

Prosodic Correspondence in Tone Sandhi*

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1. Introduction

Correspondence in OT is a relation between pairs of forms. The correspondence relation is originally proposed to stand between underlying and surface forms (i.e., Input-Output correspondence) but is later extended to relations between the reduplicant and its base (i.e., Base-Reduplicant correspondence) and between morphosyntactically related outputs (i.e., Output-Output correspondence). Drawing evidence from tone sandhi in Mandarin (Cheng 1973a; Hsiao 1991; Shih 1986; Hung 1987; Zhang Z. 1988; Zhang N. 1997; Chen 2000; Lin 2000a, 2000b, 2000c; among others) and Sixian-Hakka (Hsu 1996, Hsiao 2000), this paper argues that the correspondence relation should be extended to stand between outputs that are related in the prosodic structures. Prosodic units have long been observed to play crucial roles in speech production/comprehension (Speer et al 1989, Shattuk-Hufnagel and Turk 1996, Gerken 1996b) as well as in phonology (Selkirk 1984a, 1984b, 1986; Nespor and Vogel 1986; Shih 1986; Hsiao 1991, 1995). Prosodic structures are cognitively real units; therefore, forms related in the prosodic structures should be capable for correspondence evaluation. Since Selkirk (1986), it is generally agreed that prosodic structures, though sensitive to the morphosyntactic structures of the language, are by no means isomorphic to them. Therefore, in the prosodic correspondence model proposed, the prosodically related output forms evaluated for correspondence are not necessarily morphosyntactically related.

The paper is organized as below: §2 examines Mandarin tone sandhi and argues that tone sandhi in Mandarin can be analyzed easiest if tonal outputs which are prosodically related rather than morphosyntactically related are evaluated for correspondence. The prosodic correspondence model is proposed in §2.5. §3 examines Sixian-Hakka tone sandhi which reinforces the need for prosodic correspondence. §4 proposes prosodic constraints to account for tone sandhi domains of Sixian-Hakka and Mandarin. §5 concludes the paper.

2. Prosodic Correspondence in Mandarin Tone Sandhi

2.1 Data and Generalization

Mandarin has four tones: high level (H), rising (LH), low level (L) and falling (HL). In Mandarin, when two L tones are in juxtaposition, the tone on the left changes to a LH tone.

(1) ‘umbrella’

| | | |
|-------------|-----------|------------|
| | <i>yu</i> | <i>san</i> |
| | rain | umbrella |
| base tone | L | L |
| sandhi tone | LH | L |

In the derivational tradition, the tone sandhi rule in (2) is used to account for this tone sandhi phenomenon.

(2) Mandarin Tone Sandhi Rule: $L \rightarrow LH / ___ L$

* This paper has benefited a lot from discussions and comments from Hui-chuan Huang, Yuchau Hsiao, Fengfu Tsao, Samuel H. Wang, Hui-chuan Hsu and James Myers. All possible errors are my own responsibility.

However, not every L tone followed by another L tone changes to a sandhi LH tone. Consider the following tri-tonal examples: (Sandhi tones are in boldface hereafter.)

| | | |
|-------------|----------------------------|---------------------|
| (3) | a. ‘the umbrella is small’ | b. ‘small umbrella’ |
| | <i>yu san xiao</i> | <i>xiao yu san</i> |
| | rain umbrella small | small rain umbrella |
| base tone | L L L | L L L |
| sandhi tone | LH LH L | L LH L |

To capture this phenomenon, an appropriate tone sandhi domain within which the tone sandhi rule will apply must be defined. Several kinds of tone sandhi domains are proposed in the derivational tradition. For example, Cheng (1973) suggests that the domain for Mandarin tone sandhi is syntactically defined and that tone sandhi rules apply according to the syntactic depth. Shih (1986) argues, on the other hand, that the domain for Mandarin tone sandhi is a prosodic foot that is by no means isomorphic to the morphosyntactic structures. The parameter for deriving the prosodic foot in Shih, which is generally agreed to better capture the tone sandhi phenomena, will be reviewed in the next section. By applying the tone sandhi rule in the prosodic foot, tone sandhi in the tri-tonal strings in (3) can now be explained. In (4a)(= 3a), the tone sandhi domain is the left branching (($\sigma\sigma$) σ) (where (...) equals to the tone sandhi domain). After tone sandhi takes place in the inner constituent and changes L₁ to LH, L₂ is still available to undergo tonal change. Thus, it enters into the second cycle of rule application and changes to LH as well. As a consequence, the resultant output is **LH.LH.L**. The tonal domain for (4b) (=3b), on the other hand, is the right branching (σ ($\sigma\sigma$)). After L₂ changes to a sandhi LH tone in the first cycle of rule application, there is no tone that can trigger L₁ to undergo tonal change. As a consequence, the resultant output is L.**LH**.L.

| | | |
|--------------|--|---|
| (4) | a. ‘the umbrella is small’ | b. ‘small umbrella’ |
| | <i>yu san xiao</i> | <i>xiao yu san</i> |
| | rain umbrella small | small rain umbrella |
| base tone | ((L ₁ L ₂) L ₃) | (L ₁ (L ₂ L ₃)) |
| first cycle | LH | LH |
| second cycle | LH | n.a |
| sandhi tone | LH LH L | L LH L |

2.2 Shih’s (1986) Analysis

Shih (1986) proposes that the domain of Mandarin tone sandhi is prosodically defined and that it is the foot that constitutes the domain of Mandarin tone sandhi. The Foot Formation Rule proposed in Shih (1986) to derive prosodic feet is given below, where the formation of the IC foot should precede that of the DM foot and the super-foot.

(5) 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.

The FFR correctly predicts that the tonal domains for *yu san xiao* ‘the umbrella is small’ and *xiao yu san* ‘small umbrella’ are (($\sigma\sigma$) σ) and (σ ($\sigma\sigma$)) respectively; and thus the tonal changes of them are properly accounted for (ref. (4)).

(6) 'The umbrella is small'

yu san xiao
rain umbrella small
┌───┐ IC ───┐ f
└───┘
LH LH L

(7) ‘small umbrella’

xiao yu san
small rain umbrella
┌───┐ IC ───┐ f
└───┘
L LH L

However, though the FFR seems to account for the above tri-tonal examples, it has the residual problem of failing to account for tone sandhi in prepositional phrases (PP). Compare (8) and (9) below. (8) is non-PP while (9) is PP. (8) and (9) have exactly the same immediate constituencies and underlying tones. Thus, according to the FFR, the tone sandhi domains predicted for them would be the same. However, their tonal outputs are different. The unmarked readings for (8) and (9) are H.**LH.LH**.L and H.L.**LH**.L respectively. Obviously, the tone sandhi domains for them must be (σ (($\sigma\sigma$) σ)) (i.e., (H.((**LH.LH**).L))) and ($\sigma\sigma$)($\sigma\sigma$) (i.e., (H.L).(LH.L)) respectively. However, the prosodic domain ($\sigma\sigma$)($\sigma\sigma$) cannot be predicted by the FFR.

(8) 'The cat walks with an umbrella.'

mao da san zou
cat hit umbrella walk
┌───┐ IC ───┐ f
└───┘
H LH LH L

(9) 'The cat is smaller than the dog.'

mao bi gou xiao
cat compare dog small
┌───┐ IC ───┐ f
└───┘
?? **H LH LH L**

To predict the correct tonal domain, Shih suggests that the formation of IC foot (i.e. FFR-IC) should be skipped in these kinds of word strings, and that such strings should be parsed into the DM feet directly, as shown in (10).

(10) 'The cat is smaller than the dog'

mao bi gou xiao
cat compare dog small
┌───┐ DM ───┐ DM
└───┘
H L LH L

However, the claim that FFR-IC should be skipped in all and only PP is no more than a stipulation. Here below, an attempt of OT analysis is made. Just as Shih (1986), the present analysis assumes that the tone sandhi domain of Mandarin tone sandhi is a prosodic foot. However, unlike Shih's approach, the analysis in this paper provides a unified solution for tone sandhi in both PP and non-PP utterances without stipulation.

2.3 Theories and Assumptions Adopted in the Present Analysis of Tone Sandhi

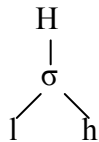
Before providing a formal analysis, I discuss some theories and assumptions that are essential in the following OT analysis.

2.3.1 The Internal Structure of Tone

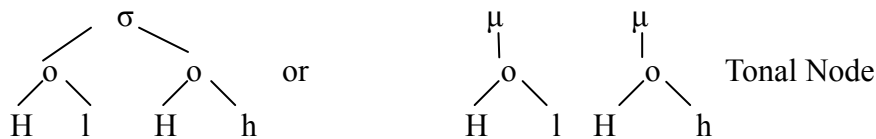
As summarized in Yip (2002a), there are four different models of tonal geometry for the internal structure of tone. They are listed below:

(Yip 2002a: 52-53)

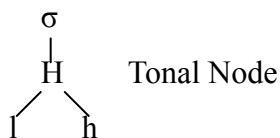
- (11) Models in which the features are entirely independent of each other, and there is no tonal node dominating them both: Yip 1980, also Hyman 1993:81 (8a)



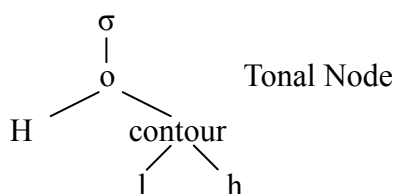
- (12) Models in which the two features are sisters under a Tonal Node, and each half of the contour tone is entirely independent: Duanmu 1990, 1994, Clements 1981, Snider 1990.



- (13) Models in which the register feature is the Tonal Node, dominating the Tone features: Yip 1989, also Hyman 1993: 81 (8d)



- (14) Models in which Tone features are dominated by a node of their own, called Contour, which is a sister to the Register feature, and where both are dominated by a Tonal Node: Bao 1990, Snider 1999.

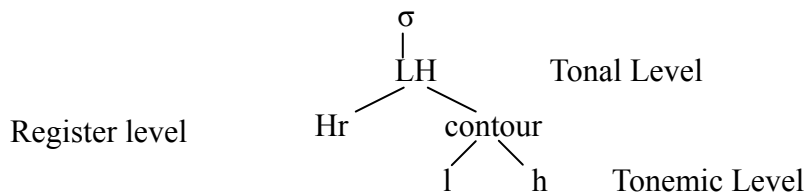


Among the four models of tonal geometry, Bao's model is the most powerful one. His model predicts that registers are free to spread alone, the whole tone is able to spread as a unit, contours are able to spread independent of registers, and that features dominated by the contour can spread alone. The other models cannot make the same predictions. Bao's model,

though powerful, is proved to be necessary because all the patterns predicted in Bao do occur in natural languages.¹ Therefore, Bao's model is adopted here, but with some labeling differences.

In the present study, the tones, which are represented as H, L, M, HL, LH, etc., belong to the tonal level. The high and the low registers are represented as Hr, and Lr respectively. They belong to the register level. The features dominated by contours are represented as h and l. They are referred to as tonemes and they belong to the tonemic level.

(15)



2.3.2 Allotone Generation and Allotone Selection

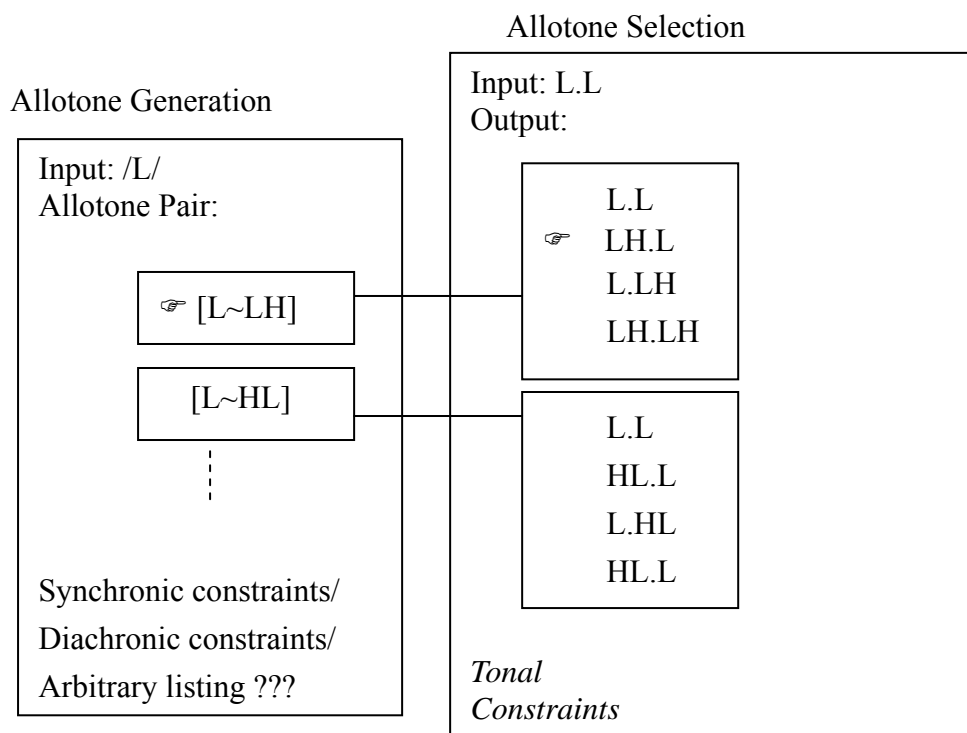
Recently, it has been proposed that in dealing with phonological alternations, two mechanisms must be distinguished: one is allomorph generation; the other is allomorph selection (Hayes 1990, Tsay and Myers 1996, Yip 2002a, b). Allomorph generation refers to the generation of the allomorph, while allomorph selection refers to the selection of the proper allomorph for a particular environment from a set of allomorph paradigm. For instance, in Mandarin tone sandhi, tonal allomorph generation will generate the allotones L and LH for an Mandarin input L, while the mechanism of tonal allomorph selection decides that the LH tone will surface before L, and L will occur elsewhere.

In tone sandhi, while it has generally been agreed that allotone selection can be controlled by phonological markedness, there are different views regarding how allotones are generated. The different views can be categorized into two types. One is that the allotone pairings are phonologically determined, and thus can be predicted by rules, as in the derivational theory (Wang 1967, Yip 1980) or by constraint interactions, as in the Optimality Theory (Horwood 2000). The other view is that allotone pairings cannot be determined by synchronic phonological conditions. They are determined by information in historical tonal categories (Chen 2000) or are just arbitrarily decided and listed in the mental lexicon (Tsay and Myers 1996, Yip 2002a).

In the present study, due to the limit of time and space, the issue concerning how the allotones are generated will not be addressed. The present analysis presumes the results of allotone generation. Thus the constraints proposed in this paper would be to decide among all the possible combinations of the allotones. For instance, for a Mandarin bi-tonal input /L.L/, the allotone pair [L~LH] predicted by the mechanism of allotone generation is presumed. Thus, the candidates considered for evaluation will be L.L, LH.L, L.LH, and LH.LH.

¹ Please refer to Bao (1990), Chen (2000) and Yip (2002a) for detailed discussion/comparison of the different models of tonal geometry.

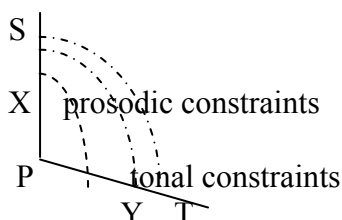
(16) Allotone Generation and Allotone Selection (Mandarin Tone Sandhi)



2.3.3 Separation of Tonal Constraints and Prosodic Constraints

In the present analysis, I adopt Hsiao's (1996, 2000b) view that in OT accounts of tone sandhi, constraints that evaluate tonal changes and constraints that determine tone sandhi domains (i.e., prosodic domains) should be separated. Hsiao (1996, 2002b), based on the Correspondence Theory, proposes that the syntactic level, the prosodic level and the phonological level of grammar should have at least the following three correspondence relationships: (a) the correspondence between the syntax and the prosodic levels (i.e., the S-P Correspondence), (b) the correspondence between the prosodic and the phonological (or tonal) levels (i.e., the P-T Correspondence), and (c) the correspondence between (a) and (b) (i.e., the X-Y Correspondence). The relationships are depicted below:

(17) (Hsiao 2000b)



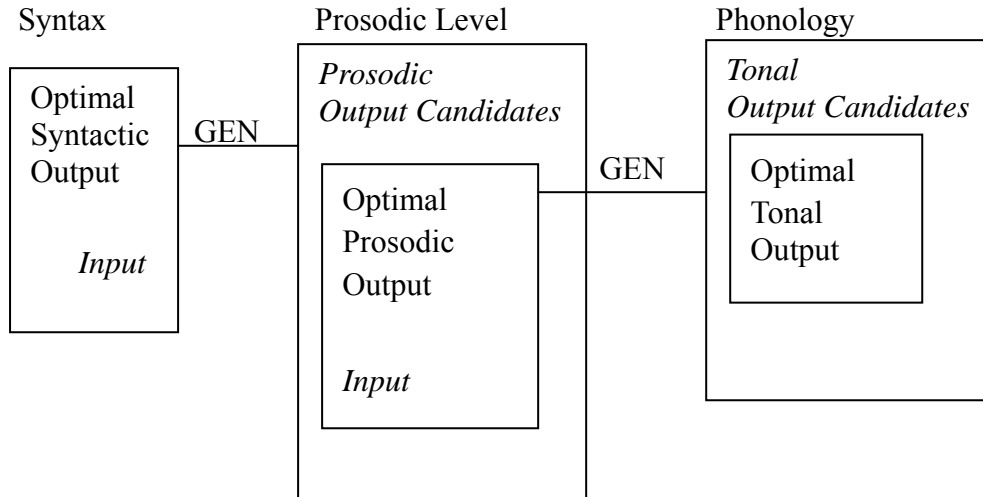
(S = Syntactic level; P = Prosodic level; T = Tonal level;
 X = S-P Correspondence; Y = P-T Correspondence)

The three correspondence relations take place in parallel. In other words, there is no serial derivation among these three relations. Here below is citation from Hsiao (2000b) showing how tonal and prosodic structures map.

(Hsiao 2000b: 11)

While the optimal syntactic form serves as an input taken by GEN and assigned to prosodic output candidates, the optimal prosodic form is an input taken by GEN and assigned to tonal candidates. All candidates are evaluated in parallel at each individual grammar component.

(18)



The model proposed by Hsiao is based on the Indirect Reference Hypothesis (Nespor and Vogel 1986, Selkirk 1986) which posits that the prosodic structure is a separate level between phonology and syntax. Therefore, in the present analysis, two sets of constraints are essential for tone sandhi analysis of each dialect/language. The tonal constraints set takes care of the tonal changes (allotone selection) and the prosodic constraints set determines the prosodic domain for tone sandhi. The constraints sets are separated but are evaluated in parallel to determine the final tonal output.

2.4 An Attempt of OT Analysis

2.4.1 Bi-tonal Strings

Consider first the tonal fact in Mandarin that identical tones cannot occur in juxtaposition. It is not a very surprising fact because it has long been observed that adjacent identical elements tend to be avoided (Obligatory Contour Principle (Leben 1973, Goldsmith 1976). Thus, the tonal facts can be captured by the OCP-T(L) constraint below:

(19) OCP-T(L): Avoid adjacent low tones at the tonal level. (*a categorical constraint*)

The markedness constraint is inherently in conflict with IO faithfulness constraint.

(20) IDENT-IO-T: Input-Output corresponding tones (at the tonal level) are identical. (*a gradient constraint*)

The IDENT-IO-T constraint is a faithfulness constraint that requires identity between inputs and outputs. The markedness constraints must dominate the faithfulness constraint to ensure that impermissible underlying tonal sequences will not surface without undergoing some changes.

(21) OCP-T(L) >> IDENT-IO-T

Input: L.L

Output: **LH.L** > L.L

(> = more harmonic than)

In addition to the IDENT-IO-T, another faithfulness constraint IDENT-IO-T-R is in need.

(22) IDENT-IO-T-R: The rightmost tone of an utterance (at the tonal level) is identical to its input correspondent.

The IDENT-IO-T-R constraint belongs to one of the positional faithfulness constraints proposed in Beckman (1998) which is inspired by the Parse(F) constraints of Selkirk (1994). The positional faithfulness constraints state that "correspondent segments in a privileged position must have identical specification for [F]." Since Mandarin belongs to a right-prominent system which tends to maintain the identity of the rightmost tone while allowing tones to change in the other positions, the IDENT-IO-T-R constraint is therefore proposed to ensure that when two identical tones are adjacent, it is always the tone at the left edge of an utterance, but not at the right edge, that undergoes tonal change. There is no crucial ranking between the IDENT-IO-T-R constraint and the OCP-T(L) constraint. Thus they are proposed to be equally ranked. The constraint ranking proposed for the tonal constraints is:

(23) The tonal constraint ranking for Mandarin tone sandhi:

{ IDENT-IO-T-R, OCP-T(L) } >> IDENT-IO-T

(24) below demonstrates how the constraints account for tone sandhi in the bi-tonal strings.

(24) *yu san* ‘umbrella’

Input: L.L → Output: **LH.L**

| L.L | IDENT-IO-T-R | OCP-T(L) | IDENT-IO-T |
|-----------|--------------|----------|------------|
| a. LH.LH | *! | * | ** |
| b. L.LH | *! | | * |
| c. L.L | | *! | |
| ☞ d. LH.L | | | * |

2.4.2 Tri-tonal Strings

Consider now tone sandhi in the tri-tonal strings. The constraints proposed above are not sufficient to account for different tonal patterns in the tri-tonal strings. Recall that the tri-tonal strings *yu san xiao* ‘the umbrella is small’ and *xiao yu san* ‘small umbrella’ have different tonal outputs. While the tonal output of the former is **LH.LH.L**, the tonal output of the latter is L.**LH.L**. The constraints proposed can account for the tonal output of L.**LH.L**, but cannot account for the tonal output of **LH.LH.L**.

(25) *xiao yu san* ‘small umbrella’

Input: L.L.L → Output: L.**LH.L**

| L.L.L | IDENT-IO-T-R | OCP-T(L) | IDENT-IO-T |
|-------------|--------------|----------|------------|
| a. LH.LH.L | | | **! |
| ☞ b. L.LH.L | | | * |
| c. L.L.L | | *!* | |

(26) *yu san xiao* ‘the umbrella is small’

Input: L.L.L → Output: **LH.LH.L**

| | L.L.L | IDENT-IO-T-R | OCP-T(L) | IDENT-IO-T |
|---|------------|--------------|----------|------------|
| ☞ | a. LH.LH.L | | | **! |
| ☛ | b. L.LH.L | | | * |
| | c. L.L.L | | *!* | |

(the pointing hand outside the tableau points out the attested output failed to be selected by the constraint set; ☛ points out the unattested output wrongly selected by the constraints set)

To predict the attested output **LH.LH.L** for *yu san xiao* ‘the umbrella is small’, a markedness constraint that forbids L tones to surface will be helpful.

(27) *L: No L tones. (a gradient constraint)

(28) *yu san xiao* ‘the umbrella is small’

Input: L.L.L → Output: **LH.LH.L**

| | L.L.L | IDENT-IO-T-R | OCP-T(L) | *L | IDENT-IO-T |
|---|------------|--------------|----------|-----|------------|
| ☞ | a. LH.LH.L | | | * | ** |
| | b. L.LH.L | | | **! | * |
| | c. L.L.L | | *!* | *** | |

However, the *L constraint, which helps to rule out the unattested output L.LH.L for *yu san xiao* ‘the umbrella is small’, will also wrongly rule out the attested output L.LH.L for *xiao yu san* ‘small umbrella’, as illustrated below:

(29) *xiao yu san* ‘small umbrella’

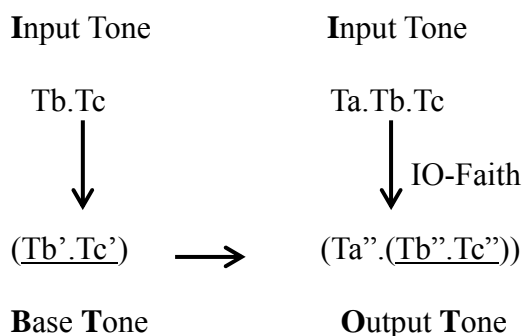
Input: L.L.L → Output: L.LH.L

| | L.L.L | IDENT-IO-T-R | OCP-T(L) | *L | IDENT-IO-T |
|---|------------|--------------|----------|-----|------------|
| ☛ | a. LH.LH.L | | | * | ** |
| ☞ | b. L.LH.L | | | **! | * |
| | c. L.L.L | | *!* | *** | |

2.4.3 The IDENT-BOT Constraint

As a matter of fact, to account for the two tonal patterns, a properly defined tone sandhi domain is necessary. Let us assume that the tone sandhi domains of *yu san xiao* ‘the umbrella is small’ and *xiao yu san* ‘small umbrella’ are ((σσ)σ) and (σ(σσ)) respectively (a set of prosodic constraints will be proposed to define the Mandarin tone sandhi domains in §4). We propose that the bi-tonal sequence in the inner domain of the tonal output is evaluated with a bi-tonal base with which it shares the same underlying tones. This is captured by the IDENT-BOT constraint below.

(30) IDENT-BOT: Corresponding tones in the bases and the outputs must be identical. (*a gradient constraint*) (e.g. Tb^{''}.Tc^{''} must be identical to Tb'.Tc') (to be revised)



BOT-IDENTITY

(31) and (32) below demonstrate that the IDENT-BOT constraint, when ranks above the IDENT-IO-T constraint, can correctly predict the outputs for both *yu san xiao* ‘the umbrella is small’ and *xiao yu san* ‘small umbrella’.

(31) *yu san xiao* ‘the umbrella is small’
 ((L.L).L) → ((**LH.LH**).L) Base: **LH.L** (←*yuL. sanL*)

| ((L.L).L) | IDENT-IO-T-R | OCP-T(L) | IDENT-BOT | IDENT-IO-T |
|------------------|--------------|----------|-----------|------------|
| ☞ a. ((LH.LH).L) | | | * | ** |
| b. ((L.LH).L) | | | **! | * |
| c. ((LH.L).L) | | *! | | * |

The tone sandhi domain of *yu san xiao* is ((σσ)σ), thus the base (*yuLH.sanL*) and its correspondence in the output (underlined) ((*yuLH.sanLH*).*xiaoL*) are evaluated by IDENT-BOT for identity. Among the three candidates in (31), only candidate (c) fully satisfies the constraint. However, the fully satisfaction of the constraint would result in a violation of the higher ranked markedness constraint OCP-T(L). Thus, candidate (c) is ruled out. Both (31a) and (31b) violate the IDENT-BOT constraint. However, (31b) ((L.LH).L) incurs more violations in the IDENT-BOT constraint than the attested output (31a) ((LH.LH).L). Because while both tones in (31b) to which the base tones correspond to (i.e. tones in the inner domain) are not identical to the base (i.e., LH.L), only one tone in the inner domain in (31a) is not identical to its corresponding base tones. Thus, (31b) is ruled out and (31a) is correctly selected as the optimal output.

The IDENT-BOT constraint, which plays the crucial role in ruling out the unattested output L.LH.L for *yu san xiao* ‘the umbrella is small’, however, will not wrongly rule out the attested output L.LH.L for *xiao yu san* ‘small umbrella’.

(32) *xiao yu san* ‘small umbrella’
 (L.(L.L)) → (L.(**LH.L**)) Base: **LH.L** (←*yuL. SanL*)

| (L.(L.L)) | IDENT-IO-T-R | OCP-T(L) | IDENT-BOT | IDENT-IO-T |
|-----------------|--------------|----------|-----------|------------|
| a. (LH.(LH.L)) | | | | **! |
| ☞ b. (L.(LH.L)) | | | | * |

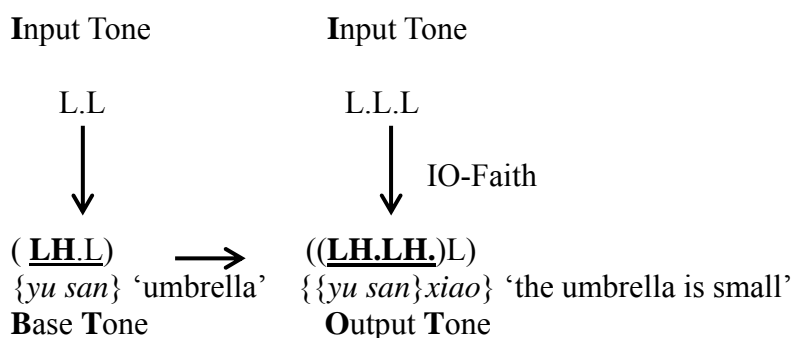
In (32), neither (a) nor (b) violates the IDENT-BOT constraint. However, as (32b) incurs fewer violations in the IDENT-IO-T constraint, it is correctly selected as the optimal candidate.

Here above, it has been shown that a properly defined tone sandhi domain as well as a correspondence constraint requiring identity between the base tones and the output tones are essential in accounting for Mandarin tone sandhi. The IDENT-BOT constraint is especially important in predicting the tonal output for tri-tonal inputs L.L.L which surface with all and only the final tone maintaining the base tone (i.e., L.L.L \rightarrow **LH.LH.L**). Before proposing constraints to define the Mandarin tone sandhi domain, I would like to address the nature of the correspondence constraint IDENT-BOT.

2.5 Prosodic Correspondence

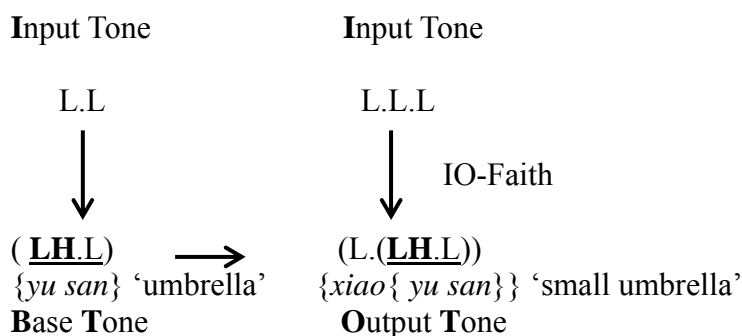
The IDENT-BOT constraint requires that corresponding tones in the bases and the outputs must be identical. In the OT literature, two forms can be related for identity if the forms are in the relation of input and output, base and reduplicant and morphosyntactically related forms such as truncated and base forms. How are the tonal bases and the tonal outputs in Mandarin tone sandhi related? Consider the examples discussed above, *yu san xiao* ‘the umbrella is small’ and *xiao yu san* ‘small umbrella’. In both examples, the tone sandhi domains and the morphosyntactic structures of the strings are isomorphic. In (33), the base *yuLH sanL* and the output *yuLH sanLH xiaoL* are syntactically related. In (34), the base *yuLH sanL* and the output *xiaoL yuLH sanL* are morphologically related. Thus the bases and the outputs seem to be related by the morphosyntactic structures. ($\{\dots\}$ = morphosyntactic structures = Immediate Constituency²)

(33)



BOT-IDENTITY

(34)



BOT-IDENTITY

² The immediate constituents of A will be the nodes which are immediately dominated by A. (Radford 1988)

Consequently, the IDENT-BOT constraint can be regarded as belonging to the Output-Output correspondence constraint family which requires the outputs evaluated for correspondence to be morphosyntactically related. Thus, the IDENT-BOT constraint can be stated more clearly as:

(35) IDENT-BOT: Corresponding tones in the **morphosyntactically** related bases and outputs must be identical. (*a gradient constraint*) (to be revised)

However, examples below show that the base tones and the output tones cannot be morphosyntactically related as the tone sandhi domains and the morphosyntactic structures of the strings do not coincide. To account for (36a), (36b), (36c), (37a), (37b), and (37c), tone sandhi must operate in the tone sandhi domains in (36a'), (36b'), (36c'), (37'a), (37b'), and (37c') respectively. However, there are mismatches between the tone sandhi domains and the morphosyntactic structures of the strings.

(36) Examples of phrases with functional categories

- | | | | |
|---|---|----|--------------------------------|
| a | <i>mai ba san</i> 'buy an umbrella' | a' | {σ{σσ}} |
| | Input: L.L.L → Output: LH.LH.L | | ((LH.LH).L) |
| b | <i>mai dian jiu</i> 'by some wine' | b' | {σ{σσ}} |
| | Input: L.L.L → Output: LH.LH.L | | ((LH.LH).L) |
| c | <i>gou bi ma xiao</i> | c' | {σ {{σσ}σ}} |
| | 'the dogs are smaller than the horses' | | (LH.L)(LH.L) |
| | Input: L.L.L.L → Output: LH.L.LH.L | | |

(37) Examples of tri-tonal transliterations

- | | | | |
|---|---------------------------------------|----|----------------------|
| a | <i>ya er ma</i> 'Armagh' | a' | {σσσ} |
| | Input: L.L.L → Output: LH.LH.L | | ((LH.LH).L) |
| b | <i>ma er mu</i> 'Malmo' | b' | {σσσ} |
| | Input: L.L.L → Output: LH.LH.L | | ((LH.LH).L) |
| c | <i>mu bi er</i> 'Mobile' | c' | {σσσ} |
| | Input: L.L.L → Output: LH.LH.L | | ((LH.LH).L) |

Consider (36) first. (36) are phrases that contain functional words (e.g. Prep. classifier, pronoun, etc.). In (36a), for instance, while the morphosyntactic structure is right branching {σ{σσ}}, the tonal domain is left branching ((σσ)σ). (37), on the other hands, are examples of transliterations of place names. Transliterations do not have internal morphosyntactic structures; thus, the inner constituent of the tonal domains cannot possibly match any morphosyntactic structures. Yet, tone sandhi in (36) and (37) must rely on the IDENT-BOT constraint as most of the examples belongs to the pattern of L.L.L → **LH.LH.L**. Clearly, to account for (36) and (37), the tone sandhi domains cannot be morphosyntactically defined. Following Shih (1986), it is proposed here that Mandarin tone sandhi domains are prosodically defined. The prosodic domains, which sometimes match the morphosyntactic structures (as in (33) and (34)), are not necessarily isomorphic to them. Examples in (36) and (37) are cases where the prosodic domains and the morphosyntactic structures mismatch. Thus, the bases and the outputs referred to for correspondence by the IDENT-BOT constraint are prosodically related. The IDENT-BOT constraint is revised as below:

(38) IDENT-BOT: Corresponding tones in the **prosodically** related bases and outputs must be identical. (*a gradient constraint*)

However, the question is: are the bases that are prosodically defined legal bases? One of the important characteristics of the bases is that a base must be a freestanding unit (Benua 1995, 1997; Kager 1999b). Nonetheless, it is unlikely that bases in (36) and (37) such as *mai ba* (in *mai ba san*), *gou bi* (in *gou bi ma xiao*), and *mu bi* (in *mu bi er*), etc. can constitute freestanding units as far as the information in the segmental level is concerned. Based on the autosegmental status of tone, it is argued here that in accounting for tone sandhi, only information in the tonal level is significant. It has long been observed that tonal processes often take place without paying respect to the information in the segmental level. Studies of tone sandhi in nonsense words also support this view.³ As shown below, tone sandhi takes place in nonsense words.

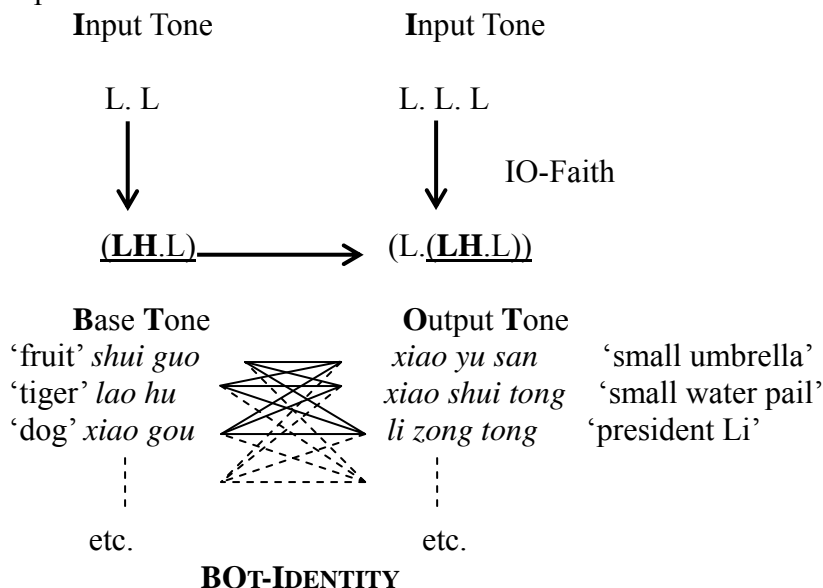
(39) Tone sandhi in nonsense words

- a. $huoL.quL \rightarrow huoLH.quL$
- b. $huoL.quL.jiL \rightarrow huoLH.quLH.jiL$

Since nonsense words have no information in the lexicon, tone sandhi observed in nonsense words proves that tonal changes pay little or no attention to the lexical information.

Though the bases in (36) and (37) do not constitute freestanding units segmentally, in the tonal level, they are undoubtedly legal to surface in the output. In Mandarin which disallows all and only identical L tones to occur in juxtaposition, all bi-tonal sequences other than L.L are legal tonal strings to occur at surface. The base tones can be associated with any freestanding segments. The tonal base is a freestanding tonal sequence that shares the input with the tonal output to which it prosodically relates. The segmental base to which the tonal base associates is a freestanding form as well, but it needs not be part of the segmental output to which the tonal output associates. This can be exemplified by the correspondence relation in Mandarin below:

(40) Correspondence schema in Mandarin

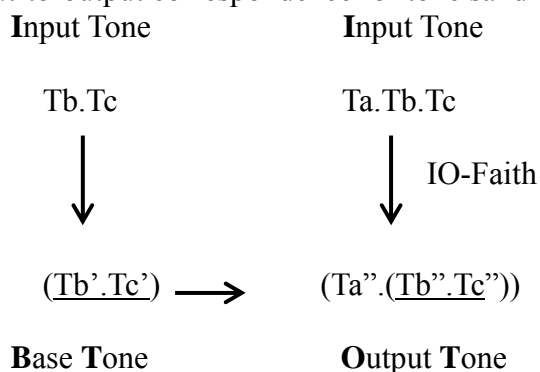


Here above, I have shown that a constraint requiring identity between the tonal bases and the tonal outputs plays a very important role in accounting for Mandarin tone sandhi. The

³ In the speech perception experiment carried out by Speer, Shih and Slowiaczek (1989), it is shown that listeners are able to predict tone sandhi even without input from lexical words half of the times.

correspondence model which is proposed for tone sandhi is schematized below:

(41) Output-to-output correspondence for tone sandhi



BOT-IDENTITY

(...) = prosodic structure

In the correspondence model, two correspondence relations are involved, an input-to-output relation and a base-to-output relation. The 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 the prosodic structures rather than by the morphosyntactic structures. Therefore, the tonal sequence Tb''.Tc'' within the inner prosodic constituent of (Ta''.(Tb''.Tc'')) is evaluated with Tb'.Tc' for correspondence. It should be noted that the tonal base is the tonal sequence that is minimally less prosodically complex than the final tonal output. For example, in the tonal strings that contain the extended prosodic structures (((σσ)₁σ)₂σ)₃, the tonal information in prosodic constituent 1 would serve as the base of constituent 2, and the tonal information in prosodic constituent 2 would serve as the base of prosodic constituent 3. Thus the tonal output in prosodic constituent 1 is referred to for correspondence by the tonal output in constituent 2. The tonal output in constituent 3 would refer to the tonal output in constituent 2, but not in constituent 1, for correspondence. The correspondences between constituent 2 and 1 as well as between constituent 3 and 2 take place in parallel. Like in paradigms (Benua 1997), the relation between the base and the output is asymmetrical. The base is prosodically prior to the output. Thus, while the output forms can copy the bases, the bases cannot copy the forms in the output. (That is, the base forms cannot be influenced by the outputs.) In sum, the tonal bases evaluated for correspondence in tone sandhi are freestanding tones that share underlying information with the tonal outputs and are minimally less prosodically complex than the tonal outputs.⁴

⁴ The Stress-ID constraint proposed in Duanmu (1997) to account for the domain of Shanghai tone sandhi also evaluates two outputs that share information in the inputs. (Duanmu 1997: 499)

Stress-ID: Given a compound [X Y], where X and Y are its immediate constituents, the surface stress locations in the X part and the Y part of the compound should be identical to those in [X] and [Y] respectively, where [X] and [Y] are independent occurrences of X and Y respectively.

However, there are two fundamental differences between Duanmu's study and the present study. First, in Duanmu's study, the output forms predicted from output-to-output correspondence are the domains where tone sandhi takes place, while in our study, the output forms predicted are the tonal outputs. Secondly, in Duanmu's study, the two outputs related for correspondence are morphosyntactically related while in the present study, the outputs related for correspondence are prosodically related.

The tonal correspondence model proposed here is an extension of the Correspondence Theory (McCarthy and Prince 1995). The correspondence relations could stand between underlying and surface forms (Input-output identity), between reduplicant and its base (base-reduplicant identity), between morphosyntactically related outputs (output-output identity), and as argued here, between prosodically related tonal outputs (output-tone-output-tone identity).

Prosodic structures could be referred to for correspondence just like the morphosyntactic structures because prosodic structures, like morphosyntactic structures, are cognitively real units. Evidence from psycholinguistic experiments show that human beings are not only sensitive to the prosodic structures but also attend to them in speech production/comprehension. For examples, Shattuck-Hufnagel and Turk (1996:227) observe that the prosody of speech (such as lengthening) is sensitive to the prosodic structures but not the syntactic structures, and Gerken (1996b) observes that prosodic changes are often observed at prosodic boundaries rather than syntactic boundaries. In a tone sandhi experiment, Speer et al. (1989) demonstrate that subjects of the experiments rely on the prosodic structures of the phrase to determine whether or not tone sandhi has applied. As a matter of fact, listeners are sensitive to and refer to information in the prosodic structures even when they are very young. Gerken's (1996b) experiment, for instance, points out that whether an object in young children's speeches is deleted or not has a lot to do with where the object is situated in a prosodic structure, but not in a syntactic structure. Phonologically, it has become a major view among researchers that phonological processes operate on prosodic structures but not on syntactic structures. (Selkirk 1984a, 1984b, 1986; Nespors and Vogel 1986). In tone sandhi, for instance, Shih (1986) proposes that the tone sandhi domain of Mandarin is the prosodic foot which is not isomorphic to the syntactic structures, and Hsiao (1991, 1995) argues that the tone sandhi domain of Taiwanese is the phonological phrase, rather than the syntactic phrase.

The reason that prosodically related output tonal strings prefer to be identical could be due to the consideration of minimizing the memory load. It has been observed in some psychological experiments that prosodic information plays a very important status in the cognitive process. Prosody can enhance word recognition (Lindfield et al. 1999), facilitate the process of comprehension (Sanderman and Collier 1997) and can keep utterances in memory (Speer et al. 1996). Identical prosodies actually do a lot of help in the cognitive process. In an interesting experiment, Speer et al. (1993) observe that previously heard sentences, even nonsense utterances, could be recognized more accurately on a second presentation if they were spoken with the same prosody as on their first presentation. The fact that even nonsense utterance could be recognized more accurately on a second presentation shows that it is the prosody alone, rather than the lexical meaning that enhances memory.

3. Further Evidence of Prosodic Correspondence from Sixian-Hakka Tone Sandhi

Here above, I have proposed a correspondence model for tone sandhi that requires identity between prosodically related bases and outputs. I have shown that the bases and the outputs must be prosodically related rather than morphosyntactically related because there are examples in Mandarin where the tone sandhi domains simply do not match the morphosyntactic structures. Here below, I would like to provide further evidence from tri-tonal sandhi in Sixian-Hakka. Tone sandhi in Sixian-Hakka and in Mandarin are very different in the tri-tonal examples. In tri-tonal strings, while tone sandhi in Mandarin is sensitive (though not isomorphic) to the morphosyntactic structures, operation of tone sandhi in Sixian-Hakka is completely blind to the morphosyntactic structures (see discussion in §

3.2). To account for the tone sandhi phenomena in Sixian-Hakka, a properly defined tone sandhi domain and the IDENT-BOT constraint are also in need. The tone sandhi domain will be shown to be prosodically defined, thus the IDENT-BOT constraint must refer to outputs that are prosodically related.

3.1 Data⁵ and Generalization

Sixian-Hakka is one of the Hakka sub-dialects spoken in Miaoli County, Taiwan. There are six tones in this dialect. They are LH(Hr,lh), L(Lr,l), ML(Lr,hl), H(Hr,h), M? (Lr,h) and H? (Hr,h). When a LH tone is followed by a LH tone, a H tone or a H? tone, tonal change occurs and changes LH to a L tone.

(42)

| 1 st tone | 2 nd tone | | |
|----------------------|----------------------|-------------|--------------|
| | LH | H | H? |
| LH | L .LH | L .H | L .H? |

Examples of the tonal changes are given below:

(43) ‘pig liver’

| | |
|-------------|----------------|
| | <i>tsu kon</i> |
| | pig liver |
| Base tone | LH.LH |
| Sandhi tone | L .LH |

(44) ‘hope’

| | |
|-------------|----------------|
| | <i>hi mong</i> |
| | hope |
| Base tone | LH.H |
| Sandhi tone | L .H |

(45) ‘thirty’

| | |
|-------------|-----------------|
| | <i>sam siip</i> |
| | three ten |
| Base tone | LH.H? |
| Sandhi tone | L .H? |

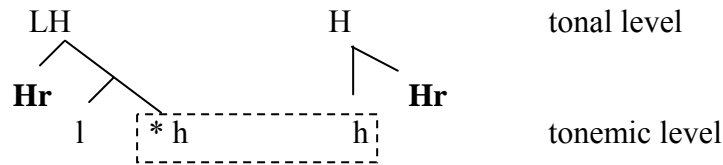
The fact that two LH tones cannot occur in juxtaposition can be easily accounted for by the OCP-T(LH) constraint.

(46) OCP-T(LH): Avoid adjacent LH tones at the tonal level. (*a categorical constraint*).

As for the disallowed tonal sequences, *LH.H, *LH.H?, it can be observed that the tones in both *LH.H and *LH.H? are partially identical. The two adjacent tones are high register (Hr) tones with h features at intersyllabic tonemic level (e.g. 47).

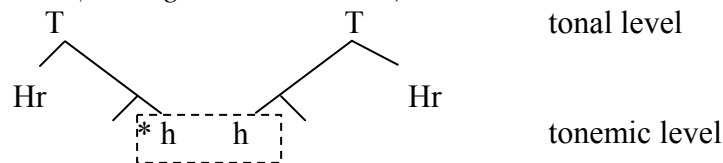
⁵ Data of Sixian-Hakka are drawn from Hsu (1996) and Hsiao (2000).

(47) *LH.H



Thus, they could be accounted for by a constraint that prohibits adjacent high register tones with high features at the intersyllabic tonemic level.

(48) HrOCP-t(h): Adjacent high register tones with h features in the intersyllabic tonemic level are prohibited.⁶ (*a categorical constraint*)



In addition to the above markedness constraints, the following faithfulness constraints, which have been proposed for Mandarin tone sandhi, are also essential in accounting for Sixian-Hakka tone sandh.

(49) IDENT-IO-T: Input-Output corresponding tones (at the tonal level) are identical. (*a gradient constraint*)

(50) IDENT-IO-T-R: The rightmost tone of an utterance (at the tonal level) is identical to its input correspondent.

The constraints OCP-T(LH), HrOCP-t(h) and IDENT-IO-T are in conflict. The markedness constraint OCP-T(LH) and HrOCP-t(h) must outrank the faithfulness constraint IDENT-IO-T to ensure that impermissible tonal sequences will not surface.

(51) { OCP-T(LH), HrOCP-t(h) } >> IDENT-IO-T

Input: LH.LH

Output: **L.LH** > LH.LH

The ranking for the tonal constraints proposed so far is:

(52) Tonal constraints and ranking for Sixian-Hakka :

{ IDENT-IO-T-R, OCP-T(LH), HrOCP-t(h) } >> IDENT-IO-T

The tableaux here below demonstrate how the bi-tonal sequences are correctly predicted for their tonal changes:

⁶ The adjacent tones with h features at the intersyllabic tonemic level are restricted to Hr tones to capture the fact that the LH.M? and the LH.ML sequences, which have h features at the intersyllabic level, do not undergo tonal change. The tonal change does not take place because M? and ML are not Hr tones.

(53) LH.LH → L.LH

| LH.LH | IDENT-IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-IO-T |
|-----------|--------------|-----------|------------|------------|
| ☞ a. L.LH | | | | * |
| b. LH.LH | | *! | | |
| c. LH.L | *! | | | * |
| d. L.L | *! | | | ** |

(54) LH.H → L.H

| LH.H | IDENT-IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-IO-T |
|----------|--------------|-----------|------------|------------|
| ☞ a. L.H | | | | * |
| b. LH.H | | | *! | |

3.2 Tri-tonal Strings

However, when it comes to tri-tonal strings, the constraints proposed above are not efficient to make the correct prediction. One important characteristic of Sixian-Hakka tri-tonal sandhi is that tone sandhi applies consistently from left to right, irrespective of the morphosyntactic structures. For example, both the morphosyntactically left branching (e.g. $\{\{tsu\ kon\} thong\}$ ‘pig liver soup’) and right branching (e.g. $\{mai\ \{tsu\ kon\}\}$ ‘buy pig liver’) utterances that are underlyingly LH.LH.LH will be derived the same tonal output L.L.LH.

(55)

| | Morpho-syn. Struc. | Input | Output | Derivation |
|----|--|----------|--------|---|
| a. | $\{\{tsu\ kon\} thong\}$ ‘pig liver soup’ $\{mai\ \{tsu\ kon\}\}$ ‘buy pig liver’ | LH.LH.LH | L.L.LH | $LH.LH.LH \rightarrow L.LH.LH \rightarrow L.L.LH$ \Rightarrow (compare w/ $LH.LH.LH \rightarrow *LH.L.LH$) |
| b. | $\{khai\ \{tsha\ hi\}\}$ ‘drive the car’ | LH.LH.H | L.L.H | $LH.LH.H \rightarrow L.LH.H \rightarrow L.L.H$ \Rightarrow (compare w/ $LH.LH.H \rightarrow *LH.L.H$) |
| c. | $\{mo\ \{kong\ fuk\}\}$ ‘not returned’ | LH.LH.H? | L.L.H? | $LH.LH.H? \rightarrow L.LH.H? \rightarrow L.L.H?$ \Rightarrow (compare w/ $LH.LH.H? \rightarrow *LH.L.H?$) |

Key: TT = current two-tone window scanned for possible rule application

\Rightarrow / \Leftarrow = the rule application directionalities by which the tonal outputs are derived

Consider the following examples first where the constraints set proposed in the previous section work all right.

(56)

| | Input | Output |
|----|----------|---------|
| a. | LH.LH.L | L.LH.L |
| b. | LH.H.ML | L.H.ML |
| c. | ML.LH.LH | ML.L.LH |
| d. | L.LH.H | L.L.H |

In (56), only one tone is conditioned for tonal change in each examples. Tone sandhi patterns of this type can be easily accounted for by the ranking in (52), as illustrated below:

(57) LH.H.ML → L.H.ML

| LH.H.ML | IDENT-IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-IO-T |
|-------------|--------------|-----------|------------|------------|
| ☞ a. L.H.ML | | | | * |
| b. LH.H.ML | | | *! | |

(58) ML.LH.LH → ML.L.LH

| ML.LH.LH | IDENT-IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-IO-T |
|--------------|--------------|-----------|------------|------------|
| ☞ a. ML.L.LH | | | | * |
| b. ML.LH.LH | | *! | | |

Now consider another tri-tonal pattern where all and only the rightmost tone remains unchanged (e.g. LH.LH.LH → **L.L.LH**). The tonal constraints set in (52) fails to make the correct prediction. As shown below, the current constraint ranking fails to select the attested output **L.L.LH**. Rather, candidate (b) is wrongly selected as the optimal candidate.

(59) LH.LH.LH → **L.L.LH**

| LH.LH.LH | IDENT-IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-IO-T |
|--------------|--------------|-----------|------------|------------|
| ☞ a. L.L.LH | | | | **! |
| ☛ b. LH.L.LH | | | | * |
| c. L.LH.LH | | *! | | * |
| d. LH.LH.LH | | *! | | |

One possible way to account for (59) is to propose that Sixian-Hakka disprefers any LH tones to surface in the output except in the utterance final position, which is due to the dominant IDENT-IO-T-R constraint. With this view, tone sandhi applies simultaneously to the string and changes all non-final LH tones to L.

(60)

Simultaneous application /LH.LH.LH/
 L.L.LH

This can be captured by the *LH constraint that bans LH tones to surface.

(61) *LH: No LH tones. (*a gradient constraint*)

By ranking it below the IDENT-IO-T-R constraint and above the IDENT-IO-T constraint, all but the final LH would change to sandhi tones and the output LH.L.LH would be successfully ruled out.

(62) IDENT-IO-T-R >> *LH >> IDENT-IO-T

Input: LH.LH.LH

Output: **L.L.LH** > LH.L.LH

However, such constraint ranking would wrongly force LH tones that are not followed by LH, H or H? tones in the underlying level to undergo tonal changes as well, as shown below:

(63) IDENT-IO-T-R >> *LH >> IDENT-IO-T
 Input: LH.ML
 Output: **L**.ML > LH.ML (wrong prediction!)

Thus, the *LH constraint should be abandoned.⁷

As a matter of fact, tri-tonal sandhi in (59) can be easily accounted if the IDENT-BOT constraint is included into the constraint set.

(64) { IDENT-IO-T-R, OCP-T(LH), HrOCP-t(h) } >> IDENT-BOT >> IDENT-IO-T

Assuming the tone sandhi domain of Sixian-Hakka is ((σσ)σ) (constraints for the tone sandhi domain will be proposed in §4, the candidate ((LH.L).LH) can be ruled out and the candidate ((L.L).LH) can be selected because the latter better satisfies the IDENT-BOT constraint.⁸

⁷ The OT analysis proposed in Hsiao (2000), which does not rely on the output-to-output correspondence constraint, has the similar problem of forcing LH tones to undergo tone sandhi even though they are not followed by LH, H and H? tones underlyingly. Consider (1) below. (In Hsiao's analysis, the H in LH is regarded as a floating tone which is not prelinked to the syllable in the underlying representation, and the high tones are regarded as constituting a separate autosegmental tier.)

(1) Input: *khoi tsha hi* LH.LH.H 'go to drive the car' (Hsiao 2000: 109)

| <i>khoi tsha hi</i> | OCP-H | Parse-R(H) | Align-R(H, P) | Max-IO(T) |
|---------------------|-------|------------|---------------|-----------|
| L L H H H | | | | |
| a. LH LH H | *!* | | *** | |
| b. LL H | | * | | ** |
| c. LH LH | | * | *!* | * |
| d. LL H H | *! | | * | * |

To select the overapplication output **L.L.H** and rule out the normal application output LH.L.H for the input /LH.LH.H/, the Align-R(H, P), which requires the right edge of every floating H to coincide with the right edge of a relevant prosodic domain, is essential and must dominate the Max-IO(T) constraint, which prohibits deletion of tones. However, the constraints and ranking (i.e., Align-R(H, P) >> Max-IO(T)) would force LH tones that are not followed by LH, H and H/ tones in the underlying level to wrongly undergo tonal changes. For example, the constraint ranking would force the LH tone in /LH.L.H/ to undergo tonal change though it is not properly conditioned, as illustrated in (2).

(2) Input: LH.L.H

| L H L H | OCP-H | Parse-R(H) | Align-R(H, P) | Max-IO(T) |
|------------|-------|------------|---------------|-----------|
| a. LL H | | * | | ** |
| b. LH L H | | * | *!* | * |

⁸ While the tone sandhi domains of Mandarin is sensitive (though not isomorphic) to the morphosyntactic structures, that of Sixian-Hakka is insensitive to the morphosyntactic structures. That is because in Sixian-Hakka, both the morphosyntactically left and right branching strings whose underlying tones are the same will have the same output tones. Thus, in Sixian-Hakka, a decision must be made concerning whether the domain of the tri-tonal strings is ((σσ)σ) or (σ(σσ)). It is proposed that the domain is the left branching ((σσ)σ). As shown below, the wrong domain (σ(σσ)) would make the wrong prediction for the input LH.LH.LH.

LH.LH.LH → (L.(L.LH)) Base: L.LH (← LH.LH)

| (LH.(LH.LH)) | IDENT- IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-BOT | IDENT-IO-T |
|----------------|---------------|-----------|------------|-----------|------------|
| a. (L.(L.LH)) | | | | | **! |
| b. (LH.(L.LH)) | | | | | * |

(65) LH.LH.LH → ((L.L).LH) Base: L. LH (←LH. LH)

| ((LH.LH).LH) | IDENT-IO-T-R | OCP-T(LH) | HrOCP-t(h) | IDENT-BOT | IDENT-IO-T |
|-----------------|--------------|-----------|------------|-----------|------------|
| ☞ a. ((L.L).LH) | | | | * | ** |
| b. ((LH.L).LH) | | | | **! | * |
| c. ((L.LH).LH) | | *! | | | * |
| d. ((LH.LH).LH) | | *! | | * | |

Thus, the IDENT-BOT constraint plays the crucial role in selecting the attested candidate for the tonal pattern where all but the last tone stays unchanged (i.e., T.T.T → **T.T.T**).⁹ The tone sandhi domain in Sixian-Hakka is prosodically defined. The prosodic domain ((σσ)σ) is not necessarily isomorphic to morphosyntactic structures. For example, though the prosodic domain matches the morphosyntactic structures of the strings such as *{tsu kon}thong* ‘pig liver soup’ whose morphosyntactic structure is left branching, the domain does not coincide with the morphosyntactic structures of the strings that are morphosyntactically right branching (e.g. *{mai {tsu kon}}* ‘buy pig liver’). Thus, the bases and the outputs related for correspondence should not be related by the morphosyntactic structures but are related by the prosodic structures.

In sum, tone sandhi in Sixian-Hakka provides further support to the prosodic correspondence model.

3.3 Overapplication and Identity Preservation

Here above, I have shown that IDENT-BOT which maximizes identity between prosodically related tonal outputs plays crucial roles in accounting for tone sandhi in Mandarin and Sixian-Hakka, especially in predicting the tonal outputs that involve tonal changes of all but the rightmost tone; that is, T.T.T → **T.T.T** (e.g. 66A). (66A) are examples where IDENT-BOT is crucial. On the other hand, (66B) are examples where IDENT-BOT is not that crucial.

(66)

| Dialects | IDENT-BOT | | A | | B | |
|-----------------|-----------|----------------|----------|----------|-------------|----------------|
| | | | Crucial | | Non-crucial | |
| | Input | Output | Input | Output | Input | Output |
| a. Mandarin | L.L.L | LH.LH.L | L.L.L | L.L.L | L.L.L | L.LH.L |
| b. Sixian-Hakka | LH.LH.LH | L.L.LH | LH.LH.ML | LH.LH.ML | LH.LH.ML | L.LH.ML |

By examining examples in (66A) and (66B) more closely, it could be found that the nature of the outputs is quite different. While examples in (66A) show overapplication and are opaque, examples in (66B) display normal application and are transparent. Overapplication refers to forms that are non-surface-apparent, that is, forms that has shown to undergo a process, though the structure description is not clear in the output.¹⁰ Normal application, on the other

⁹ Notice that the inclusion of the IDENT-BOT constraint will not influence the prediction for the bi-tonal sequences or the tri-tonal strings discussed above.

¹⁰ The term ‘non-surface-apparent’ come from McCarthy (1999). Phenomena that are not surface apparent are resulted from *overapplication* of the phonological rules.

Some generalization G shapes the surface form F, but the conditions that make G applicable are not visible in F. Serialism explains this by saying that the conditions on G are relevant only at the stage of the

hand, does not involve unconditioned changes. For example, (66Aa) involves overapplication because the structure description (i.e., L) of the Mandarin tone sandhi rule ($L \rightarrow LH / _ L$) that triggers the tonal change of the leftmost L tone is not recoverable at surface. It has been destroyed by a latter application of tone sandhi rule. Thus, it looks as if the tone sandhi rule has overapplied. (66Ba), on the other hand, shows normal application because the L tone that triggers the tonal change of the L tone in the middle is clear at surface. Studies in reduplications (McCarthy and Prince 1995) and paradigms (Benua 1997) show that opacities do not occur without any purposes. They are often the result of identity reasons. The correlation between opacity and identity is also born out in tone sandhi. The fact that IDENT-BOT, which requires identity between prosodically related outputs, plays the crucial role in accounting for overapplication patterns implies that overapplication in tone sandhi is an identity effect. Tone sandhi overapplies in order to maximize identity between prosodically related outputs. The maximization of identity is important in tone sandhi; even though it would result in forms that are non-transparent.¹¹

In the next section, prosodic constraints are proposed to account for the prosodic domains of Mandarin and Sixian-Hakka tone sandhi. We start from the tone sandhi domain of Sixian-Hakka, which is the relatively simple one.

4. Prosodic Constraints for Tone Sandhi Domains

4.1 Prosodic Constraints for Sixian-Hakka Tone Sandhi

Recall that the tone sandhi domain of Sixian-Hakka tone sandhi is $((\sigma\sigma)\sigma)$. In this section, I demonstrate how the tone sandhi domain is accounted for by the prosodic constraints. The tone sandhi domain $((\sigma\sigma)\sigma)$ can be derived by the simple interaction of the following prosodic constraints:

- (67) ALLFTL: Every foot stands at the left edge of the utterance. (*a categorical constraint*)
- (68) PARSESYLL: Parse every syllable into higher prosodic levels. (*a categorical constraint*)
- (69) BINBRAN: Phonological structures are binary branching. (*categorical constraint*)
- (70) FTBIN: Foot must be binary under syllabic analysis. (*a gradient constraint*)

derivation when G is in force. Later stages may obliterate the conditions that make G applicable (e.g. by destroying the triggering environment for a rule). (McCarthy 1999: 332)

In other words, an output form has shown to undergo a process, though the structure description is not clear in the output. *Overapplication* can be illustrated by the non-tonal example in Tunica (Haas 1940, Kenstowicz and Kisseberth 1979, Kager 1999b):

/ηI↔πυ?ΑκI/
 ηI↔πυ/□κI Vowel harmony
 ηI↔π?□κI Syncope
 [ηI↔π?□κI]

In the example, first, the initial vowel of the suffix /?ακI/ copies the backness and rounding of the rightmost stem vowel, then the unstressed vowel standing immediately before /?/ is deleted by the syncope rule. Since the consonant that triggers vowel harmony is deleted, the structure description of vowel harmony is no longer visible in the output. The phenomenon is the result of counterbleeding rule ordering because the application of the syncope rule could have destroyed the structure description of (/bled) the vowel harmony rule but the ordering is such that both rules apply. The application of the vowel harmony rule counterbleeds the syncope rule.

¹¹ Kiparsky (1973) claims that grammars should avoid rule orderings that produce opacity because opaque interactions are too abstract to be learned. On the other hand, Kisserberth (1973) and Kaye (1974) argue that opacity is functionally motivated because it makes lexical representation recoverable from output representations.

The constraints, BINBRAN and FTBIN, though seem similar, could have quite different effects. While the FTBIN constraint requires that a foot must contain 2 syllables, the BINBRAN constraint requires that every phonological unit (such as syllables, feet, and phonological phrases) must be binary branching. Thus, though the two constraints would have the same effects on prosodic structures like $(\sigma\sigma)(\sigma)$ and $(\sigma\sigma\sigma)$ (ref. (71)), their effects on domains such as $((\sigma\sigma)\sigma)$ are different. While the prosodic structure $((\sigma\sigma)\sigma)$ would incur violation in the FTBIN constraint because its outer foot contains more than two syllables, it satisfies the BINBRAN constraint because the outer foot is binary branching; it dominates two constituents, a binary foot and a syllable.

(71)

| $\{\sigma\{\sigma\sigma\}\}$ | BINBRAN | FTBIN |
|------------------------------|---------|-------|
| a. $(\sigma\sigma)(\sigma)$ | * | * |
| b. $(\sigma\sigma\sigma)$ | * | * |
| c. $((\sigma\sigma)\sigma)$ | | * |

As for the ranking among the constraints, the only crucial ranking is between the PARSESYLL constraint and the FTBIN constraint where the former must dominate the latter:

(72) PARSESYLL >> FTBIN

Input: $\sigma\sigma\sigma$

Output: $((\sigma\sigma)\sigma) > (\sigma\sigma)\sigma$

The prosodic constraint ranking proposed for tri-tonal strings of Sixian-Hakka tone sandhi is listed below:

(73) Prosodic constraint ranking for Sixian-Hakka tone sandhi

$\{\text{PARSESYLL, *BINBRAN, ALLFTL}\} >> \text{FTBIN}$

The tableaux below illustrate how the prosodic constraints predict the tonal domain for tri-tonal examples. (74) and (75) are examples with different morphosyntactic structures. It is shown that the prosodic constraints always select $((\sigma\sigma)\sigma)$ as the tonal domain, regardless of the morphosyntactic branching of the input.

(74)

| $\{\sigma\{\sigma\sigma\}\}$ | PARSESYLL | *BINBRAN | ALLFTL | FTBIN |
|------------------------------|-----------|----------|--------|-------|
| a. $((\sigma\sigma)\sigma)$ | | | | * |
| b. $((\sigma)\sigma\sigma)$ | | *! | | * |
| c. $(\sigma(\sigma\sigma))$ | | | *! | * |
| d. $(\sigma\sigma)(\sigma)$ | | *! | * | * |
| e. $(\sigma\sigma)\sigma$ | *! | | | |
| f. $\sigma(\sigma\sigma)$ | *! | | * | |
| g. $\sigma\sigma\sigma$ | *! | | | |
| h. $(\sigma\sigma\sigma)$ | | *! | | * |

(75)

| $\{\{\sigma\sigma\}\sigma\}$ | PARSESYLL | *BINBRAN | ALLFTL | FTBIN |
|------------------------------|-----------|----------|--------|-------|
| a. $((\sigma\sigma)\sigma)$ | | | | * |
| b. $((\sigma)\sigma\sigma)$ | | *! | | * |
| c. $(\sigma(\sigma\sigma))$ | | | *! | * |
| d. $(\sigma\sigma)(\sigma)$ | | *! | * | * |
| e. $(\sigma\sigma)\sigma$ | *! | | | |
| f. $\sigma(\sigma\sigma)$ | *! | | * | |
| g. $\sigma\sigma\sigma$ | *! | | | |
| h. $(\sigma\sigma\sigma)$ | | *! | | * |

4.2 Prosodic Constraints for Mandarin Tone Sandhi

This section presents a set of ranked prosodic constraints to derive the tone sandhi domains for Mandarin. The tone sandhi domains, though sometimes coincide with the morphosyntactic structures, are by no means isomorphic to them. The non-isomorphism between the prosodic structures and the morphosyntactic structures is most clearly illustrated by tone sandhi in PP discussed in §4.2.2, where it is shown that the tone sandhi domain needs to rely on information out of morphosyntactic structures; i.e., prosodic word. Tone sandhi in PP and non-PP has long been observed to be different (Shih 1986, Zhang 1997, Lin 2000, among others). As mentioned above, the difference of the tonal patterns is left unresolved in the derivational analysis in Shih (1986). In the present analysis, just like that proposed in Shih (1986), we assume that the tone sandhi domain of Mandarin tone sandhi is a prosodic foot. However, unlike Shih's approach, the analysis in this paper provides a unified solution for tone sandhi in both PP and non-PP utterances without stipulation.

4.2.1 The Non-PP Utterances

To account for Mandarin tone sandhi, the following three constraints PARSESYLL, *BINBRAN and FTBIN that are proposed for Sixian-Hakka tone sandhi are also in need with the ranking $\{\text{PARSESYLL}, *BINBRAN\} \gg \text{FTBIN}$. The domination of PARSESYLL and *BINBRAN over the FTBIN constraint will predict two tonal domains for tri-tonal strings. They are $((\sigma\sigma)\sigma)$ (76a) and $(\sigma(\sigma\sigma))$ (76b). How should the decision be made between $((\sigma\sigma)\sigma)$ and $(\sigma(\sigma\sigma))$?

(76)

| $\sigma\sigma\sigma$ | PARSESYLL | *BinBran | FTBIN |
|-----------------------------|-----------|----------|-------|
| a. $((\sigma\sigma)\sigma)$ | | | * |
| b. $(\sigma(\sigma\sigma))$ | | | * |
| c. $(\sigma)(\sigma\sigma)$ | | *! | * |
| d. $\sigma(\sigma\sigma)$ | *! | | |
| e. $(\sigma\sigma\sigma)$ | | *! | * |

Since Selkirk (1986), it is often agreed that prosodic structures of a language are sensitive, though not necessarily isomorphic, to that language's syntactic structure (Shih 1986, Hsiao 1991, 1995, etc.). In the derivational tradition, the End-based Theory (Selkirk 1986) is proposed to account for the relation between the prosodic and the syntactic structures, where the prosodic structures are posited to be defined in terms of the right or left ends of syntactic constituents of designate types. In OT, the edge sharing phenomena between syntactic and prosodic structures are captured by the family of Generalized Alignment constraint proposed in McCarthy and Prince (1993).

(77) Generalized Alignment (McCarthy & Prince 1993: 80)
 Align (Cat1, Edge1, Cat, Edge 2) = def
 \forall Cat1 \exists Cat2 such that Edge 1 of Cat1 and Edge2 of Cat2 coincide.
 Where Cat1, Cat2 \in PCat \cup GCat
 Edge1, Edge2 {Right, Left}

The Generalized Alignment constraint is based on the End-based Theory but is extended to account for the edge sharing phenomena of all kinds of grammatical categories, including morphological as well as syntactic categories, and all kinds of prosodic categories, including the word-internal prosodic categories such as syllables, feet, and features.

In Mandarin, the foot formation is also sensitive to the syntactic structures, in particular, the immediate constituent (IC) of a sentence (Shih 1986). To predict the foot formation in Mandarin, the following alignment constraint is proposed.

- (78) The ALIGNIC/FT Constraint (ALIGNIC/FT) (*a gradient constraint*)
- a. ALIGN(IC, FT)L: The left edge of every immediate constituent (IC) is aligned with the left edge of some foot (Ft).
 - b. ALIGN(IC, FT)R: The right edge of every immediate constituent (IC) is aligned with the right edge of some foot (Ft).

The ALIGNIC/FT constraint requires that the left and the right edges of every IC must be aligned with the left and the right edges of a foot. This constraint can now make decision between the output foot structures $(\sigma(\sigma\sigma))$ and $((\sigma\sigma)\sigma)$ generated from tri-tonal inputs. The ALIGNIC/FT constraint would select $(\sigma(\sigma\sigma))$, but not $((\sigma\sigma)\sigma)$, as the optimal foot structure if the morphosyntactic structure of the input is $\{\sigma\{\sigma\sigma\}\}$ because the left edge of the second syllable in the latter foot structure which is an IC boundary is not left aligned with a foot boundary. It should be noted, however, that it is not always true that the left and the right edges of every IC are always aligned with the left and the right edges of a foot in the attested output. For instance, for quadrasyllabic input with recursive IC structures like $\{xiang\{mai\{shui\ tong\}\}\}$ 'want to buy water pail', the attested foot domain is always not the one that obeys the ALIGNIC/FT constraint, namely $(xiang(mai(shui\ tong)))$, but is the one that has the structure $(xiang\ mai)(shui\ tong)$, unless the string is a single lexical word that will be discussed later in (86B). Obviously, the selection of $(\sigma\sigma)(\sigma\sigma)$ before $(\sigma(\sigma(\sigma\sigma)))$ for the input $\{\sigma\{\sigma\{\sigma\sigma\}\}\}$ is to minimize the violations in the FTBIN constraint, even though the ALIGNIC/FT constraint would be sacrificed a bit. The tableaux here below show that the FTBIN constraint can be ranked equal to (e.g. (79)) or higher (e.g. (80)) than the ALIGNIC/FT constraint, but never lower than it (e.g. (81)).

(79) 'want to buy water pail'

| <i>xiang mai shui tong</i> want buy water pail $\{\sigma\{\sigma\{\sigma\sigma\}\}\}$ | FTBIN | ALIGNIC/FT | |
|---|-------|------------|---|
| | | L | R |
| a. $(\sigma(\sigma(\sigma\sigma)))$ | *** | | |
| ☞ b. $(\sigma\sigma)(\sigma\sigma)$ | | * | |

(80) 'want to buy water pail'

| | | | |
|--|-------|------------|---|
| <i>xiang mai shui tong</i> want buy water pail $\{\sigma\{\sigma\{\sigma\sigma}\}\}$ | FTBIN | ALIGNIC/FT | |
| | | L | R |
| a. $(\sigma(\sigma(\sigma\sigma)))$ | ***! | | |
| ☞ b. $(\sigma\sigma)(\sigma\sigma)$ | | * | |

(81) ‘want to buy water pail’

| | | | |
|--|------------|---|-------|
| <i>xiang mai shui tong</i> want buy water pail $\{\sigma\{\sigma\{\sigma\sigma}\}\}$ | ALIGNIC/FT | | FTBIN |
| | L | R | |
| ☞ a. $(\sigma(\sigma(\sigma\sigma)))$ | | | *** |
| b. $(\sigma\sigma)(\sigma\sigma)$ | *! | | |

The following example further shows that the FTBIN constraint must not dominate the ALIGNIC/FT constraint.

(82) ‘want to hit the dog to flat’

| | | | |
|---|-------|------------|---|
| <i>xiang da bian gou</i> want hit flat dog $\{\sigma\{\{\sigma\sigma\}\sigma\}$ | FTBIN | ALIGNIC/FT | |
| | | L | R |
| ☞ a. $(\sigma((\sigma\sigma)\sigma))$ | **! | | |
| ☛ b. $(\sigma\sigma)(\sigma\sigma)$ | | * | * |

Thus, the FTBIN constraint must be equally ranked with the ALIGNIC/FT constraint. In addition, the ALIGNFT/IC constraint is in need to select (82a) as the optimal domain, as shown in (84).

(83) The ALIGNFT/IC Constraint (ALIGNIC/FT) (*a gradient constraint*)

- a. ALIGN(FT, IC),L: The left edge of every foot (Ft) is aligned with the left edge of some immediate constituent (IC).
- b. ALIGN(FT, IC),R: The right edge of every foot (Ft) is aligned with the right edge of some immediate constituent (IC).

The constraints of ALIGNFT/IC proposed here and ALIGNIC/FT proposed above have different effects. The ALIGNFT/IC constraint requires that the left and the right edges of *every* foot is aligned with the left and the right edges of *some* IC. It does not care about whether the left and the right edges of *every* IC is aligned with the corresponding edges of *some* foot or not. On the contrary, ALIGNIC/FT requires that the left and the right edges of *every* IC is aligned with the left and the right edges of *some* foot. It does not care whether *every* foot is aligned with *some* IC (McCarthy and Prince 1993a). The combination of the two constraints thus prefers complete coincidence between the prosodic and the morphosyntactic structures.

The ALIGNIC/FT constraint is ranked below the FTBIN constraint and the ALIGNIC/FT constraint so that it is only effective when FTBIN and ALIGNIC/FT fail to pick out the attested candidate.

(84) ‘want to hit the dog to flat’

| | | | | | |
|--|-------|------------|---|------------|---|
| <i>xiang da bian gou</i> want hit flat dog {σ{{σσ} σ}} | FTBIN | ALIGNIC/FT | | ALIGNFT/IC | |
| | | L | R | L | R |
| ☞ a. (σ(σσ)σ) | ** | | | | |
| b. (σσ)(σσ) | | * | * | *! | * |

In sum, the current constraint ranking for Mandarin is:

(85) { PARSESYLL, *BINBRAN } >> { FTBIN, ALIGNIC/FT } >> ALIGNFT/IC

In the preceding passage, I have shown that the FTBIN constraint should be equally ranked with the ALIGNIC/FT constraint to predict the correct tonal domains. However, there seem to be some cases that show that the ALIGNIC/FT constraint should outrank the FTBIN constraint. Compare A column with B column in (86).

(86)

| (A) { FTBIN , ALIGNIC/FT } | (B) ALIGNIC/FT >> FTBIN |
|---|--|
| ‘want to buy water pail’ <i>xiang mai shui tong</i> want buy water pail {σ {σ{σσ}}} (LH.L)(LH.L) | ‘soft dog biscuit’ <i>ruan gou bing gan</i> soft dog biscuit {σ{σ{σσ}}} (L.(LH.(L.H))) |
| ‘It’s good to have only few casinos’ <i>du chang shao hao</i> gamble factory few good {{{σσ}σ}σ} (LH.L)(LH.L) | ‘to Mr. Proctor’ <i>fu dao zhang qi</i> proctor open {{{σσ}σ}σ} (((LH.LH.)LH.)L) |

The examples in column A and column B have exactly the same immediate constituencies, but surprisingly, the attested foot structures for them are completely different. Therefore, it is clear that a constraint ranking that could predict the outputs for column A would certainly fail to predict the outputs for column B. To derive the foot structures in column A, where the ALIGNIC/FT constraint is sacrificed to satisfy the FTBIN constraint, the ALIGNIC/FT constraint cannot outrank the FTBIN constraint. On the contrary, to derive the foot structures in column B, where the FTBIN constraint is sacrificed to satisfy the ALIGNIC/FT constraint, the ALIGNIC/FT constraint must outrank the FTBIN constraint as shown below:

(87) ‘soft dog biscuit’

| | | | |
|--|------------|---|-------|
| <i>ruan gou bing gan</i> soft dog biscuit {σ{σ{σσ}}} | ALIGNIC/FT | | FTBIN |
| | L | R | |
| ☞ a. (σ(σ(σσ))) | | | *** |
| b. (σσ)(σσ) | *! | | |

The examples above seem to present a ranking paradox between the FTBIN constraint and the ALIGNIC/FT constraint. However, by having a closer examination of the above examples, it can be noticed that despite the fact that the examples in the two columns have the same IC structures, they have very different (grammatical) word structures (as oppose to

the prosodic word structures here below). (88) and (89) illustrate the differences between the word structures of the examples in (86A) and (86B). (<...> = grammatical word)

(88)

| | | |
|-------------------------|---|--|
| | ‘want to buy water pail’ <i>xiang mai shui tong</i> want buy water pail | ‘soft dog biscuit’ <i>ruan gou bing gan</i> soft dog biscuit |
| Immediate Constituency | {σ{σ{σσ}}} | {σ{σ{σσ}}} |
| Word Structure | <σ><σ><σσ> | <σ<σ<σσ>>> ¹² |
| Prosodic Foot Structure | (σσ)(σσ) | (σ(σ(σσ))) |

(89)

| | | |
|-------------------------|--|--|
| | ‘It’s good to have only few Casino’ <i>du chang shao hao</i> gamble factory few good | ‘to Mr. Proctor’ <i>fu dao zhang qi</i> proctor open |
| Immediate Constituency | {{{σσ}σ}σ} | {{{σσ}σ}σ} |
| Word Structure | <σσ><σ><σ> | <<σσ>σ><σ> |
| Prosodic Foot Structure | (σσ)(σσ) | ((σ(σσ)σ)σ) |

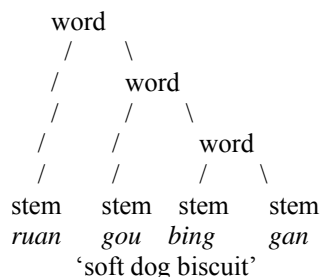
The problem of why the examples in columns (86A) and (86B) have exactly the same IC structures but have completely different foot structures becomes explicable. The reason why the foot structures for column B should not be (σσ)(σσ) is that it would break the grammatical word into two pieces.¹³ Take (90) for illustration:

(90) ‘to Mr. Proctor’

< (σ₁σ₂)_{f1} > (σ₃> <σ₄>)_{f2}
fu dao zhang qi
 proctor open

In (90), σ₁, σ₂ and σ₃ constitute a grammatical word, but f₂ would separate σ₃ from σ₁ and σ₂ and group it with σ₄. To avoid breaking a single grammatical word into pieces, we can resort to the following alignment constraint that requires the left and the right edges of every

¹² Following Ito & Mester (1998:36), I refer to the terminal elements in the tree diagrams of compounds or words consisting of complex morphological objects as stems and the non-terminal elements as (grammatical) words. For example, the word internal structures of the complex word *ruan gou bing gan* is <*ruan* <*gou* <*bing gan* >>> as depicted below.



¹³ That grammatical words in Mandarin should not be broken into different feet was first pointed out by Shih (1986: 136-142). However, Shih does not provide an analysis to them. Clearly, the FFR proposed in Shih cannot make the prediction for the different foot structures in (85A) and (85B), as (85A) and (85B) have exactly the same IC structures.

foot to be aligned with the corresponding edges of a word.

(91) The ALIGN_{FT/WD} Constraint (ALIGN_{FT/WD}) (*a gradient constraint*)

- a. ALIGN_(FT, WD)L: The left edge of every foot (Ft) is aligned with the left edge of some (grammatical) word (Wd).
- b. ALIGN_(FT, WD)R: The right edge of every foot (Ft) is aligned with the right edge of some (grammatical) word (Wd).

The ALIGN_{FT/WD} constraint should outrank the FT_{BIN} constraint. The ranking proposed for the present prosodic constraints is:

(92) { PARSE_{SYLL}, BIN_{BRAN} } >> ALIGN_{FT/WD} >> { FT_{BIN}, ALIGN_{IC/FT} } >> ALIGN_{FT/IC}

The following tableau illustrates how the constraint ranking in (92) functions to predict the domain output for Mandarin tone sandhi.

(93) ‘to Mr. proctor’

| <i>fu dao zhang qi</i> proctor open {{{σσ}σ}σ} <<<σσ>σ><σ> | PARSE SYLL | *BIN BRAN | ALIGN _{FT/WD} | | FT _{BIN} | ALIGN _{IC/FT} | | ALIGN _{FT/IC} | |
|---|---------------|--------------|------------------------|---|-------------------|------------------------|---|------------------------|---|
| | | | L | R | | L | R | L | R |
| ☞ a. (((σσ)σ)σ) | | | | | *** | | | | |
| b. (σσ)(σσ) | | | *! | | | | * | * | |

4.2.2 The PP Utterances

Consider now PP. Tone sandhi patterns of PP and non-PP with the same morphosyntactic structures could be quite distinct. This can be illustrated by the following two examples:

(94)

| | a. <i>ma bi gou xiao</i> horse compare dog small ‘the horse is smaller than the dog’ | b. <i>xiang da bian gou</i> want hit flat dog ‘want to hit the dog to flat’ |
|-------------------------|--|---|
| Immediate Constituency | {σ{{σσ}σ}} | {σ{{σσ}σ}} |
| Word Structure | <σ><σ><σ><σ> | <σ><σ><σ><σ> |
| Prosodic Foot Structure | (LH.L)(LH.L) | (L.((LH.LH).L)) |

Clearly, the tonal patterns of (94a) must be derived from (σσ)(σσ) while that of (94b) must be derived from (σ((σσ)σ)).

The different tone sandhi domains of course could not be explained by the morphosyntactic structures, but will be shown to be explicable based on information outside of them. As shown below, the two examples actually have different prosodic word structures.

(95)

| | | |
|-------------------------|--|---|
| | a. <i>ma bi gou xiao</i> horse compare dog small 'the horse is smaller than the dog' | b. <i>xiang da bian gou</i> want hit flat dog 'want to hit the dog to flat' |
| Prosodic Word Structure | [σ]σ[σ][σ] | [σ][σ][σ][σ] |
| Prosodic Foot Structure | (LH.L)(LH.L) | (L.((LH.LH.)L)) |
| | *(LH.((L.LH).L)) | *(L.LH).(LH.L) |

[...] = prosodic word

The prosodic word in Mandarin is defined here as equal to a lexical word (e.g. Noun, Verb, Adjective, etc). The functional categories (e.g. Prep. classifier, pronoun, etc.) do not constitute prosodic words. For example, in the string, *ma bi gou xiao* 'the horse is smaller than the dog', *ma*, *gou* and *xiao* are lexical categories and form prosodic words respectively. The word *bi* is a function word, and therefore does not form a prosodic word. The prosodic structure for the string is thus [ma] bi [gou][xiao].¹⁴

Thus, the difference between tone sandhi domains of (95a) and (95b) can be captured by the constraint that requires the left edge of a prosodic foot be aligned with the left edge of a prosodic word.

(96) ALIGN(FT, PRWD)L: The left edge of every foot (Ft) is aligned with the left edge of some prosodic word (Prwd). (*a gradient constraint*)

The newly proposed constraint is ranked below the FTBIN constraint and above the ALIGNFT/IC constraint.

(97) { PARSESYLL, BINBRAN } >> ALIGNFT/WD >> { FTBIN, ALIGNIC/FT } >> ALIGN(FT, PRWD)L >> ALIGNFT/IC

The following tableaux show how the constraint ranking in (97) functions to predict the domain outputs for PP and non-PP in Mandarin tone sandhi.

¹⁴ In OT, this can be captured by positing the following two constraints. However, for ease of discussion, it is omitted in this paper.

(1) AlignLex/Prwd Constraint (= (WdCon) Selkirk 1995)

- a. Align(Lex, Prwd)L: The left edge of every Lexical word (Lex) is aligned with the left edge of some Prosodic word (Prwd).
- b. Align(Lex, Prwd)R: The right edge of every Lexical word (Lex) is aligned with the right edge of some Prosodic word (Prwd).

(2) Align Prwd/Lex Constraint (= (PwCon) Selkirk 1995)

- a. Align(Prwd, Lex)L: The left edge of every Prosodic word (Prwd) is aligned with the left edge of some Lexical word (Lex).
- b. Align(Prwd, Lex)R: The right edge of every Prosodic word (Prwd) is aligned with the right edge of some Lexical word (Lex).

(98) ‘The horse is smaller than the dog.’ (with PP)

| <i>ma bi gou xiao</i> {σ{{σσ}σ}} <σ><σ><σ><σ> [σ]σ[σ][σ] | ALIGNFT/WD | | FTBIN | ALIGNIC/FT | | ALIGN (FT, PRWD)L | ALIGNFT/IC | |
|---|------------|---|-------|------------|---|----------------------|------------|---|
| | L | R | | L | R | | L | R |
| a. (σ((σσ)σ)) | | | ** | | | *! | | |
| ☞ b. (σσ)(σσ) | | | | * | * | | * | * |
| c. (σ(σ(σσ))) | | | ***! | | * | * | * | |
| d. (((σσ)σ)σ) | | | ***! | * | | | | * |

(99) ‘want to hit the dog to flat’ (without PP)

| <i>xiang da bian gou</i> want hit flat dog {σ {{σσ} σ}} <σ><σ><σ><σ> [σ][σ][σ][σ] | ALIGNFT/WD | | FTBIN | ALIGNIC/FT | | ALIGN (FT, PRWD)L | ALIGNFT/IC | |
|---|------------|---|-------|------------|---|----------------------|------------|---|
| | L | R | | L | R | | L | R |
| ☞ a. (σ((σσ)σ)) | | | ** | | | | | |
| b. (σσ)(σσ) | | | | * | * | | *! | * |
| c. (σ(σ(σσ))) | | | ***! | | * | | * | |
| d. (((σσ)σ)σ) | | | ***! | * | | | | * |

The domain (σ((σσ)σ)) is selected for (99) but not for (98) because the left edge of the inner foot is aligned with the left edge of a prosodic word in the former, but not in the latter. Because the preposition *bi* in the latter does not form a prosodic word. The newly proposed constraint ALIGN(FT, PRWD)L would not influence the analysis of the non-prepositional examples above because all the non-prepositional words are lexical words, thus constitute prosodic words. Consequently, the new constraint functions the same as the dominant ALIGN(FT, WD)L constraint in the non-prepositional strings.

4.2.3 Transliterations

Recall that the prosodic domain for native Mandarin tone sandhi can vary between ((σσ)σ) and (σ(σσ)) depending on the morphosyntactic and prosodic structures of the word strings. However, the prosodic domain of tri-tonal transliterations, which have no internal morphosyntactic structures, is consistently ((σσ)σ). Can the prosodic constraints set proposed above make the correct prediction for the tone sandhi domain for transliterations? As can be seen below, the prosodic constraint set for native words can successfully select ((σσ)σ) and rule out (σ(σσ)) for transliterations.

(100) ‘Armagh’

| <i>ya er ma</i> {σσσ} <σσσ> [σσσ] | ALIGNFT/WD | | FTBIN | ALIGNIC/FT | | ALIGN (FT, PRWD)L | ALIGNFT/IC | |
|--|------------|---|-------|------------|---|----------------------|------------|---|
| | L | R | | L | R | | L | R |
| ☞ a. ((σσ)σ) | | * | * | | | | | * |
| b. (σ(σσ)) | * | | * | | | *! | * | |

As transliterations have no internal word structures, the internal domains of candidates

(a) and (b) in (100) will each incur a violation in the ALIGN_{FT/WD} constraint. Candidate (a) violates the constraint because the right edge of the inner foot is not aligned with the corresponding edge of a word while candidate (b) violates the constraint because the left edge of the inner foot is not aligned with the corresponding edge of a word. As for the FT_{BIN} constraint and the ALIGN_{IC/Ft} constraint, both candidate (a) and (b) incur one violations in the former and no violations in the latter. Consider now the ALIGN_{(FT, PRWD)L} constraint. Transliterations are lexical words; therefore, for transliterations, the (grammatical) word structures equal to the prosodic word structures. Since violations to the ALIGN_{(FT, PRWD)L} will only be violated when the *left* edge of a foot is not aligned with the corresponding edge of the prosodic word, candidate (b) is ruled out by the constraint. Consequently, the left branching prosodic domain is correctly selected for transliterations.

In sum, the discussion on the prosodic domains for PP/ non-PP as well as on transliterations shows that the prosodic structures in Mandarin, though sensitive to the morphosyntactic structures, are by no means equal to them. Thus, the tone sandhi domains of Mandarin tone sandhi are prosodically defined.

5. Conclusion

Based on observations of tone sandhi in Mandarin and Sixian-Hakka, a prosodic correspondence model is proposed for the tone sandhi phenomena. The correspondence model requires identity between tonal outputs that stand in certain prosodic relationships. The prosodic correspondence model proposed here is an extension of the Correspondence Theory (McCarthy and Prince 1995) which are previously argued to regulate identity relationships between underlying and surface forms (Input-output identity), between reduplicant and its base (base-reduplicant identity), and between morphosyntactically related outputs (output-output identity). In the model proposed here, the two tonal outputs evaluated for correspondence are related by prosodic structures which are by no means isomorphic to the morphosyntactic structures. The bases evaluated for correspondence in tone sandhi are output tones that share underlying information with the tonal outputs and are minimally less prosodically complex than the tonal outputs. Maximization of identity between prosodically related tonal outputs plays an important role in tone sandhi. A tonal output would strive to be more like the tonal base to which it prosodically relates, even though the maximization of identity would sometimes generates forms that are less transparent.

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