and L. The constraint is partly inspired by his talk.

[7] Positional Markedness Constraints (Steriade 1997, Zoll 1998, Lombardi 2001) state that certain marked structures either must (as in the positive positional markedness constraints) or cannot (as in the negative positional markedness constraints) occur in particular positions.

[8] This is also evident in quadri-tonal sandhi. We know that an HM tone changes to a sandhi **H** tone when it is followed by another tone (HM → H/__T). Nonetheless, in quadri-tonal strings, non-utterance final HM tones would surface as **H** even though they are not followed by any other tones in the tonal domain.

e.g. *yin er ji tang* 'white fungus chicken soup'

(ML.HM)(.MH.MH) → (ML.**H**)(MH.**M**)

change. Thus, a constraint that requires an input ML tone to stay intact in the output is necessary. And the constraint must outrank the FALL]u constraint to ensure that non-utterance-final ML tones would not be wrongly forced to change. Thus, PARSEML >> FALL]u. The fifth constraint is OCP, which prohibits adjacent H or M tones in the intersyllabic position. The constraint mainly functions to capture the tonal changes of MH. Thus MH tones would not change to **H** after MH (i.e., * M[H.**H**]) and to **M** after LM (i.e., *L[M.**M**]). Nonetheless, not all output forms obey the constraint. It is violated, for instance, by HM.HM → [**H**.H]M; but HM has to change because of FALL]u; hence FALL]u >> OCP. The sixth constraint is *POLAR. The constraint is necessary because OCP does not suffice to describe the tonal changes of MH. OCP falls short of explaining why MH after ML changes to **M**, but not **H** because neither M[L.**M**] nor M[L.**H**] violates OCP. *POLAR serves to reject the latter. *POLAR is phonetically based. Articulatorily, intersyllabic contours are hard to produce already; producing contours that are 100% of the pitch range apart would be harder than producing contours that are 50% of the pitch range apart. Note that *POLAR is violated by HM.LM → **H**.**L**, but HM has to change because of FALL]u. Hence FALL]u >> *POLAR.

The constraint hierarchy proposed for Chengdu tone sandhi is PARSEML >> FALL]u >> IDENT-IO-T-L >> *RISE >> {*POLAR, OCP}. (8) illustrates how the constraints work to capture the basic tonal facts.[9]

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[9] In the present study, for the sake of clarity, the constraints proposed in the body of the text would only serve to select the optimal candidate among all the possible combinations of the allotones of a given tone. (The allotones of an input /MH/ are [MH~M~H], those of /HM/ are [HM~H], and those of /LM/ are [LM~L]). Thus, for a bi-tonal input /MH.MH/, the output candidates considered for evaluation would be [MH.MH], [MH.M], [MH.H], [M.MH], [M.M], [M.H], [H.MH], [H.M], and [H.H] (but not, for instance, [MH.*LM*]). The tonal combinations that are not composed of the allotones can be easily ruled out by a set of constraints that function to generate the allotones of a given tone (ref. (1)-(6)). When ranking the constraints that generate the allotones (i.e., constraints (1)-(4)) above the constraints that select the optimal candidate among the allotone combinations (i.e., the constraints proposed in the body of the text), all the tonal combinations that are not composed of the allotones would be quite readily ruled out before entering the constraints that select the allotone combinations (ref. (7)).
(1) LINEARITY: No tonemic feature reversals in input and output tones. (Thus, for an input /MH/, the output [HM] would violate the constraint)
(2) DEP: No toneme could be added. (Thus, for an input /LM/, the output [H] would incur a violation to the constraint because H is added)
(3) ANCHOR-LEFT: The toneme at the left edge of an output tone should be the same as that of its corresponding input tone. (Thus, for an input /MH/, the output [M], but not the output [LM], satisfies the constraint)
(4) ALIGN-H-LEFT: Every tone must begin with the H toneme. (Thus, [H] and [HM] satisfy the constraint, but [MH], and [LM] don't)
(5) Ranking for constraints of allotone generation: {LINEARITY, DEP} >>{ANCHOR-LEFT ,ALIGN-H-L}

(8) MH.MH → MH.**M**

H.MH	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	OCP
a. MH.MH			**!		
b. MH.**H**			*		*!
☞c. MH.**M**			*		
d. **H.M**		*!			

2.2 More tonal facts

How do tones behave when they are in strings of three tones? How do the rules interact to produce tri-tonal sandhi? In most tri-tonal combinations, the same outputs are yielded regardless of the direction in which the rules apply. There are, however, seven tonal combinations that are derived by operating tone sandhi in a fixed direction. As shown in (9) and (10) respectively, while the tonal outputs of pattern (1), (2) and (3) must be derived with a right-to-left direction, those of pattern (4) to pattern (7) must be derived by a left-to-right direction. Operating tone sandhi in the reverse direction would lead to unattested outputs.

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(6) /MH/: [MH~H~M] /HM/: [HM~H] /LM/: [LM~L]

	MH	LIN	DEP	AN-L	A-H-L	HM	LIN	DEP	AN-L	A-H-L	LM	LIN	DEP	AN-L	A-H-L
a. H	☞ (H)			*		☞ (H)							*!(H)	*	
b. MH	☞ (MH)				*		*!		*	*			*!(H)	*	*
c. M	☞ (M)				*				*!	*				*!	*
d. HM		*!		*		☞ (HM)							*!(H)	*	
e. LM			* !(L)	*	*			*! (L)	*	*	☞ (LM)				*
f. L			* !(L)	*	*			*!(L)	*	*	☞ (L)				*
g. ML			* !(L)		*			*!(L)	*	*		*!		*	*

(7) /MH.MH/

MH.MH	ALLOTONE GENERATION				ALLOTONE SELECTION	
	LIN	DEP	AN-L	A-H-L	CON1	CON2 …
a. MH.**H**			*	→	→	
b. MH.MH				* →	→	
c. MH.**M**				* →	→	
d. MH.HM	*!		*			
e. MH.LM		* !(L)	*	*		

(9)

a. ⇦	(P1) MH.MH.MH→ MH.MH.**M**→ MH.**M.M** (P2) ML.MH.MH→ ML.MH.**M**→ ML.**M.M** (P3) HM.MH.MH→ HM.MH.**M**→ **H.M.M**	{{*xing qi*} *tian*} 'Sunday'; {*shao* {*ji gong*}} 'rooster soup' {{*liu sheng*} *ji*} 'gramophone' {{*shui xian*} *hua* } 'narcissus'; {*gui* {*dong ge*}} 'shortie'
b. ⇨	*(P1) MH.MH.MH→ MH.**M**.MH→*MH.**M.H*** *(P2) ML.MH.MH→ ML.**M**.MH→ *ML.**M.H*** *(P3) HM.MH.MH→ **H.M**.MH→ ***H.M.H***	

Key: {…}= the edges of a morphosyntactic constituent; T.T = current two-tone window scanned for possible rule application; ⇨/⇦ = the rule application directions by which the tonal outputs are derived

(10)

a. ⇨	(P4) MH.LM.MH→ MH.**L**.MH → MH.**L.M** (P5) ML.LM.MH→ ML.**L**.MH →ML.**L.M** (P6) HM.LM.MH→ **H.L**.MH →**H.L.M** (P7) LM.LM.MH→ LM.**L**.MH →LM.**L.M**	{{*san zi*} *jing*} 'the Trimetrical Classic' {{*zhi bu* } *ji*} 'weaving machine' {{*da zi*} *ji*} 'typewriter; {*xiao* {*jiao che*}} 'a sedan' {{*kuai ji*}*shi*} 'accountant;{*da*{*hou tian*}} 'three days later'
b. ⇦	*(P4) MH.LM.MH→ MH.LM.**H** → *MH.**L.H*** *(P5) ML.LM.MH→ ML.LM.**H** → *ML.**L.H*** *(P6) HM.LM.MH→ HM.LM.**H** → ***H.L.H*** *(P7) LM.LM.MH→ LM.LM.**H** → *LM.**L.H***	

The question is, what determines in which direction tone sandhi operates? Obviously, directionality of rule application cannot be governed by the morphosyntactic structures of the tri-syllabic word strings. For example, underlying MH.MH.MH (i.e. (P1)) changes to MH.**M.M** no matter whether the string is morphosyntactically left branching (e.g. {{*xing qi*} *tian*} 'Sunday') or right branching (e.g.{*shao* {*ji gong*}} 'rooster soup'). Chen (2004:806) proposes six general principles as the possible criteria that govern the rule application directionality. They are Structure Affinity, Temporal Sequence, Derivational Economy, Transparency, Simplicity, and Wellformedness. Structure Affinity refers to cyclicity following the syntactic bracketing. Temporal Sequence refers to the temporal sequence of speech organization; thus it prefers left-to-right directionality. Derivational Economy chooses the shortest derivational path; thus it prefers bleeding and counterfeeding. Transparency, on the other hand, favors feeding and bleeding. Simplicity prefers simple (level) to complex (contour) tones. Finally, Wellformedness favors a derivation that yields unmarked tonal combinations.

The fact that rule application directionality in Chengdu tri-tonal strings are not sensitive to morphosyntactic structures has obviously ruled out the possibility of Structure Affinity as the governing factor of tone sandhi operation directionality in Chengdu tri-tonal strings. Similarly, tone sandhi operation directionality cannot be governed by the principle of Temporal Sequence, as both left-to-right and right-to-left rule application directions are observed in the seven patterns. I will show in §2.5.2 that the remaining principles, i.e., Derivational Economy, Transparency, Simplicity and Wellformedness, also fail to account for Chengdu tone sandhi.

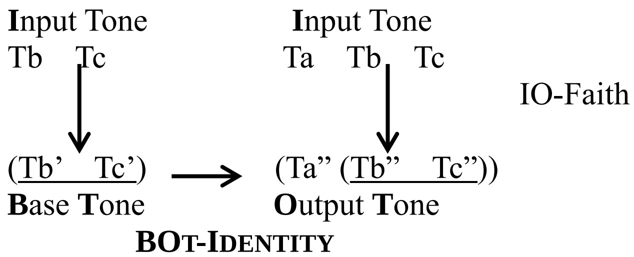
2.3 Prosodic correspondence and tri-tonal domain

Before proposing an account for tri-tonal sandhi, in this subsection, I review the Theory of Prosodic Correspondence proposed in Lin (2005b), which is essential for the OT analysis of Chengdu tone sandhi, and propose the tone sandhi domain for tri-tonal sandhi.

2.3.1 Prosodic correspondence (Lin 2005b)

Based on observations of tone sandhi in Beijing Mandarin and Sixian-Hakka, Lin (2005b) proposes a prosodic correspondence model for tone sandhi. The correspondence model requires identity between tonal outputs that stand in certain prosodic relationships. The proposed model is illustrated below.

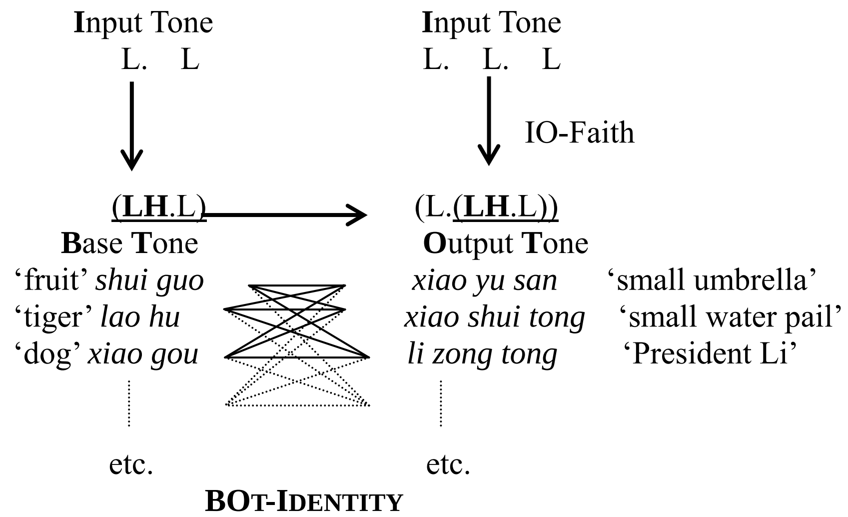
(11) Correspondence Model for Tone Sandhi (Lin 2005b:238)



Key: '(…)' = the left and the right edges of a prosodic constituent

In the model, base-tone-to-output-tone correspondence governs two freestanding tonal outputs that are compositionally related. Unlike the transderivational model proposed in Benua (1997), the two tonal outputs are related by prosodic structure rather than by morphosyntactic structure. Forms related via prosodic structure are capable of correspondence evaluation because prosodic units are cognitively real units; they have long been observed to play crucial roles in speech production/comprehension (Speer et al 1989, Gerken 1996, Shattuck-Hufnagel and Turk 1996) as well as in phonology (Selkirk 1984, 1986, Nespor and Vogel 1986, Shih 1986, Hsiao 1991, 1995). In correspondence relations, the tonal bases are freestanding tones that share underlying information with the tonal outputs and are minimally less prosodically complex than the tonal outputs. For example, in (11), (Ta".(Tb".Tc")) and (Tb'.Tc') are prosodically related, and the Tb".Tc" in (Ta".(Tb".Tc")) and the base (Tb'.Tc') share the same underlying tones Tb.Tc. Thus, (Ta".(Tb".Tc")) and (Tb'.Tc') are capable of correspondence evaluation. Based on the autosegmental status of tone, only tonal information is considered significant in the correspondence model; information in the segmental tier is of no importance. In the correspondence model, the tonal base and the tonal output are output tonal strings that can associate with any freestanding segments. For example, in the following correspondence schema (12), the tonal base is a freestanding tonal sequence [i.e., (LH.L)] that shares the tonal input [i.e., /L.L/] with the tonal output to which it prosodically relates [i.e., (L.(LH.L))]. The segmental base to which the tonal base associates is a freestanding form as well, but it need not be part of the segmental output to which the tonal output associates. Thus, while the tonal base **LH**.L could be associated with *shui.guo* 'fruit', the tonal output L.**LH**.L could be associated with *xiao.yu.san* 'small umbrella', even though the segmental information of 'fruit' and 'small umbrella' is completely different.[10] The correspondence relationship is captured by the constraint IDENT-BOT in (13).

(12) Correspondence schema in Beijing Mandarin (Lin 2005b:241)



(13) IDENT-BOT: Corresponding tones in the prosodically related bases and outputs must be identical. (Lin 2005b:240)

The prosodic correspondence model and IDENT-BOT imply that in tone sandhi, prosodically related tonal sequences tend to be identical. Actually, maximization of identity between prosodically related tonal outputs is observed to play an important role in tone sandhi of various languages such as Beijing Mandarin and Sixian-Hakka (Lin 2005b), Boshan (Lin 2004b), Hakha-Lai (Lin 2005a), and Tianjin (Lin 2003, 2005b). In those languages, tonal outputs tend to be more like the tonal bases to

[10] For details, please refer to Lin (2005b).

which they prosodically relate, even though the maximization of identity would sometimes generate forms that are less transparent. In this paper, I will show that this is also true in Chengdu. The seemingly unpredictable directionality of tonal operation in Chengdu can also be attributed to the desire of identity maximization between prosodically related outputs and is properly accounted for by the interaction of IDENT-BOT and the markedness constraints.

2.3.2 Tri-tonal domain of Chengdu

In dealing with tone sandhi (no matter in a rule-based analysis or in a constraint-based analysis), one of the most important things is to determine the domain within which tone sandhi operates (Shih 1986, Chen 1987a, Hsiao 1991, Lin 2000b, among others). Once the domain is determined, tone sandhi can be accounted for. In the literature, there are basically two approaches concerning how the tone sandhi domain is defined. One approach contends that the tone sandhi directly operates on the morphosyntactic structures (Chen 1987a, Lin J. 1994, among others). The other contends that tone sandhi should not operate directly on the morphosyntactic structures. Thus, the tone sandhi domain should be a kind of prosodic structure which mediates between syntax and phonology. (Shih 1986, Hsiao 1995, Lin 2000b, among others). As shown in §2.2, the operation of tone sandhi in tri-tonal strings in Chengdu is insensitive to the morphosyntactic structures. Thus, the tone sandhi domain definitely cannot be determined based on the morphosyntactic structures. In tri-tonal strings of Chengdu, a decision must be made concerning whether the domain is ((σσ)σ) or (σ(σσ)). It is proposed here that the tone sandhi domain of Chengdu is the right branching (σ(σσ)) foot.

The claim for the tri-tonal domain to be (σ(σσ)) might seem *ad hoc*. However, when we compare the domains proposed for other languages that involve directional tone sandhi, referred to as *morphosyntactically insensitive languages*, a correlation between the prosodic domain and the position of prominence can be observed. As shown in (14), while the domain of a left prominent language is right aligned, that of a right prominent language is left aligned. Thus, for languages whose tone sandhi is blind to morphosyntactic structures,[11] prosodic domains can be independently defined

[11] It is worth noting that all the morphosyntactically insensitive languages discussed here involve mutual tone sandhi. Mutual tone sandhi refers to the tone sandhi phenomena where the sandhi form is conditioned by the pitch value of both the sandhi tone and the neighboring tone (Liu 1987). Languages that involve purely independent and contextual tone sandhi are not discussed. Independent tone sandhi refers to the type of tone sandhi where the sandhi form is conditioned solely by the sandhi tone itself regardless of the pitch value of the adjacent tone, though the presence of the adjacent tone is crucial (Liu 1987). Taiwanese tone sandhi (Chen 1987a, 2000, Hsiao 1995, 2000a, Lin 2000a, among others), for instance, belongs to the class of independent tone sandhi. As illustrated in (1), the /H/ tone changes to **M** no matter whether it is followed by /M/ or /LM/.

according to the location of prominence.

(14)

Edge of Prominence	Prosodic Domain	Languages
a. left prominent T.T → $T_{TRI}.\mathbf{T}_{TAR}$	(σ(σσ))	Chengdu Hakha-Lai (Lin 2005a)
b. right prominent T.T → $\mathbf{T}_{TAR}.T_{TRI}$	((σσ)σ)	Tianjin (Lin 2003, 2005b), Boshan (Lin 2004b) Sixian-Hakka (Lin 2005b)

Key: T_{TRI} = triggering tone; T_{TAR} = target tone

The proposal of tonal domains actually leads to another interesting observation. As operating tone sandhi in a right aligned domain (σ(σσ)) implies a right-to-left tonal operation directionality and operating tone sandhi in a left aligned domain ((σσ)σ) implies a left-to-right operation directionality, both the right aligned domain in left prominent languages and the left aligned domain in right prominent languages

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Contextual tone sandhi refers to the type of tone sandhi where the sandhi form is conditioned solely by the value of the adjacent tone regardless of the pitch value of the sandhi tone (Liu 1987). Shanghai tone sandhi (Selkirk and Shen 1990, Duanmu 1992, Chen 2000, among others), for example, is a kind of contextual tone sandhi. Shanghai is a left prominent Chinese dialect. In (2), /LH/ changes to **H** after /LH/ but **L** after /HL/.

(1) Taiwanese as independent tone sandhi	(2) Shanghai as contextual tone sandhi
a. H.M → **M**.M (e.g. *tang po* 'eastern')	a. LH.LH → **L**.H (e.g. *ze'pe* 'Japan')
b. H.LM → **M**.LM (e.g. *tang ping* 'east side')	b. HL.LH → **H**.L (e.g. *fe ga* 'tomato')

For both independent tone sandhi and contextual tone sandhi, since the tonal values of neighboring tones do not matter, tonal changes in the non-prominent position simply take place simultaneously. Thus, the question of rule application directionalities would not exist. For example, in Taiwanese, a base tone changes to a sandhi tone in front of any tone; thus the tone sandhi rule will take place and change all the non-final tones into sandhi tones simultaneously.

(3) Taiwanese tone sandhi: change tones in the non-prominent (i.e., domain-final) position to sandhi tones.

Underlying representation	$T_1.T_2.T_3.$
Tonal change	$\mathbf{T_1.T_2.}$
Surface presentation	$\mathbf{T_1.T_2}.T_3.$

Shanghai tone sandhi involves tonal deletion of old features in the non-prominent position and reassignment of new tonal features. Thus, the tonal deletion can take place simultaneously to delete the tonal features of the tones in non-prominent positions. Then the reassignment process takes place and fills the toneless syllables with the feature of the prominent syllable simultaneously.

(4) Shanghai tone sandhi: (a) deletion of the tonal features in the non-prominent (i.e., domain-initial) position, (b) reassignment of the tonal features from the tonal feature in the first syllable.

Underlying representation	$HL_1.T_2.T_3$
Tonal deletion	$ø_2.ø_3$
Tonal filling	$L_2.L_3$
Surface presentation	$\mathbf{H_1.\ L_2.L_3}$

It is worth noting that both independent and contextual tone sandhi are categorized as positional types of tone sandhi (that is, tone changes caused by purely positional factors) in Yip (1995), as opposed to tonal changes that are caused by a specific tonal environment, such as assimilation and dissimilation. Some languages would involve a mixture of different types of tone sandhi. For example, Chengdu involves both mutual (the tonal changes of MH) and independent tone sandhi (the tonal changes of HM and LM). As long as mutual tone sandhi is involved, the question of tone sandhi operation directionality exists.

actually both entail a target-to-trigger tone sandhi operation directionality.[12]

The tri-tonal domain for Chengdu tone sandhi (σ(σσ)) can be accounted for by the prosodic constraints below. Tableaux (18) and (19) illustrate how the prosodic constraints predict the foot domain (σ(σσ)) for tri-tonal examples regardless of the morphosyntactic structure of the input.

(15) ALLFTR: Every foot stands at the right edge of the utterance.

(16) PARSESYLL: Parse syllables into feet.

(17) BINBRAN: Phonological feet are binary branching.

(18)

{σ{σσ}}	PARSESYLL	ALLFTR	BINBRAN
a. ((σσ)σ)		*!	
☞ b. (σ(σσ))			
c. (σσ)(σ)		*!	*
d. σ(σσ)	*!		
e. (σσσ)			*!

(19)

{{σσ}σ}	PARSESYLL	ALLFTR	BINBRAN
a. ((σσ)σ)		*!	
☞ b. (σ(σσ))			
c. (σσ)(σ)		*!	*
d. σ(σσ)	*!		
e. (σσσ)			*!

In sum, in tri-tonal strings of Chengdu, information in morphosyntactic structures is not respected. The prosodic domain is a right branching foot (σ(σσ)) no matter whether the string is left or right branching morphosyntactically. The prediction of the domain for tri-tonal strings relies crucially on the ALLFTR constraint, which prefers every foot to stand at the right edge of an utterance.

[12] The target-to-trigger directionality proposed here is contrary to Howard's (1972) theory. Hyman and VanBik (2004) pointed out that the trigger-to-target directionality proposed in Howard (1972) is not attested in the tone sandhi phenomena in Hakha-Lai and at least some Chinese dialects. The present analysis suggests a possible explanation for the target-to-trigger directionality, that is, to achieve identity between prosodically related outputs.

2.4 Tri-tonal strings, normal application and underapplication

Consider again the 7 tri-tonal patterns that are direction-sensitive. As mentioned, (P1)-(P3) must be derived with a right-to-left direction, while (P4)-(P7) must be derived with a left-to-right direction.

(20)

a.	(P1) MH.MH.MH→ MH.MH.**M** → MH.**M.M**	b.	(P4) MH.LM.MH→ MH.**L.**MH → MH.**L.M**
⇦	(P2) ML.MH.MH→ ML.MH.**M** → ML.**M.M**	⇨	(P5) ML.LM.MH→ ML.**L.**MH →ML.**L.M**
	(P3) HM.MH.MH→ HM.MH.**M** → **H.M.M**		(P6) HM.LM.MH→ **H.L.**MH →**H.L.M**
			(P7) LM.LM.MH→ LM.**L.**MH →LM.**L.M**

The rule application directionality in which the outputs are derived, as mentioned above, is not governed by morphosyntactic structures nor by principles such as Temporal Sequence, Derivational Economy, Transparency, Simplicity and Wellformedness (see discussions in §2.2 and §2.5.2). But is rule application directionality truly unpredictable? An intriguing phenomenon may be found when we look more closely into the outputs derived by the different directions. There is a correlation between rule application directionality and whether the output is transparent (i.e., showing *normal application*) or opaque (i.e. showing *over-* or *underapplication*).[13] Normal application refers to output forms that are neither non-surface-true nor non-surface-apparent while over- and underapplication refer to forms that are non-surface-apparent and non-surface-true respectively.[14] As shown in (21), while (P1)-(P3), which are derived with a right-to-left directionality, are opaque, (P3)-(P7), which are generated with the opposite directionality, are transparent. (P1)-(P3) belong to underapplication because impermissible sequences are observed at the surface.[15]

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[13] The correlation between conflicting directionalities and different application modes observed in Chengdu is also reported in Boshan (Lin 2004b), in Hakha-Lai (Lin 2005a) and in Tianjin (Lin 2003, 2005b).

[14] The terms 'non-surface-true' and 'non-surface-apparent' come from McCarthy (1999). A generalization is non-surface-true if a set of forms fail to undergo a process even though the structure description is met at the surface level; in other words, there are impermissible forms at the surface. On the other hand, a generalization is non-surface-apparent if the structure description of a rule application is not recoverable at the surface level; in other words, there are unconditioned changes at the surface.

[15] Notice that (P1)-(P3) also have the characteristic of overapplication. For example, in (P1), the rightmost underlying MH tone changes to **M** even though at the surface it is not preceded by any tone that ends in non-mid pitch (ref. rule (1E)). In Chengdu tone sandhi, the distinction between over- and underapplication is noncrucial. Both over- and underapplication contain opaque forms, which are contrary to the transparent forms in normal application. In the present study, (P1)-(P3), which exhibit the characteristics of both over- and underapplication, are regarded as underapplication for two reasons. First, underapplications are more marked than overapplications. Second, the characteristic of underapplications, i.e., containing impermissible output sequences, is easier to detect at the surface than that of overapplications which often need to refer to information

(21)

	Input	*Output*	*Directionality*	*Application Mode*
P1	MH.MH.MH	MH.**M**.**M**	⇦	Underapplication
P2	ML.MH.MH	ML.**M**.**M**	⇦	Underapplication
P3	HM.MH.MH	**H**.**M**.**M**	⇦	Underapplication
P4	MH.LM.MH	MH.**L**.**M**	⇨	Normal Application
P5	ML.LM.MH	ML.**L**.**M**	⇨	Normal Application
P6	HM.LM.MH	**H**.**L**.**M**	⇨	Normal Application
P7	LM.LM.MH	LM.**L**.**M**	⇨	Normal Application

Take (P1) for instance. The output MH.**M.M** contains the impermissible sequence **M.M** since the sequence has mid tones in the intersyllabic position. The output clearly violates OCP.

2.4.1 Underapplication

Within the seven tonal patterns, (P1), (P2) and (P3), which are derived by the right-to-left direction, involve underapplication of tone sandhi since the outputs are non-surface-true. Normal application of tone sandhi would have yielded MH.**M.H**, ML.**M.H**, and **H**.**M.H** for (P1)-(P3) respectively, which are supposed to be better candidates than their underapplication counterparts based on the current constraint ranking, because none of them violates OCP (e.g. (22)).

(22)

	Input	Attested Output (underapplication) ⇦	*Unattested Output (normal application)* ⇨
P1	MH.MH.MH	MH.**M.M**	*MH.**M.H***
P2	ML.MH.MH	ML.**M.M**	*ML.**M.H***
P3	HM.MH.MH	**H.M.M**	***H.M.H***

in the input.

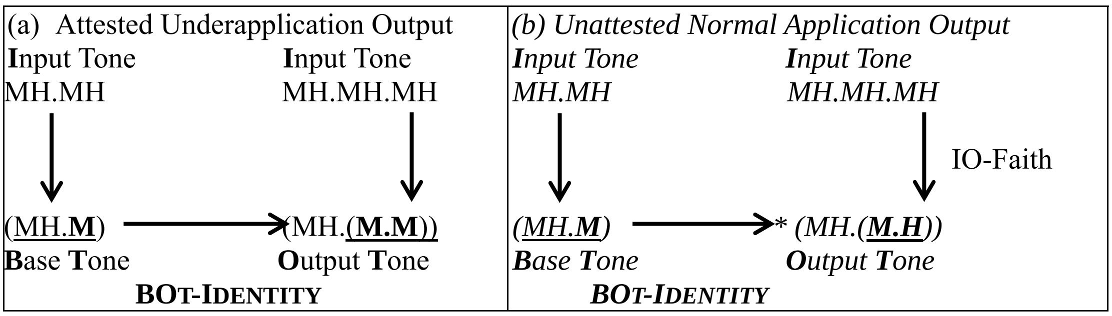
(23) (P1) MH.MH.MH→ MH.**M**.**M**

	MH.MH.MH	*RISE	*POLAR	OCP
☞	a. MH.**M**.**M** (underapplication) ⇦	*		*!
	💣 b. MH.**M**.**H** (normal application) ⇨	*		

(Pointing hands outside the tableau point out the attested candidates that the constraints fail to select.)

Thus, what causes tone sandhi to underapply in (P1)-(P3)? In §2.3, I have mentioned that evidence from Beijing Mandarin, Sixian-Hakka, Boshan and Hakha-Lai has shown the importance of identity preservation between prosodically related outputs in tone sandhi, even if the satisfaction of it would sometimes generate forms that are less transparent. This is exactly what happens in Chengdu. Underapplication in Chengdu is caused by the desire to maximize identity between tri-tonal outputs and their prosodically related base tones. As mentioned above, the tri-tonal sandhi domain of Chengdu is (σ(σσ)). When we compare the schema in (24a) for the attested underapplication output with that in (24b) for the unattested normal application output, we can clearly see that the tonal output in the internal prosodic structure of (24a) (i.e., (MH.(**M.M**)) is more like the base (i.e., MH.**M**) than that in (24b) [i.e., (MH.(**M.H**))] since while both tones in the internal domain of (24b) are different from the base, only one tone in the internal domain of (24a) is different from the base. Thus, outputs of underapplication in Chengdu are driven by the need to satisfy IDENT-BOT.

(24)



(25) IDENT-BOT: Corresponding tones in the prosodically related bases and outputs must be identical.

Because underapplication entails the existence of impermissible tonal sequences, it seems IDENT-BOT must be ranked above OCP to allow underapplication candidates to surface.

(26) IDENT-BOT >> OCP
Input: MH.MH.MH Base: MH.**M** (←MH.MH)
Output: (MH.(**M.M**)) > (MH.(**M.H**))

However, this ranking falls short in rejecting MH.**H.M** which is also a possible candidate for the input MH.MH.MH. As shown below, both the attested output MH.**M.M** and the unattested output MH.**H.M** incur the same violations. Both MH.**M.M** and MH.**H.M** violate IDENT-BOT once because the internal feet of both candidates contain one tone that is different from the tonal base. Both MH.**M.M** and MH.**H.M** incur a violation in OCP because the two-tone-sequence at the *right* edge in the former and at the *left* edge in the latter do not conform to OCP.

(27) (P1) MH.MH.MH→ (MH(**M.M**)) Base: MH.**M** (← Input: MH.MH)

(MH.(MH.MH))	IDENT-BOT	OCP
☞ a. (MH.(**M.M**))	*	* (**M.M**)
💣 b. (MH.(**H.M**))	*	* (MH.**H**)

How could the problem be solved? By observing the underapplication outputs (i.e., (P1), (P2) and (P3)) more closely, it can be seen that the impermissible sequences in those underapplication outputs always occur at the right (non-prominent) edge, but not the left (prominent) edge of a string.

(28)

Dialect/Language	Underapplication	Location of marked sequence (underlined)
Chengdu (left-prominent)	MH.**M.M**	*non-prominent* edge
	ML.**M.M**	
	HM.**M.M**	

Interestingly, the same is also observed in the underapplication outputs in Hakha-Lai (Lin 2005a) and Boshan (Lin 2004b). In Hakha-Lai, which is also a *left* prominent language, it is found that the impermissible sequences always occur at the non-prominent (*non-left*) edge, but not at the prominent (*left*) edge of a string. On the other hand, in Boshan, which is a *right* prominent language, it is found that the impermissible sequences always occur at the non-prominent (*left*) edge, but not at the prominent (*right*) edge of a string. Thus, the marked sequences in the attested underapplication outputs never occur at the prominent position.

(29)

Dialect/Language	Underapplication	Location of marked sequence (underlined)
Hakha-Lai (left-prominent) (Lin 2005a)	LH.**HL.HL** LH.**HL.HL**.L LH.**HL.HL.HL** %**H** **HL.HL** %**H** **HL**.HL	*non-prominent* edge
Boshan (right-prominent) Lin (2004b)	55.**55**.214	*non-prominent* edge
	55.**55**.214	
	55.55.214	

In Boshan (Lin 2004b:104) and Hakha-Lai (Lin 2005a), it is proposed that the markedness constraint should be divided into two constraints: one penalizes marked sequences at the prominent position (MC-POS) and the other penalizes marked sequences in general (MC-FREE). When MC-POS outranks IDENT-BOT which in turn outranks MC-FREE (i.e., MC-POS >> IDENT-BOT >> MC-FREE), impermissible tonal sequences at the non-prominent position that are caused by identity preservation would be tolerated. It is proposed here that underapplication in Chengdu also needs the division of the markedness constraints into MC-POS and MC-FREE. Since Chengdu is a left prominent language, the MC-POS constraint would penalize impermissible sequences at the left edge. The following constraint is proposed.[16]

(30) $_U$[OCP: At the left edge of an utterance, adjacent H's or M's in intersyllabic positions are not permitted.

Following the schema MC-POS >> IDENT-BOT>> MC-FREE, $_U$[OCP should dominate IDENT-BOT which in turn must dominate OCP to make the correct prediction for underapplication outputs.

[16] The MC-POS constraint proposed here belongs to the family of Positional Markedness Constraints (Steriade 1997, Zoll 1998, Lombardi 2001). Relating the markedness position to the prominent position would seem strange as, according to the positional faithfulness constraint, the prominent position should be the position that promotes more contrast. However, I argue that the status of the prominent position to promote more contrast is still maintained despite the positional markedness constraints proposed here. That is because the positional markedness constraint proposed in this paper refers to *sequences* (e.g. u[OCP means the bi-tonal sequence having adjacent H's or M's in intersyllabic positions is not allowed). In other words, it is a sequential markedness constraint. The sequential positional markedness constraints only require that the marked *sequence* cannot occur in the prominent position and that tonal changes need to take place to repair the marked structure. According to the positional faithfulness constraint proposed in this study, when marked structures appear, it is the tone on the non-prominent end of the sequence that undergoes tone sandhi. As a consequence, the tone in the prominent position remains unchanged and the prominent position would still promote more contrast.

(31) (P1) MH.MH.MH→ (MH(**M**.**M**)) Base: MH.**M** (← MH.MH)

(MH.(MH.MH))	U[OCP	IDENT-BOT	OCP
☞ a. (MH.(**M**.**M**))		*	*
b. (MH.(**H**.**M**))	*!	*	*

Thus, the final ranking for Chengdu is: PARSEML >> FALL]$_U$ >> IDENT-IO-T-L >> *RISE >> {*POLAR, $_U$[OCP } >> IDENT-BOT >> OCP >> IDENT-IO-T. The tableaux below demonstrate how the constraint ranking correctly predicts tone sandhi of (P1)-(P3).[17]

(32) (P1) MH.MH.MH→ (MH(**M**.**M**)) Base: MH.**M** (← MH.MH)

(MH.(MH.MH))	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	U[OCP	IDENT-BOT	OCP
☞a. (MH.(**M**.**M**)) (underapplication) ⇦			*			*	*
b. (MH.(**M**.**H**)) (normal application) ⇨			*			**!	

(33) (P2) ML.MH.MH→ (ML(**M**.**M**)) Base: MH.**M** (← MH.MH)

(ML.(MH.MH))	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	U[OCP	IDENT-BOT	OCP
☞a. (ML.(**M**.**M**)) (underapplication) ⇦	*					*	*
b. (ML.(**M**.**H**)) (normal application) ⇨	*					**!	

(34) (P3) HM.MH.MH→ (**H**(**M**.**M**)) Base: MH.**M** (← MH.MH)

(HM.(MH.MH))	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	U[OCP	IDENT-BOT	OCP
☞a. (**H**.(**M**.**M**)) (underapplication) ⇦		*				*	*
b. (**H**.(**M**.**H**)) (normal application) ⇨		*				**!	

In sum, identity preservation is important in tone sandhi. It may force a tonal output to deviate from the canonical surface patterns of the language, so that it becomes more like a tonal base to which it prosodically relates.

[17] For the sake of clarity, only candidates that are derived by the left-to-right and the right-to-left directionalities are presented in the tableaux. The constraints proposed can, however, work to pick out the attested outputs among all the possible combinations of the allotones of the input tones. In the following tableaux, the PARSEML constraint, which is never violated, will also be omitted for simplicity.

2.4.2 Normal application

Among the seven patterns, (P4) to (P7), which are derived by the left-to-right rule application directionality, involve normal application. As shown above, maximizing identity between prosodically related outputs is important in Chengdu tone sandhi. It causes tone sandhi to apply from right to left in (P1)-(P3) and the resultant outputs of such directionality belong to that of underapplication. However, if preserving identity is so important in Chengdu tone sandhi, what prevents tone sandhi from applying right-to-left in (P4)-(P7)? As shown below, the outputs derived by a right-to-left directionality would be more similar to their corresponding bases than the normal application outputs derived by a left-to-right directionality.

(35)

	Input	Base	Attested Output (normal application) Less similar ⇨	*Unattested Output (underapplication) More similar* ⇦
P4	(MH.(LM.MH))	(LM.**H**)	(MH.(**L.M**))	**(MH.(**L.H**))*
P5	(ML.(LM.MH))	(LM.**H**)	(ML.(**L.M**))	**(ML.(**L.H**))*
P6	(HM.(LM.MH))	(LM.**H**)	(**H**.(**L.M**))	**(**H**.(**L.H**))*
P7	(LM.(LM.MH))	(LM.**H**)	(LM.(**L.M**))	**(LM.(**L.H**))*

It is actually rather clear why tone sandhi does not apply right-to-left to increase identity in (P4)-(P7): to prevent highly marked forms from occurring. This is reflected by *Polar >> Ident-BOt. For instance, in (P4), if tone sandhi operated right-to-left, the resultant output would contain the **L**.**H** sequence that violates *Polar. As shown below, the normal application patterns are accounted for by the same set of constraints proposed for the underapplication patterns.

(36) (P4) MH.LM.MH→ (MH(**L**.**M**)) Base: LM.**H** (← LM.MH)

(MH.(LM.MH))	Fall]u	Ident-IO-T-L	*Rise	*Polar	u[OCP	Ident-BOt	OCP
☞a. (MH.(**L**.**M**)) (normal application) ⇨			*	*		**	
b. (MH.(**L**.**H**)) (underapplication) ⇦			*	**!		*	

(37) (P5) ML.LM.MH→ (ML(**L**.**M**)) Base: LM.**H** (← LM.MH)

(ML.(LM.MH))	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	U[OCP	IDENT-BOT	OCP
☞a. (ML.(**L**.**M**)) (normal application) ⇨	*					**	
b. (ML.(**L**.**H**)) (underapplication) ⇦	*			*!		*	

(38) (P6) HM.LM.MH→ (**H**.(**L**.**M**)) Base: LM.**H** (← LM.MH)

(HM.(LM.MH))	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	U[OCP	IDENT-BOT	OCP
☞a. (**H**.(**L**.**M**)) (normal application) ⇨		*		*		**	
b. (**H**.(**L**.**H**)) (underapplication) ⇦		*		**!		*	

(39) (P7) LM.LM.MH→ (LM(**L**.**M**)) Base: LM.**H** (← LM.MH)

(LM.(LM.MH))	FALL]u	IDENT-IO-T-L	*RISE	*POLAR	U[OCP	IDENT-BOT	OCP
☞a. (LM.(**L**.**M**)) (normal application) ⇨			*			**	
b. (LM.(**L**.**H**)) (underapplication) ⇦			*	*!		*	

In sum, identity preservation is important in Chengdu tone sandhi. It causes tone sandhi to apply right-to-left in (P1)-(P3). However, if such application direction would result in marked forms, tone sandhi will apply in the reverse direction. Thus, the different tone sandhi operation directions in Chengdu tri-tonal sandhi are naturally captured by the interaction of the markedness constraint *POLAR and the faithfulness constraint IDENT-BOT.

2.5 Alternative analyses

Two alternative analyses are considered in this section and shown to fall short in accounting for Chengdu tri-tonal sandhi.

2.5.1 Problem of the rule-based analyses

In the rule-based analysis of tone sandhi, one of the most important things is to determine the domain within which tone sandhi should apply. Once the domain is determined, tone sandhi can be accounted for. For example, in accounting for

Beijing Mandarin, Shih (1986:102) proposes that the tone sandhi domain for Beijing Mandarin is a prosodic foot, which is defined by the rule in (40). According to the FFR rule, the domains for morphosyntactically distinct tri-tonal examples are different (e.g. (41)). As a consequence, different tonal outputs are correctly predicted.

(40) Foot Formation Rule (FFR) (Shih 1986:110)
Foot (f) Construction
a. IC: Link immediate constituents into disyllabic feet.
b. DM: Scanning from left to right, string together unpaired syllables into binary feet, unless they branch to the opposite direction.
Super-foot (f') Construction
Join any leftover monosyllable to a neighboring binary foot according to the direction of syntactic branching.

(41)

	mai hao jiu 'buy good wine'	*mai hao jiu* 'have bought wine'
Immediate Constituency	{σ{σσ}}	{{σσ}σ}
Prosodic Foot Structure	(σ(σσ))	((σσ)σ)
Derivation:		
Input: Cycle 1 Cycle 2 Output:	(**L**.(**L**.**L**)) LH n/a **L.LH.L**	((**L**.**L**).**L**) LH LH **LH.LH.L**

Rule-based analysis seems to work in accounting for Beijing Mandarin tone sandhi.[18] However, when it comes to directional tone sandhi, such as Chengdu tone sandhi, where morphosyntactic structures seem to play no role, a rule-based analysis fails to work. The major problem is that in Chengdu, tone sandhi would operate left-to-right in some patterns and right-to-left in others, regardless of the information in morphosyntactic structures. Left-to-right application directionality implies that tone sandhi operates cyclically in the domain ((σσ)σ) while right-to-left application directionality implies tone sandhi applies cyclically in the domain (σ(σσ)). Since there is no objective way to determine the rule application directions, there is no objective way to determine the tone sandhi domain within which tone sandhi operates as well. Thus, stipulations of the directions in which the tone sandhi rules should apply are indispensable.

Though it has been proposed in the present study that the tonal domain for

[18] There are still some residual problems left unresolved in the rule-based analysis for Beijing Mandarin tone sandhi. Please refer to Shih (1986:136), Zhang N. (1997) and Lin (2000a, 2001, 2004a, 2005b) for discussion.

Chengdu tri-tonal sandhi is (σ(σσ)), the domain proposed under the OT framework cannot be directly incorporated in the rule-based analysis. That is because tone sandhi does not always apply right-to-left in Chengdu even though the domain is (σ(σσ)). The domain (σ(σσ)) merely reflects the fact that right-to-left rule application directionality is the norm in Chengdu tone sandhi. Recall that (P4)-(P7) of the seven tonal patterns actually have the tone sandhi rules operating from left to right. In OT, the domain proposed for Chengdu tone sandhi works because in the framework, constraints are violable. The different directions are caused by the interaction of the constraints, especially the markedness constraint *POLAR and the constraint requiring output-to-output correspondence, i.e., IDENT-BOT. The domination of the markedness constraint over IDENT-BOT predicts that tone sandhi applies right-to-left to achieve identity between prosodically related outputs, unless such directionality would produce highly marked forms. In that case, tone sandhi applies left-to-right.

However, in the rule-based analysis, the different directions cannot be accounted for by a single tone sandhi domain. If the tone sandhi domain for Chengdu is assumed to be (σ(σσ)), then only the tonal patterns that are derived by right-to-left directionality (i.e., (P1)-(P3)) can be accounted for (e.g. (42)). The tonal patterns that are derived by the left-to-right directionality (i.e., (P4)-(P7)) can never be accounted for by the same domain. Thus, the conflicting directions can only resort to stipulations such as those listed in (43).

(42)

	(P1) MH.MH.MH → MH.**M.M**	(P2) ML.MH.MH→ ML.**M.M**
Input:	(MH.(MH.MH))	(ML.(MH.MH))
Cycle 1	**M**	**M**
Cycle 2	**M**	**M**
Output:	MH.**M**. **M**	ML. **M**. **M**
	(P4) MH.LM.MH→ MH.**L.M**	(P5) ML.LM.MH→ML.**L.M**
Input:	(MH.(LM.MH))	(ML.(LM.MH))
Cycle 1	**H**	**H**
Cycle 2	**L**	**L**
Output:	* MH. **L**. **H**	* ML.**L**. **H**

(43) a. For inputs /MH.MH.MH/, /ML.MH.MH/ and /HM.MH.MH/, tone sandhi should apply from right to left.

b. For inputs /MH.LM.MH/, /ML.LM.MH/, /HM.LM.MH/ and /LM.LM.MH/, tone sandhi should apply from left to right.

2.5.2 Problems of the principles

In §2.2, we have shown that neither the principle of Structure Affinity nor the principle of Temporal Sequence can function to predict tone sandhi operation directionality in Chengdu. In this section, we will test the remaining four principles, i.e., Derivational Economy, Transparency, Wellformedness and Simplicity.

We shall first consider Derivational Economy. Derivational Economy prefers tonal changes that are derived by the shortest derivational path. However, as shown below, the attested outputs are not derived by the most economical derivation path, since the attested outputs and the unattested outputs are derived by the same steps of derivation in all seven patterns.

(44)

	Attested Outputs		Unattested Outputs	
(P1)	a.	MH.MH.MH→ MH.MH.**M** → MH.**M.M**	a'.	MH.MH.MH→ MH.**M**.MH →*MH.**M.H**
(P2)	⇦	ML.MH.MH→ ML.MH.**M** → ML.**M.M**	⇨	ML.MH.MH→ ML.**M**.MH → *ML.**M.H**
(P3)		HM.MH.MH→ HM.MH.**M** → **H.M.M**		HM.MH.MH→ **H.M**.MH → ***H.M.H**
(P4)	b.	MH.LM.MH→ MH.**L**.MH → MH.**L.M**	b'.	MH.LM.MH→ MH.LM.**H** → *MH.**L.H**
(P5)	⇨	ML.LM.MH→ ML.**L**.MH →ML.**L.M**	⇦	ML.LM.MH→ ML.LM.**H** → *ML.**L.H**
(P6)		HM.LM.MH→ **H.L**.MH →**H.L.M**		HM.LM.MH→ HM.LM.**H** → ***H.L.H**
(P7)		LM.LM.MH→ LM.**L**.MH →LM.**L.M**		LM.LM.MH→ LM.LM.**H** → *LM.**L.H**

Next, we should consider the principle of Transparency. Transparency prefers transparent outputs to opaque outputs that are either non-surface-true or non-surface-apparent. Transparency also fails to account for Chengdu tri-tonal sandhi because as mentioned, though the outputs of (P4)-(P7) are transparent (showing normal application), those of (P1)-(P3) are opaque. As a matter of fact, the impermissible sequences observed in (P1)-(P3) also indicate that the next principle Wellformedness, which prefers a derivation that yields unmarked tonal combinations, is not able to govern the tonal changes.[19]

Finally, we consider the principle of Simplicity. Simplicity prefers level tones to contour tones. As illustrated below, the principle of Simplicity also fails because the attested outputs and the unattested outputs contain the same number of level tones.

[19] Though there is an overlapping between the criteria of Transparency and Wellformedness, the two criteria should not be mixed. That is because though transparent outputs are always wellformed, wellformed outputs are not necessarily transparent. Some opaque outputs (particularly non-surface-apparent outputs) could be wellformed. (ref.Lin 2004b, Lin 2005a).

(45)

	Attested Output		*Unattested Outputs*	
	Input	*Output*	*Input*	*Output*
P1	MH.MH.MH	MH.**M.M**	*MH.MH.MH*	**MH.**M.H***
P2	ML.MH.MH	ML.**M.M**	*ML.MH.MH*	**ML.**M.H***
P4	MH.LM.MH	MH.**L.M**	*MH.LM.MH*	**MH.**L.H***
P5	ML.LM.MH	ML.**L.M**	*ML.LM.MH*	**ML.**L.H***

3. Quadri-tonal sandhi

3.1 Morphosyntactic sensitivity

In §2, we have shown that the operation of tone sandhi in tri-tonal strings is insensitive to morphosyntactic structures. Tone sandhi normally operates from right to left to maximize identity between prosodically related outputs unless such directionality would result in highly marked forms. The norm of directionality is reflected by the right branching tonal domain (σ(σσ)). And the domain is due to the ALLFTR constraint which requires every foot to stand at the right edge of an utterance. How about tone sandhi in longer strings such as quadri-tonal strings? Is tone sandhi still insensitive to morphosyntactic structures? If yes, it would mean that the norm of tone sandhi operation directionality remains from right to left irrespective of morphosyntactic structures and that ALLFTR still plays the dominant role. As a consequence, the tonal domain for quadri-tonal strings would be (σ(σ(σσ))). If, on the other hand, tone sandhi in quadri-tonal strings starts to pay respect to morphosyntactic structures, it would mean that some alignment constraints that align the edges of morphosyntactic and prosodic structures must start to play certain roles, and that the tone sandhi domain would start to vary according to morphosyntactic structures.

Lin (2004a) examined quadri-tonal strings in Sixian-Hakka and Tianjin and showed that tone sandhi operation directionality in tri-tonal and quadri-tonal strings of morphosyntactically insensitive languages could be quite different. Sixian-Hakka and Tianjin, like Chengdu, are morphosyntactically insensitive languages because the operations of tone sandhi in tri-tonal strings are completely insensitive to morphosyntactic structures. This can be illustrated in (46) and (48) respectively. Sixian-Hakka and Tianjin are right prominent languages. In both languages, tone sandhi normally applies from left to right (target to trigger) in the domain ((σσ)σ) in tri-tonal strings, no matter whether the strings are morphosyntactically left- or right-branching.

(46) Sixian-Hakka Tri-tonal strings

{{*tsu kon*}*thong*}'pig liver soup'; {*mai* {*tsu kon*}} 'buy pig liver'
((LH.LH).LH)→ ((**L**.LH).LH) →((**L.L**).LH)

(47) Sixian-Hakka Quadri-tonal strings

a. 2+2: {*sam pi*}{*ka pi*} 'three cups of coffee' (LH.LH)(.LH.LH) → (**L**.LH.)(**L**.LH); *Compare with: (((LH.LH).LH).LH) → (((**L**.LH).LH).LH) → (((**L.L**).LH).LH)*(((**L.L**).**L**).LH)*
b. 1+3: {*mai* {*seu* {*sien tshau*}}} 'buy hot-sien tshau' (((LH.LH).LH).ML → (((**L**.LH).LH).ML → (((**L.L**).LH).ML →(n/a) ((**L.L**.)LH).ML) *Compare with: (LH.(LH.(LH.ML))) → (n/a) (LH.(LH.(LH.ML))) → *(LH.(**L**.(LH.ML)))*

(48) Tianjin Tri-tonal strings

{{*si ji*} *qing*} 'evergreen';{*zuo* {*dian che*}} 'take a tram'
((HL.HL).L) → ((**L**.HL).L) → ((**L.H**).L)

(49) Tianjin Quadri-tonal strings

a. 2+2: {*xin chun* }{*jia jie*} 'new spring good holiday' (L.L)(.L.H) → (**LH**.L).(L.H) *Compare with: (((L.L).L).H) → (((**LH**.L).L).H) → (((**LH.LH**).L).H) →(n/a) *(((**LH.LH**).L).H)*
b. 1+3: {*da* {{*bao xian*}*xiang*} 'hit safety box' ((LH.LH).LH).L → ((**H**.LH).LH).L → (((**H.H**).LH).L) → (n/a) (((**H.H**).LH).L) *Compare with: (LH.((LH.LH).L))→(LH.((**H**.LH).L))→(n/a) (LH.((**H**.LH).L))→(n/a) *(LH.((**H**.LH).L))*

However, in quadri-tonal strings, tone sandhi in Sixian-Hakka and Tianjin becomes sensitive to morphosyntactic structure. This is illustrated in (47a) and (49a) respectively. As clearly shown, the correct tonal outputs must be derived by applying tone sandhi in the domain (σσ)(σσ), which is isomorphic to the morphosyntactic structures of the strings. If tone sandhi applied from left to right in the domain (((σσ)σ)σ), following the norm of directionality in tri-tonal strings of Sixian-Hakka and Tianjin, the resultant outputs would be unattested. But why does tone sandhi start to pay respect to morphosyntactic structure in quadri-tonal strings in Sixian-Hakka and Tianjin? The reason, as argued in Lin (2004a), is that both Tianjin and Sixian-Hakka have an upper limit on the size of the tone sandhi domain, which is three syllables. When the word strings exceed the upper limit of the domain size, in order not to generate domains larger than the upper limit, they are divided into independent domains [such as (σσ)(σσ)] rather than being wrapped into undivided ones [such as (((σσ)σ)σ) or (σ(σ(σσ)))]. The separation of the strings into different domains is not *ad hoc*, but is sensitive to morphosyntactic structure. It is worth noting that though tone sandhi in quadri-tonal strings in Sixian-Hakka and Tianjin starts to pay respect to morphosyntactic structure, it does not mean that it pays full respect to it. Take (47b) for instance. In (47b), tone sandhi must not be derived from right to left following morphosyntactic structure. Otherwise, the resultant output would be the unattested *LH.**L**.LH.ML.[20]

How about quadri-tonal strings in Chengdu? The investigation of quadri-tonal strings of Chengdu shows that they behave similarly to Sixian-Hakka and Tianjin. In other words, tone sandhi starts to pay some respect to morphosyntactic structures in the quadri-tonal strings. As shown in (50), in strings with the structure {σσ}{σσ}, i.e. "2+2", the tonal output must be derived by operating tone sandhi on the domain (σσ)(σσ), which happens to be isomorphic to morphosyntactic structure of the strings. Operating tone sandhi from right to left (following the norm of directionality in tri-tonal strings) on the tonal domain (σ(σ(σσ))) would result in the unattested output *(MH.(**M**.(**M**.**M**))).

(50) 2+2: {σσ}{σσ}: (σσ)(σσ)

Input	*Output*	*Example*	
a. MH.MH.MH.MH	(MH.**M**)(MH.**M**)	{*xiang gu*}{*ji tang*}	'mushroom chicken soup'
b. MH.MH.MH.HM	(MH.**M**)(MH.HM)	{*hua sheng*}{*chun juan*}	'peanut spring roll'
c. ML.HM.MH.MH	(ML.**H**)(MH.**M**)	{*yin er*}{*ji tang*}	'white fungus chicken soup'

However, (51) and (52) show that the tone sandhi domain doesn't fully respect morphosyntactic structure. (51) and (52) both have the "1+3" structure; however, the morphosyntactic structure of the internal "3" is actually different. In (51) (i.e., Type I of "1+3"), the "3" has a left branching morphosyntactic structure while the "3" in (52) (i.e., Type II of "1+3") has a right branching one. As the corresponding outputs of (51) and (52) are the same, it is clear that the internal morphosyntactic structures of "3" are not respected in quadri-tonal sandhi.

(51) 1+3 (Type I): σ{{σσ}σ}: σ(σσσ)

Input	*Output*	*Example*	
a. MH.MH.MH.MH	MH.(MH.**M**.**M**)	{*xin*{{*san xian*}*tang*}}	'new soup of three delicacies'
b. MH.ML.MH.MH	MH.(ML.**M**.**M**)	{*xiang*{{*nan gua*}*tang*}}	'savory pumpkin soup'
c. MH.ML.LM.MH	MH.(ML.**L**.**M**)	{*xiang*{{*niu rou*}*tang*}}	'savory beef soup'

[20] The domains in (47b) and (49b) are clearly larger than three syllables. The reason why tone sandhi domains in them do not split into two domains, (σσ)(σσ), is to avoid splitting a lexical word into two domains (a phenomenon commonly known as Lexical Integrity). For details, please refer to Lin (2004a:239-252).

(52) 1+3 (Type II): σ{σ{σσ}}: σ(σσσ)

Input	*Output*	*Example*	
a. MH.MH.MH.MH	MH.(MH.**M**.**M**)	{*suan*{*bing*{*guo ba*}}}	'sour cold rice crust'
b. MH.ML.MH.MH	MH(ML.**M**.**M**)	{*sheng*{*bai*{*xiang gu*}}}	'uncooked white mushroom'
c. MH.ML.LM.MH	MH.(ML.**L**.**M**)	{*xin*{*xian*{*rou song*}}}	'new salty fried pork flakes'

Note that tone sandhi in the "3" is based on tri-tonal sandhi (ref. §2.4). Thus, the tonal domain of the internal "3" should follow that of tri-tonal sandhi, i.e., (σ(σσ)). How about the "1" to the left of "3"? Does it form a quadri-syllabic foot with the "3" to its right? That is, (σ(σ(σσ)))? The fact that the tone standing at the left edge of the "3" remains unchanged implies that it must stand at the left edge of a domain, thus the "3" cannot form a foot with "1". It is proposed that the domain for the "1+3" strings is σ(σ(σσ)).[21]

Consider now the "3+1" strings. The "3+1" strings can also be divided into two types according to the morphosyntactic bracketing of the "3". The tone sandhi phenomena observed in the "3+1" strings further support that tone sandhi in quadri-tonal strings does not fully respect morphosyntactic structures. Had tone sandhi paid full respect to the morphosyntactic structures in the "3+1" strings, it should have operated in the tonal domain of (σσσ)σ (more specifically, ((σσ)σ)σ in Type I and (σ(σσ))σ in Type II). Nonetheless, that is not attested in either type of the "3+1" strings. As illustrated in (53) and (54), while the tonal outputs of Type I must be derived by operating tone sandhi on the domain (σσ)(σσ), those of Type II must be derived by operating tone sandhi on the domain σ(σσσ) [more specifically, σ(σ(σσ)), since tone sandhi in the "3" is also based on tri-tonal sandhi, and as mentioned, the domain of tri-tonal sandhi is (σ(σσ))].

(53) 3+1 (Type I): {{σσ}σ}σ: (σσ)(σσ)

Input	*Output*	*Example*	
a. MH.MH.MH.MH	(MH.**M**)(MH.**M**)	{{{*hua sheng*}*tang*}*xiang*}	'peanut soup smells good'
b. MH.LM.MH.MH	(MH.**L**)(MH.**M**)	{{{*ji dan*}*tang*}*xiang*}	'egg soup smells good'
c. ML.MH.MH.LM	(ML.**M**)(MH.**L**)	{{{*nan gua*}*tang*}*gui*}	'pumpkin soup expensive'

[21] Note that though the 1st syllable is not parsed into the foot structure which is immediately higher than the syllable in the prosodic hierarchy (i.e., utterance >> intonational phrase >> phonological phrase >> foot >> syllable; Selkirk 1984), it is nonetheless parsed into the utterance. Of course, having a syllable immediately dominated not by the foot but by other structures would violate the Exhaustivity principle (Exhaustivity: a constituent of level C^i in the Prosodic Hierarchy may not dominate a constituent of level C^{i-1+n} (Selkirk 1995)) of the Strict Layer Hypothesis. Nonetheless, as pointed out in Selkirk (1995), the Exhaustivity principle has been shown to be violable in various research.

(54) 3+1 (Type II): {σ{σσ}}σ: σ(σ(σσ))

Input	*Output*	*Example*	
a. MH.MH.LM.MH	MH.(MH.(**L.M**))	{{*bing*{*ji dan*}}*duo*}	'plenty of icy eggs'
b. ML.MH.LM.MH	ML.(MH.(**L.M**))	{{*yang*{*shi fu*}}*xin*}	'Master Yang is new'
c. LM.MH.MH.MH	LM.(MH.(**M.M**))	{{*da*{*hua sheng*}}*xiang*}	'big peanut smells good'

Thus, Chengdu quadri-tonal sandhi, like those observed in Sixian-Hakka and Tianjin, becomes sensitive to, though not fully respectful of morphosyntactic structure.

3.2 Quadri-tonal domain of Chengdu

We should consider now how tonal domains are determined by prosodic constraints. Recall that in tri-tonal strings in Chengdu, information in morphosyntactic structures is not respected. Thus, the prosodic domain is right branching (σ(σσ)) no matter whether the string is left or right branching morphosyntactically. The prediction of the domain for tri-tonal sequences relies crucially on ALLFTR, which prefers every foot to stand at the right edge of an utterance. However, as shown in (50), the prosodic domain of "2+2" strings is composed of two independent feet (σσ)(σσ). Since ALLFTR prefers every foot to stand at the right edge of an utterance, groupings of the syllables of an utterance into independent feet [such as (σσ)(σσ)] would incur violations of ALLFTR.

It is argued here that the reason the utterance is divided into 2 independent feet rather than being wrapped into a four-syllabic foot to satisfy ALLFTR is that Chengdu, similar to Sixian-Hakka and Tianjin, has an upper limit on the size of the foot and the upper limit is also 3 syllables. This can be captured by the constraint FT≦3σ.

(55) FT≦3σ: A foot must be equal to or less than 3 syllables

To select (σσ)(σσ) and rule out (σ(σ(σσ))) for the "2+2" strings, FT≦3σ must dominate ALLFTR. Thus, the current constraint ranking for Chengdu is: FT≦3σ >> {ALLFTR, PARSESYLL, BINBRAN}. However, it should be noticed that the current constraint ranking cannot avoid choosing the unattested foot σ(σ(σσ)) which is also a possible domain candidate for the "2+2" structure.

(56) 2 + 2

{σσ}{σσ}	FT≦3σ	ALLFTR	PARSESYLL
☞ a. (σσ)(σσ)		*	
💣 b. σ(σ(σσ))			*

To rule out the domain σ(σ(σσ)) for {σσ}{σσ}, we need to rely on alignment constraints that align the edges of morphosyntactic structures and foot structures. The constraint ALIGNFT/MS is proposed. It is ranked lower than FT≦3σ so that it will only become effective when FT≦3σ is violated. (58) shows how the ranking FT ≦3σ >> {ALLFTR, PARSESYLL} >> ALIGNFT/MS >> BINBRAN predicts the tone sandhi domain for {σσ}{σσ}.

(57) ALIGNFT/MS: The left/right edge of every foot (Ft) is aligned with the left/right edge of some morphosyntactic structures (MS).

(58) 2 + 2

{σσ}{σσ}	FT≦3σ	ALLFTR	PARSESYLL	ALIGNFT/MS	BINBRAN
☞ a. (σσ)(σσ)		*			
b. (σ(σ(σσ)))	*!			* (L edge)	
c. σ(σ(σσ))			*	*! (L edge)	
d. ((σσ)σ)σ		**!	*	* (R edge)	

We should now consider the "1+3" strings. As mentioned above, the tonal domain for "1+3" has two characteristics. First, the domain for the "3" is (σ(σσ)), irrespective of morphosyntactic structure. Second, the "3" does not form a foot with the "1". That is, σ(σ(σσ)). The two characteristics are readily captured by the constraints proposed so far. Consider the second characteristic first. The reason why the "1" does not form a foot with the "3" [i.e., *(σ(σ(σσ)))] is to avoid violating FT≦3σ. As for the first characteristic, the fact that the foot structure of "3" is (σ(σσ)) is reflected by the high ranking ALLFTR.

(59) 1 + 3 (Type I)

{σ{{σσ}σ}}	FT≦3σ	ALLFTR	PARSESYLL	ALIGNFT/MS	BINBRAN
a. (σσ)(σσ)		*		**! (L/R edge)	
☞ b. σ(σ(σσ))			*	* (L edge)	
c. σ((σσ)σ)		*	*!		
d. (σ)(σ(σσ))		*		**! (L/R edge)	*
e. ((σσ)σ)σ		**!	*	* (R edge)	
f. (σ(σ(σσ)))	*!			*! (L edge)	

(60) 1 + 3 (Type II)

{σ{σ{σσ}}}	FT≦3σ	ALLFTR	PARSESYLL	ALIGNFT/MS	BINBRAN
a. (σσ)(σσ)		*		*! (R edge)	
☞b. σ(σ(σσ))			*		
c. σ((σσ)σ)		*	*!	* (R edge)	
d. (σ)(σ(σσ))		*		*! (R edge)	*
e. ((σσ)σ)σ		**!	*	** (R edge)	
f. (σ(σ(σσ)))	*!				

Consider finally the "3+1" strings. As mentioned above, the tone sandhi domain for Type I "3+1" is (σσ)(σσ) while that of Type II "3+1" is σ(σ(σσ)). The tableaux below show that the domains can be correctly predicted by the current constraint ranking. The tableaux also explain the puzzle why the prosodic domain for "3+1" is not (σσσ)σ [either ((σσ)σ)σ or (σ(σσ))σ] but is (σσ)(σσ) in Type I and σ(σ(σσ)) in Type II. As suggested in the tableaux, the reason why the tonal domains of "3+1" are (σσ)(σσ) and σ(σ(σσ)) rather than *(σ(σσ))σ or *((σσ)σ)σ is to avoid having two feet not aligned to the right edge of the utterance, which could have to do with the tendency that left prominent languages tend to have their feet aligned to the right (ref. §2.3.2). In addition, the fact that, unlike the "1+3" strings, the tonal domains of Type I and Type II of the "3+1" strings are different also suggests that ALIGNFT/MS does play a role in predicting the tone sandhi domains of the quadri-tonal sandhi in Chengdu. Thus, quadri-tonal sandhi, unlike tri-tonal sandhi, does respect morphosyntactic structure.

(61) 3 + 1 (Type I)

{{{σσ}σ}σ}	FT≦3σ	ALLFTR	PARSESYLL	ALIGNFT/MS	BINBRAN
☞ a. (σσ)(σσ)		*		* (L edge)	
b. σ(σ(σσ))			*	**! (L edge)	
c. σ((σσ)σ)		*	*!	* (L edge)	
d. ((σσ)σ)σ		**!	*		
e. (σ(σσ))σ		**!	*	* (L edge)	

(62) 3 + 1 (Type II)

{{σ{σσ}}σ}	FT≦3σ	ALLFTR	PARSESYLL	ALIGNFT/MS	BINBRAN
a. (σσ)(σσ)		*		**! (L/R edge)	
☞ b. σ(σ(σσ))			*	* (L edge)	
c. σ((σσ)σ)		*	*!		
d. ((σσ)σ)σ		**!	*	* (R edge)	
e. (σ(σσ))σ		**!	*		

The addition of the two constraints: FT≦3σ, ALIGNFT/MS, will not influence the prediction for the tri-tonal domain as (σ(σσ)). The top-ranked FT≦3σ has no effect on the tri-tonal strings because the largest foot a tri-tonal string can construct could not possibly be larger than three syllables. ALIGNFT/MS does not influence the selection of the correct domain for tri-tonal strings simply because it is ranked below ALLFTR, which plays the key role in choosing the right branching domain for the tri-tonal strings.

In sum, even for morphosyntactically insensitive languages such as Chengdu, tone sandhi could become sensitive to morphosyntactic structures at some point.[22] It is because Chengdu has an upper limit on domain size. When the upper limit is exceeded, the word strings will be divided into independent domains. The separation of the word strings into different domains is not *ad hoc*, but is sensitive to morphosyntactic structures.

4. Conclusion

In the preceding sections, I have presented the basic tone sandhi phenomena of tri-tonal and quadri-tonal strings in Chengdu. The most challenging part of Chengdu tone sandhi is the seemingly unpredictable rule application directions observed in the tri-tonal strings. However, based on OT, the factor governing the conflicting rule application directions and the motivation behind them are uncovered. It has been shown that there is an intriguing correlation between the directions of rule application and normal vs. underapplications. In tonal patterns that are direction-sensitive, the

[22] One of the reviewers suggests that maybe we should regard Chengdu tone sandhi as direction sensitive in nature and that it is just not morphosyntactically sensitive in shorter strings. I would like to regard Chengdu tone sandhi as direction insensitive in nature. That is because even though tone sandhi in quadri-tonal strings is shown to respect morphosyntactic structures, it does not fully respect them. Thus, the correlation between morphosyntactic structures and tone sandhi domains are not apparent all the time. The present paper takes the standpoint that Chengdu tone sandhi is morphosyntactically insensitive in nature and that the tone sandhi domain is generally right aligned irrespective of the morphosyntactic structures. Tone sandhi would partially respect morphosyntactic structures only when the tonal sequences must be divided into separate domains to avoid oversized ones.

right-to-left directionality would produce underapplications while the left-to-right directionality would produce normal applications. Underapplications observed in Chengdu tone sandhi have been shown to be forced by the desire for a tonal output to be more like a prosodically related base (captured by IDENT-BOT). Thus, achieving identity is the motivation lying behind the right-to-left directionality. Maximizing identity between prosodically related tonal outputs is important in Chengdu tone sandhi. However, maximization of identity is not always fulfilled. When achieving identity would produce tonal outputs that are highly marked (captured by the markedness constraint of *POLAR), identity preservation is sacrificed. In that case, tone sandhi would operate reversely from right to left and the resultant output would show the characteristics of normal application. Thus, the motivation of the left-to-right directionality is to prevent highly marked sequences from occurring. The selections between different directions fall naturally from the interaction of IDENT-BOT and the markedness constraint *POLAR. The domination of the markedness constraint over IDENT-BOT predicts that IDENT-BOT is satisfied unless the satisfaction of it would generate forms that violate the markedness constraint. The phenomena observed above are by no means unique to Chengdu tone sandhi. The same are also reported in the tone sandhi phenomena in Beijing Mandarin and Sixian-Hakka (Lin 2005b), in Boshan (Lin 2004b), in Hakha-Lai (Lin 2005a), and in Tianjin (Lin 2003, 2005b). In these languages, achieving identity between prosodically related forms plays important roles, unless marked forms would be generated. In that case, identity between prosodically related forms is sacrificed. Therefore, the phenomena observed in Chengdu are universal tendencies which deserve attention. The study of quadri-tonal sandhi shows that morphosyntactic structures, which play no role in predicting tri-tonal sandhi, are respected in quadri-tonal strings. The reason why tone sandhi starts to respect morphosyntactic structures in quadri-tonal strings is that there is an upper limit on the size of the tone sandhi domain. In order not to generate oversized domains, tonal strings are divided into smaller parts. The division of tonal strings into different tonal domains is not *ad hoc* but is based on morphosyntactic structure.

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成都話連續變調現象中的方向性

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本篇論文的主旨在於討論漢語方言中，成都話的連讀變調現象。深究的重點是成都話連讀變調現象的變調方向性及變調方向性背後之意義。成都話三字組的變調方向性有由右而左和由左而右兩種；其變調方向性完全不受構詞句法結構的影響。不過，在四字組時，成都話的變調方向卻又轉而受到構詞句法結構左右。本文根據優選理論分析後認爲，成都話三字組的變調方向性基本上是由右而左。因爲這個方向性可以使得輸出聲調和其參考的聲調（base）比較相同。當這個方向性會衍生出高度有標（highly marked）的形式時，連讀變調規則就會轉而由左而右運作。變調的方向性可以由音韻制約（markedness constraint）和輸出－輸出信實制約（OO-faithfulness constraint）之間的排列順序而得到預測。而在四字組方面，我們認爲成都話四字組的變調之所以轉而受到構詞句法結構的影響是因爲，成都話限制其聲調範疇不得大於三個音節之故。當輸入聲調大於三音節時，輸入的聲調會拆成較小的範疇。在將聲調拆成較小的範疇時並非武斷的，而是根據構詞句法結構。

關鍵詞：成都話、連讀變調、二字組、三字組、四字組、變調方向性、優選理論