Complex variations of Mandarin T3 tone sandhi in violable cyclicity of PF postsyntactic linearization

Liu Haiyang

Abstract

Variations in Mandarin T3 tone sandhi have been a headache over decades both in theoretical and experimental research in Chinese phonology (See Cheng 1970, 1973; Selkirk 1984; Shih 1986; Kaisse 1985, 1990; Chen 2008; Wang and Lin 2011; Zhang 2014 among others). To accommodate the perplexing variations, I propose a "violable cyclicity" based on the direct spell-out model of PF linearization (Pak 2008; Embick 2007, 2010) in Distributed Morphology (Halle & Marantz 1993; Harley & Noyer 1999; Embick & Noyer 2007 among others). The morphosyntactic cyclicity between the post-syntactic linearization cycles interacts with the phonological cyclicity of bleeding features in Mandarin T3 tone sandhi, forming a special "double-cyclicity". This mechanism can derive accurate and sufficient T3 sandhi variations, compared with alternative approaches, e.g., prosodic analysis based on recursive metrical foot formation.

It may suggest that the syntax-related properties (e.g., the recursive foot formation mapped from syntactic hierarchies) are too strict when we handle the current perplexing data of cyclic phrasal phonological phenomena. The PF linearization process can ease the limitation of recursive prosodic structure mapped from syntactic hierarchy, providing the possibility of flexible postlexical cyclicity shown in Mandarin T3 tone sandhi. We would expect that the current study provides a meaningful analysis to support the direct spell-out models at the morphosyntax and phonology interface. The case of "unusual" cyclicity in phrasal/postlexical phonology may give us a new perspective to look at the information transmission from morphosyntax to phonology.

1. Introduction

In Mandarin there are 4 lexical tones, T1 high-level, T2 high-rising, T3 low-dipping and T4 high-falling tones (Chao 1968). Mandarin T3 tone sandhi is a typical external tonal sandhi phenomenon applying across word boundaries, citation form T3 (low-dipping) is changed to sandhi form T2 (high-rising) if followed by another T3: T3 → T2 / ___T3.

In this paper, we argue that Mandarin T3 tone sandhi can be better accommodated in the direct spellout model of multiple-stage PF linearization, with variability of prosodic factors, e.g., speech rate, only at the late stage of PF (Pak 2008).

The data of T3 tone sandhi in Mandarin Chinese shows that sandhi domains are derived from "a series of linearization procedures to create 'sub-units' of various sizes" at PF (Pak 2008), under the general framework of Distributed Morphology (Halle & Marantz 1993;

Harley & Noyer 1999; Embick & Noyer 2007 among others). Only at the late stage of PF (Late-Linearization), prosodic factors start to join the play. The current approach follows the derivational computation of phonological domains (Alessandra & Tobias 2015), in contrast with representational computation, e.g., Optimality theory (McCarthy & Prince 1995). Phonological domains are constrained by spelled out morphosyntactic structures undergoing a series of linearization operations at PF, but mediated by prosodic/rhythmic variability only at the late stage of PF.

Post-syntactic operations are abundantly investigated in the field of morphosyntax and its interface with Phonology (PF) and Semantics (LF) (see Marantz 1988; Bobaljik 2005, 2008; Boskovic 1998, 2001, 2011, 2017; Arregi & Nevins 2007, 2008a, 2008b, 2017; Embick 2007, 2010, 2013; Embick & Marantz 2008; Embick & Noyer 1999, 2001, 2007; Myler 2013, 2017 among others). More recent discussions of post-syntactic movements focused on verbal morphosyntax and the PF interface can be found in many discussions (e.g., see Talic 2019, Martinović 2019, Pietraszko 2021 among others).

In Distributed Morphology, PF is a complex structure, where various kinds of PF movements take place, e.g., linearization, morphological merger, local dislocation, impoverishment rules, etc. In Pak (2008), PF linearization is divided into several stages. In early operations, i.e., LIN and Concatenation operations, early short linearized strings are conditioned by c-command relations between Morphological words. In late operations, early linearized strings are linked into integral longer chains Chaining operation, and integral linearized chains are merged or split according to prosodic factors at Late-Linearization operation, when the speech-rate sensitive phonological rules apply at this late stage (see section 2 for detailed discussion).

The direct spell-out model of PF linearization in Pak (2008) is shown graphically in (1), phonological rules apply directly in the domains derived from multiple stages of post-syntactic linearization at PF. In (1), suppose a sequence of M-words (Embick 2007, 2010) of (M1 M2 M3 M4). At Concatenation, c-command conditioned early linearized strings are specified as (M1 M2) and (M2 M3 M4), with red brackets indicating the c-command linearized string and blue brackets indicating non c-command linearized string. At Chaining, a longer linearization chain is constructed by the early linearized strings, the domain **c**. At Late-Linearization, domains of speech-rate sensitive phonological rules (e.g., T3 tone sandhi) are merged into larger domains in fast speech, the domain **d**, and split into smaller domains in slow speech, the domain **e**.

(1) Linearization model in Pak (2008)

	M1 M2 M3 M4
Concatenation:	**a**. (M1 M2) **b**. (M2 M3 M4)
Chaining:	**c**. M1-M2-M3-M4
Late-Linearization:	**d**. (M1 M2 M3 M4…) in fast speech rate **e**. (M1) (M2) (M3) (M4) or (M1 M2) (M3 M4)... in slow speech rate

The current study shows that complex variations in long sequences of words involving consecutive T3 sandhi behaviors are potentially due to the double-adjustion system: some variations are induced by **prosodic factors**, e.g, speech rate, and some other variations must be induced by **underlying morphosyntactic factors**. Here, this morphosyntactic factor is the "violable cyclicity" of post-syntactic linearization between the early linearization cycles at Concatenation.

We would like to introduce a violabe cyclicity at Chaining operation in (1). The linearization structure at Chaining is not shown as a flat linearized chain like (M1-M2-M3-M4) in (1), instead, a cyclic chain, e.g, (M1 (M2) M3 M4), needs to be formed, which is illustrated in (2). The (M1 M2) and (M2 M3 M4) are multiple cycles of domain. In In Default Form **c1**, the linearization chain is constructed **from the most embedded inner cycle to outer cycle** (right to left). In Violated Form **c2**, the linearization chain is constructed **from outer to inner cycle** (left to right). More Violated Forms can be formed if we increase the number of cycles of linearization at Concatenation, as the orders between linearization cycles can be extremely flexible, e.g., in 3 cycles, flexible orders can be 1-2-3; 3-2-1; 2-1-3; 2-3-1,1-3-2. This provides abundant possibilities to derive T3 tone sandhi variations in the postlexical cyclicity.

(2) Modified version of linearization model in Pak (2008)

M1 M2 M3 M4

Concatenation: **a**. (M1 M2)
b. (M2 M3 M4)

Chaining: (M1 (M2) M3 M4)

c1. default (M2 M3 M4) —1° cycle
(M1 M2) —2° cycle

c2. violated (M1 M2) —2° cycle
(M2 M3 M4) —1° cycle

Late-Linearization: **d**. (M1 M2 M3 M4…) in fast speech rate
e. (M1) (M2) (M3) (M4) or (M1 M2) (M3 M4)...
in slow speech rate

The direction that phrasal phonological rules applies need to be refined in the current model: in more common cases of tone-spreading type of sandhi phenomena, it is supposed to apply in the Default Form of direction from right to left, both inside the early linearized strings (**a** domain in (1/2)), e.g., Luganda Low-tone deletion (LTD), and in the late integral linearized chains (**c1** domain in (2)), e.g., Luganda High Tone Anticipation (HTA).

However, some phrasal phonological phenomena, i.e., Mandarin T3 tone sandhi, are equipped with bleeding effects. In a domain involving consecutive sandhi behaviors, e.g., in a domain bearing base tone of (T3 T3' T3"). According to the sandhi rule T3: T3 → T2 / ___T3, the sandhi of T3' bleeds the sandhi of T3. The bleeding effect naturally raises the issue of cyclicity, which means sandhi rule applies in repeated times, and at the same time, the different forms of cyclicity derive different surface results (with bleeding effects or not). If sandhi rule applies from the inner (most embedded) cycle (T3' T3'') to outer cycle (T3 T3' T3''), the surface tone is (T3 T2 T3), whereas the counter-order from outer to inner cycle derives surface tone of (T2 T2 T3).

To incorporate these tonal behaviors with bleeding effects, the direction of phonological rules application are modified as below:

(3) Phrasal phonological rules application in domains of PF linearization:

Early rules: Early rules follow either right-to-left or left-to-right direction to apply in early linearization cycles, which are the **a)** and **b)** domains in (2) above.

Late rules:

i. Many late phonological rules follow the Default Form of "right to left" cyclic order (linearization cyclicity) between early linearization cycles, which is the default **c1** domain in (2).

ii. Some phonological rules with bleeding effects can violate the linearization cyclicity in **i**. Under deliberate or careful reading, these phonological rules apply from left to right between early linearization cycles, which is the violated **c2** domain in (2) above. In the situation of more cycles, these phonological rules apply in flexible orders between cycles (with more possible readings).

In strings of words without internal morphosyntactic structures, T3 tone sandhi shows pure phonological cyclicity induced by phonological bleeding effects. **In strings of words with morphosyntactic structures**, T3 tone sandhi shows complex and elusive cyclic applications in the "double-cyclicity" induced by the phonological bleeding effects interacted in PF linearization cycles.

In the classical data of T3 Mandarin tone sandhi (Cheng 1973; Shih 1986) in (4), the early linearization cycles determine that the sandhi in the first cycle between "hao (*good*)" and "jiu (*wine*)" bleeds the second cycle between "mai (*buy*)" and "hao (*good*)". This kind of directional cyclicity is violated if speakers deliberately produce sandhi between "mai (*buy*)" and "hao (*good*)", which removes the basic bleeding case.

Different from the classical prosodic analysis in Shih (1986), in section 2.2, we argue that this change can hardly be explained by purely prosodic factors, e.g., speech rate. The sandhi between "mai *(buy*)" and "hao (*good*)" being deliberately produced is due to the fact that "mai (*buy*)" and "hao (*good*)" belong to **one single early linearization cycle**. In (4) below, when we apply T3 tone sandhi rule in the two orders of linearization cyclicity, we have the two variations of readings, surface tone of Default Form is (T2 T2 T3 T2 T3), and the surface tone of Violated Form is (T2 T3 T2 T2 T3) (see complete results of sandhi variations of this classical data in section 7.2).

(4) [$_{S}$[$_{NP}$ Lao-Li][$_{VP}$ mai[$_{NP}$ hao-jiu]]]*([$_{S}$[$_{NP}$Old-Li][$_{VP}$ buy[$_{NP}$good wine]]])*(T3→3 T2→3)

(3 3 3 3 3) *base tone*

(**P** **M** $_{n}$ (**M** $_{n}$) (**P** $_{c}$) **M** $_{n}$) *cyclic cycles of linearization*

Default Form–The application of T3 tone sandhi follows the order of 1°, 2° to 3°.

(3 3) 1°cycle-base tone

(2 3) 1°*cycle-surface tone*

(3 2) 2° cycle-base tone

(3 2) 2° *cycle-surface tone (T3 tone sandhi NA)*

(2 2 3) 3° cycle-base tone

(2 2 3) 3° *cycle-surface tone*

2 2 3 2 3 surface tone

Violated Form–The application of T3 tone sandhi follows the order of 2° to 1°/3°.

(3 3) 2° cycle-base tone

(2 3) 2° *cycle-surface tone*

(3 3 2) (3 3) 1° and 3° cycle-base tone

(2 3 2) (2 3) 1° *and* 3° *cycle-surface tone*

2 3 2 2 3 surface tone

The current model shows better capability to derive T3 tone sandhi variations in complex interactions between morphosyntactic basis and prosodic/phonetics/rhythmic variability. Both morphosyntactic interactions of cyclic linearization chains, and phonetic/phonological factors (e.g., speech rate and cliticization in Shih 1986, Chen 2008) abundantly derive variations in different cases. Additionally, the lexical sandhi domain is constrained by underlying morphological structures when the compound words show complex internal morphological structures. When no morphological relations are shown in a string of words, e.g., telephone numbers or loanwords, it is constrained by rhythmic factors, e.g., disyllabic or trisyllabic foot construction. This corresponds to our proposal that only the interaction of morphosyntactic and prosodic factors can derive sufficient T3 tone sandhi variations. See section 7.3 for a detailed discussion.

In the current study, based on the data of Mandarin T3 tone sandhi, the modified direct spell-out model of post-syntactic linearization at PF predicts accurate and sufficient variations in Mandarin T3 tone sandhi, by creating flexibility in cyclicity of postlexical/phrasal phonology. Speaking from the data of a typical and perplexing external tonal sandhi phenomenon—Mandarin T3 tone sandhi, we would expect that the current study provides a meaningful analysis to support the direct spell-out models at the morphosyntax and phonology interface.

I will proceed as follows: In section 2, I introduce the phenomenon of sandhi variations in Mandarin T3 tone sandhi with relevant literature, and demonstrate some problematic data in the relevant approaches, e.g., the prosodic analysis. In section 3, I introduce the current approach in the framework of Distributed Morphology. In section 4, I introduce the modified post-syntactic linearization model in Pak (2008) to accommodate the data of variations in Mandarin T3 tone sandhi. In section 5, I discuss the bleeding features of Mandarin T3 tone sandhi and the double-cyclicity (violable cyclicity) in the current model. In section 6, I introduce the morphosyntactic algorithm to illustrate the cyclic linearization chains in the current model. In section 7, I provide the solution to sandhi variations in Mandarin T3 tone sandhi. In section 8, I draw the final conclusion.

2. Perplexing variations of Mandarin T3 tone sandhi

Tone sandhi is a phonological process by which lexical tones exhibit contextually determined alternation (Zhang 2014). In Chinese Mandarin, pitch tone is associated with each syllable, which corresponds to morpheme. There are four basic lexical tones: T1 high-level, T2 high-rising, T3 low-dipping and T4 high-falling tones (Chao, 1968). Tone sandhi in Chinese Mandarin is a typical sandhi behavior, citation form T3 (low-dipping) is changed to sandhi form T2 (high-rising) if followed by another T3: T3 → T2 / ___T3.

Mandarin T3 tone sandhi has been a headache for many decades in the literature. A large amount of effort from different theoretical frameworks continuously contribute to the study of Mandarin T3 tone sandhi. Chen (1987) pioneered the research of syntax-phonology/prosody interface with data of Xiamen tone sandhi, but he assumes Mandarin T3 tone sandhi to be "most investigated but least known" among tonal sandhi phenomena across Chinese languages. In more recent literature, e.g., Zhang (2014), Mandarin T3 sandhi variations in long sequences of words are still considered to be perplexing.

2.1. Cyclic application in the prosodic analysis

In the classical literature related to T3 tone sandhi variations (e.g, Cheng 1970, 1973; Liu 1980; Selkirk 1984; Kaisse 1990; Chen 2008), the prosodic analysis in Shih (1986) has been considered to be the most successful approach. Shih (1986) proposed to account for the domain of Mandarin T3 tone sandhi, based on recursive prosodic structures—foot (**f**) and super-foot (**f'**) construction. To derive the sandhi domain based on recursive metrical foot construction, Shih (1986) adopted the Foot Formation Rule (FFR) in (5), originated from Chen (1983).

(5) Foot Formation Rule (FFR)

I. Foot (**f**) Construction

a. IC (Immediate Constituency): Link immediate constituents into disyllabic feet

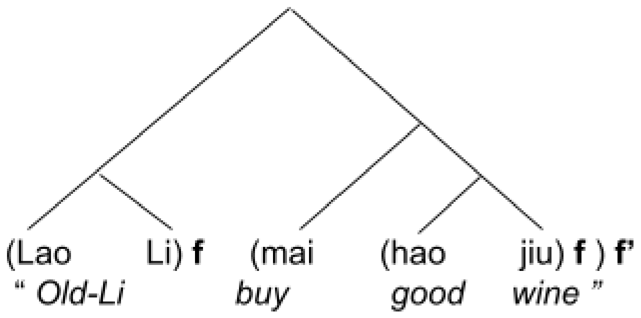
b. DM (Double Meter): Scanning from left to right, string together unpaired syllables into binary feet, unless they branch to the opposite direction.

II. Super-foot (**f'**) Construction

Join any leftover monosyllable to a neighboring binary foot according to the direction of syntactic branching.

Let's look at the classical data: $[_S[_{NP}$ Lao-Li$][_{VP}$ mai$[_{NP}$ hao-jiu$]]]$ *($[_S[_{NP}$ Old-Li$][_{VP}$ buy$[_{NP}$ good wine$]]]$)*. According to (5), we can derive the foot formation of this data in (6). In IC rule (Immediate Constituency), "Modifier-Noun" structure "hao-jiu (*good-wine*)" and "Lao-li (*Old Li*)" are two disyllabic feet (**f**). In Super-foot (**f'**) Construction, according to the direction of syntactic branching, the verb “mai (*buy*)" combines with “hao-jiu (*good-wine*)” to form a super-foot (**f’**), “mai hao-jiu (*buy good-wine*)” .

(6)



To accommodate variations, Shih (1986) uses the speech rate to induce the shift of initial cycles of sandhi application in the recursive sandhi foot structure, e.g., from foot cycle (**f** cycle) to super-foot cycle (**f’**cycle).

For example, if the disyllabic foot is produced by 0.5 second, the foot level is activated as the initial cycle of sandhi application. If the trisyllabic or quadrisyllabic foot is produced by 0.5 second, the super foot level is activated as the initial cycle of sandhi application.

The variations are directly constrained by variable initial sandhi cycles, which are induced by different speech rates. This is illustrated in (7), using the same phrase “$[_S[_{NP}$ Lao-Li]$[_{VP}$mai$[_{NP}$hao-jiu]]]*$[_S[_{NP}$ Old-Li]$[_{VP}$buy$[_{NP}$ good wine]]]*”. The foot construction of this phrase, as shown in (6), is divided into (Lao-Li$_f$) (mai (hao jiu$_f$)$_{f'}$) “*(Old-Li$_f$)(buy (good wine$_f$)$_{f'}$)*”.

Variable initial sandhi cycle activated by different speech rate in Shih (1986)

(7) Adagio (**f**=0.5 second, TS starts at **f-level**)

(Lao-Li$_f$) (mai (hao jiu$_f$)$_{f'}$) *(Old-Li$_f$) (buy (good wine$_f$)$_{f'}$)*

3	3	3	3	3	Base tone
2	3		2	3	f-level, obl.
2	***3***	***3***	***2***	***3***	**Surface tone A**
		NA			f’-level, opt.
	2				p-level, opt.
2	***2***	***3***	***2***	***3***	**Surface tone B**

Allegro (**f’**=0.20 second, TS starts at **f’-level**)

(Lao-Li$_f$) (mai (hao jiu$_f$)$_{f'}$) *(Old-Li$_f$) (buy (good wine$_f$)$_{f'}$)*

3	3	3	3	3	Base tone
2	3	2	2	3	f’-level, obl.
		NA			p-level, opt.
2	***3***	***2***	***2***	***3***	**Surface tone C**

Presto (**p**=0.20 second, TS starts at **p-level**)
(Lao-Li$_{\mathbf{f}}$) (mai (hao jiu$_{\mathbf{f}}$)$_{\mathbf{f'}}$) *(Old-Li$_{f}$) (buy (good wine$_{f}$)$_{f'}$)*
3 3 3 3 3 UL
2 3 2 2 3 Surface tone D

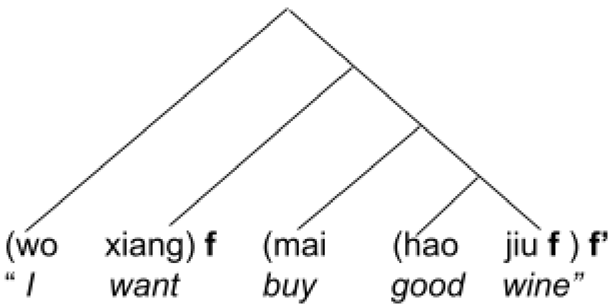
Adagio speech rate activates the foot cycle (**f** cycle) as the initial sandhi cycle, and the higher cycle, e.g., super-foot cycle (**f'** cycle), remains to be optional, yielding the surface tone **A** and **B**. Allegro and presto speech rates activate the super-foot cycle (**f'** cycle) and the phrasal cycle (**p** cycle) as the initial sandhi cycle, yielding surface tone **C** and **D**, respectively.

2.2. Problematic data of variations in metrical foot construction

As the foot construction constrained by speech rates to be the only factor to induce the variation readings, we will provide some empirical data to show the metrical feet are not sufficient to derive variations. Some data share the same foot construction determined by (5), but with different sandhi variations. In this case, (5) may not be sufficient to derive complete variations in the large scale of data.

For example, think about this phrase: "[$_{CP}$wo[$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]]] (3 3 3 3 3 3) (*[$_{CP}$I[$_{VP}$want [$_{CP}$PRO [$_{VP}$buy [$_{NP}$good wine]]]]]*)". According to (5), we can derive the foot formation in (8). In IC rule (Immediate Constituency), [$_{NP}$hao-jiu] "*[$_{NP}$good wine]*" forms a disyllabic foot **f**. In DM rule (Double Meter), we scan from left to right, the subject "wo (I)" and the first verb "xiang (want)" form a disyllabic foot **f.** In Super-foot (**f'**) construction, according to the direction of syntactic branching, the second verb "mai (buy)" is combined with the lexical word [$_{NP}$hao-jiu] "*[$_{NP}$good wine]*" to form a super-foot (**f'**).

(8)



The logical possibilities of variations[1] in "[$_{CP}$wo[$_{VP}$xiang[$_{CP}$PRO[$_{VP}$mai[$_{NP}$hao-jiu]]]]] (*[$_{CP}$I[$_{VP}$want[$_{CP}$ PRO[$_{VP}$buy[$_{NP}$good wine]]]]]*)" is different from the classical data, showing two new sandhi results surface tone **E** and **F** in (9). The key factor of two new sandhi variations is that the disyllabic foot "wo xiang (*I want*)" is not a lexical identity as the subject "Lao-Li (*Old-Li*)". Sandhi variations can be manipulated between the "wo (*I*)" and "xiang (*want*)", but the sandhi between "Lao (*Old*) and "Li (*Li*)" is an absolute case.

[1] Here to create the results of sandhi variations, we imitate the requirements in the classical data "[$_{S}$[$_{NP}$Lao-Li][$_{VP}$mai[$_{NP}$hao-jiu]]] *([$_{S}$[$_{NP}$ Old-Li][$_{VP}$buy[$_{NP}$ good wine]]])*". We count every possible combination of sandhi reading, unless that certain sandhi is an absolute case, e.g., between the lexical subject "Lao-Li" and object "hao-jiu".

(9) logical possibilities of "[$_{CP}$wo[$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai[$_{NP}$hao-jiu]]]]]
(3→T3; 2→T2)
[$_{CP}$wo[$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]]]
(*[$_{CP}$I [$_{VP}$want [$_{CP}$ PRO [$_{VP}$buy [$_{NP}$good wine]]]]]*)

3	***3***	***3***	***3***	***3***	***base tone***
2	***3***	***2***	***2***	***3***	***surface tone A***
2	***2***	***3***	***2***	***3***	***surface tone B***
2	***2***	***2***	***2***	***3***	***surface tone C***
2	***3***	***3***	***2***	***3***	***surface tone D***
3	***2***	***3***	***2***	***3***	***surface tone E***
3	***2***	***2***	***2***	***3***	***surface tone F***

The prosodic structure of this data is the same with "[$_{S}$[$_{NP}$ Lao-Li][$_{VP}$ mai[$_{NP}$ hao-jiu]]] *([$_{S}$[$_{NP}$Old-Li][$_{VP}$buy[$_{NP}$ good wine]]])*" in (6). We can derive the variations induced by different initial sandhi cycles mediated by speech rate in (10), which is the same results of "[$_{S}$[$_{NP}$Lao-li][$_{VP}$mai[$_{NP}$hao-jiu]]] *([$_{S}$[$_{NP}$ Old-Li][$_{VP}$buy[$_{NP}$good wine]]])*" in (7).

Variable initial sandhi cycle activated by different speech rate in Shih (1986)

(10) Adagio (**f**=0.5 second, TS starts at **f-level**)
(wo xiang$_{f}$) (mai (hao jiu$_{f}$)$_{f'}$) "*(I want$_{f}$) (buy (good wine$_{f}$)$_{f'}$)*"

3	3	3	3	3	Base tone
2	3		2	3	f-level, obl.
2	***3***	***3***	***2***	***3***	***(9)*Surface tone D**
		NA			f'-level, opt.
	2				p-level, opt.
2	***2***	***3***	***2***	***3***	***(9)*Surface tone B**

Allegro (**f'**=0.20 second, TS starts at **f'-level**)
(wo xiang$_{f}$) (mai (hao jiu$_{f}$)$_{f'}$) "*(I want$_{f}$) (buy (good wine$_{f}$)$_{f'}$)*"

3	3	3	3	3	Base tone
2	3	2	2	3	f'-level, obl.
		NA			p-level, opt.
2	***3***	***2***	***2***	***3***	***(9)*Surface tone A**

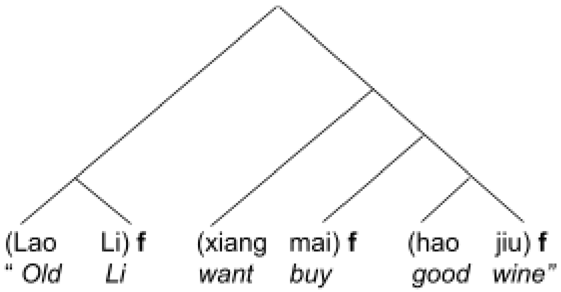
Presto (**p**=0.20 second, TS starts at **p-level**)
(wo xiang$_{f}$) (mai (hao jiu$_{f}$)$_{f'}$) "*(I want$_{f}$) (buy (good wine$_{f}$)$_{f'}$)*"

3	3	3	3	3	UL
2	**2**	**2**	**2**	**3**	***(9)*Surface tone C**

The problem pops up. Apparently, we couldn't derive the surface tone **E** and **F** of (9) in the prosodic approach in (10). This problem is unexpected if we adopt that the sandhi domain is mapped from the metrical foot construction. In the prosodic analysis, no matter how different the underlying morphosyntactic structures are, two phrases sharing the same foot construction in (6) and (8) should derive the same sandhi results of variations, which is obviously not supported by the comparison of (9) and (10). Two phrases with different underlying morphosyntactic structures, but the same prosodic structure, **do show different sandhi results in the possibility of variations.** The underlying morphosyntactic structures have direct impact on sandhi domains, not just indirect influences mediated solely by metrical/prosodic domains, e.g., foot.

Let's take another example. We can combine the two data above to have a new phrase: $_{S}$[$_{NP}$Lao-Li][$_{VP}$xiang[$_{CP}$PRO[$_{VP}$mai[$_{NP}$hao-jiu]]](*$_{S}$[$_{NP}$Old-Li][$_{VP}$want[$_{CP}$PRO[$_{VP}$buy[$_{NP}$good wine]]]*). The metrical foot construction is given in (11). In IC rule (Immediate Constituency), immediate constituents [$_{NP}$hao-jiu] "*[$_{NP}$good wine]*" and "Lao-Li (*Old-Li*)" are two disyllabic feet **f**. In DM rule (Double Meter), we scan from left to right, the subject "xiang (*want*)" and the second verb "mai (*buy*)" form a disyllabic foot **f.** There are three feet **f** in this data. No super-foot can be constructed.

(11)



Comparatively, The logical possibilities of sandhi variations in this data are given in (12). To test the sandhi variations, we count every possible reading. Some readings involving many adjacent T3s without undergoing sandhis are less common, e.g., the surface tone B, G, and H. These readings can be realistic in slow speech rate, or when we deliberately emphasize some words. See a discussion in section 7.2. We still consider these variations to be possible readings. However, other more common variations will be focused as they demonstrate close relations with underlying morphosyntactic structure, e.g., the surface tone A, D and F.

(12) logical possibilities of "$_{S}$[$_{NP}$Lao-Li][$_{VP}$xiang[$_{CP}$PRO[$_{VP}$mai[$_{NP}$hao-jiu]]]] (3→T3; 2→T2)"
$_{S}$[$_{NP}$Lao-Li][$_{VP}$xiang [$_{CP}$PRO[$_{VP}$mai[$_{NP}$hao-jiu]]]]
(*$_{S}$[$_{NP}$Old-Li][$_{VP}$want[$_{CP}$PRO[$_{VP}$buy[$_{NP}$good wine]]]*)

3	3	3	3	3	3	*base tone*
(**P**	**M** $_n$	(**M** $_n$)	**M** $_c$	(**P** $_c$)	**M** $_n$)	*cyclic cycles of linearization*
2	***2***	***3***	***2***	***2***	***3***	***surface tone A***
2	***2***	***3***	***3***	***2***	***3***	***surface tone B***
2	***2***	***2***	***2***	***2***	***3***	***surface tone C***
2	***2***	***2***	***3***	***2***	***3***	***surface tone D***
2	***3***	***2***	***3***	***2***	***3***	***surface tone E***
2	***3***	***2***	***2***	***2***	***3***	***surface tone F***
2	***3***	***3***	***2***	***2***	***3***	***surface tone G***
2	***3***	***3***	***3***	***2***	***3***	***surface tone H***

According to (11), We can derive the variations induced by different initial sandhi cycles mediated by speech rate in (13). Apparently, we can only derive two sandhi variations in the metrical foot construction. As our discussion goes on, we will gradually show that surface A, D and F are very closely related to the underlying morphosyntactic structures.

Variable initial sandhi cycle activated by different speech rate in Shih (1986)

(13) Adagio (**f**=0.5 second, TS starts at **f-level**)

(Lao-Li$_f$) (xiang mai$_f$) (hao jiu$_f$) "*(Old-Li$_f$) (want buy$_f$) (good wine$_f$)*"

3	3	3	3	3	3	Base tone
2	3	2	3	2	3	f-level, obl.
2	***3***	***2***	***3***	***2***	***3***	***(12)*****Surface tone E**

Presto (**p**=0.20 second, TS starts at **p-level**)

(Lao-Li$_f$) (xiang mai$_f$) (hao jiu$_f$) "*(Old-Li$_f$) (want buy$_f$) (good wine$_f$)*"

3	3	3	3	3	3	Base tone
2	2	2	2	2	3	p-level, obl.
2	***2***	***2***	***2***	***2***	***3***	***(12)*****Surface tone C**

2.3. Other approaches: OT and lexical sandhi domain

Chen (2009) introduces a canonical representational approach—Optimality theory (OT) (McCarthy & Prince 1995) to construct postlexical sandhi domains, and morphologically complex compound words follow the cyclic derivational approach to construct the lexical sandhi domains.

Chen (2009) reveals important observations about lexical sandhi domains, e.g., complex compound words with internal morphological structures. In "**[[[**zhan lan$_N$**]** guan$_N$**]** zhang$_N$**]** (T3 T3 T3 T3)"*(director of exhibition hall)* and "**[**jia$_A$**[**xiao$_A$**[**guang bo$_N$**]]]** (T3 T3 T3 T1) (*fake rumors*)", T3 sandhi applies in a cyclic way, from "left to right (outer to inner cycles)", and from "right to left (inner to outer cycles)", respectively.

The OT framework in Chen (2009) does not involve the complex issues of variations, and it seems to be hard to provide a OT approach in cyclic application of lexical sandhi domain mentioned above. Moreover, pure OT analysis (e.g., Feng 2003) seems to encounter the difficulty in simplifying consistent rankings of constraints between different morphosyntactic structures. Due to these factors, we are not going to dig into the OT-based frameworks in the following discussions. A discussion about the puzzle of lexical sandhi domains inspired by Chen (2009) can be found in section 7.3, which also serves as an additional case to support our current approach.

3. The current approach in the Distributed Morphology

In this section, we introduce the current approach in the framework of Distributed Morphology.

3.1. Basics and incorporated compounding structure

In Distributed Morphology, which is a non-lexicalist theoretical school, morphology and syntax belong to one computational system: words are derived by roots (e.g., √CAT) and abstract morphemes (e.g., [Past] or [pl]) undergoing syntactic operations (e.g., move or merge). Morphemes are divided into functional morphemes and (lexical) roots in (14). Roots are incorporated into the categorical heads to be licensed as noun, verb or adjective, etc. Categorical heads are phase heads, i.e., n° v°, a°, etc., (Marantz 1995, 2001), which determine their own spell-out domains.

The word internal syntax and cyclic spell-out domains of categorical heads are proved to be functional to account for a bunch of puzzles at the morphosyntax and phonology, e.g., word stress shift in English and Spanish (Marvin 2013; Oltra-Massuet and Arregi 2005). Unlike the stress assignment, Mandarin T3 tone sandhi seems to show insensitivity to phase effects. Traditional phases (e.g., CP, VP, DP) cannot be definite boundaries to block T3 sandhi. The data of variations in the following sections will continuously show that Mandarin T3 tone sandhi is drastically insensitive to phases in the long sequences of words, where the sandhi domains can be extremely flexible at important phase boundaries (e.g., CP/VP/DP) in different conditioned cases.

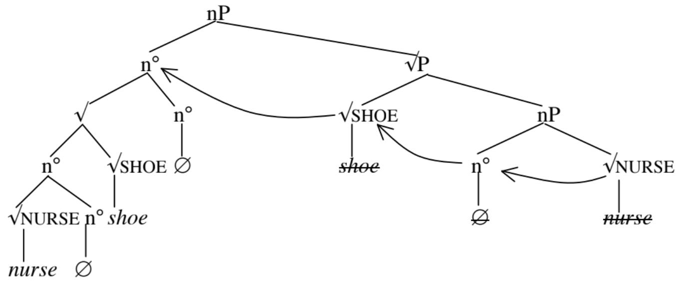
(14) Terminals (Embick 2010)
  a. Functional Morphemes: Terminal nodes consisting of (bundles of) grammatical features, such as past or pl, etc.; these do not have phonological representations.
  b. Roots: Members of the open-class or “lexical” vocabulary: items such as √CAT, √OX or √KICK.

Morphological word (M-words) is the basic unit to construct the post-syntactic linearization chains at PF. See (15) in Embick (2010).

(15) Morphological words and subwords (Embick 2010)
  a. M-words: (Potentially complex) head not dominated by further head-projections (Chomsky 2001 H^{o}_{max}).
  b. Subwords: Terminal nodes within an M-Word (i.e., either a Root or a bundle of morphosyntactic features).

In Harley (2010), compound words (with complex morphological structures) are derived under syntactic incorporation movements. In N-N compound words, non-head nouns incorporate into the acategorial root of the head noun, prior to its own incorporation into its category-defining n° head” (Harley 2010). In “nurse shoes" in (16) below, “*nurse”* is incorporated into “√*shoes”*, prior to its incorporation into n°.

(16) Incorporated Compounding structure (Harley 2010)



Let’s recall the definition of M-word in (15): (Potentially complex) head not dominated by further head-projections. In (17), the incorporated compounding structure is **two** M-words. When the noun “NURSE” is incorporated into the Root “√SHOE” in the first step, the incorporated structure combined by the noun “NURSE”, and Root “√SHOE” prevents the nP from being licensed **directly** by the second n° head of Root“√SHOE”. In this case, a RootP (“√”node on the left in the tree) blocks between two n° heads.

Note that Harley (2010) includes several types of compound words. They are synthetic compound words (e.g., truck-driver), primary (root) compound words without deverbal heads (e.g., nurseshoe), and phrasal compounds (e.g., bikini-girl-sitting-on-the-beach). Limited to the types of compound words that can be found in the data of T3 tone sandhi, the discussion related to compound words will only focus on primary (root) words.[2] This study follows the logic to investigate morphosyntax and phonology using phonological data as the original starting point. For the morphological analysis lacking the sufficient available data from the Mandarin T3 tone sandhi, it is not realistic to propose any morphosyntactic analysis without any relevant solid support from phonology in the current study.

Additionally, follow the observations in the literature of “lexical” characteristics in “Modifier-Noun” structure in Chinese (see Zhu 1956; Shih 1986; Sproat and Shih 1991; Duanmu 1993b), “Modifier-Noun” structures (e.g., Adjective-Noun structures) are considered to be incorporated structures in the current system.

This is, by no means, to advocate or defend that all Chinese compounds are definitely incorporated compounding structures in a larger linguistic context. In the current case of Mandarin T3 external tonal sandhi in the non-lexicalist frameworks (e.g., Distributed Morphology), we choose to analyze the two types of structures (i.e., N-N and A-N structures) as incorporated structures, instead of other syntactic structures/operations, e.g., adjunction structures in Embick (2007).

Embick (2007) treats complex compound words as M-word internally successive adjunction structures. In the assumption of adjunction structures, there would be only **one** M-word inside compound words. According to the data of Mandarin T3 tone sandhi, the adjunction structure of compound word as **one** Morphological word is faced with some essential challenges. The concatenation of Subwords should be accomplished prior to the concatenation of M-words. In the two-layer ontology of linearization (M-Words and

[2] T3 tone sandhi requires two T3s to be adjacent, which are very rare to be found in the data of other types of compound words, such as synthetic compounds.

Subwords) mentioned in Embick (2007), the different types of concatenation of Subwords or M-words can not be related to each other. If we follow the compound words as adjunction structures in the current data of Mandarin T3 tone sandhi, the Subwords from compound words should be retrieved and concatenated to other simple words (simple M-words), which would violate the essential hypothesis of linearization in Embick (2007). Or at least, more conditions should be raised to ease the conflict, bringing in more challenges to the current system. For these reasons, we will stick to the incorporated compounding structures in Harley (2010), which is shown to be compatible with our data of T3 tone sandhi as our discussion continues.

3.2. Two-layer syntax and interaction of linearization

Before we head to the discussion about post-syntactic linearization model at complex derivational component PF, we would like to discuss a bit more about the two-layer of syntax in piece-based morphological theories, e.g., M-word and subword in Distributed Morphology. We would like to see what post-syntactic linearization process faces in this kind of two-layer of syntax, or "two-step ontology" in Embick (2007).

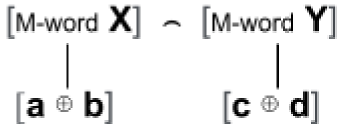
Crucially, linearization is faced with the division of linearization of M-words and Linearization of Subwords. In such a piece-based morphological theory, syntax is divided into **two** layers. Traditional syntax (or phrasal syntax) are syntactic relations between M-words. Within each M-word, the second layer of syntax deals with the syntactic relations between subwords.

Pure logically, the linearization of only subwords from different M-words can construct a functional logic purely from the second layer of syntax. However, this is counterintuitive. When we articulate a phrase, we should consider both the phrasal syntactic relations, which are the syntactic relations between M-words, and extend into syntactic relations inside each M-word. Pure logic between the subwords from different M-words without consideration of phrasal syntax, is grammatically meaningless.

In Embick (2007), he also proposes that linearization of M-words and linearization of Subwords within each M-word is sufficient to order the phrase marker. We can give a quick look at the Typed linearization hypothesis from Embick (2007).

There are at least two types of linearization (Embick 2007): M-words and Subwords. Where uppercase X, Y are M-words and lower case a and b are Subwords, linearization procedures generate two types of concatenation statements, $X \frown Y$ and $a \oplus b$. The procedure derives: (i) concatenation statements between M-words and (ii) concatenation statements between Subwords **within** a particular M-word. It does not derive any concatenation statements between Subwords of adjacent M-words. See (17) for a graphic illustration. In (17), there is no linearization between the (a, b) Subwords of M-word X and the (c, d) Subwords of M-word Y

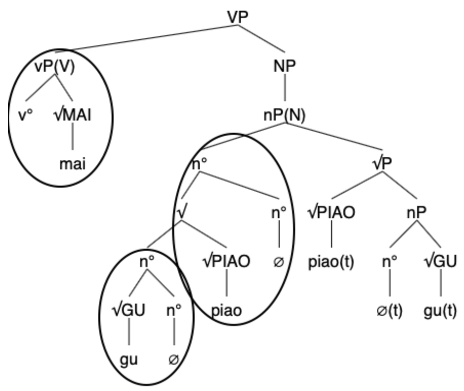
(17) M-word and subword linearization (Embick 2007), marked as "$\frown$", "$\oplus$" respectively



3.3. Linearization of incorporated compounding structures

In 3.1, we have shown that incorporated compounding structures are **two** M-words according to the definition of M-words. To better understand how the post-syntactic linearization process proceeds in the incorporated compounding structures, and interact with traditionally phrasal syntax, we take a concrete example of the T3 tone sandhi data: "[$_V$mai [$_N$gu-piao]] *[$_V$buy [$_N$stocks]]*" in (18).

(18) Syntax structure of "[$_V$mai [$_N$gu-piao]] *[$_V$buy[$_N$stocks]]*" (M-words marked in circle "◯")



In (18), the Verb-Object structure consists of a verb and a N-N compound word, which takes the incorporated compounding structure. "GU-PIAO (*stocks*)" is a primary (root) compound, in which "GU" means "share" and "PIAO" means "ticket". When the noun "GU" is incorporated into the Root "√PIAO", Root "√PIAO" prevents the nP (noun "GU") from being licensed **directly** by the second n° head of Root "√PIAO". In this case, a RootP ("√"node on the left in the tree) blocks between two n° heads. The incorporated compounding structure then combines directly with the tree of traditional phrasal syntax. nP takes the position of N of NP. Root "MAI (*buy*)" merges with its category-head v^o, which takes the position of V of VP. V merges with NP "GU-PIAO(*stocks*)" to be the big VP. In this structure, there are 3 M-words. The linearization chain is illustrated in (19).

(19) Linearization of M-words "[$_V$mai [$_N$gu-piao]] *[$_V$buy[$_N$stocks]]*", marked as "⌢".

There is no meaningful content (Subwords) within M-words in (19), hence the linearization of subwords is omitted. As we can see, the N-N compound word "gu-piao (*stocks*)" are separated into two M-words, constructing the integrated linearized chain with the M-word verb "Mai (*buy*)"

As discussed in section 3.1, there are a lot of observations in Chinese linguistics about "lexical" characteristics in "Modifier-Noun" structure (see Zhu 1956, Shih 1986, Sproat and Shih 1991, Duanmu 1993b), e.g., Adjective-Noun structures.

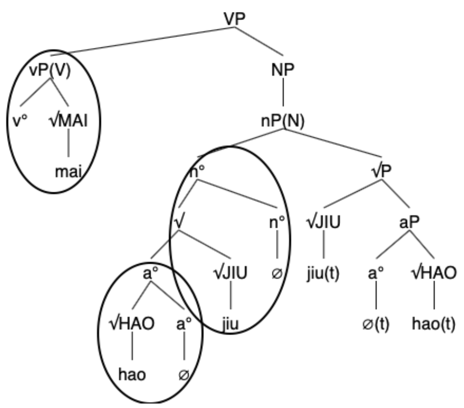
There has been a lot of debate about whether "Adjective-Noun" structures belong to phrasal or lexical identities across the languages. The classical example in English is the different positions of prominence between the phrase "black bírd" and the compound word "bláckbird"."black bírd" has final stress whereas "bláckbird" has the initial stress.

In the relevant literature of Distributed Morphology (Scott & Punske 2013), phrasal adjunct structure (the adjective taking the traditional adjunct position of NP) and complement structure (incorporated structures) are distinguished to account for initial-stress and final-stress between "black bírd" and "bláckbird". They argue that the incorporated compound structure of "bláckbird" can account for the initial-stress pattern, adopting the sentential prominence formulation with highest phase condition in Kratzer and Selkirk (2007).

However, Mandarin word stress still remains to be a mystery in the literature (see Chao 1968; Yip 1980; Lin et al. 1984; Kratochvil 1969, 1974; Duanmu 1993a; Chen 2009 among others), which means the similar evidence may not be available from stress assignment in Mandarin.

To protect the lexical identity of "Modifier-Noun" structures in the current piece-based theory, I also choose to analyze "Modifier-Noun" structures of Chinese in the similar incorporated compounding structures in Harley (2010). See the sample data "$_V$[mai $_N$[$_A$hao-$_N$jiu]] *$_V$[buy $_N$[$_A$good $_N$wine]]*" in (20).

(20) Syntax structure of "$_V$[mai $_N$[$_A$hao-$_N$jiu]] *$_V$[buy$_N$[$_A$good $_N$wine]]*" (M-words marked in circle "○")



(20) is a similar Verb-Object structure. The only difference is the A-N structure "HAO-JIU (good-wine)" substitutes the N-N structure "GU-PIAO (stocks)", which also takes the incorporated compounding structure.

As we can see here, the A-N structure “HAO-JIU (good-wine)” is separated into two M-words, constructing the integrated linearized chain with the M-word verb “MAI (*buy*)”. When the adjective “HAO (*good*)” is incorporated into the Root “√JIU (*wine*)”, Root “√JIU (*wine*)” prevents the nP (noun “HAO (*good*)”) from being licensed **directly** by the second n° head of “√JIU (*wine*)”. In this case, a RootP (“√”node on the left in the tree) blocks between two n° heads. The incorporated compounding structure then combines directly with the tree of traditional phrasal syntax. nP takes the position of N of NP. Root “√Mai (buy)” merges with its category-head v°, which takes the position of V of VP. V merges with NP “HAO-JIU (good-wine)” to be the big VP. In this structure, there are 3 M-words. The linearization chain is illustrated in (21).

(21) Linearization of M-words ${}_{V}$[mai ${}_{N}$[${}_{A}$hao-${}_{N}$jiu]] “${}_{V}$[*buy* ${}_{N}$[${}_{A}$*good* ${}_{N}$*wine*]]”, marked as “⌢”.

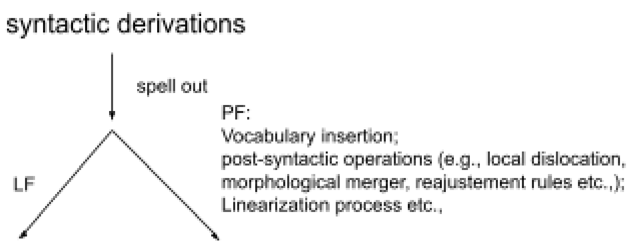
[M-word **MAI**] ⌢ [M-word **HAO**] ⌢ [M-word **JIU**]

3.4. Linearization model in Pak (2008), Embick (2007, 2010)

After the basics in Distributed Morphology, we will introduce the architecture of grammar in Distributed Morphology and the direct spell-out model of PF linearization in Pak (2008).

Syntax is the starting point to create complex objects from different types of morphemes. Hierarchical syntactic structures (including the word formation structures) are spelled out phase-cyclically to LF and PF (See (22) for graphical illustration). Measured by both temporal and structural differences, PF in Distributed Morphology is a complex system, where Morphological and phonological changes interact with each other. Vocabulary insertion adds phonological content to functional morphemes. Structural readjustments, such as morphological merger, local dislocation, to account for the “morphology-syntax mismatches” (Pak 2008). Post-syntactic operations, e.g., morphological merger and local dislocation start at the beginning of PF. Linearization from subword and M-word and the Vocabulary Insertion take place along the way of the PF system. Morphological conditioned phonological changes, e.g., readjustment rules, are late operations at PF.

(22) Grammar architecture in DM (Embick 2010)



In the direct spell-out hypothesis (Pak 2008), phrasal phonological rules are specified directly in multiple stages of derivations at PF, i.e., linearization process, which is divided into different stages, e.g., LIN, Concatenation, Chaining and Late-Linearization processes.

The notion when we refer to “linearization” means the general process when the hierarchical syntactic structures are linearly ordered.

We summarize the PF linearization process equipped with several different stages of derivations in Pak (2008) and Embick (2007, 2010) in (23). Phonological rules apply directly in the domains derived from multiple stages of post-syntactic linearization at PF.

In (23), suppose a sequence of M-words (Embick 2007, 2010) of (M1 M2 M3 M4). At Concatenation, c-command conditioned early linearized strings are specified as (M1 M2) and (M2 M3 M4), with red brackets indicating the c-command linearized string and blue brackets indicating non c-command linearized string. At Chaining, a longer linearization chain is constructed by the early linearized strings, the domain **c**. At Late-Linearization, domains of speech-rate sensitive phonological rules (e.g., T3 tone sandhi) are merged into larger domains in fast speech, the domain **d**, and split into smaller domains in slow speech, the domain **e**.

(23) Linearization model in Pak (2008)

M1 M2 M3 M4

Concatenation:	**a**. (M1 M2) **b**. (M2 M3 M4)
Chaining:	**c**. M1-M2-M3-M4
Late-Linearization:	**d**. (M1 M2 M3 M4…) in fast speech rate **e**. (M1) (M2) (M3) (M4) or (M1 M2) (M3 M4)... in slow speech rate

At the stage of Concatenation, there are two types of concatenation statements conditioned by c-command relations in (24).

(24) Two types of Concatenation statements (Pak 2008)
At the second stage of Concatenation, when the adjacency *-statements are established between M-Words. Two types of Concatenation statements are derived, conditioned by the c-command relations between the adjacent M-Words:

a. Head-left Concatenation: identifies pairs of M-words X, Y where (i) X is left-adjacent to Y, and (ii) X c-commands Y. (marked in red brackets)

b. Phrase-left Concatenation: identifies pairs of M-words X, Y where (i) X is left-adjacent to Y, and (ii) X does not c-command Y. (marked in blue brackets)

Late phonological rules are often sensitive to prosodic factors, e.g., speech rate. As discussed in section 2, the current case of Mandarin T3 tone sandhi is obviously influenced by the prosodic fatores, e.g., speech rate. Under current approach, it is in the very late stage of Late-Linearization that prosodic factors join into the play under the current model.

Depending on the different stages in the linearization process, Pak (2008) shows two types of phrasal phonological rules. Early rules are the type of phonological rules which apply at the early second stage of Concatenation, and Late rules apply at the late stage of Chaining.

Early rules are restricted to smaller domains: **one** of the two types of Concatenation statements in (24), i.e., the head-left concatenation or the Phrase-left concatenation, corresponding to the domain **a** and **b** in (23). Luganda Low-Tone Deletion (LTD) is one of such rules, applying in the head-left concatenated domains, i.e., between a head and the subsequent M-Word.

Chaining rules (Late rules) target the larger domains at the third stage after the Chaining operation. Lugand High-tone Anticipation (HTA) is a Chaining rule, applying throughout the spell-out domains within one phase cycle, e.g., the domain **c** in (23).

An additional type is the Late-Linearization rule, showing strong sensitivity to prosodic factors. The current case of T3 tone sandhi in Mandarin Chinese is one of these rules. Fast speech rate can merge a very large sandhi domain, regardless of the internal morphosyntactic structures, and slow speech rate can split sandhi domains into very small pieces, e.g., the domain **d** and **e** in (23).

4. Modification of post-syntactic linearization model in Pak (2008)

In (23), M1, M2 and M3 are linearized by the *Head-left concatenation statements* (**c-commanded** type—red brackets), and M3 and M4 are linearized by the *Phrasal-left concatenation statements* (**non c-commanded** type—blue brackets). Subsequently, through Chaining operation this sequence forms a single flat linearized chain, (M1 M2 M3 M4).

However, the current data of T3 tone sandhi shows that the cyclicity feature can be highly manipulated between cycles of *two types of Concatenation statements*.

For a phrase that interacts with multiple cycles of *two types of Concatenation statements*, T3 sandhi applying "from right to left (from **most embedded linearization cycles** to **outer linearization cycles)**" derives the "bleeding sandhi forms (named Default Form)". Moreover, this cyclicity of post-syntactic linearization can also be violable. T3 sandhi applying "from left to right" (from **outer linearization cycles** to **most embedded linearization cycles)** derives the "non-bleeding sandhi forms (named Violated Form)".

Back to the post-syntactic linearization model in Pak (2008), the current data of T3 tone sandhi shows that the Chaining operation may be more complex than what we expect. Instead of a more direct candidate such as "M1-M2-M3-M4", the "M1-M2-M3-M4" shows a more complex internal structure involving the interaction between *two types of Concatenation statements*.

We would like to introduce a violabe cyclicity at Chaining operation in (23). In (25), I mark the concatenation statements (M3 M4) and (M1 M2 M3) as the 1° and 2° linearized strings. The linearization structure at Chaining is not shown as a flat linearized chain like (M1-M2-M3-M4) in (23), instead, a cyclic chain, e.g, (M1 (M2) M3 M4), needs to be formed, which is illustrated in (25). The (M1 M2) and (M2 M3 M4) are multiple cycles of domain. In Default Form **c1**, the linearization chain is constructed **from the most embedded inner cycle to outer cycle** (right to left). In Violated Form **c2**, the linearization chain is constructed **from outer to inner cycle** (left to right). More Violated Forms can be formed if we increase the number of cycles of linearization at Concatenation, as the orders between linearization cycles can be extremely flexible, e.g., in 3 cycles, flexible orders can be 1-2-3;

3-2-1; 2-1-3; 2-3-1,1-3-2 etc. This provides abundant possibilities to derive T3 tone sandhi variations in the postlexical cyclicity.

(25) Modified version of linearization model in Pak (2008)

M1 M2 M3 M4

Concatenation: **a**. (M1 M2)
b. (M2 M3 M4)

Chaining: (M1 (M2) M3 M4)

c1. default (M2 M3 M4) —1° cycle
(M1 M2) —2° cycle

c2. violated (M1 M2) —2° cycle
(M2 M3 M4) —1° cycle

Late-Linearization: **d**. (M1 M2 M3 M4…) in fast speech rate
e. (M1) (M2) (M3) (M4) or (M1 M2) (M3 M4)... in slow speech rate

We may notice that Pak (2008)'s model is restricted to each spell-out phase, that is to say, the materials spelt out in each phase undergo the linearization process for phrasal phonological rules to apply in the respective phase. Similar to many typical external sandhi rules, e.g., *t*-flapping in English (Alessandra & Tobias 2015), the data of Mandarin T3 tone sandhi shows insensitivity to phase boundaries, e.g., the subject and predicate are perfect matches to activate sandhi in certain circumstances, ignoring the VP boundary.

The data of T3 tone sandhi below can be accommodated to the modified version of the linearization model in the scale of the whole phrase marker. However, this does not affect Pak's model, which is another idiosyncratic feature of many external sandhi rules. Suppose a longer string of words in the linearization process with 4 cycles, e.g., (**M1** (**M2**) **M3** (**M4**) **M5** (**M6** **M7**) **M8**). In the linearization model, phase markers can be inserted in the linearization chains. For example, VP boundary can be between **M3** and **M4**, (**M1** (**M2**) **M3** $_{\text{PHASE 2}}$ || $_{\text{PHASE 1}}$ (**M4**) **M5** (**M6** **M7**). The phrasal phonological rules sensitive to phases markers apply in each phases, e.g., the tone-spreading rules, whereas some external sandhi rules insensitive to phase markers can apply in the domains derived from the spell-out materials from separate phases in the linearization process, e.g., Mandarin T3 tone sandhi, t-flapping etc.

4. Bleeding feature of Mandarin T3 tone sandhi —"double-cyclicity"

Let's recall the rule of Mandarin T3 tone sandhi: citation form T3 (low-dipping) is changed to sandhi form T2 (high-rising) if followed by another T3 (low-dipping): T3 → T2 / ___T3. Though there are many discussions available in the literature focused on the unusual feature of cyclic application (cyclicity) of Mandarin T3 tone sandhi as a phrasal phonological rule, no account directly focuses on the bleeding feature that derives the cyclic application of the sandhi rule.

Most studies tend to provide solutions of sandhi domain construction which motivates Mandarin T3 tone sandhi rule to apply in a cyclic way. If we are restricted to how the cyclic sandhi domains can be derived, it obviously reduces the high-level flexibility of Mandarin T3 tone sandhi behaviors. Phonological bleeding features can provide a more flexible perspective, e.g., the direction that sandhi rule applies in a determined domain. We may encounter great difficulty (as shown in the literature) to investigate the absolute sandhi domain construction, which is sometimes too fixed to reduce the capability to accommodate the complexity of T3 sandhi behaviors. Instead, the direction that sandhi rule applies in a determined domain can also induce abundant changes in sandhi behaviors.

The linearization process establishes the basic relations of cyclicity to construct sandhi domains, but this cyclicity can be violated by variable directions/orders that T3 tone sandhi applies (to activate the phonological bleeding effects or not). This special phenomenon can be called "**double-cyclicity**": the **morphosyntactic cyclicity** of sandhi domain construction and the **phonological cyclicity** in the application of T3 Mandarin tone sandhi rule with bleeding features.

Double-cyclicity raises a very interesting issue: two positive cyclicities make a positive offset, becoming negative in the cyclicity. The effects of cyclicity in T3 sandhi domain construction can be **erased** if the cyclicity of bleeding effects in T3 sandhi rule is activated. In the sequence of (T3 T3' T3''), the cyclic effects of the sandhi domains, e.g., (T3 (T3') T3''), are erased if T3 sandhi rule applies from outer cycle (red cycle) to the most embedded inner cycle (blue cycle). The interaction between the two types of cyclicity are more abundant, if we increase the number of basic cycles of sandhi domains. For example, let's suppose a sequence of five M-words bearing the basic tone of 5 consecutive T3s have 3 cycles of underlying sandhi domains: (M1 (M2) M3 (M4) M5). The results of the interaction of double-cyclicity are given in (30). The T3 sandhi rule applies in a flexible way between cyclic cycles of linearization chains. Due to the bleeding effects, the results of **26a, 26b, 26c, 26d** derive different sandhi behaviors.

(26) Interaction of double-cyclicity: variable orders followed by the application of T3 sandhi rule (T3: T3 → T2 / ___T3) in the cyclic cycles of underlying sandhi domains derived from PF linearization.

(M1 (M2) M3 (M4) M5) →

a. 1. (M4 M5)
2. (M2 M3 M4)
3. (M1 M2)

b. 1. (M1 M2)
2. (M2 M3 M4)
3. (M4 M5)

c. 1. (M2 M3 M4)
2. (M1 M2) (M4 M5)

d. 1. (M1 M2) (M4 M5)
2. (M2 M3 M4)

This interaction probably doesn't mean that, in the linearization process under discussion, the order of Default Form of linearization chains in **26a** will be twisted at PF to construct new linearized chains such as **26b, 26c, 26d**. However, the T3 sandhi rule follows flexible orders to apply in these cyclic cycles, derving variable sandhi results, instead of the underlying linearization chains at PF being changed into various forms.

In terms of the bleeding feature and the special issue of double-cyclicity, Mandarin T3 tone sandhi is a special case to Pak's direct-interface model. We compare this with other tonal phenomena at phrasal level in Pak (2008).

Traditionally, the more investigated tone-spreading type of phrasal phonological rules has no bleeding effects within its own context. For example, in Pak (2008), the H-Tone Anticipation (HTA) applies from right to left in a specific domain formed by linearized M-words. "When a H L word is preceded by words that end with at least one toneless mora, the H tone spreads *leftward* through a potentially indefinite string of toneless moras, stopping short of the first mora of the domain." H-tone spreads leftward in both partial linearized strings and the concatenated chains. Bleeding cases only occur when different tone-spreading rules interact, as mentioned in Pak (2008) that Low-Tone Deletion (LTD) may bleed HTA in some cases.

Mandarin T3 tone sandhi, on the contrary, applying from right to left (from most embedded inner cycle to outer cycles in the current approach), or from left to right (from outer cycles to inner cycles), makes a difference due to this bleeding feature it carries. The bleeding feature makes a difference in Pak's model when the partial linearization cycles are linked together by the operation of Chaining.

6. The morphosyntactic algorithm

The algorithm of the modified linearization process at PF is established in this section. The alphabetic algorithm helps to easily represent the linearization process, e.g., the c-command relations in different types of Concatenation statements, improving the readability in the data section below.

We will stick to the two types of Concatenation statements in Pak (2008): Head-left Concatenation statement and phrasal-left Concatenation statement. The first step is to distinguish the phrasal and the non-phrasal (head) locality features of M-Words. See M-words with different locality features in (27), marked with "**P**" and "**M**".

(27) Two types of locality features of M-words

P: M-word in locality of complex internal syntactic structure (e.g. N in NP in concatenation with subsequent V).

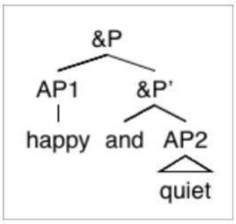
M: M-word in locality of simple internal syntactic structure (e.g. V in VP in concatenation with subsequent Object NP. The locality of V can only be limited to the head position of VP instead of entire complete VP)

An example from Chen (2018) illustrates the difference between "**P**"and "**M**": In (28) from Chen (2018), "Assume that 'kah (and)' or an empty operator is the head of &P, and that the first AP 'khoai-lok (happy)' is the specifier of the &P while the second AP "peng-cheng (quiet)" is the complement, the head of &P 'kah (and)' is not a phrasal category. " So we can generate a syntactic tree with &P in (29), the head of the &P—'kah (and)' is not a phrasal category, which means it belongs to "**M**" locality instead of "**P**".

(28) Example of M-words locality features (Chen 2018)

in koe-tioh chin khoai-lok # (kah) peng-cheng # e seng-oah #
They live very happy and quiet E life
"They lead a very happy and quiet life"

(29) Syntactic tree of the example of M-words locality features



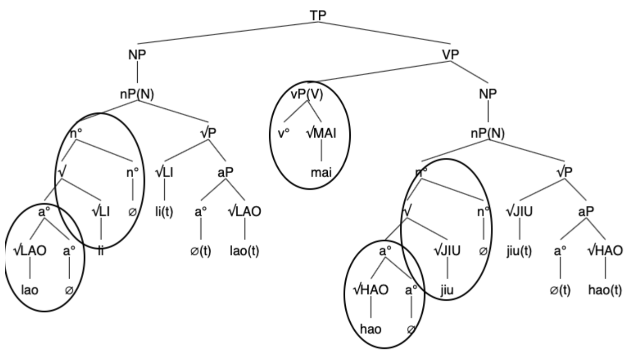
Some more symbols to establish the algorithm include sandhi domains, c-command relations, are listed in (30):

(30) More symbols of c-command relations, sandhi domain, etc.

(): T3 sandhi rule domain. (A B) means the M-Words A and B belong to one sandhi domains
(red brackets**)** means sandhi domains derived by c-commanded linearized chains—Head-left Concatenation statement
(blue brackets**)** means sandhi domains derived by non c-commanded linearized chains—Phrasal-left Concatenation statement
A B c: Morphological word A c-commands B
A B n: Morphological word A doesn't c-command B

According to the discussion of the linearization of incorporated compounding structures in section 3.3, the syntactic tree of the classical data (6) is illustrated in (31).

(31) Syntactic tree of $[_S[_{NP}$ Lao-Li$][_{VP}$ mai$[_{NP}$ hao-jiu$]]]$ *($[_S[_{NP}$ Old-Li$][_{VP}$ buy$[_{NP}$ good wine$]]]$)* (◯ → M-words)



The subject noun "Lao-Li (*Old Li*)" is a nickname for people with the surname "Li", and the object noun "hao jiu *(good wine)*" is a "Modifier-Noun" structure, both taking the form of incorporated compounding structures. Inside of the incorporated compounding structures, the non-head nouns "Lao (*old*)" and "Hao (*good*)" belong to the **P** locality, and the head nouns "Li (*Li*)" and "jiu (*wine*)" belong to the **M** locality. The non-head nouns "Lao (*old*)" and "Hao (*good*)" do not c-command the head nouns "Li (*Li*)" and "jiu (*wine*)". The verb "Mai (*buy*)" belongs to **M** locality. Subsequently, by establishing the c-command or non c-command relations between each two M-words, the cyclic linearization chains can be illustrated with an algorithm in (32). The phrase has 3 basic cycles of linearization chains as sandhi domains by default.

(32) $[_S[_{NP}$ Lao-Li$][_{VP}$ mai$[_{NP}$ hao-jiu$]]]$ *($[_S[_{NP}$ Old-Li$][_{VP}$ buy$[_{NP}$ good wine$]]]$)*
(3 3 3 3 3) *base tone*
(**P** $\mathbf{M}_n$ ($\mathbf{M}_n$) ($\mathbf{P}_c$) $\mathbf{M}_n$) *cyclic cycles of linearization*
($\mathbf{P}_c$ $\mathbf{M}_n$) *1° cycle*
($\mathbf{M}_n$ $\mathbf{P}_c$) *2° cycle*
(**P** $\mathbf{M}_n$ $\mathbf{M}_n$) *3° cycle*

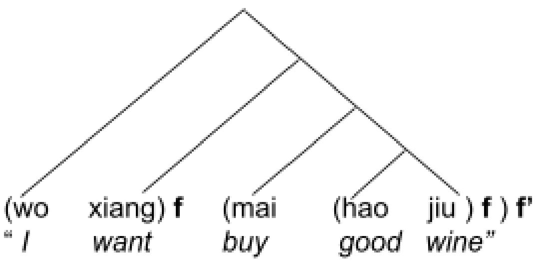
7. Solution to sandhi variations

7.1. Unsolved data in section 2

As mentioned in section 2.2, we have shown that speech rate cannot be the only factor to derive abundant variations in Mandarin T3 tone sandhi. We will use the modified direct spell-out linearization model in section 4 and 6, to derive the sandhi variations of the unsolved data in section 2.2. Some more data will be provided to show the powerful capability of the direct spell-out model: morphosyntactic cyclicity of PF linearization chains interacts with phonological cyclicity of T3 sandhi rule (double-cyclicity/violable cyclicity).

Let's go back to the data of long sequence of words bearing consecutive 5 T3s in section 2.2, "$[_{TP}$wo$[_{VP}$xiang $[_{TP}$PRO $[_{VP}$mai $[_{NP}$hao-jiu$]]]]]$ *($[_{TP}$I$[_{VP}$want $[_{TP}$ PRO $[_{VP}$buy $[_{NP}$good wine$]]]]]$)*". The recursive foot construction and the logical possibilities of sandhi variations of this phrase are repeated in (33) and (34), respectively.

(33)



(34) logical possibilities of "[$_{CP}$wo[$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]]] (3→T3; 2→T2)
[$_{CP}$wo[$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]]]
([$_{CP}$I[$_{VP}$want [$_{CP}$ PRO [$_{VP}$buy [$_{NP}$good wine]]]]])

3	***3***	***3***	***3***	***3***	***base tone***
2	***3***	***2***	***2***	***3***	***surface tone A***
2	***2***	***3***	***2***	***3***	***surface tone B***
2	***2***	***2***	***2***	***3***	***surface tone C***
2	***3***	***3***	***2***	***3***	***surface tone D***
3	***2***	***3***	***2***	***3***	***surface tone E***
3	***2***	***2***	***2***	***3***	***surface tone F***

According to section 6, the cyclic linearization chains can be represented in (35).

(35) [$_{CP}$wo [$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]]]
([$_{CP}$I [$_{VP}$want[$_{CP}$PRO [$_{VP}$buy [$_{NP}$good wine]]])

3	3	3	3	3	*base tone*
(**P**	(**M** $_n$)	**M** $_c$	(**P** $_c$)	**M** $_n$)	*cyclic cycles of linearization*
			(**P** $_c$	**M** $_n$)	1° ***cycle***
	(**M** $_n$	**M** $_c$	**P** $_c$)		2° ***cycle***
(**P**	**M** $_n$)				3° ***cycle***

To derive all the possibilities of variations in (34), especially sandhi results of E and F, we apply the T3 tone sandhi rule in the cyclic linearization cycles in (35), to activate the double-cyclicity phenomena. The sandhi variations are given in (36). In the following context, we will only write the surface tone of each linearization cycle for simplification.

(36) **<u>Chaining stage:</u>**
[$_{CP}$wo [$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]]](*[$_{CP}$I [$_{VP}$want[$_{CP}$PRO[$_{VP}$buy [$_{NP}$good wine]]]*)

3	3	3	3	3	*base tone*
(**p**	(**m** $_n$)	**M** $_c$	(**p** $_c$)	**m** $_n$)	*cyclic cycles of linearization*

Default Form– The application of T3 tone sandhi follows the order of 1°, 2° to 3°.

			(2	3)	1° cycle
	(2	3	2)		2° cycle
(3	2)				3° cycle
3	**2**	**3**	**2**	**3**	***surface tone E***

Violated Form 1–The application of T3 tone sandhi follows the order of 2° to 1°/3°.

	(2	2	3)		2° cycle
(3	2)		(2	3)	1° and 3° cycle
3	**2**	**2**	**2**	**3**	***surface tone F***

Violated Form 2–The application of T3 tone sandhi follows the order of 1°/3° to 2°.

(2	3)		(2	3)	1° and 3° cycle
	(2	3	2)		2° cycle
2	**2**	**3**	**2**	**3**	***surface tone B***

Violated Form 3i–The application of T3 tone sandhi follows the order of 3°, 2° to 1°

(2	3)				3° cycle
	(3	2	3)		2° cycle
			(2	3)	1° cycle
2	**3**	**2**	**2**	**3**	***surface tone A***

Violated Form 3ii– The application of T3 tone sandhi follows the order of 3°, 2° to 1°

(2	3)					3° cycle
	(2	2	3)			2° cycle
			(2	3)		1° cycle
2	**2**	**2**	**2**	**3**		***surface tone C***

Late-Linearization stage:

$[_{CP}$wo$[_{VP}$xiang$[_{CP}$PRO$[_{VP}$mai$[_{NP}$hao-jiu]]]]]$(*[_{CP}$I$[_{VP}$want$[_{CP}$PRO$[_{VP}$buy$[_{NP}$good wine]]]*)

3	3	3	3	3	*base tone*
(**p**	(**m** $_n$)	**M** $_c$	(**p** $_c$)	**m** $_n$)	*cyclic cycles of linearization*
(3	3	3	3	3)	merged cycles in fast speech rate
2	**2**	**2**	**2**	**3**	***surface tone C (repeated)***
(3	3)	(3)	(3	3)	split cycles in slow speech rate
2	**3**	**3**	**2**	**3**	***surface tone D***

In Default Form, T3 tone sandhi follows the inner (most embedded) cycle to the outer cycle of linearization chains (1°, 2° to 3° cycles), deriving E. In Violated Forms, T3 tone sandhi follows the twisted orders: 2° to 1°/ 3°, OR 1°/3° to 2°, OR 3°, 2° to 1° cycles, producing the violated forms of 1, 2, 3i and 3ii and deriving F, B, A, C. In Violated Form 3ii, T3 from 3° cycle optionally remains unchanged (T2s from early cycles are not possible to undergo any change though), which is similar to cyclic Phonological Impenetrability Effects. Different from classical PIC effects related to syntactic cyclic phases, here Phonological Impenetrability Effects are potentially determined by the cyclic cycles of post-syntactic linearization chains at PF. But this condition is banned in the "must-go" sandhi situation, e.g., only two adjacent T3s (T3 T3) → (T2 T3). At Late-Linearization, larger sandhi domains are merged in fast speech rate and smaller sandhi domains are split in slow speech rate, deriving C, D (C is repeated).

As discussed in section 2.2, the variations of this data can not be accounted for in the prosodic analysis in Shih (1986), which shares the same sandhi results (fewer than logical possibilities in (3)) from similar prosodic foot construction of the classical data $[_S[_{NP}$Lao-Li$][_{VP}$mai$[_{NP}$hao-jiu]]]$(*[_S[_{NP}$Old-Li$][_{VP}$buy$[_{NP}$goodwine]]]*), but different in underlying morphosyntactic structures proved in the current model.

The analysis above shows the underlying morphosyntactic structures may indeed have a strong influence, in contrast with the claim that prosodic structures are the only decisive factor to derive sandhi variations. We can conclude this in (37).

(37) T3 sandhi variations at two stages of linearization process at PF:

1. Morphosyntax induced variation at the Chaining stage: the PF linearization cycles interacted with cyclic T3 tone sandhi with bleeding features (double-cyclicity/violable cyclicity)
2. Prosody induced variations in the Late-Linearization stage: the prosodic factor, e.g., speech rate/emphatic boundaries. The cyclic linearization chains are splitted into smaller sizes in slow speech rate and merged into larger sizes in fast speech rate.

7.2. Prosodic factors at the late stage of Late-linearization operation?

To argue that the function of prosodic/rhythmic factors only perform at the very late stage, more evidence needs to be provided.

We go back to the classical example "$_{S}$[$_{NP}$ Lao-Li][$_{VP}$ mai[$_{NP}$ hao-jiu]]] (*$_{S}$[$_{NP}$ Old-Li][$_{VP}$ buy[$_{NP}$ good wine]]]*) (Chen 1984; Shih 1986)", to illustrate the two stages of mechanism in (37). The morphosyntax induced variations at Chaining stage are illustrated in (38).

(38) **Chaining stage:**

$_{S}$[$_{NP}$ Lao-Li][$_{VP}$ mai[$_{NP}$ hao-jiu]]] (*$_{S}$[$_{NP}$ Old-Li][$_{VP}$ buy[$_{NP}$ good wine]]]*)
3 3 3 3 3 *base tone*
(**P** **M** $_{n}$ (**M** $_{n}$) (**P** $_{c}$) **M** $_{n}$) *cyclic cycles of linearization*
Default Form– The application of T3 tone sandhi follows the order of 1°, 2° to 3°.
(2 3) 1° *cycle*
(3 2) 2° *cycle*
(2 2 3) 3° *cycle*
2 2 3 2 3 ***(7) surface tone B***
Violated Form 1–The application of T3 tone sandhi follows the order of2° to 1°/3°.
(2 3) 2° *cycle*
(2 3 2) (2 3) 1° *and* 3° *cycle*
2 3 2 2 3 ***(7) surface tone C***
Violated Form 2–The application of T3 tone sandhi follows the order of1°/3° to 2°.
(2 2 3) (2 3) 1° *and* 3° *cycle*
(3 2) 2° *cycle*
2 2 3 2 3 ***(7) surface tone B (repeated form)***
Violated Form 3–The application of T3 tone sandhi follows the order of3°,2° to 1°.
(2 2 3) 3° *cycle*
(2 3) 2° *cycle*
(2 3) 1° *cycle*
2 2 2 2 3 ***(7) surface tone D***

The application of T3 tone sandhi follows the order of 1°, 2° to 3°, or 2° to 1°/3°, or 1°/3° to 2° or 3°, 2° to 1° in the linearization cycles, activating the effects of double-cyclicity and producing the morphosyntactic sandhi variations at the early stage of linearization process.

However, as we notice, there must be something more to derive 4 possible readings in (7) from Shih (1986). As Pak (2008) claims, the prosodic factors at Late-Linearization stage surely have strong influence to derive more variations in (39).

(39) **Late-Linearization stage**

[$_{S}$[$_{NP}$ Lao-Li][$_{VP}$ mai[$_{NP}$ hao-jiu]]] (*$_{S}$[$_{NP}$ Old-Li][$_{VP}$ buy[$_{NP}$ good wine]]]*)
3 3 3 3 3 *base tone*
(**P** **M** $_{n}$ (**M** $_{n}$) (**P** $_{c}$) **M** $_{n}$) *cyclic cycles of linearization*

(**P** **M** $_{n}$) (**M** $_{n}$) (**P** $_{c}$ **M** $_{n}$) ***split cycles in slow speech rate***
2 3 3 2 3 ***(7) surface tone A***

(**P** **M** $_{n}$ **M** $_{n}$ **P** $_{c}$ **M** $_{n}$) ***merged cycles in fast speech rate***
2 2 2 2 3 ***(7) surface tone D (repeated form)***

The influence of prosodic factors (e.g., speech rates to derive more possible sandhi variations) should be under certain restrictions. In extremely slow speech rate, smaller split domains than (P M_n)(M_n)(P_c M_n) in (40), e.g., (P)(M_n)(M_n)(P_c)(M_n), can be formed at the stage of Late-Linearization, but may not be meaningful to natural articulation. In some longer phrases of more words, an integral sequence of the sandhi domain, e.g., (P M_n M_n P_c M_n) may not be realistic within the limits of fast speech rate in natural articulation.

7.2. More sample data

We go back to the second unsolved data in section 2.2: $_S$[$_{NP}$Lao-Li][$_{VP}$xiang[$_{CP}$PRO [$_{VP}$mai [$_{NP}$hao-jiu]]]](*$_S$[$_{NP}$Old-Li][$_{VP}$want[$_{CP}$PRO[$_{VP}$buy[$_{NP}$good wine]]]*). The logical possibilities of sandhi variations in this data is repeated in (40). Comparatively, see (41) for the sandhi variations at the Chaining stage in the current model.

(40) logical possibilities of "$_S$[$_{NP}$Lao-Li][$_{VP}$xiang[$_{CP}$PRO[$_{VP}$mai[$_{NP}$hao-jiu]]]] (3→T3; 2→T2)"
$_S$[$_{NP}$Lao-Li][$_{VP}$xiang [$_{CP}$PRO[$_{VP}$mai[$_{NP}$hao-jiu]]]]
(*$_S$[$_{NP}$Old-Li][$_{VP}$want[$_{CP}$PRO[$_{VP}$buy[$_{NP}$good wine]]]*)

3	3	3	3	3	3	*base tone*
(**P**	**M_n**	(**M_n**)	**M_c**	(**P_c**)	**M_n**)	*cyclic cycles of linearization*
2	***2***	***3***	***2***	***2***	***3***	***surface tone A***
2	***2***	***3***	***3***	***2***	***3***	***surface tone B***
2	***2***	***2***	***2***	***2***	***3***	***surface tone C***
2	***2***	***2***	***3***	***2***	***3***	***surface tone D***
2	***3***	***2***	***3***	***2***	***3***	***surface tone E***
2	***3***	***2***	***2***	***2***	***3***	***surface tone F***
2	***3***	***3***	***2***	***2***	***3***	***surface tone G***
2	***3***	***3***	***3***	***2***	***3***	***surface tone H***

(41) **Chaining stage:**
$_S$[$_{NP}$Lao-Li] [$_{VP}$xiang[$_{CP}$PRO [$_{VP}$mai[$_{NP}$hao-jiu]]]]
(*$_S$[$_{NP}$Old-Li][$_{VP}$want[$_{CP}$PRO[$_{VP}$buy[$_{NP}$good wine]]]*)

3	3	3	3	3	3	*base tone*
(**P**	**M_n**	(**M_n**)	**M_c**	(**P_c**)	**M_n**)	*cyclic cycles of linearization*

Default Form– The application of T3 tone sandhi follows the order of 1°, 2° to 3°.

				(2	3)	1° ***cycle***
		(2	3	2)		2° ***cycle***
(2	3	2)				3° ***cycle***
2	**3**	**2**	**3**	**2**	**3**	***(40)surface tone E***

Violated Form 1–The application of T3 tone sandhi follows the order of 2° to 1°/3°.

		(2	2	3)		2° ***cycle***
(2	3	2)		(2	3)	1° ***and*** 3° ***cycle***
2	**3**	**2**	**2**	**2**	**3**	***(40)surface tone F***

Violated Form 2–The application of T3 tone sandhi follows the order of 1°/3° to 2°.

(2	2	3)		(2	3)	1° ***and*** 3° ***cycle***
		(2	3	2)		2° ***cycle***
2	**2**	**2**	**3**	**2**	**3**	***(40)surface tone D***

Violated Form 3i–The application of T3 tone sandhi follows the order of 3°, 2° to 1°

(2 2 3) 3° ***cycle***

(2 2 3) 2° ***cycle***

(2 3) 1° ***cycle***

2 2 2 2 2 3 ***(40)surface tone C***

Violated Form 3ii–The application of T3 tone sandhi follows the order of 3°, 2° to 1°

(2 2 3) 3° ***cycle***

(3 2 3) 2° ***cycle***

(2 3) 1° ***cycle***

2 2 3 2 2 3 ***(41)surface tone A***

In Default Form, the application of T3 tone sandhi follows the inner (most embedded) cycle to the outer cycle of linearization chains, 1º , 2º to 3º cycles, deriving E. In Violated Forms, the application of T3 tone sandhi follows the twisted orders: 2º to 1º/ 3º , OR 1º/3º to 2º, OR 3º, 2º to 1º cycles, producing the violated forms of 1, 2, 3i and 3ii and deriving F, D, C, A. In Violated Form 3i, T3 from 3º cycle undergoes sandhi in the later cycles. In Violated Form 3ii, T3 from 3º cycle optionally remains unchanged (without undergoing sandhi) in the later cycles. The sandhi variations at the Late-Linearization stage are given in (42).

(42) **Late-Linearization stage:**

$_{S}[_{NP}$Lao-Li][$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai[$_{NP}$hao-jiu]]]]

($_{S}[_{NP}$Old-Li][$_{VP}$want[$_{CP}$PRO[$_{VP}$buy[$_{NP}$good wine]]])

3 3 3 3 3 3 *base tone*

(**P** **M** $_{\mathbf{n}}$ (**M** $_{\mathbf{n}}$) **M** $_{\mathbf{c}}$ (**P** $_{\mathbf{c}}$) **M** $_{\mathbf{n}}$) *cyclic cycles of linearization*

(P M $_n$) (M $_n$) (M $_c$) (P $_c$ M $_n$) *split cycles in slow speech rate-option 1*

2 3 3 3 2 3 ***(41)surface tone H***

(P M $_n$) (M $_n$ M $_c$) (P $_c$ M $_n$) *split cycles in slow speech rate-option 2*

2 3 2 3 2 3 ***(41)surface tone E (repeated)***

(P M $_n$ M $_n$) (M $_c$) (P $_c$ M $_n$) *split cycles in slow speech rate-option 3*

2 2 3 3 2 3 ***(41) surface tone B***

(P M $_n$) (M $_n$) (M $_c$ P $_c$ M $_n$) *split cycles in slow speech rate-option 4*

2 3 3 2 2 3 ***(41) surface tone G***

(P M $_n$ M $_n$ M $_c$ P $_c$ M $_n$) *merged cycles in fast speech rate*

2 2 2 2 2 3 ***(41)surface tone C (repeated)***

In (42), surface tone H, E(repeated), B, G are derived in split domains by slow speech rate, and surface tone C (repeated) can be derived in merged domains by fast speech rate. We can see from option 1 to 4, splitting the domains into smaller pieces seems to have multiple choices. Besides the lexical identity of the subject "Lao-Li (*Old-Li*) and the object "hao-jiu (*good-wine*)", the two monosyllabic verbs can be split into random single monosyllabic domains, or randomly join in adjacent lexical identities, producing variable combinations. In some circumstances, it may be related to other prosodic/phonetic factors, e.g., the emphatic boundaries mentioned in Chen (2009). For example in surface tone B, an emphatic boundary can be inserted after the verb “mai (*buy*)” to emphasize “mai (*buy*)” , (P M_n M_n) (M_c) % (P_c M_n). In surface tone G, an emphatic boundary can be inserted after the verb “xiang (*want*)” to emphasize “xiang (*want*)”, (P M_n M_n) % (M_c) (P_c M_n). All the sandhi results here can be manipulated by deliberate/conditional readings by native speakers. However, the surface tone B, G, H are comparatively less common options due to the many adjacent T3s without undergoing sandhi in these options.

Alternatively, the foot formation of this data in the prosodic analysis according to the rule in (7) are 3 independent disyllabic feet, (Lao-Li_f) (xiang mai_f)(hao-jiu_f) “*(old-li_f) (want buy_f) (good-$wine_f$)*”. In IC rule (Immediate Constituency), two lexical identities—the subject (Old-Li_f) “*(old-li_f)*” and object (hao-jiu_f) “*(good-$wine_f$)*” are immediate constituents linked into disyllabic feet. In DM rule (Double Meter), we scan from left to right, and string together unpaired syllables—two verbs (hao-jiu_f) “*(want buy_f)*” into binary feet.

In this case, independent disyllabic feet derive very limited variations in the system of prosodic analysis, as the lack of super-foot level fails to induce the shifting of initial sandhi cycles from foot level to super-foot level. In this way, we will only have the possible variation on foot level and phrasal level, that is surface tone E and surface tone C, respectively. The rest of surface tones can hardly be derived from metrical foot construction.

In the examples above, we mainly use the “double-verb” structure: the matrix verb is combined directly with the verb in the subordination clause. We can choose a different morphosyntactic structure. An example of a long sequence can be found in Chen (2009), “[$_{NP}$fang-dong][$_{NegP}$bu[$_{VP}$yun-xu[$_{IP}$[$_{NP}$wo][$_{VP}$ $_{PRO}$yang xiao-mao]]]]*[$_{NP}$landlord] [$_{NegP}$not [$_{VP}$ allow[$_{IP}$[$_{NP}$me][$_{VP}$ $_{PRO}$keep kitten]]]]*”. In this data, we have the special morphosyntactic structure of object nouns, the matrix verb “ yun-xu (*allow*)” is combined with the object noun “wo (*I*)”, which also serves as the subject of the subordination clause.The logical possibilities of this data is given in (43).

(43) logical possibilities of“[$_{NP}$fang-dong][$_{NegP}$bu[$_{VP}$yun-xu[$_{IP}$[$_{NP}$wo][$_{VP}$ $_{PRO}$yang xiao-mao]]]] (T3→3; T2→2)
[$_{NP}$fang-dong][$_{NegP}$bu[$_{VP}$yun-xu[$_{IP}$[$_{NP}$wo][$_{VP}$ $_{PRO}$ yang xiao-gou]]]] (*[$_{NP}$landlord][$_{NegP}$not[$_{VP}$ allow[$_{IP}$[$_{NP}$me][$_{VP}$ $_{PRO}$ keep puppies]]]]*)

2	1	4	3	3	3	3	3	3	*base tone*
(**P**	**M_n**	(**M_n**)	(**P_c**)	**M_n**	(**M_n**)	**M_c**	(**P_c**)	**M_n**)	*cycles of linearization*
			2	***2***	***3***	***2***	***2***	***3***	***surface tone A***
			2	***2***	***3***	***3***	***2***	***3***	***surface tone B***
			2	***2***	***2***	***2***	***2***	***3***	***surface tone C***
			2	***2***	***2***	***3***	***2***	***3***	***surface tone D***
			2	***3***	***2***	***3***	***2***	***3***	***surface tone E***
			2	***3***	***2***	***2***	***2***	***3***	***surface tone F***
			2	***3***	***3***	***2***	***2***	***3***	***surface tone G***
			2	***3***	***3***	***3***	***2***	***3***	***surface tone H***

From (43), we know that the interaction of linearization cycles is the same situation with the case of (40). The VP phrase shares the same results of linearization cycles with (41). The VP phrase’s default form of cyclic cycles of linearization is given in (44). And the complete sandhi results are the same with (41) and (42).

(44) logical possibilities of"[$_{NP}$fang-dong][$_{NegP}$bu[$_{VP}$yun-xu[$_{IP}$[$_{NP}$wo][$_{VP\ PRO}$yang xiao-mao]]]] (T3→3; T2→2)

[$_{NP}$fang-dong][$_{NegP}$bu[$_{VP}$yun-xu[$_{IP}$[$_{NP}$wo][$_{VP\ PRO}$ yang xiao-gou]]]] (*[$_{NP}$landlord][$_{NegP}$not[$_{VP}$ allow[$_{IP}$[$_{NP}$me][$_{VP\ PRO}$ keep puppies]]]]*)

2	1	4	3	3	3	3	3	3	*base tone*
(**P**	**M** $_n$	(**M** $_n$)	(**P** $_c$)	**M** $_n$	(**M** $_n$)	**M** $_c$	(**P** $_c$)	**M** $_n$)	*cycles of linearization*

Default Form– The application of T3 tone sandhi follows the order of 1°, 2° to 3°.

							(2	3)	1° ***cycle***
					(2	3	2)		2° ***cycle***
			(2	3	2)				3° ***cycle***
			2	**3**	**2**	**3**	**2**	**3**	***(43)surface tone E***

Note that the position of object nouns is occupied by the object pronouns "wo (*I*)", which is an exceptional case in Chen (2009). As argued in Chen (2009), the object pronoun "wo (*I*)" is a phonological clitic. The clitic "wo (*I*)" depends phonologically on the matrix verb "yun-xu (*allow*)" to construct a single sandhi domain, instead of joining in the second verb "yang (*keep*)". The probability of surface tone A is bigger than surface tone E in (44).

I believe Chen's observation to be true. In a relevant empirical study Wang and Lin (2011), the object pronouns (e.g., "wo (*I*)") behave differently compared to the other common object nouns (e.g., "gou (*dog*)"). The object pronouns should join the adjacent prepositions or verbs to be a single sandhi domain.

The clitics (e.g., the object pronouns) have priority to construct the single sandhi domain with the adjacent verbs or prepositions at the Late-Linearization stage, where all the possible prosodic/phonetic/rhythmic factors come into effect. When clitics appear at the late stage, the possibilities of different kinds of sandhi variations are influenced, e.g., the probability of surface tone A is bigger than surface tone E in (44). If we change the object noun from "wo (*I*)" to "gou (*dog*)", according to Chen (2009) and Wang and Lin (2011), we would expect that the possibilities of surface tone A and surface tone E are more balanced.

In the current study, we mainly focus on the sandhi variations, or the possible sandhi results in a single long sequence. To discuss the probability between different sandhi variations, more solid empirical experiments should be performed. As argued by Chen (2009), I do believe phonological clitics have an impact in sandhi domains, which needs to be treated as a special case in the alternative approaches in the literature.

7.3. The disputed lexical sandhi domains in Shih (1986) and Chen (2009)

In this section, we use another mystery of Mandarin T3 tone sandhi—the traditional lexical sandhi domain to support the current hypothesis: variations are derived at two different stages at PF, from two different sources (morphosyntax and prosody), and the prosodic factors only takes into effects at very late stage in the linearization process at PF.

In terms of the lexical foot formation in T3 tone sandhi, Shih (1986) holds a relatively vague point of view. She argues that there may be some lexical rule of dividing syllables into disyllabic or trisyllable foot. For example, in a long sequence of telephone numbers (5 5 5

5 5 5) with all T3 tones, the natural sandhi domains are distributed into rhythmically-balanced disyllabic or trisyllabic units, e.g., (5 5 5 5 5 5) —> (5 5 5) (5 5 5) or (5 5) (5 5) (5 5).

In Shih (1986), lexical integrity is a device she uses to account for some complex cases, such as "[$_A$xiao [$_N$gou [$_N$bin gan]]]"(T3 T3 T3 T1) (*small dog-biscuits*)". The lexical integrity of the N-word "gou bin gan (*dog-biscuits*)" inhibits the first syllable "xiao (*small*)" and the second syllable "gou(*dog*)" from joining into a disyllabic foot.

In Chen (2009), the internal structure of compound words needs to be considered. Chen (2009) argues for a cyclic sandhi application in compound words, and the internal morphological structures of compound words have a crucial impact on the sandhi results.

In compound words with complex internal morphosyntactic structures, e.g., "[[[zhan lan$_N$] guan$_N$] zhang$_N$] (T3 T3 T3 T3) (*director of exhibition hall*)". In the prosodic analysis, two convenient prosodic feet are constructed—(zhan lan$_f$)(guan zhang$_f$), the wrong sandhi result is derived as (T2 T3 T2 T3). Following a cyclic sandhi application in Chen (2009), the sandhi domains are derived in a successive way:[zhan lan$_N$] → [zhan lan guan$_N$] → [zhan lan guan zhang$_N$], deriving the right sandhi form (T2 T2 T2 T3).

Another example is "[jia [xiao [guang bo]]] (T3 T3 T3 T1) (*fake rumors*)", a complex "Adjective + Noun" structure (Modifier-Noun). As discussed in section 3.3, I will follow both Chen (2009) and Shih (1986) to consider "Adjective + Noun" as lexicalized identity. T3 tone sandhi follows the first cycle "[$_N$guang bo](*radio*)" to the second cycle "[$_A$xiao[$_N$guang bo]](*rumor*)", to the third cycle "[$_A$jia [$_A$xiao [$_N$guang bo]]](*fake rumor*)", deriving the right sandhi form (T3 T2 T3 T1). By the same token, in the prosodic analysis, the foot construction is divided into two disyllabic feet— (jia xiao$_f$) (guang bo$_f$), deriving a wrong sandhi result.

From the two examples above, we have reasons to believe the lexical sandhi domains are formed in a cyclic way, which is related to the internal structure of compound words, as stated in Chen (2009).

One may would like to adjust the foot construction in the prosodic approach to incorporate these complex morphological compound words, e.g., insert a super plus foot level (f'')to derive the multiple levels of cyclic formation of compound words, (guang bo$_f$) → (xiao guang bo$_{f'}$) → (jia xiao guang bo$_{f''}$). This may be functional, but an alternative way that we would like to adopt here is that lexical sandhi domain is shown to have two stages of domain construction.

At the early stage, the compound words with internal morphological structures follow a cyclic formation of sandhi domains. At the late stage, "lexical" words without internal morphological structures are divided into disyllabic or trisyllabic feet, e.g., a sequence of the telephone numbers or lownwords of translation. Prosodic factors and the rhythmic factors (disyllabic or trisyllabic units) would influence the long sequence of flat lexical structures at the later stage of Late-Linearization.

Purely from the lexical level, this may seem to complicate the situation. Combined with the previous analysis in the data at the postlexical level, the two-stage model of T3 sandhi variations provides the possibility to link all the problems we encountered in the path to discover Mandarin T3 tone sandhi, which makes the logic to be complete in the big picture.

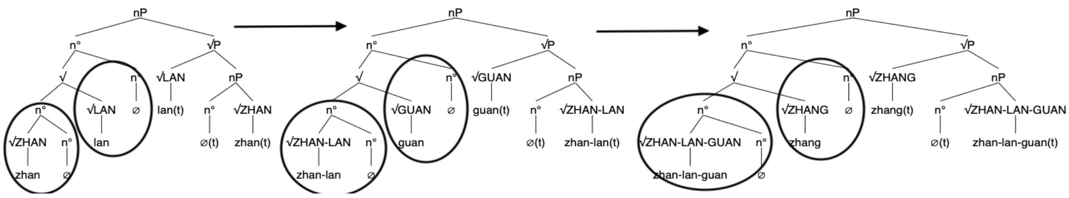
7.4. Lexical sandhi domains in the current approach

In the current approach, we use incorporated compounding structure in the complex compound words, lexical and postlexical sandhi domains can be potentially unified to be consistent in the direct spell-out approach of cyclic post-syntactic linearization at PF.

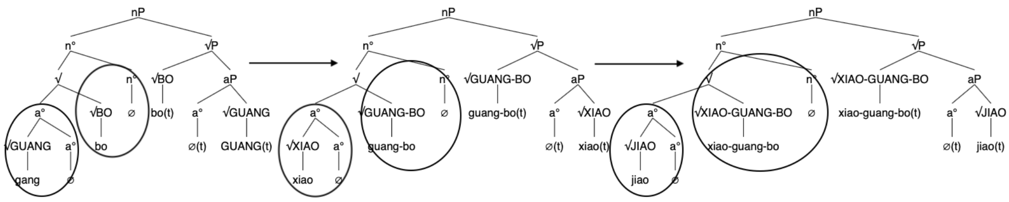
In the background of piece-based morphological theories, though far from perfect, it can relieve the pain of compound words with complex morphological structures in T3 tone sandhi. The only thing we need is to combine the incorporated compounding structure in Harley (2010) with the model of remuneration of roots (Shwayder 2015).

To imitate the cyclic formation of compound words in Chen (2009), We adopt the model of remuneration of roots (Shwayder 2015) to form successive incorporation movements. See the syntactic tree of remuneration of roots in (45) for "**[**jia **[**xiao **[**guang bo**]]]** (T3 T3 T3 T1) (*fake rumors*)", and (46) for "**[[[**zhan lan$_{\mathbf{N}}$**]** guan$_{\mathbf{N}}$**]** zhang$_{\mathbf{N}}$**]** (T3 T3 T3 T3) (*director of exhibition hall*)".

(45) Syntactic incorporated compounding structure of "**[[[**zhan lan$_{\mathbf{N}}$**]** guan$_{\mathbf{N}}$**]** zhang$_{\mathbf{N}}$**]** (T3 T3 T3 T3) (*director of exhibition hall*)" (○ → M-words)



(46) syntactic tree of remuneration of roots in the data of "**[**jia**[**xiao**[**guang bo**]]]** (T3 T3 T3 T1) (*fake rumors*)". (○ → M-words)



In the three separate steps of root remuneration in (45) and (46), a cyclic application of T3 tone sandhi rule similar to Chen (2009) can be achieved, illustrated in (47) and (48).

(47) Cyclic application of T3 in "**[[[**zhan lan$_{\mathbf{N}}$**]** guan$_{\mathbf{N}}$**]** zhang$_{\mathbf{N}}$**]** (T3 T3 T3 T3) (*director of exhibition hall*)". (T3→3, T2→2)

[[[zhan lan$_{\mathbf{N}}$**]** guan$_{\mathbf{N}}$**]** zhang$_{\mathbf{N}}$**]** (T3 T3 T3 T3) (*director of exhibition hall*)

(3 3 3 3) basic tone
(3 3) *1° cycle basic tone*
(2 3) 1° cycle surface tone
(2 3 3) *2° cycle basic tone*
(2 2 3) 2° cycle surface tone
(2 2 3 3) *3° cycle basic tone*
(2 2 2 3) 3° cycle surface tone

(48) Cyclic application of T3 in "**[**$_{A}$jia **[**$_{A}$xiao **[**$_{N}$guang bo**]]]** (T3 T3 T3 T1) (*fake rumors*)". (T3→3, T2→2)

[$_{A}$jia **[**$_{A}$xiao **[**$_{N}$guang bo**]]]**(*fake rumors*)

(3	3	3	1)	basic tone
		(3	1)	*1° cycle basic tone T3 tone sandhi NA*
		(3	**1)**	**1° cycle surface tone**
	(2	3	1)	*2° cycle basic tone*
	(2	**3**	**1)**	**2° cycle surface tone**
(3	2	3	1)	*3° cycle basic tone T3 tone sandhi NA*
(3	**2**	**3**	**1)**	**3° cycle surface tone**

In (45), the noun "**[**zhan lan$_{N}$**]**(*exhibition*)" is constructed in the first step of incorporation movement, "**[**zhan lan$_{N}$**]**guan$_{N}$**]**(*exhibition hall*)" is constructed in the second step, "**[[[**zhan lan$_{N}$**]** guan$_{N}$**]**zhang$_{N}$**]** (*director of exhibition hall*)" is constructed in the final step of incorporation movement. The relevant sandhi results in (47) are as follows: 1. "**[**zhan lan$_{N}$**]**(*exhibition*)" (T3 T3) → (T2 T3). 2. "**[**zhan lan$_{N}$**]**guan$_{N}$**]**(*exhibition hall*)" (T2 T3 T3) → (T2 T2 T3). 3. "**[[[**zhan lan$_{N}$**]** guan$_{N}$**]** zhang$_{N}$**]** " (T2 T2 T3 T3) → the right sandhi form (T2 T2 T2 T3).

In (46), the noun "**[**$_{N}$guang bo**]**(*radio*)" is constructed in the first step of incorporation movement, the "Adjective + noun" structure—"**[**$_{A}$xiao**[**$_{N}$guang bo**]]**(*rumor*)", is constructed in the second cycle, the "Adjective + noun" structure—"**[**$_{A}$jia **[**$_{A}$xiao **[**$_{N}$guang bo**]]]**(*fake rumor*)" is constructed in the final step of incorporation movement. The relevant sandhi results in (48) are as follows: 1. "**[**$_{N}$guang bo**]**(*radio*)" (T3 T1) → (T3 T1). 2. "**[**$_{A}$xiao**[**$_{N}$guang bo**]]**(*rumor*)" (T3 T3 T1) → (T2 T3 T1). 3. "**[**$_{A}$jia **[**$_{A}$xiao **[**$_{N}$guang bo**]]]**(*fake rumor*)" (T3 T3 T3 T1) → the right sandhi form (T3 T2 T3 T1).

We still know very little about these compound words with complex morphological structure in Chinese languages. We have no idea why the formation of Chinese compounds are comparatively so diverse and abundant, with flexible combinations involving nouns, adjectives, and verbs, which clearly occupies an important position in the study of Chinese morphology (Packard 2000). Sometimes, traditional lexicalist approaches encounter challenges in the real data from phonology and semantics. Sometimes we even do not know where we should begin to investigate the problematic data. Starting from the pure morphology/lexicon, or from the data of phonology and semantics? Compound words may still be a mystery in Chinese linguistics for some more time.

7.5. Exceptions in the literature: prepositions and classifiers

Many exceptional cases are discussed in the classical literature mentioned in the previous accounts, e.g., prosodic and OT analysis. We will focus on the exception of prepositions mentioned in both prosodic and OT accounts, to show that the current approach can help with the problematic data of prepositions and classifiers.

Let's look at the example of the preposition phrase mentioned in Shih (1986) and Chen (2009), "[$_{NP}$mao$_{VP}$[$_{PP}$[bi gou] xiao] (*[$_{NP}$cat $_{VP}$[$_{PP}$[than dog] small])".* The possibilities of sandhi variations in this data are given in (49) and the sandhi results are given in (50). Some other less common sandhi forms involving many adjacent T3s are omitted, e.g., (2 2 3 3) or

(2 3 3 3). To derive these less common variations, we can follow the case (42) to split the sandhi domains into random smaller pieces in slow speech rate, or insert deliberate emphatic boundaries to create more adjacent T3s, without undergoing sandhi.

(49) logical possibilities of "[$_{NP}$gou$_{VP}$[$_{PP}$[bi ma] xiao] (*[$_{NP}$dog$_{VP}$[$_{PP}$[than horse] small])"*

[$_{NP}$gou$_{VP}$[$_{PP}$[bi ma] xiao] *[$_{NP}$dog$_{P}$[$_{PP}$[than horse] small]*

(3	3	3	3)	base tone
(**P**	(**M** $_n$)	(**P** $_c$)	**M** $_n$)	cyclic cycles of linearization
2	**3**	**2**	**3**	**surface tone A**
2	**2**	**2**	**3**	**surface tone B**
3	**2**	**2**	**3**	**surface tone C**

(50) Sandhi results of "[$_{NP}$gou$_{VP}$[$_{PP}$[bi ma] xiao] (*[$_{NP}$dog$_{VP}$[$_{PP}$[than horse] small])".*

(T3→3, T2→2)

[$_{NP}$gou$_{VP}$[$_{PP}$[bi ma] xiao] *[$_{NP}$dog$_{P}$[$_{PP}$[than horse] small]*

(3 3 3 3) base tone

(**P** (**M** $_n$) (**P** $_c$) **M** $_n$) cyclic cycles of linearization

Default Form– The application of T3 tone sandhi follows the order of 1°, 2° to 3°.

		(2	3)	*1° cycle*
	(3	2)		*2° cycle*
(2	3)			*3° cycle*
2	**3**	**2**	**3**	**(49) surface tone A**

Violated Form 1–The application of T3 tone sandhi follows the order of 2° to 1°/3°.

	(2	3)		*2° cycle*
(3	2)	(2	3)	*1° and 3° cycle*
3	**2**	**2**	**3**	**(49) surface tone C**

Violated Form 2–The application of T3 tone sandhi follows the order of 1°/3° to 2°.

(2	3)	(2	3)	*1° and 3° cycle*
	(3	2)		*2° cycle*
2	**3**	**2**	**3**	**(49) surface tone A (repeated)**

Violated Form 3–The application of T3 tone sandhi follows the order of3°, 2° to 1°

(2	3)			*3° cycle*
	(2	3)		*2° cycle*
		(2	3)	1° *cycle*
2	**2**	**2**	**3**	**(49) surface tone B**

In Default Form, the application of T3 tone sandhi follows the inner (most embedded) cycle to the outer cycle of linearization chains (1°, 2° to 3°,), deriving surface tone A. In Violated Forms, the application of T3 tone sandhi follows the twisted orders: 2° to 1°/ 3°, OR 1°/3° to 2°, OR 3°, 2° to 1° cycles, producing the violated forms of 1, 2, 3 and deriving C, A (repeated), B.

We also take a look at the special case of classifiers, which are also mentioned in Shih (1986) and Chen (2009), "[$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)" and "[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)" . The possibilities of sandhi variations in the two sample data are given in (51) and the sandhi results are given in (52).

(51) logical possibilities of "[$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)" and "[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] ([$_{NP}$*I [$_{VP}$ buy [$_{CIP}$ some [wine]]]*)".

[$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)
(3 3 3) base tone
(**M** **M** $_{c}$ **P** $_{c}$) cyclic cycles of linearization
2 2 3 surface tone A

[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] ([$_{NP}$*I [$_{VP}$ buy [$_{CIP}$ some [wine]]]*)
(3 3 3 3) base tone
(**P** (**M** $_{n}$) **M** $_{n}$ **P** $_{c}$) cyclic cycles of linearization
2 3 2 3 surface tone B
2 2 2 3 surface tone C
3 2 2 3 surface tone D

(52) Sandhi results of "[$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)" and "[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] ([$_{NP}$*I [$_{VP}$ buy [$_{CIP}$ some [wine]]]*)". (T3→3, T2→2)

[$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)
(3 3 3) base tone
(**M** **M** $_{c}$ **P** $_{c}$) cyclic cycles of linearization
2 2 3 (51) surface tone A

[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] ([$_{NP}$*I [$_{VP}$ buy [$_{CIP}$ some [wine]]]*)
(3 3 3 3) base tone
(**P** (**M** $_{n}$) **M** $_{n}$ **P** $_{c}$) cyclic cycles of linearization
Default Form– The application of T3 tone sandhi follows the order of 1° to 2°.
(2 2 3) *1° cycle*
(3 2) *2° cycle*
3 2 2 3 (51) surface tone D
Violated Form i–The application of T3 tone sandhi follows the order of 2° to 1°
(2 3) *2° cycle*
(2 2 3) *1° cycle*
2 2 2 3 (51) surface tone C
Violated Form ii–The application of T3 tone sandhi follows the order of 2° to 1°
(2 3) *2° cycle*
(3 2 3) *1° cycle*
2 3 2 3 (51) surface tone B

In the data of "[$_{VP}$ mai [$_{CIP}$ dian [jiu]]] (*[$_{VP}$ buy [$_{CIP}$ some [wine]]]*)", only one linearization cycle is formed, and there is only one surface tone A. In the data of "[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] ([$_{NP}$*I [$_{VP}$ buy [$_{CIP}$ some [wine]]]*)", in Default Form, the application of T3 tone sandhi follows the inner (most embedded) cycle to the outer cycle of linearization chains, 1° to 2° cycles, deriving surface tone D. In Violated Forms, the application of T3 tone sandhi follows the twisted orders: 2° to 1° cycles, producing the violated forms of i and ii, and deriving surface tone C and B.

The prepositions and classifiers are exceptional cases in both prosodic and OT analysis. For example in the prepositional phrase (49), according to the IC rule in foot formation, the preposition "bi (*than*)" and "ma (*horse*)" is a disyllabic foot, "(bi ma$_{f}$) (*than horse$_{f}$*)".

According to the super-foot rule, "(gou (bi $ma_{\mathbf{f}}$) $xiao_{\mathbf{f'}}$) (*dog* (*than* $horse_{\mathbf{f}}$) $small_{\mathbf{f'}}$)" is a super foot. In this way, we cannot derive the (49) surface tone A, but we can either apply T3 sandhi in foot or super-foot level to derive (49) surface tone B and C.

By the same token, in the classifier case (52), "[$_{NP}$ wo [$_{VP}$ mai [$_{CIP}$ dian [jiu]]] ([$_{NP}$*I* [$_{VP}$ *buy* [$_{CIP}$ *some* [*wine*]]]])", by IC rule (Immediate Constituency), "(dian $jiu_{\mathbf{f}}$) (*some* $wine_{\mathbf{f}}$)" forms a disyllabic foot **f**. By DM rule (Double Meter), we scan from left to right, the subject "wo (*I*)" and the verb "mai (*buy*)" form a disyllabic foot **f,** "(wo $mai_{\mathbf{f}}$) (*I* $buy_{\mathbf{f}}$)". Two disyllabic feet are constructed in this data of the classifier, "(wo $mai_{\mathbf{f}}$) (dian $jiu_{\mathbf{f}}$) (*I* $buy_{\mathbf{f}}$) (*some* $wine_{\mathbf{f}}$)". In this case, we cannot derive (52) surface tone A, but we can apply T3 sandhi in foot level and phase level to derive (52) surface tone B and C.

Note in (52), the surface tone B is probably a blocked sandhi form. Comparatively, the D and C are much better choices. Similar to the object pronouns discussed in section 7.2, the classifiers are phonological clitics dependent phonologically on the adjacent verbs and subsequently join the adjacent sandhi domains, as they lack the status to be considered independent phonological identities. In this case, "dian (*some*)" depends on the previous verb "mai (*buy*)", subsequently forming a single sandhi domain, which blocks surface tone B.

8. Conclusion

First, I would like to take the perspective of the "marked" feature of cyclicity in postlexical/phrasal phonology, to discuss the different forms of cyclicity that we can achieve in the direct and indirect approaches. Second, I will go back to the insights of the current case study to the general direct spell-out approach at the morphosyntax and phonology interface.

8.1. Recursion of foot construction vs Cyclicity of post-syntactic linearization chain

As we introduced in section 6, the prosodic analysis uses the recursive metrical foot construction (foot **f** and super foot **f'**) to derive the cyclicity of bleeding features in mandarin T3 tone sandhi. In the approach of the current study, we use the violable cyclicity of post-syntactic linearization, interacted with the cyclicity of bleeding features in Mandarin T3 tone sandhi (double-cyclicity).

According to several meaningful cases in the data, we have shown that the current direct spell-out model based on cyclic PF linearization can be potentially more capable to predict accurate and sufficient variations in Mandarin T3 tone sandhi, compared with the indirect inference approach of the intermediate prosodic constituents, e.g., the recursive foot construction.

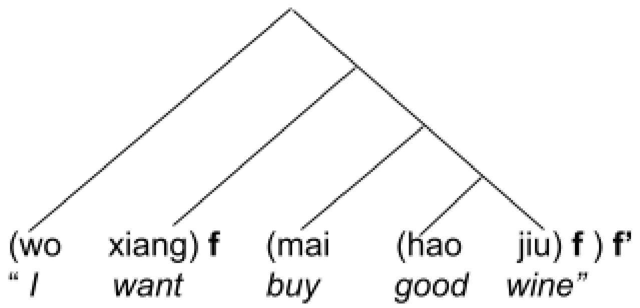
Pure logically, to derive "marked" cyclicity of mandarin T3 tone sandhi with bleeding feature, if we would like to follow the derivational approach (in the case that Mandarin T3 tone sandhi has been proved to encounter difficulties in the pure OT-based study, e.g., Feng 2003, Chen 2009), we should create some cyclic structures to account for the cyclic pattern shown in the variations of Mandarin T3 tone sandhi.

In the prosodic analysis, we take a close look at the recursion of foot construction. In the super-foot (**f'**) construction, any leftover monosyllable is joined into a neighboring binary foot according to the direction of syntactic branching (see (7) in section 2.2). In Shih (1986), a super-foot (**f'**) is either a trisyllabic or quadrisyllabic foot.

A super-foot (**f'**) can be a trisyllabic foot. In "(mai (hao jiu$_{f}$)$_{f'}$) *(buy (good wine$_{f}$)$_{f'}$)*", the monosyllabic verb "mai (*buy*)" joins into disyllabic (**f**) "hao jiu (*good wine*)". And a super-foot (**f'**) can also be a quadrisyllabic foot. In " (xiao (shui tong$_{f}$) li$_{f'}$) *(small (water-bucket) inside$_{f}$)$_{f'}$)*", which means "*inside the small water bucket*", both the adjective "xiao (*small*)" and the preposition "li (*inside*)" join into the disyllabic noun "shui-tong (*water-bucket*)" to be a quadrisyllabic foot (**f'**).

We can know that a super-foot (**f'**) always contains a disyllabic foot (**f**), by adding one or two monosyllables to one side or two sides of this disyllabic foot structure (**f**), respectively. This type of cyclic structure is an "**Include Structure"**, e.g., the "(mai (hao jiu$_{f}$)$_{f'}$) *(buy (good wine$_{f}$)$_{f'}$)*" in the repeated data of (53).

(53)



The only way to induce cyclicity in this kind of "Include Structure", as shown in Shih (1986), is to activate different cycles of foot level as the sandhi domain. That is to say, changing the sandhi domain of disyllabic foot "hao jiu (*good wine*)" to the larger domain of trisyllabic foot "(mai hao jiu$_{f'}$) *(buy good wine$_{f'}$)*".

Besides this form of cyclicity, the foot formation in the algorithm in (7) in section 2.2 is not equipped with other options to derive cyclicity. A very important reason is that other parts of the foot formation are not overlapped structure, hence they either form **Include Structure** between super-foot (**f'**), and foot (**f**), e.g., between "(mai hao jiu$_{f'}$) *(buy good wine$_{f'}$)*" and "hao jiu (*good wine*)", or **Parallel structure** between adjacent feet, e.g., between (mai hao jiu$_{f'}$) *(buy good wine$_{f'}$)*" and "wo xiang (*I want*)". This strict policy of "contained recursion" is very common in the structure of prosodic constituents in prosodic phonology (Nespor and Vogel 1986). The intermediate prosodic constituents are mapped from syntactic structures, promoting the feature of recursion in syntactic trees, e.g., different syntactic phrases (NP/VP/AP.etc) are independently recursive structures without overlapping areas.

On the contrary, in the direct spell-out approach of the post-syntactic linearization model at PF, this strict recursion is released by the linearization operation removing the syntactic hierarchy. From this aspect, the direct spell-out model achieves a flexibility in the construction of phonological domains in a loose relation with the syntax, compared with the indirect approaches mapping directly from syntactic hierarchy.

In the default cyclic linearization chains of [$_{CP}$wo[$_{VP}$xiang [$_{CP}$PRO [$_{VP}$mai[$_{NP}$hao-jiu]]]]] "(*[$_{CP}$I[$_{VP}$want [$_{CP}$PRO [$_{VP}$buy [$_{NP}$good wine]]]]]*)", which is represented in (54).

(54) $[_{CP}$wo$[_{VP}$xiang $[_{CP}$PRO $[_{VP}$mai$[_{NP}$hao-jiu]]]]]

“(*$[_{CP}$I$[_{VP}$want $[_{CP}$PRO $[_{VP}$buy $[_{NP}$good wine]]]]]*)”

3	3		3	3	3	*base tone*
(**P**	(**M** $_n$)		**M** $_c$	(**P** $_c$)	**M** $_n$)	*cyclic cycles of linearization*
				(**P** $_c$	**M** $_n$)	1° ***cycle***
	(**M** $_n$		**M** $_c$	**P** $_c$)		2° ***cycle***
(**P**	**M** $_n$)					3° ***cycle***

We can see the cyclic linearization chains conditioned by c-command relations share overlapped structures between M-words, providing the natural model to maximize bleeding effects of Mandarin T3 tone sandhi, which is also equipped with more flexibility when T3 sandhi rule follows the twisted orders between 1°, 2° and 3° cyclic linearization chains. This violable cyclicity of linearization chains (or interactive double-cyclicity) can provide more possibilities in abundant variations of Mandarin T3 tone sandhi.

The indirect inference approaches (e.g., Prosodic phonology) share intimate relations with syntactic hierarchies, which is a more “syntactic” approach compared to other post-syntactic or PF approaches, though the latter is given a name called direct spell-out or direct-syntax approach. The “seemingly syntactic” post-syntactic approach (e.g., PF linearizations), is removed with some crucial syntax-related properties (e.g., hierarchical structures), which provide more possibilities in postlexical cyclicity (e.g., the current T3 tone sandhi case), easing the limitations of recursivity in the foot formation of prosodic analysis.

8.2. The indispensable morphosyntactic cues in T3 tone sandhi variations and final remarks

Based on the data of Mandarin T3 tone sandhi, the direct spell-out model of post-syntactic linearization at PF accurately predicts sufficient variations in Mandarin T3 tone sandhi, by creating flexibility in cyclicity of postlexical/phrasal phonology. Focusing on the data of a typical and perplexing external tonal sandhi phenomenon—Mandarin T3 tone sandhi, we would expect that the current study provides a meaningful analysis to support the direct spell-out models at the morphosyntax and phonology interface.

In the data of section 7, we have seen that the indispensable function from underlying morphosyntactic structures (the PF linearization structures in the current approach) to derive the sufficient possibilities of Mandarin T3 sandhi variations, compared with the recursive foot construction from indirect approaches (e.g., Prosodic phonology). Solely by the recursive foot constructions mapped from morphosyntactic structures, some crucial T3 sandhi variations can not be achieved.

Another important factor in Mandarin T3 sandhi variations is the sensitivity of speech rate as a postlexical phenomenon, which is often considered as a defense of the indirect inference approaches (e.g., Prosodic phonology).

From the data of section 7, we have also seen that some surface tones of sandhi variations are induced solely by lower or faster speech rate. This point may continuously develop. We have seen in section 7.3 that the purely lexical domain without morphological relations (e.g., the telephone numbers or loanwords from other languages) can indeed be restricted by some pure rhythmic fatores, e.g., the disyllabic or trisyllabic foot construction originated from poetic rhythms in Chen (1983).

We may naturally think that only intermediate prosodic constituents can be influenced by prosodic factors, e.g., speech rate, emphatic breaks. As mentioned in Bennett and Elfner (2019), this view is probably out-of-dated. Many so-called direct syntax approaches have involved the role of prosodic factors to influence postlexical phonology, e.g., the Late-Linearization stage in the direct spell-out model of Pak (2008).

We may wonder how prosodic factors can influence the PF post-syntactic linearization chains. This is a question that we don't know. By the same token, having a name of prosodic domains may not naturally mean that we can easily explain, for example, how the initial T3 sandhi cycle is shifted from disyllabic foot cycle to trisyllabic super-foot cycle in the fast speech rate. The only thing we know is, for the phonological phenomena with speech rate sensitivity, the faster speech rate induces the larger phonological domains, whereas the slower speech rate induces the smaller phonological domains. We can call the domains of these special phonological phenomena either "prosodic domains" or "PF domains", meaning where these special phonological phenomena occur or special phonological rules apply.

Purely logically, in the current case of Mandarin T3 tone sandhi variations, I would suggest the logical problem still remains how we create the sufficient and accurate cyclic structure/mechanism to derive the cyclicity of T3 sandhi variations. In other words, the main task relies on comparing the accuracy of cyclicity induced by shift of prosodic foot cycles, or by the violable cyclicity in the interaction of post-syntactic PF linearization chains.

As discussed above, we have already known that some sandhi variations cannot be derived by pure recursive foot construction. If we acknowledge that prosodic factors are indispensable in T3 tone sandhi variations, it is necessary to understand that, by the same token, the underlying morphosyntactic factors have much more crucial and direct influence on T3 sandhi variations, other than the function to be mapped to prosodic structures. And the "seemingly syntactic" post-syntactic approach (e.g., PF linearizations), is removed with some crucial syntax-related properties (e.g., hierarchical structures), easing the limitations of recursion in metrical foot formation, which provide more possibilities in postlexical cyclicity (e.g., the current T3 tone sandhi case).

In many relevant literature about phrasal phonology at the morphosyntax and phonology interface (e.g., Bonet et al. 2019; Cheng and Downing 2016; Downing 2010; D'Alessandro and Scheer 2015; Dobashi 2004, 2009, 2010 among others), a lot of effort has been distributed to the flexible morphosyntactic boundaries (e.g., the CP/VP/DP boundaries) at the morphosyntax and phonology interface (e.g., direct phase boundaries or indirect prosodic phrasing), in the hope to eliminate the large amount of problematic data in broad external sandhi or other phrasal phenomena data. It may suggest that the strong syntax-related properties (e.g., the strictly contained recursive structures mapped from syntax) could be one of the potential reasons that we need to look into. Overall, the current case of "unusual" cyclicity in postlexical phonology may give us a new perspective to look at the long standing debate about the information transmission from morphosyntax to phonology.

References

Arregi, Karlos and Oltra-Massuet, Isabel. (2005). Stress-by-structure in Spanish. *Linguistic Inquiry 36:43–84*

Arregi, Karlos and Nevins, Andrew. (2007). Obliteration vs. impoverishment in the Basque g-/z-constraint. *In Proceedings of the 26th Penn Linguistics Colloquium, Penn Working Papers in Linguistics 13.1:1–14. Penn Linguistics Club, Philadelphia.*

Arregi, Karlos and Nevins, Andrew. (2008a). A principled order to postsyntactic operations. *Ms., University of Illinois at Urbana Champaign and Harvard University, Cambridge, MA.*

Arregi, Karlos and Nevins, Andrew. (2008b). Agreement and clitic restrictions in Basque. *In Agreement Restrictions, 49–85. Berlin: Mouton de Gruyter.*

Arregi, Karlos and Nevins, Andrew. (2017). Presyntactic morphology or postsyntactic morphology and explanatoriness in the Basque auxiliary. *The morphosyntax-phonology connection: Locality and directionality at the interface, 401–418. Oxford: Oxford University Press.*

Bobaljik, Jonathan. (2008). Where's phi? Agreement as a post-syntactic operation. *Phi-Theory: Phi features across interfaces and modules.*

Bošković, Željko. (2001). On the nature of the syntax-phonology interface: Cliticization and related phenomena. *On the Nature of the Syntax-Phonology Interface, 2001.*

Bošković, Željko. (2011). Rescue by PF deletion, traces as (non) interveners, and the that-trace effect. *Linguistic inquiry, 2011.*

Bošković, Željko. (2017). Tone sandhi in Taiwanese and phasal spell-out. *GENGO KENKYU (Journal of the Linguistic Society of Japan)*Bošković, Željko. (1998). LF movement and the Minimalist Program. *North East Linguistics Society 28.*

Bennett, Ryan and Elfner, Emily. (2019). The syntax-prosody interface. *Annual Review of Linguistics, 5: 151-171.*

Bonet E., Cheng L.L., Downing L. & Mascaró J. (2019), (In)Direct reference in the phonology-syntax interface under phase theory: a response to Modular PIC, *Linguistic Inquiry* 50(4): 751-777.

Chao, Yuenren. (1968). A Grammar of Spoken Chinese. *Berkeley and Los Angeles:University of California Press.*

Cheng, Chin Chuan. (1970). Domain of phonological rule application. *Studies presented to Robert B. Lee by his students 39-60.*

Cheng, Chin Chuan. (1973). A synchronic phonology of mandarin. *Mouton, the Hague.*

Cheng L.L. & Downing L.J. (2016), Phasal Syntax = Cyclic Phonology?, *Syntax* 19(2): 156-191.

Chen, Mao-Hsu. (2018), Tone sandhi Phenomena In Taiwan Southern Min. *PUBLICLY ACCESSIBLE PENN DISSERTATIONS 3049.*

Chen, Matthew Y. (2009). Tone sandhi-Patterns across Chinese Dialects. *Cambridge University Press.*

Chen, Matthew Y. (1983). Unfolding latent principles of literary taste- poetry as a window onto language. *Paper presented at the 4th international comparative literature conference. Taipei.*

D'Alessandro, Roberta and Scheer, Tobias. (2015). Modular PIC. *Linguistic Inquiry (2015) 46 (4): 593–624.*

Dobashi, Yoshihito. 2004. Multiple spell-out, Label-free syntax, and PF-interface. *Explorations in English Linguistics* 19, 1-47.

Dobashi, Yoshihito. 2009. Multiple spell-out, assembly problem, and syntax-phonology mapping. *In Janet Grijzenhout & Baris Kabak (eds.), Phonological Domains: Universals and Deviations. Berlin: Mouton de Gruyter, 195-220.*

Dobashi, Yoshihito. 2010. Computational efficiency in the syntax-phonology interface. In: Special issue on Mapping asymmetries: phonology, syntax and information structure. *The Linguistics Review* 27:3, 241-260.

Downing, Laura J. 2010. An edge-based approach to the alignment of syntactic phases and prosodic phrases. *In Nigel Vincent & Louise Mycock (eds.), Special issue: The Prosody-Syntax Connection. Transactions of the Philological Society* 108:3, 352-369.

Duanmu, San. (1991). Stress and syntax–phonology mismatches: tonal domains in Danyang and Shanghai. *In D. Bates (ed.), Proceedings of the Tenth West Coast Conference on Formal Linguistics, Stanford Linguistic Association, pp.127–137.*

Duanmu, San. (1992a). End-based theory, cyclic stress, and tonal domains. *Proceedings of the Chicago Linguistic Society Meeting.*

Duanmu, San. (1993a). Rime length, stress, and association domains. *Journal of East Asian Linguistics 2, 1--44, 1993. Kluwer Academic Publishers. Printed in the Netherlands.*

Duanmu, San. (1993b). Distinctions between word and phrase in Chinese. *University of Michigan. In Jerry Packard (ed.), Word Formation in Chinese.*

Embick, David. (2007). Linearization and Local Dislocations, Derivational Mechanics and Interactions. *Linguistics analysis 33.*

Embick, David. (2010). Localism versus Globalism in Morphology and Phonology. *Linguistic Inquiry Monographs (60).*

Embick, David and Noyer, Rolf. (2007). Distributed Morphology and the Syntax/Morphology Interface. *G. Ramchand and C. Reiss eds., The Oxford Handbook of Linguistic Interfaces, Oxford University Press.*

Embick, David and Noyer, Rolf. (1999). Locality in Post-Syntactic Operations. *MIT Working Papers in Linguistics 34, 265–317.*

Embick, David and Noyer, Rolf. (2001). Movement Operations after Syntax. *Linguistic Inquiry, Volume 32, Number 4, Fall 2001, 555–595.*

Embick, David and Marantz, Alec. (2008) Architecture and blocking. *Linguistic inquiry, Volume 39, Issue 1, pages 1-53.*

Feng, Wei. (2003). Third-tone sandhi in Mandarin Chinese: An experimentally based optimality theoretic account. *PhD dissertation, University of Arizona.*

Harley, Heidi. (2010). Compounding in Distributed Morphology. *The Oxford Handbook of Compounding, Edited by Rochelle Lieber and Pavol Štekauer, Print Publication Date: Jul 2011 Subject: Linguistics, Language and Cognition Online Publication Date: Sep 2012 DOI: 10.1093/oxfordhb/9780199695720.013.0007.*

Harley, Heidi & Noyer Rolf. (1999). Distributed morphology. *Glot International, Volume 4, Issue 4, April 1999.*

Halle, Morris and Marantz, Alec (1993), Distributed morphology and the pieces of inflection. *The View from Building 20, Cambridge, MA: MIT Press: 111–176.*

Kaisse, Ellen M. (1985). Connected Speech. *New York: Academic Press.*

Kaisse, Ellen M. (1990). Toward a typology of postlexical rules. *In Sharon Inkelas and Draga Zec (eds.), The Phonology–Syntax Connection, pp.127–144. University of Chicago Press.*

Kratzer, Angelika and Selkirk, Elisabeth, (2007), Phase theory and prosodic spellout: The case of verbs. *The Linguistic Review 24 (2007), DOI 10.1515/TLR.2007.005*

Kratochvil, Paul. (1969). Syllabic volume as acoustic correlate of perceptual prominence in Peking dialect. *Unicorn (Princeton Chinese Linguistics Project) 5:1–28.*

Kratochvil, Paul. (1974). Stress shift mechanism and its role in Peking dialect. *Modern Asian Studies 8.4:433–458.*

Lin, Mao-can, Yan, Jing-zhu, and Sun, Guo-hua. (1984). Beijinghua liangzizu zhengchang zhongyin de chubu shiyan [A preliminary experimental study on the normal stress of disyllabic words in Beijing]. *Fangyan 57–73.*

Liu, F. H. (1980). Mandarin in Tone Sandhi: a case of interaction between syntax and phonology. *Paper delivered at the summer meeting of Linguistics Society of America, Albuquerque, New Mexico.*

Marantz, Alec. (1988). Clitics, morphological merger, and the mapping to phonological structure. *Theoretical morphology, Pages 253-270, Academic Press.*

Marantz, Alec. (1995). "Cat" as a phrasal idiom: Consequences of late insertion in Distributed Morphology.

Marantz, Alec. (2001). 'Words', *paper presented at the West Coast Conference on Formal Linguistics, University of Southern California Los Angeles, 24 February, 2001. Available online at http://web.mit.edu/marantz/Public/EALING/WordsWCCFL.pdf.*

Martinović, Martina (2019). Interleaving syntax and postsyntax: Spell-out before syntactic movement. *Syntax. DOI: 10.1111/synt.12169.*

Marvin, Tatjana. (2013). “Is word structure relevant for stress assignment?” *in Alec Marantz and Ora Matushansky, eds. Distributed Morphology Today: Morphemes for Morris Halle, MIT Press, Cambridge, MA.*

McCarthy, John J. & Prince, Alan. (1995). Faithfulness and reduplicative identity. *In Jill Beckman, Laura Walsh Dickey & Suzanne Urbanczyk (eds.), Papers in Optimality Theory. University of Massachusetts Occasional Papers **18**. Amherst, Mass.: Graduate Linguistic Student Association. pp. 249–384.*

Myler, Neil. (2013). Linearization and post-syntactic operations in the Quechua DP. *Challenges to linearization, 2013, Degruyter.*

Myler, Neil. (2017). Exceptions to the Mirror Principle and morphophonological ‘action at a distance’: The role of ‘word’-internal phrasal movement and spell-out. *The structure of words at the interfaces. Oxford University Press.*

Oltra-Massuet, Isabel and Arregi, Karlos. (2005). Stress-by-Structure in Spanish. *Linguistic Inquiry. Vol. 36, No. 1 (Winter, 2005), pp. 43-84.*

Pak, Marjorie. (2008), The post-syntactic derivation and its phonological reflexes. *University of Pennsylvania PhD dissertation.*

Packard, Jerome L. (2000). The Morphology of Chinese: *A Linguistic and Cognitive Approach. Cambridge University Press.*

Pietraszko, A. (2021). Cyclic Selection. Auxiliaries are merged, not inserted. *To appear in Linguistic Inquiry.*

Selkirk, E. O. (1984). Phonology and syntax: the relations between sound and structure. *The MIT press.*

Shih, Chilin. (1986). The Prosodic Domain of Tone Sandhi in Chinese. *Ph.D. dissertation, University of California, San Diego.*

Shwayder, Kobey. (2015). Word-Level Recursion in Spanish Compounds. *University of Pennsylvania linguistics working paper Volume 21 Issue 1 Proceedings from PLC 38, article 28.*

Scott, Jackson and Punske, Jeffrey. (2013). Deriving English compound stress: insights from Distributed Morphology and multiple spell-out. *Linguistic Analysis 38 (3-4), 243-274.*

Sproat, Richard and Chilin Shih. (1991). The cross-linguistic distribution of adjective ordering restrictions. *In Carol Georgopoulos and Roberta Ishihara (eds.), Interdisciplinary Approaches to Language: Essays in Honor of S-Y. Kuroda, pp.565–594. Dordrecht: Kluwer Academic.*

Sproat, Richard (1985), On deriving the lexicon. *PhD dissertation. Massachusetts Institute of Technology.*

Talić, Aida. (2019). Upward P-cliticization, accent shift, and extraction out of PP. *Natural Language and Linguistic Theory 37(3).*

Vogel, Irene and Nespor, Marina (1986). Prosodic Phonology: With a New Foreword. *De Gruyter Mouton.*

Wang, Chiung-Yao and Lin, Yen-Hwei. (2011). Variation in Tone 3 Sandhi: The case of prepositions and pronouns. *Proceedings of the 23rd North American Conference on Chinese Linguistics (NACCL-23), 2011. Volume 1, edited by Zhuo Jing-Schmidt, University of Oregon, Eugene. Pages 138-155.*

Wurmbrand, Susi and Bobaljik, Jonathan. (2005). Adjacency, PF, and extraposition. *Linguistic studies in honor of Henk van Riemsdijk, Pages* 679-688

Yip, Moira. (1980). The tonal phonology of Chinese. Ph.D. dissertation. *Massachusetts Institute of Technology.*

Zhu, Dexi. (1956). Xiandai hanyu xingrongci de yanjiu [A study on adjectives in modern Chinese]. *Yuyan yanjiu 1:83–112.*

Zhang, Jie. (2014). Tones, Tonal Phonology, and Tone Sandhi. *The handbook of Chinese linguistics edited by C.-T. James Huang, Y.-H. Audrey Li, Andrew Simpson.*