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Recursive and non-recursive tone sandhi domains in Laoling trisyllabic sequences

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Abstract. In previous studies, variations of tone sandhi domains of tri-tonal sequences are either recursive or non-recursive domains, differing only in prosodic branching. In Laoling, however, both recursive, e.g., (σ(σσ)), ((σσ)σ), and non-recursive variant domains, e.g., (σ)(σσ), (σσ)(σ), are observed. In traditional Optimality Theory (Prince & Smolensky 1993), such variations cannot be predicted. In this study, we combine Coetzee's (2006) Rank-Ordering model of EVAL with McCarthy's (2010) Harmonic Serialism and demonstrate how both recursive and non-recursive domains and their varying frequencies can be predicted.

Keywords. tone sandhi domain; recursivity; variation; Optimality Theory; Harmonic Serialism; Rank-Ordering model of EVAL

1. Introduction. It has been established in the past that the application of sandhi rules is confined by prosodic domain boundaries (Duanmu 1991, Chen 1987, 2000, Lin 2008, etc.). Rules are observed to be blocked by prosodic boundaries or to apply cyclically from one disyllabic sequence to the other. Thus, to describe how tone sandhi applies in a language, one must first describe how the sandhi domains are formed.

Previous studies on tone sandhi domain show that a language either has recursive domains, where tone sandhi applies cyclically from the inner to the outer domain (e.g., Mandarin Chinese), or non-recursive domains, where tone sandhi applies simultaneously within each domain (e.g., Xiamen, Shanghai). Nevertheless, this is not the case in Laoling, a northern Mandarin dialect spoken in Laoling City, Shandong Province, China. Our data show that Laoling has both recursive and non-recursive domain variations with different frequencies of occurrence. Such variations cannot be predicted in traditional Optimality Theory (Prince & Smolensky 1993/2004), let alone their frequencies.

Following Chen (2000), we assume that the prosodic domain is the Minimal Rhythmic Unit, as it is argued to be the case in the Mandarin dialects, and suggest an analysis under the framework of Harmonic Serialism (McCarthy 2010), combined with Coetzee's (2006) Rank-ordering model of EVAL to predict the recursive and non-recursive domain variations in Laoling trisyllables.

2. Tone sandhi domains in trisyllabic sequences. Tone sandhi, like many phonological rules, operates locally within a prosodic domain, which is a unit of speech bigger than a segment, such as the syllable, foot, phonological word, phonological phrase, intonational phrase, utterance, etc. (Nespor & Vogel 1986). To generalize about the tone patterns in trisyllabic and longer sequences in a language, one must learn how the prosodic domain for tone sandhi is formed.

Three different prosodic domains of tone sandhi for Asian tonal languages have been proposed in the past, as shown in (1). Syntactic domains are marked by square brackets, and prosodic domains by parentheses. In Xiamen, a Min dialect, tone sandhi applies within the phonological phrase, which is demarcated by syntactic maximal projections (XP) that are not adjuncts (Chen 1987). Domain-final tones retain their base tones, while non-final tones become

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sandhi tones. As shown in (1a), the Xiamen noun phrase has two readings that differ in meaning (S = sandhi tone; B = base tone). In the first reading, the determiner phrase (DP), *mua-a*, is an argument governed by the inflectional phrase (IP), so a prosodic boundary is drawn after the DP, and the base tone of *-a* is retained, as it is domain-final. In the second reading, the noun phrase (NP), *mua-a*, is not an argument but an adjunct to the adjective head, *tua*, so no prosodic boundaries are drawn between them, and the base tone of *-a* is changed to a sandhi tone.

In Mandarin Chinese, the tone sandhi domain is argued to be the Minimal Rhythmic Unit (MRU), which contains at least two syllables, and most ideally only two syllables, based on the fact that Mandarin strongly prefers disyllabic or quadrisyllabic compounds and idioms that are easily decomposed into disyllabic MRUs (see Chen 2000:369-372 for the role of syntax in MRU formation). As shown in (1b), two MRU are formed in the quadrisyllabic verb phrase (VP). Mandarin Third Tone Sandhi, where an L tone becomes an MH tone before another L tone, applies within the MRUs and changes the first and third tones into ML.

In Shanghai, a Wu dialect, the sandhi domain is the stress foot, defined through cyclic stress assignment (Duanmu 1991). In (1c), the tones on stressed syllables are boldfaced. An unstressed syllable loses its lexical tone, as indicated by “o” in the parentheses. Then, the tone of the stressed syllable spreads rightward to the unstressed syllable within the foot. The remaining unstressed syllable not associated with a tone is assigned a default low tone.

(1) Types of prosodic domains

a. Phonological phrase: Xiamen (Chen 1987:116)
‘buns (on which) the sesame-seeds are big’
[[mua-a]$_{\text{DP}}$ # tua]$_{\text{IP}}$ # e]$_{\text{CP}}$ sio-piã
sesame-seed big COMP bun
(S B)$_{\text{PhP}}$ (B)$_{\text{PhP}}$ (B)$_{\text{PhP}}$ (S B)$_{\text{PhP}}$

‘buns (which are) as big as sesame-seeds’ (tiny buns)
[[mua-a]$_{\text{NP}}$ = tua]$_{\text{AP}}$ # e]$_{\text{CP}}$ sio-piã
sesame-seed big COMP bun
(S S B)$_{\text{PhP}}$ (B)$_{\text{PhP}}$ (S B)$_{\text{PhP}}$

b. Minimal Rhythmic Unit: Mandarin Chinese (Chen 2000:374)
‘want to buy antiques’
[xiang [mai [gu dong]$_{\text{NP}}$]$_{\text{VP}}$]$_{\text{VP}}$
want buy antique
(L L)$_{\text{MRU}}$ (L L)$_{\text{MRU}}$ – base tones
(MH L)$_{\text{MRU}}$ (MH L)$_{\text{MRU}}$ – Apply T3 sandhi

c. Stress foot: Shanghai (Chen 2000:313)
‘pour a cup of tea’
[tɔ [[qiq pe]$_{\text{NP}}$ zo]$_{\text{NP}}$]$_{\text{VP}}$
pour one cup tea
(**MH** MH HL) (**LH**) – base tones
(**MH** o o) (**LH**) – Delete unstressed tone
(**M** H o) (**LH**) – Spread stressed tone spread

The dialect of focus in the present study is Laoling, a subdialect of Shandong, which belongs to the Mandarin dialects, so we assume for now that the prosodic domain is the MRU, analogous to Mandarin Chinese.

3. Prosodic domain variations. The prosodic domain of a language may exhibit free variations, which lead to alternative tone sandhi patterns. In Shanghai, as shown in (2a), stress (indicated “x”) assignment forms a disyllabic trochaic foot followed by a monosyllabic foot. The stressless syllable undergoes tone deletion. The preceding tone splits and spreads to the stressless syllable, which renders the first reading. Shanghai has an optional rule that reduces morpheme stress and induces a trisyllabic foot, in which tone deletion and tone spread apply to derive the second reading.

In Mandarin Chinese, as shown in (2b), MRU formation may form the first two syllables or the last two syllables into a disyllabic MRU, and then form a trisyllabic MRU to avoid monosyllabic MRUs, producing a left-branching and a right-branching prosodic domain. Tone sandhi applies cyclically within MRUs, from the innermost bracketed units to the outermost. In the first reading, when tone sandhi applies within the disyllabic MRU at the end of the phrase, the tone sandhi environment for the first two syllables is lost, so tone sandhi is not applicable in the trisyllabic MRU. In the second reading, tone sandhi applies within the disyllabic MRU at the beginning of the phrase and later within the trisyllabic MRU.

(2) Domain variations within a language

a. Shanghai (Chen 2000:311)

x	compound stress
(x .) (x)	word stress
[[hõ.moq] zã]	‘redwood bed’
LH LH LH	base tones
(LH o) (LH)	tone deletion
(L H) (LH)	tone spread – reading 1
(x . .)	optional stress reduction
[[hõ.moq] zã]	‘redwood bed’
LH LH LH	base tones
(LH o o)	tone deletion
(L H o)	tone spread – reading 2

b. Mandarin Chinese (Chen 2000:419)

gou [yao wo]	‘the dog bit me’
L L L	base tones
(L (L L))	MRU formation
(MH L)	T3S
(L MH L)	T3S not applicable – reading 1
((L L) L)	alternative MRU formation
(MH L)	T3S
(MH L L)	T3S – reading 2

From the above languages with prosodic domain variations, it seems that a language allows either recursive (as in Mandarin) or non-recursive domain variations (as in Shanghai), but not both. Namely, recursive and non-recursive prosodic domains do not coexist in a language, even in languages that allow domain variations. However, Laoling trisyllabic tone patterns suggest otherwise, as will be shown in the next section.

4. The Laoling dialect. Laoling is a Shandong dialect spoken in Laoling city, located in the northwest area of Shandong Province. Based on Cao (2007) and our data, it has four lexical tones: LM (13), ML (31), HM (53), H (55), and eight regular sandhi rules, as shown in (3). The sandhi position is always non-final. Rules (2a-c) produce a high register rising sandhi tone (MH), which does not pertain to the tonal inventory and only occurs in the non-final syllable.

(3) a. LM.LM → MH.LM
b. LM.ML → MH.ML
c. ML.ML → MH.ML
d. HM.ML → H.ML
e. HM.H → ML.H
f. HM.HM → ML.HM
g. H.H → ML.H
h. H.LM → HM.LM

To investigate how the tone sandhi domain is defined in Laoling, we examined patterns where different outputs are derived when tone sandhi operates in different directions, to see whether MRU formation scans from the first two syllables or the last two (i.e., from left to right, or right to left). These patterns are referred to as direction-sensitive patterns, a term borrowed from Lin (2008). There are 19 direction-sensitive patterns out of all 64 tri-tonal combinations, as shown in (4). The first column lists the trisyllabic base tone sequences. The sandhi patterns where tone sandhi applies from left to right and right to left are given in the second and third columns. Our data were provided by three native Laoling speakers, who were given a list of tri-syllabic words or phrases and instructed to read each item as naturally as possible.

(4) Direction-sensitive patterns

Base tones	L → R	R → L
HM.HM.H	ML.ML.H	H.ML.H
ML.HM.HM	ML.ML.HM	MH.ML.HM
ML.HM.H	ML.ML.H	MH.ML.H
ML.ML.ML	MH.MH.ML	ML.MH.ML
ML.H.H	ML.ML.H	MH.ML.H
HM.H.H	ML.ML.H	H.ML.H
HM.ML.ML	H.MH.ML	HM.MH.ML
HM.HM.HM	ML.ML.HM	H.ML.HM
H.H.H	ML.ML.H	H.ML.H
H.H.LM	ML.HM.LM	H.HM.LM
H.LM.LM	HM.MH.LM	H.MH.LM
H.LM.ML	HM.MH.ML	H.MH.ML
H.HM.ML	H.H.ML	ML.H.ML
LM.LM.LM	MH.MH.LM	LM.MH.LM
LM.LM.ML	MH.MH.ML	LM.MH.ML
LM.ML.ML	MH.MH.ML	LM.MH.ML
LM.HM.H	LM.ML.H	MH.ML.H
LM.H.H	LM.ML.H	MH.ML.H
LM.HM.HM	LM.ML.HM	MH.ML.HM

We observe four types of tone sandhi domains, as shown in (5). The left-branching recursive domain, ((σσ) σ), implies that sandhi rules scan from the leftmost disyllabic string to the rightmost string, while the right-branching recursive domain, (σ(σσ)), implies that tone sandhi operates from the rightmost disyllabic string to the left. In the non-recursive domain, (σ)(σσ), tone sandhi only applies to the rightmost disyllable; whereas, in (σσ)(σ), tone sandhi applies only to the leftmost disyllable.

Different sandhi domains affect the surface tonal sequence. For instance, two surface patterns are found in the base sequence /HM.HM.HM/. When the domain is ((σσ)σ), rule (3f) applies to the leftmost disyllabic sequences first and then to the rightmost sequence, resulting in [ML.ML.HM]. When the domain is (σ(σσ)), rule (3f) first applies to the rightmost disyllabic sequence and the intermediate form feeds rule (3d), resulting in [H.ML.HM].

(5) Percentages of different domain variations

Morpho-syntactic Structure	Tone sandhi domain				Total
	(σ)(σσ)	((σσ)σ)	(σ(σσ))	(σσ)(σ)	
[[σσ]σ]	43% (51/119) /HM.H.H/ (HM)(ML.H)	29% (35/119) /HM.HM.HM/ ((ML.ML)HM)	25% (30/119) /HM.HM.HM/ (H (ML.HM))	3% (3/119) /HM.H.H/ (ML.H)(H)	119
[σ[σσ]]	53% (100/189) /H.HM.ML/ (H)(H.ML)	28.5% (54/189) /H.H.LM/ ((ML.HM)LM)	18.5% (35/189) /H.HM.ML/ (ML.(H.ML))	0%	189

We observe in (5) that, first, syntactic branching cannot directly predict the boundaries of the sandhi domain in Laoling. A tonal sequence with a left-branching morpho-syntactic structure may have either a left-branching or right-branching foot domain, as shown in the sequences, /HM.H.H/, /HM.HM.HM/ and /H.HM.ML/. Second, an underlying tri-tonal string (e.g., /HM.H.H/) may derive into more than one surface output (HM.ML.H or ML.H.H) due to different sandhi domains. Third, regardless of the morpho-syntactic structure, the most frequent foot domain is (σ)(σσ), followed by ((σσ)σ) and (σ(σσ)). The least preferred domain is (σσ)(σ). The following analysis aims to derive all four sandhi domains and predict their frequency.

5. A constraint-based analysis. In traditional Optimality Theory (Prince & Smolensky 1993/2004), recursive and non-recursive domains are incompatible within a language. Opposing constraints like NON-RECURSIVITY (Selkirk 1996) versus Wrap XP (Truckenbrodt 1995, 1999), and Match XP (Selkirk 2011) have been proposed to exclude and include recursive prosodic structures. Languages with NON-RECURSIVITY ranking higher than Wrap XP or Match XP forbids recursive structures, while those with an opposite ranking allow them. To the authors' knowledge, no theories have been proposed to deal with variations that involve both recursive and non-recursive domains. The Laoling data show that such variations are indeed attested and need to be taken into account. We suggest a Harmonic Serialism (McCarthy 2010) account that combines Coetzee's (2006) Rank-ordering model of EVAL.

Harmonic Serialism (HS) is a derivational model of OT in which an input is gradually altered through many stages until the input and the output converge. At each stage of the derivation, only one change from the input to the output is allowed, so each possible output candidate can only differ from the input by a single alteration. The output of a derivation is fed to the next stage as an input for another evaluation. The derivation is complete when the output is isomorphic to the input.

The Rank-ordering model of EVAL (ROE) provides a device for predicting language-internal variations and their frequency of occurrence based on structural well-formedness in parallel OT. The device is a cut-off line in the constraint hierarchy to separate the constraints into two strata. Constraints above the cut-off act just like the constraints in traditional OT. Only the candidate(s) that best satisfy the constraint hierarchy above the cut-off may survive. If two or more candidates tie with each other, variants are predicted. In contrast, constraints below the cut-off cannot rule out candidates as ungrammatical. The variants that violate constraints below the cut-off only differ in structural well-formedness. A variant that violates the higher-ranked constraints below the cut-off is less well-formed and less frequently attested than one that violates the lower-ranked constraints below the cut-off. In essence, ROE is compatible with HS, as both theories admit a fixed constraint hierarchy, as opposed to theories that allow multiple rankings within a language (Stratal OT: Kiparsky 1998, Partial ordering: Anttila & Cho 1998, Floating constraints: Reynolds 1994, etc.).

We adopt the constraints in (6) for MRU formation in Laoling. It should be noted that "the foot" in the constraints refers to the MRU, not in the sense of a stress foot as in Shanghai.

(6) Prosodic constraints

a. ALLFTRT: Assign one violation mark for every syllable standing between the right edge of a foot (MRU) and the right edge of a prosodic word.

b. PARSESYLL: Assign one violation mark for every syllable that is not parsed into feet.

c. FTBIN: Assign one violation mark for every foot (MRU) with more or less than two syllables.

e. *FINAL-MONOFT: Assign one violation mark for every monosyllabic foot (MRU) in the final position (Zuo 2002).

f. NON-RECURSIVITY: No foot (MRU) dominates a foot (MRU) (Selkirk 1996).

In the following HS tableaux, a cut-off line is drawn between PARSESYLL and *FINAL-MONOFT. Candidates that best satisfy constraints FTBIN and PARSESYLL are submitted as inputs to the next stage of evaluation. Violations of *FINAL-MONOFT, NON-RECURSIVITY, and ALLFTRT only affect the well-formedness of a variant.

FTBIN dominates PARSESYLL so that the trisyllabic MRU, (7a-iii), is ruled out at stage one. Candidates (7a-i and ii) have fewer violations of PARSESYLL than (7a-iv and v), so they survive as inputs to the next stage. Variant (7a-i) is more well-formed than (7a-ii), because the latter incurs one violation of ALLFTRT.

These inputs are fed to separate stage two evaluations, as in (7b) and (7e). In (7b), two variants are derived and convergence is achieved respectively in (7c, d). In (7e), two variants are derived, and convergence is achieved in (7f, g).

(7) Tableau illustration: Harmonic Serialism and ROE combined

a. Stage 1: /σσσ/ → σ(σσ) or (σσ)σ

/σσσ/	FTBIN	PARSESYLL	*FINAL-MONOFT	NON-RECURSIVITY	ALLFTRT
→i. σ(σσ)		*			
→ii. (σσ)σ		*			*
iii. (σσσ)	*!				
iv. (σ)σσ		**!			**
v. σσ(σ)		**!	*		

b. Stage 2-1: σ(σσ) → (σ)(σσ) or (σ(σσ))

σ(σσ)	FtBin	ParseSyll	*Final-MonoFt	Non-Recursivity	AllFtRt
→i. (σ)(σσ)	*				**
→ii. (σ(σσ))	*			*	

c. Convergence: (σ)(σσ) → (σ)(σσ)

(σ)(σσ)	FtBin	ParseSyll	*Final-MonoFt	Non-Recursivity	AllFtRt
→i. (σ)(σσ)	*				**
ii. ((σ)(σσ))	**!			*	**

d. Convergence: (σ(σσ)) → (σ(σσ))

e. Stage 2-2: (σσ)σ → ((σσ)σ) or (σσ)(σ)

(σσ)σ	FtBin	ParseSyll	*Final-MonoFt	Non-Recursivity	AllFtRt
→i. ((σσ)σ)	*			*	*
→ii. (σσ)(σ)	*		*		*

f. Convergence: ((σσ)σ) → ((σσ)σ)

g. Convergence: (σσ)(σ) → (σσ)(σ)

A few implications follow from the present analysis:

1. Trisyllabic MRUs are forbidden. = (7a-iii)
2. Formation of disyllabic MRUs from the right edge is preferred, compared to that from the left edge. = (7a-i) > (7a-ii)
3. Non-recursive MRUs are preferred when disyllabic MRUs are first formed on the right edge. = (7b-i) > (7b-ii)
4. Recursive MRUs are preferred when disyllabic MRUs are first formed on the left edge. = (7e-i) > (7e-ii)

These implications predict the order of domain preference as shown in (8). It matches roughly, though not precisely, the domain frequencies in the Laoling data in (5), encapsulated in (9). The most well-formed and thus frequent tone sandhi domain is (σ)(σσ), where tone sandhi applies only in the rightmost MRU and is blocked in the first two syllables. The least preferred domain is (σσ)(σ), where tone sandhi applies only in the leftmost MRU and is blocked in the last two syllables.

(8) (σ)(σσ) > (σ(σσ)) > ((σσ)σ) > (σσ)(σ)

(9) (σ)(σσ) > ((σσ)σ) > (σ(σσ)) > (σσ)(σ)

However, the present analysis deviates from the Laoling data in the distribution of the recursive domains. Our analysis predicts (σ(σσ)) to be more well-formed than ((σσ)σ), while this is not the case in Laoling. Surely, more investigation is required to take into consideration whether other factors such as syntactic relations, semantic functions, tonal markedness, etc. interact with MRU formation.

6. Conclusion. The proposed analysis succeeds in deriving both recursive and non-recursive prosodic domain variations using a combined approach of Harmonic Serialism and ROE. We predict (σ)(σσ) to be the most well-formed, and (σσ)(σ) the least well-formed, as attested in Laoling. The well-formedness of the recursive domains, ((σσ)σ) and (σ(σσ)), is between (σ)(σσ) and (σσ)(σ). But questions remain as to why ((σσ)σ) is more frequent than (σ(σσ)) in Laoling. We suggest a closer examination of the syntactic and semantic information and tonal markedness for future research.

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